St. GREGORIOS DENTAL COLLEGE

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DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS

LIBRARY DISSERTATION

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CAST METAL RESTORATIONS

CONTENTS

INTRODUCTION

With the advent of topical and systemic fluoride and other preventative treatments in general dentistry in the mid-1900s, more patients have since entered their adult years with fewer and smaller direct posterior restorations.[1-3] Often, as these patients age, these fillings and the surrounding supporting tooth structure become worn and damaged, in some cases, severely. The lack of dimensional stability of the existing direct filling and parafunctional habits can contribute to the breakdown of the occlusal table.[4]

A common occurrence at the patient's recall examination is the failing posterior occlusal amalgam or composite restoration. Despite a lack of structural compromise to the proximal walls, full or partial coverage crowns are often prescribed and placed as long-term restorative solutions, owing to a perceived lack of retention. Chemically bonded porcelains have helped to address these concerns, but their lack of long-term predictability and inertness remain as issues.[5-6]

Cast metal restorations offer a conservative alternative to these more extensive restorations, using the advantages of cast metal to restore and, in some cases, re-establish the occlusal table of the compromised posterior tooth.[7]

Of all the many methods and processes which have been discovered and developed, relative to dentistry, there is none that has been of so great a benefit and so far-reaching in its effects as that of the cast restoration. The understanding and utilization of this process has revolutionized dental procedure, both in the operative and prosthetic fields, its advent marks the beginning of one of the great epochs of dental history.[8]

Many instances and clinical situations warrant the clinician to opt for cast restoration. These provide long lasting restorations and maintain the proximal contact for a considerable period of time. The configuration of contacts and contours can also be modified with the help of these restorations.

Basically, the cast restorations are fabricated from either noble metals or base metals. ‘Noble’ refers to metals with marked resistance to oxidation and chemical reaction. Sometimes, the term ‘precious’ is also used. Precious usually refers to economic value. ‘Base metal’ refers to the metal elements that are chemically reactive to their environment. Recently, titanium has also been used for casting. These restorations require meticulous approach towards cavity preparation and its fabrication.[9]

The process has many steps, involves numerous dental materials, and requires meticulous attention to detail. Typically, a dental laboratory is involved, and the dentist and the laboratory technician must be devoted to perfection. The high degree of satisfaction and service derived from a properly made cast-metal restoration is a reward for the painstaking application required.

The Class II inlay involves the occlusal surface and one or more proximal surfaces of a posterior tooth. When cusp tips are covered, the term onlay is used. The procedure requires two appointments: the first for preparing the tooth and making an impression, and the second for delivering the restoration to the patient. The fabrication process is referred to as an indirect procedure because the casting is made on a replica of the prepared tooth in a dental laboratory.[10]

HISTORY

History of casting of objects in gold by the wax elimination process dates back to four or five thousand years ago by the Chinese. The Italian artisan Benvenuto Cellini described the use of this technique to make statues and artistic pieces.[9]

The evidence for the use of cast restoration was found in Mesopotamia (3000 BC) where copper was used to cast. The art of casting was introduced in Egypt (2500 BC) where the lost wax moulding process was first developed for gold casting. Etruscans (500 BC) produced bridges made of soldered gold bands. The Romans adapted and developed a technique for dental prosthesis which completely disappeared in Europe until the 18th century. After that, the Chinese developed specific bronze alloys and created an elaborate use of lost-wax process to produce castings. The oldest castings were gold inlays found in teeth of natives of Ecuador and Pre-Columbian Indians.[11-13]

There is evidence that the Mayan and Aztecs made gold castings in mould prepared from clay or plaster of Paris. After the introduction of dental cement oxychloride of zinc in 1860, various materials were used for the construction of dental inlay, for example, grounded porcelain and gold foil.[14]

In 1884, Aquilhon de Saran of Paris melted 24 Carat gold in an investment mould to form inlays. Dr D. Philbrook in 1897 described a method of casting for restoration of posterior teeth.

In 1907, William H. Taggart introduced the lost wax technique for making gold castings.[15]

Van Horn introduced different methods of compensation for alloy shrinkage, Weinstein added boric acid and Moore added chlorides to the investment material to minimize shrinkage and enhance thermal expansion, respectively.[16]

INDICATIONS

a) Extensive Tooth Involvement

Amalgam is limited in its ability to replace tooth structure; beyond this limit it can only act as a foundation for reinforcing cast restorations. Cast restoration is the ultimate in efficiently replacing lost tooth structure and supporting remaining tooth structure.

Extensive tooth loss in mandibular right molar, indicated for a cast restoration

b) As an adjunct to successful periodontal therapy by correction of tooth anomalies which predispose to periodontal problems

Cast restorations can do this by:

- Physiologically restoring and permanently maintaining the dimensions of the contact and contour, marginal ridges and embrasures, which are vital for the health of the periodontium.
- Splinting teeth loosened by periodontitis to a better plane by supporting tooth or teeth. The rigid connection of several cast

restorations assures the distribution of applied forces to the best supported teeth while minimizing the forces on the disabled teeth.

c) **Correction of occlusion**

If any drastic change is planned for the occlusal table or occluding parts of a tooth, cast restorations are ideal. This is very essential for a sound periodontium and a pathology-free, functional stomato-gnathic system.

d) **Restoration of endodontically treated teeth**

When teeth undergo endodontic therapy, they lose structure and become brittle. Almost always the clinical crown portion of the tooth will need a reinforcing restoration i.e. a cast restoration.

e) **Support for and preparatory to partial or complete dentures**

Whether they are a clasp type, over-denture type, precision attachment or bar attachment type, most removable prostheses will need cast restorations on or in the abutment teeth to hold or accommodate the retainers for the denture.

f) **Esthetics**

Of all metallic restorations (with the exception of direct gold restorations), properly fitted cast restorations are most esthetic. Cast alloys will not discolour the remaining tooth structure.

g) **Patients with low incidence of plaque accumulation**

Patients to receive a cast restoration should have their plaque accumulation under rigid control to avoid problems due to the weak link of the tooth cement-cast interphase.

h) Subgingival lesions

In cavities with subgingival margins where the prolonged exclusion of moisture is impossible, finished and polished gold alloys are the restorative materials most compatible with the periodontium. Therefore, these restorations are considered the most practical for subgingival lesions.[9]

Subgingival lesion on maxillary first molar

i) Functionally sound stomato-gnathic system with complete freedom of the mandible to move without any pre-mature contacts

Patients having their teeth restored by cast restoration should be checked and analysed stomato-gnathically to be sure of the soundness and function of the system. If any pathologies discovered, the causes should be diagnosed and treated and if any malfunction is not going to be corrected by the contemplated cast restorations, should be treated prior to the cast restoration procedure. If this is not done, cast restorations and procedure may seriously complicate the treatment.

j) Cracked teeth (Vertically, horizontally or diagonally)

Cast restorations are the most rigid and subsequently the most efficient way of restoring and splinting, the cracked, separated segments of a tooth. This prevents further propagation of the cracked and occasionally promotes healing of some cracks.

k) Retainers for fixed prostheses

l) Dissimilar metals

Whenever cast restorations are prevalent in the mouth, it is logical to fabricate new restorations in similar methods, as it minimizes galvanism, pre-mature abrasion, anodic dissolution of any other less noble metals or mechanical failures of other less qualified restorative materials. Approximating dissimilar materials, continuously or momentarily can enhance diffusion of restorative materials with high diffusion indices. (e.g. amalgam) to the cast alloy which has very low diffusion indices at mouth temperature. This will lead to vacancy porosities in the former material and alloying of the latter materials, which may weaken them. [17]

CONTRAINDICATIONS

Physiologically young dentition with large pulp chambers and incompletely mineralised dentin are poor candidates for cast restorations, as the extensiveness of tooth preparation and the variables encountered during the multi-step procedures may traumatize these vulnerable tissues.[17]

a. High Caries Rate

Facial and lingual (especially lingual) smooth-surface caries indicates a high caries activity that should be brought under control before expensive cast-metal restorations are used. Patients with rampant caries and poor oral hygiene should not be given cast restoration.

b. Young Patient

With younger patients, direct restorative materials (e.g., composite or amalgam) are indicated unless the tooth is severely broken or endodontically treated. An indirect procedure requires longer and more numerous appointments, access is more difficult, the clinical crowns are shorter, and younger patients may neglect oral hygiene, resulting in additional caries.

c. Esthetics

The dentist must consider the esthetic impact (display of metal) of the cast-metal restoration. This factor usually limits the use of cast-metal restorations to tooth surfaces that are hidden at a conversational distance. Composite and porcelain restorations are alternatives in esthetically sensitive areas.

d. Small Restorations

Due to the success of amalgam and composite, few cast-metal inlays are done in small Class I and II restorations.[18]

e. Developing and deciduous teeth

Growth or resorption may be affected by the traumatic nature of the procedures for cast restorations.

f. Occlusal disharmony

Cast restorations should not be used in patients with severe occlusal interference or other defects in the stomatognathic system. In case of extensive occlusal wear facets involving the remaining ridge of the tooth, inlays and onlays are generally contraindicated.[9]

ADVANTAGES

a. Strength

The inherent strength of dental casting alloys allows them to restore large damaged or missing areas and be used in ways that protect the tooth from future fracture injury. Such restorations include onlays and crowns. Yield strength, compressive strength, tensile strength and shear strength of alloys used for cast restorations are far greater than those of any materials used intraorally (some cast alloys have five times the ultimate strength of amalgam). One of the main uses of cast inlay in operative dentistry is in situations when a restorative material is needed to impart resistance to the tooth rather than depending on tooth structure to provide resistance form to the restoration.[7]

b. Biocompatibility

As previously mentioned, high-gold dental casting alloys are unreactive in the oral environment. Its biocompatibility can be helpful for many patients who have allergies or sensitivities to other restorative materials.

c. Low Wear

Although individual casting alloys vary in their wear resistance, castings can withstand occlusal loads with minimal changes. This is especially important in large restorations that restore a large percentage of occlusal contacts.

d. Control of Contour and Contact

Through use of indirect technique, the dentist has great control over contours and contacts. Control becomes especially important when the restoration is larger and more complex.

e. Reproducibility

Cast techniques and materials can reproduce precise form and minute detail. Additionally, these materials will maintain this detail under functional stresses.

f. As the cast inlay contains one or more noble metals, they are not significantly affected by tarnish and corrosion processes in the oral environment. This major advantage improves longevity, esthetics and biologic qualities of inlays.[9]

g. The nature of building a metallic restoration instantaneously with a casting procedure as opposed to an incremental build-up in amalgam imparts advantages to the final restoration, e.g. **fewer voids, no layering effect, less internal stresses**, fairly even stress patterns of the entire structure and maximum bonding between the component phases.

h. Cast restorations can be **finished and polished** outside the oral cavity, thereby producing surface with maximum biological acceptance.

i. Freedom from volume change after placement.

j. Gold castings have a **coefficient of thermal expansion** (12 × 10–6/°C) similar to that of tooth structure.[18]

DISADVANTAGES

a. Number of Appointments and Increased Chair Time

The cast inlay or onlay requires at least two appointments and more chair time than a direct restoration, such as amalgam or composite.

b. Temporary Restoration

Patients must have temporary restorations between the preparation and delivery appointments. Temporaries occasionally loosen or break, requiring additional visits.

c. Cost

In some instances, cost to the patient becomes a major consideration in the decision to restore teeth with cast-metal restorations. The cost of materials, laboratory bills, and the time involved make indirect cast restorations more expensive than direct restorations.

d. Technique sensitive

Every step of the indirect procedure requires diligence and attention to detail. Errors at any part of the long, multistep process tend to be compounded.

e. Splitting Forces

Small inlays may produce a wedging effect on facial or lingual tooth structure and increase the potential for splitting the tooth. Onlays do not have this disadvantage.

f. Being a cemented restoration, several interphases will be created at the tooth cement casting junction. These inter phases and the leakage accompanying them will become more significant due to the fact that cast fabrications involve a number of channels using different materials like impressions, models, etc. each of which possesses inherent discrepancies. This produces a restoration, which is microscopically ill fitting. Leakage around and under a cast restoration is the most complicated and has the highest dimension among all restorative materials. This leakage is pronounced gingivally than in other parts of the restorations.[9]

g. Cast inlay restorations necessitate extensive tooth involvement in the preparation, which create possible hazards for the vital dental tissues.

h. The cathode nature of cast gold dental alloys towards amalgam may lead to galvanic deterioration of amalgam if these two restorations are placed adjacent to or opposite to each other. As a by-product of this dissimilar metal cell corrosion, the freed mercury will contaminate the cast alloy itself.

i. The procedure for cast inlay restoration fabrication is lengthy, requiring more than one visit. It may require temporary coverage during inter-appointments. Cast alloys are much more expensive than other restorative materials, due to the inherent expense of the alloy.

j. Some cast alloys and ceramics have very high abrasive resistance, much more than that of tooth enamel. So, if a restoration is made for a patient replacing occluding surfaces and opposing natural teeth during functional mandibular relations, there may be abrasive differences between natural dentition and cast restoration, with the teeth being abraded much more easily. Such an abrasive difference will lead to an imbalance in occlusion resulting in tooth shifting, tilting or rotating and leading to occlusal interferences during mandibular movements.

REVIEW OF LITERATURE

***Moffa JP, Guckes AD, Okawa MT and Lilly GE (1973)*: In this study, they did an evaluation of nonprecious alloys for use with porcelain veneers and provided quantitative information about the levels of beryllium produced during the finishing and polishing of cast base metal dental alloys with their harmful effects.

***Shillingburg HT, Hobo S and Fisher DW (1977)*: Studied preparation design and margin distortion in porcelain-fused-to-metal restorations. The results of this study suggested that thermal incompatibility stresses were likely to cause margin distortion in metal ceramic crowns. However, subsequent studies support other potential mechanisms, including the effect of excessive sand blasting time and/or pressure.

***Tupac RG, Neacy K (1981)*: 'Gingitage' involves simultaneous subgingival tooth preparation and intentional rotary diamond instrument curettage of the inner lining of the gingival sulcus. Gingitage or rotary gingival curettage, promoted as a method for handling the interfering tissue during restorative procedures, is intended to eliminate the trauma of pressure packing or the necessity of electrosurgery around subgingival tooth preparations. A series of diamond instruments of special shape and grit allows the crevicular epithelium to be removed at the same time the preparation finish line is completed. Increased impression material volume is allowed in the finish line areas. Emphasis is placed on non-pressure retraction cord insertion.

***Baran GR (1983)*: Did an extensive study on metallurgy of sixteen commercially available Ni-Cr alloys for fixed prosthodontics and compared their alloy compositions, mechanical properties (yield strength, tensile strength, %

elongation and hardness number), microstructures and clinically relevant considerations for the use of these alloys.

Schoenrock AG (1989)**:** The laminar impression technique is a precise, rapid, and predictable alternative to traditional methods of impression-making. A preliminary impression is made using plastic "triple-arch" type trays and high-stiffness vinyl polysiloxane jaw relation registration material. After tooth preparation, tissue management and retraction, this registration can be used for provisional fabrication. Two holes are then drilled through the facial wall of the tray into the region of the preparation. The tray is replaced in the mouth and light-bodied vinyl polysiloxane impression material is injected into the holes by using an "automixing" gun system. Concluded that the laminar technique is an alternative to traditional impression methods. The simplicity, speed, predictability, economy and precision in the impression procedure makes it a useful technique.

Hoffman JM, Rubin MK (1989)**:** The procedure is presented for the construction of a direct provisional acrylic resin restoration by means of an interocclusal wax impression. This technique requires no preparation or laboratory time and quickly results in a restoration that accurately covers all margins of the preparation and restores proper contact, contour, and occlusion. This procedure can also be used for large restorations, immediate fixed partial dentures, final impressions of preparations, provisional crowns to fit existing removable partial dentures, and some office emergencies, needing rapidly constructed provisional restorations.

Cullen DR, Mikesell JW, Sandrik JL (1991)**:** Numerous factors are involved in making an accurate void-free dental artificial stone cast or die. The relationship of the wettability of an elastomeric impression material and its interaction with the gypsum slurry is an important factor. This study examined the relative "pourability" of several impression materials by counting the number of resultant voids in artificial stone casts containing 48-point angles. Those elastomers that exhibited the lowest contact angle with water produced artificial stone casts with the fewest voids. Surfactants applied to the impression material significantly reduced the number of voids in artificial stone casts, as did modified elastomers designated by the manufacturer as hydrophilic.

Weine FS, Wax A, Wenckus S (1991)**:** In this study, observed a total of 211 consecutive patients of a restorative dentist who received full-mouth radiographs between October 1988 and March 1989 which were screened for teeth treated endodontically at least 10 years earlier. In all, 51 patients had 138 teeth treated and restored. All involved teeth were restored with tapered smooth posts, cores with complete or 7/8 cast ferrules, and an onlay or cast precious metal crown (with or without veneering). No posts, splints, or bridges were loose, and only one crown was loose. There were nine failures in 138 teeth (6.5%) – three restorative, two endodontic, two root fractures, and two periodontal. Concluded that the success rate for the endodontic treatment alone is 98.5%. When tapered smooth posts are used properly, retentive problems do not occur.

Vassilakos N, Fernandes CP (1993)**:** Investigation carried out on the wettability of commonly used elastomeric impression materials and their gypsum castability. The wettability is evaluated by determining the contact angles of drops of a CaSO4 aqueous solution on flat impression surfaces. Gypsum castability is determined by counting the number of voids formed in die stone casts made from impressions of a critical die. All specimens used in this study were exposed to saliva to simulate clinical conditions, where materials spontaneously acquire salivary origin biofilms. The results indicate that condensation silicones and conventional addition silicones exhibited the largest contact angles and the highest number of voids. The new generation of ‘hydrophilic’ addition silicones has higher wettability than the conventional silicones and an improved gypsum castability, comparable to that of the polyether materials.

Carr A.B., Cai Z., Brantley W.A.(1993)**:** Did a study on new high palladium casting alloys (generation 1&2). For the five high-palladium alloys studied, the following conclusions were drawn:

- An increase in the investment burn out temperature from 1400°F to 1500 °F had little effect on the microstructure and hardness, but grain or dendritic size was found to vary substantially.
- Hot tears were more prevalent in the alloys when the higher burnout temperature was used.
- Heat treatment simulating porcelain firing cycles for these alloys generally caused decrease in hardness.

Creugers HJ, Mentink AGB, Kayser AF (1993)**:** The data on posts and cores are analysed by meta-analysis. Since the characteristics of the selected studies were too heterogeneous, they could not be combined for an overall survival assessment, and therefore the survivals are presented separately. The endpoints of the survival curves after 6 years were 81% for resin composite build-ups in combination with screw posts and both 91% for two studies including cast posts and cores. The survivals of these studies varied from 98.6% survival after a follow-up of more than 10 years to 77.6% survival after a mean follow-up period of 5.2 years.

Reisbick NH and Brantley WA (1995)**:** Conducted a study on mechanical properties and microstructural variations for recasting low gold alloys. They concluded that significant decrease in yield strength and percentage elongation were observed for recasting these alloys but not in tensile strength when the Type III gold alloys were recasted upto 3 times. Scanning electron microscope examination revealed that the number of casting defects (principally porosity) increased with the number of times the alloy was melted.

***Trier AC. Merle H. Parker, Stephen M, Brousseau SJ (1998)*:** The concept of limiting taper has been described as a boundary between tapers that provide and those that do not provide resistance form for a preparation. There is controversy as to whether this boundary that divides preparations with and without resistance form translates clinically into a boundary for success. Concluded that the clinical dislodgment of cast restorations is associated with the lack of resistance form in the preparations. Observed a relationship between clinical success or failure and the all-or-none nature of resistance form; dislodged crowns come almost exclusively from preparations.

***Randall RC, Wilson NHF (1998)*:** It is generally accepted that glass ionomers inhibit secondary caries in vivo, and data from in vitro studies support this effect. The study done on a systematic assessment, from the literature, of clinical evidence for the ability of glass-ionomer restoratives to inhibit secondary caries at the restoration margin. Tabulation of these papers by occurrence of secondary caries in the glass-ionomer or control groups demonstrated an even distribution between positive and negative outcomes. Valid evidence is best obtained from randomized, controlled studies of sufficient sample size. No conclusive evidence for or against a treatment effect of inhibition of secondary caries by the glass-ionomer restoratives was obtained from the systematic review.

Gordon J (1998)**:** An extensive survey is conducted to determine the current prevalence of intracoronal tooth-coloured restorations. Members of the American Academy of Esthetic Dentistry were the participants in this survey. The participants were asked 21 basic questions related to all aspects of tooth-coloured restorations. Definite responses were reported in percentages designating every subtitle of each question. Findings indicated that 84% of these restorations were direct placement resins, 4% were indirect placement resins, and only 2% were indirect ceramic. Survey outcomes also revealed that tooth-coloured restorations were rapidly gaining popularity in the field of restorative dentistry.

Berzins DW, Sarkar NK et al (2000)**:** Did an in-vitro electrochemical evaluation of high palladium alloys in relation to palladium allergy. The high incidence of allergic reaction was associated with Pd-Cu based alloys. The “Pd-skin” of these alloys when in contact with saliva release some Pd++ ions (an allergen) which can trigger the cascade of biological reaction involved in allergy and hypersensitivity. It is a time dependent process. In Pd alloys containing Ag, formation of Ag-Cl film on the alloy surface is supposed to prevent Pd from coming in contact with oral fluids, having a masking effect and thus avoiding allergy.

Breeding LC, Dixon DL (2000)**:** Dual-arch trays are often used to make simultaneous impressions of a prepared tooth and the opposing teeth. Many dentists are concerned with the accuracy of the casts generated from this type of impression. Investigation done to compare the accuracy of stone casts of a prepared tooth generated using 2 types of dual-arch impression tray/impression material combinations. Concluded that the plastic trays produce tooth replicas that were larger than the tooth (95 and 166µm), and the metal trays produced replicas that were smaller (-24 and -36µm). No differences in accuracy were shown between the vinyl polysiloxane and polyether impression material used.

***Ferrari M, Vichi A, Garcia-Godoy F (2000)*: The retrospective study evaluated treatment outcome of cast post and core and composipost systems after 4 years of clinical service. 95% of the teeth restored with Composiposts showed clinical success; 3% of these samples were excluded for noncompliance and 2% showed endodontic failure. Clinical success was found with 84% of teeth restored with cast post and 3% endodontic failure. Statistical evaluation shows significant differences between composiposts systems and cast post and cores. Concluded that composipost system was superior to the conventional cast post and core system after 4 years of clinical service.

***Nissan J, Laufer BZ, Brosh T, Assif D (2000)*: The study done to determine the accuracy of 3 putty-wash impression techniques using the same impression material (polyvinyl siloxane) in a laboratory model. The 3 putty-wash impression techniques used are

1) 1-step (putty and wash impression materials used simultaneously)
2) 2-step with 2-mm relief (putty first as a preliminary impression to create 2-mm wash space with prefabricated copings. In the second step, the wash stage was carried out)
3) 2-step technique with a polyethylene spacer (plastic spacer used with the putty impression first and then the wash stage).

For each technique, 15 impressions were made of a stainless-steel master model that contained 3 complete crown abutment preparations, which were used as the positive control. Accuracy was assessed by measuring 6 dimensions (intraabutment and interabutment) on stone dies poured from impressions of the master model. One-way analysis of variance showed statistically significant differences among the 3 putty-wash impression techniques, for all intraabutment and interabutment measurements ($p<0.01$). Overall discrepancies of the 2-step technique with 2-mm relief putty-wash impression technique were significantly smaller than that in the 1-step and polyethylene putty-wash impression techniques. Concluded that the polyvinyl siloxane 2-step, 2 mm, relief putty-wash impression technique is the most accurate for fabricating stone dies.

***Tufekci E, Mitchell JC et al (2002)*:** Did a study on spectroscopy measurements of elemental release from high palladium dental casting alloys into a corrosion testing medium. Highly sensitive analytical techniques show that the release of individual elements over a m period, suggesting that there may be low risk of biological reaction with the Pd-Ga alloys than with the Pd-Cu-Ga alloys tested.

***Stankiewicz NR, Wilson PR. (2002)*:** A ferrule is a metal ring or cap used to strengthen the end of a stick or tube. It has been proposed that the use of a ferrule as part of the core or artificial crown may be of benefit in reinforcing root-filled teeth. Demonstrates that a ferrule effect occurs owing to the artificial crown bracing against the dentine extending coronal to the crown margin. Concluded that a ferrule is desirable but should not be provided at the expense of the remaining tooth/root structure.

***Demarchi MGA, Sato EFL (2002)*:** The study is carried out to compare coronal microleakage of interim Post and Cores in two conditions. Twenty-eight extracted upper molars were endodontically treated and divided into two groups and controls: group A: prefabricated post and core permanently cemented; and group B: prepared for a post and restored with a temporary post crown cemented with a temporary cement. The teeth were thermocycled, immersed in black India ink for 1 week, and made transparent. Results indicated that the permanently cemented, prefabricated post and core produced the best seal ($p<0.01$); leakage was significantly greater with the temporary post crown and was similar to that of a positive control group.

Grandini S, Sapio S, Simonetti M (2003)**:** Concluded that the clinical procedure of the anatomic post can be used for reconstructing an endodontically treated tooth when the anatomy of the root canal walls after preparation is not perfectly round, and when there is an important loss of substance at the coronal level. In this manner, it is possible to obtain a fit of the individual anatomic post which is superior to any other prefabricated fibre post.

Ahmad SAH, Omar MB, Homa D. (2003)**:** Did an investigation of the cytotoxic effects of commercially available dental casting alloys and concluded the following:

- High noble alloy Bioherador N was significantly less cytotoxic than all the base metal alloys tested in this study (Ni-Cr, Co-Cr, Cu-based)
- The Ni-Cr alloy CB Soft was significantly more cytotoxic than all the Ni-Cr and Co-Cr alloys tested. This could be related to the content of Cu, low content of Cr and absence of Mo in its composition.
- Cu based alloys Thermobond showed a more severe cytotoxic reaction than all the other alloys.
- with tapers that did not provide resistance form.

Hedlund, Johansson NG, Sjogren G (2003)**:** The study carried out to evaluate the retention of prefabricated root canal posts made of a variety of materials. The posts used were cosmopost, composipost carbon fibres, Composipost ASTHETI-Plus, Composipost light-Post and Para Post Fibre White. Only the Cosmopost system exhibited retention values that were significantly lower than for the conventional cast gold alloy posts luted with zinc-phosphate cement. Concluded that when zirconium oxide ceramic posts were luted with resin composites the bonding between the ceramic and resin composite seemed to be weak.

Lane AD, Randall RC, Lane NS, Wilson NHF (2003)**:** The study carried out to establish whether a double-arch impression technique could produce restorations comparable with those produced by use of the complete-arch technique and to investigate reported time and material savings. Concluded that double-arch impressions were found to take less time, to use less material, and to be preferred by patients. Under the conditions of this study, the resulting restorations were no less accurate than those made from complete-arch impressions.

Rupp F, Axmann D, Jacobi A, Groten M, Geis-Gerstorfer J (2004)**:** The study done to determine clinically relevant accuracy of dental impressions depends on flowing and wetting properties of the applied impression materials. High – resolution drop shape analysis is used to study contact angle on thin unset films of two polyether and two vinyl polysiloxane (VPS) impression materials. Compared to vinyl polysiloxane impression materials, polyethers show pronounced and constant initial hydrophilicity throughout the prescribed working time. The kinetics of the vinyl polysiloxane impression materials towards more hydrophilic equilibrium surface states is very fast compared to polyethers. This possibly balances the disadvantages of the initial vinyl polysiloxane impression materials hydrophobicity. Both, high initial and a fast kinetics towards increased hydrophilicity may improve flowing and wetting processes during impression taking.

Kumbuloglu V, Lassila LVJ, User A, Vallittue PK (2004)**:** The study carried out to evaluate the surface microhardness and flexural and compressive strengths of five luting cements and compared the degree of conversion of dual and autopolymerized forms of four resin-based luting cements. Four resin composite luting cements-Panavia F, Variolink 2, RelyX Unicem Applicap, and RelyX ARC- and a polycarboxylate cement were used.

- The highest flexural strengths were obtained with Variolink 2, whereas the lowest were observed with Durelon.
- RelyX Unicem showed the highest hardness values, whereas Variolink 2 gave the lowest.
- The highest compressive strengths were obtained with RelyX Unicem, whereas the lowest were observed with Durelon.
- For both dual and autopolymerized groups, RelyX ARC showed the highest degrees of conversion and RelyX Unicem had the lowest. Concluded that resin composite luting cements of similar chemical characterizations differed in their physical properties, and polymerization method influenced their degree of conversion.

Behr M, Rosentritt M, Regnet R, Lang R, Handel G (2004)**:** This study compares the marginal adaptation of a new self-adhesive universal resin cement with only one application step, to the marginal adaptation of established cements and their corresponding adhesive systems. All-ceramic crowns were inserted on human molars using a new self-adhesive universal resin cement without and with one pre-treatment step, a resin cement with a smear-layer removing and a compomer cement with a smear-layer dissolving adhesive system. After simulation of five years oral stress, the marginal adaptation was evaluated by dye penetration and scanning electronic microscope analysis using the replica techniques. The results indicate that a self-adhesive universal resin cement without pre-treatment can provide a marginal adaptation at dentin which is comparable to established luting agents.

***Bateman G, Tomson P (2005)*:** Indirect restorations can provide a conservative, functional and esthetic method for managing a patient's condition. These restorations, however, are only as good as the environment in which they are placed. Many restorations, though technically satisfactory, may fail when the assessment and subsequent treatment planning were unsatisfactory. He concluded that consideration of all factors pertinent to case selection should help provide greater predictability for indirect dentistry. Often the most successful treatment plan is the one that establishes stable and sustainable oral health, addresses all of the patient's needs and is cost-effective.

***Bateman G, Tomson P (2005)*:** Modern post preparation techniques reflect a change from what was once considered a prosthodontic procedure to endodontic principles with sound understanding of mechanical objectives. He concluded that contemporary post placement technique embraces sound mechanical objectives and newer endodontic principles. Advances in preparation of the post-space, post materials and luting cements mean that greater predictability for restoration of the root-filled tooth can be achieved.

***Burke TFJ (2005)*:** Luting materials play a central role in indirect dentistry. Active materials which bond to tooth and restoration may aid in the retention of restorations, while passive materials merely fill the gap between crown and tooth. The properties of currently available luting materials, with resin-modified glass ionomer and resin materials have been found to exhibit optimum properties. However, resin luting materials have are technique sensitive. However, with the advent of self-adhesive resin luting materials has overcome most of the technique problems faced during placement of restorations. Resin materials are indicated for luting all-ceramic restorations.

***Stewardson DA (2005)*:** A fundamental pre-requisite for the construction of satisfactory indirect restorations is the ability to record an accurate and detailed impression of the dental structures. Knowledge of the key properties of the available impression materials and their handling behaviour is necessary if they are to be used effectively. A variety of techniques can be employed in different situations, each of which can be highly successful, but only if attention is paid to the detail of their execution and the clinician is aware of their individual limitations and pitfalls. Where imperfections occur, an appreciation of how they have been caused, and the strategies to take to prevent them will lead to greater success in impression taking.

***Burke TFJ (2005)*:** The provision of well-fitting, functional provisional restorations is important for a wide variety of reasons, including maintenance of the stability of inter-arch and intra-arch relationships and positional stability of prepared teeth, and the preservation of occlusal function of anterior provisional restorations by providing appropriate protrusive and lateral guidance. Provisional restorations should have sufficient strength to resist the forces of occlusion and should be luted with a cement that will resist the forces of removal yet allow easy removal at the fit appointment without leaving a residue on the prepared tooth. Concluded that though number of materials are available, bis-acrylate materials appear to offer many advantages, including:

- Low polymerization shrinkage
- Good marginal fit

- Minimal odour and taste
- Quick setting
- Ease of trimming and
- Simple cartridge delivery systems.

***Palin WM, Burke FJI (2005)*:** Computer-aided design (CAD) and computer-aided manufacturing (CAM) of indirect restorations became available to dentistry over 15 years ago, providing replication and digitization of the complex topography of tooth structure. There are now many applications, providing better mechanical properties, improved marginal integrity and enhanced esthetics, compared with traditional indirect techniques. Whether a restoration is fabricated by traditional or modern computerized systems, three functional stages are required; data acquisition, design and manufacture.

Brunton PA, Christensen GJ, Cheung SW, Burke FJT, Wilson NH (2005) concluded that :

- Amalgam was the preferred material for core build-ups in posterior teeth.
- Dentin pins were used routinely
- Indirect posts were preferred to direct posts
- Addition-cured silicone was the most widely used impression material
- Traditional glass-ionomer cements were the most popular luting cements.

CLASSIFICATION OF DENTAL CASTING ALLOYS

ALLOY TYPE BY NOBILITY

- **High Noble**

  Contains > 40 wt. % Au and > 60 wt.% of the noble metal elements (Au + Ir + Os + Pd + Pt + Rh + Ru)

- **Noble**

  Contains > 25 wt. % of the noble metal elements

- **Predominantly Base Metal**

  Contains < 25 wt. % of the noble metal elements

TYPES OF DENTAL ALLOYS

Dental alloys can be categorized as noble alloys (gold- and palladium-based) or base metal alloys (nickel- and cobalt based). Major (> 10%) and minor (< 10 %) components of these different alloy types are shown in Tables 1-4.

<u>Noble Alloys</u>

Noble/Gold-based Alloys

Noble/gold-based alloys (Table 1) have the longest history of use in dentistry and are "the standard" with which other alloys are usually compared. They are used for fabrication of inlays, crowns, fixed partial dentures, and metal ceramic restorations (PFM). Gold adds high corrosion resistance, good castability, good ductility, and the distinctive yellow gold colour. Silver reduces density, slowly whitens the alloy colour when added in increasing amounts and counteracts the redness of copper. In PFM alloys, silver may discolour porcelain veneers. Copper strengthens gold-based alloys (AuCu3). Both palladium and platinum increase casting temperature, strength, and corrosion resistance of the alloy (Tuccillo and

Nielson, 1971). Palladium lowers cost and improves rigidity and sag resistance of PFM alloys (Moffa, 1983). Zinc (traces) increases castability (Raub and Ott, 1983) and forms intermetallic (gold) compounds to harden the alloy (Labarage and Treheux, 1979). Iron improves mechanical properties and, in PFM alloys, increases sag resistance (Kojima, 1980) and bond strength with porcelain (Espevik and 0ilo, 1979). Tin acts as a bonding element in PFM alloys and a hardening agent in palladium-gold alloys (German, 1979). Iridium acts as a grain refiner in gold-based PFM alloys (Raub and Ott, 1983). Indium serves as a bonding agent in PFM alloys (Espevik and 0ilo, 1979). Germanium increases the castability of gold-copper alloys (Townsend and Hamilton, 1983).[19]

TABLE 1
NOBLE/GOLD-BASED ALLOYS: "GENERAL" CHEMICAL COMPOSITIONS

(A)	Crowns and fixed partial dentures	
	(1)	Major: gold, silver, copper
	(2)	Minor: palladium, platinum, zinc, indium, iridium, rhenium, germanium
(B)	Metal ceramic (PFM)	
	(1)	Major: gold, platinum, palladium
	(2)	Minor: rhodium, silver, indium, tin, iron, iridium, rhenium, copper

Noble/Palladium-based Alloys

Noble/palladium-based alloys (Table 2) with silver have been available since 1974 (Tuccillo, 1977). In the early 1980's, there was an increase in palladium-based formulations with reduced amounts of silver. They are used primarily for the fabrication of PFM restorations. However, a variety of type IV, extra-hard alloys exists that can be used to cast inlays, crowns, fixed partial dentures, and removable partial dentures (RPD). Palladium reduces the cost of the alloy while increasing strength, rigidity, and sag resistance (Moffa, 1983). The coefficient of thermal expansion is increased with the addition of silver (Kollmannsperger and

Helfmeier, 1983). Indium and/ or tin can be added to improve bonding with the porcelain veneer. Gallium contributes to a homogeneous microstructure. Ruthenium is used primarily as a grain refiner. Palladium based alloys absorb small amounts of carbon that increase brittleness of the alloy (Eichner, 1983). Gas porosities (CO gas) may occur after the alloy is cooled. The palladium-silver alloys are somewhat more difficult to cast (McLean, 1983).[19]

TABLE 2
NOBLE/PALLADIUM-BASED ALLOYS: "GENERAL" CHEMICAL COMPOSITIONS

(a)	Crowns and fixed partial dentures	
	(1)	Major: palladium, silver, copper, gold
	(2)	Minor: zinc, indium, iridium
(B)	Metal ceramic (PFM)	
	(1)	Major: palladium, silver, gold, copper, cobalt
	(2)	Minor: gold, platinum, indium,tin, gallium, ruthenium, rhenium

Base Metal Alloys

Base metal alloys (Tables 3 and 4) were first introduced to dentistry for the fabrication of RPD's in the early 1930's. Subsequently, they have largely replaced the noble-based alloys for RPD's. The most successful RPD alloys are cobalt-chromium-based (Table 3) and nickel-chromium-based (Table 4). There has also been an increase in the use of similar "base metal" alloys for less costly crowns, fixed partial dentures, and PFM restorations due to the dramatic increase in price of gold bullion and gold-containing dental casting alloys in the 1970' s.[20]

Base Metal Cobalt-based Alloys

Base metal/cobalt-based alloys (Table 3) are used primarily in the fabrication of RPD's. Several manufacturers (e.g., J.F. Jelenko, Dentsply) market cobalt-based alloys for PFM restorations. Cobalt provides strength, hardness, and corrosion resistance. Chromium provides hardness and resilience and increases corrosion resistance when present in at least 16 wt%. Nickel increases ductility (Asgar and

Peyton, 1961) while lowering melting temperature and hardness (Asgar and Allan, 1968). The carbon content of these alloys is critical. It is only slightly soluble in cobalt-chromium solid solution and is present mainly as dispersed carbides of chromium, cobalt, or molybdenum, increasing the strength and hardness of the alloy (Tesk and Waterstrat, 1985). Manganese is a de-oxidizer. Tungsten helps reduce formation of chromium-depleted zones.[20]

TABLE 3
BASE METAL/COBALT-BASED ALLOYS: "GENERAL" CHEMICAL COMPOSITIONS

(A)	Metal ceramic (PFM)	
	(1)	Major: cobalt, chromium, tungsten, molybdenum
	(2)	Minor: copper, silicon, gallium, aluminum, nickel, tantalum, ruthenium
(B)	Removalbe partial dentures	
	(1)	Major: cobalt, chromium, nickel
	(2)	Minor: molybdenum, tantalum, manganese, gallium, silicon, carbon, tungsten

Base Metal Nickel-based Alloys

Base metal/nickel-based alloys (Table 4) are used primarily for RPD's and PFM restorations. Nickel yields a softer alloy and lowers the melting temperature. Aluminium (Ni3Al) increases strength and hardness. Carbon may be added to increase strength but increases brittleness as well. Beryllium decreases melting temperature and corrosion resistance (Lee et al., 1985) while improving castability and bonding. Lower melting temperatures also provide a smoother casting surface that requires less finishing. Boron decreases alloy melting temperature (Haudin and Perrin, 1981). Titanium and manganese increase corrosion resistance (Meyer, 1977) and serve as bonding agents (Espevik and 0ilo, 1979). Iron increases strength (Meyer et al., 1979). Cobalt increases hardness. Copper increases corrosion resistance (Bui and Dabosi, 1981). Gallium improves castability (Kollmannsperger and Helfmeier, 1983). Yttrium aids in the adherence of oxide layers (Townsend and Hamilton, 1983). Molybdenum increases corrosion resistance (Lee et al., 1985). Tin increases strength and hardness (Ando and Nakayama, 1983).[20]

TABLE 4
BASE METAL/NICKEL-BASED ALLOYS: "GENERAL" CHEMICAL COMPOSITIONS

(A)	Crowns and fixed partial dentures	
	(1)	Major: nickel, chromium, iron
	(2)	Minor: molybdenum, silicon, manganese, boron, copper
(B)	Metal ceramic (PFM)	
	(1)	Major: nickel, chromium
	(2)	Minor: molybdenum, iron, silicon, manganese, beryllium, boron, aluminum, yttrium, tin
(C)	Removable partial dentures	
	(1)	Major: nickel, chromium
	(2)	Minor: molybdenum, iron, silicon, manganese, beryllium, boron, aluminum, carbon, cobalt, gallium, tin

The current American Dental Association classification has four alloy groups:

- High-noble (gold-platinum-palladium, gold-palladium-silver and gold-palladium)
- Noble (palladium-silver, palladium-copper-gallium, and palladium-gallium)
- Predominantly base metal (nickel-chromium and cobalt-chromium)
- Titanium and titanium alloys.

ALLOY TYPE BY PRINCIPAL THREE ELEMENTS

- Au-Pd-Ag,
- Pd-Ag-Sn,
- Ni-Cr-Be,
- Co-Cr-Mo,
- Ti-Al-V and
- Fe-Ni-Cr.

COMPOSITION OF DENTAL CASTING ALLOYS

Composition Range (weight percent) of traditional type I to IV alloys[21]

Alloy Type	Main Elements	Au	Cu	Ag	Pd	Sn, In, Fe, Zn, Ga
I	High noble (Au base)	83	06	10	0.5	Balance
II	High noble (Au base)	77	07	14	01	Balance
III	High noble (Au base)	75	09	11	3.5	Balance
III	Noble (Au base)	46	08	39	06	Balance
III	Noble (Ag base)			70	25	Balance
IV	High noble (Au base)	56	14	25	04	Balance
IV	Noble (Ag base)	15	14	45	25	Balance

Properties of traditional type I to IV alloys

	Type I	Type II	Type III	Type IV
Hardness	VHN (50 – 90)	VHN (90-120)	VHN (120 – 150)	VHN (150-200)
Tensile Strength	Quite Low 276 MPa or 40,000 PSi	345 MPa	360 MPa	462 MPa
Yield Strength	180 MPa or 26,000 PSi	300 MPa	331 MPa	703 MPa
Linear Casting Shrinkage	1.56% (according to Anusavice)	1.37%	1.42%	2.30%
Elongation	46% William O Brien 18% Anusavice	40.5% William O Brien 10% Anusavice	39.4% William O Brien 5% Anusavice	17% William O Brien 3% Anusavice

Comparison between the Dentally Applied Physical and Mechanical Properties of the Five Classes of Materials for Cast Restorations

Types of Cast Materials	Density gm/cm^3	Melting Range °F	Tensile Strength PSI	Yield Strength 0.2% PSI	Elongation	M.E. PSI	Hardness VHN	Rate of Tarnish and Corrosion
Class I	15-16	1800-2000	80,000	40,000	20-25%	10-12 million	150-170	almost 0%
Class II	11-12	2200	100,000	47,000	20%	12 million	200	2-3%
Class III	10-11	2250	140,000	65,000	15-18%	15 million	250	5-10%
Class IV	8	3500	160,000	80,000	3-11%	30 million	315	0%
Class V	2.7	3300	19,000	—	0%	60 million	350	0%

EFFECTS OF DENTAL CASTING ALLOYS

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Gold & Platinum-group-based Alloys

These are the baseline of cast dental alloys. They have stood the test of time, and any new alloy is compared to them for evaluation. According to the ADA specification # 5, these alloys should have at least 70-75% gold or one of its platinum group substitutes, i.e. platinum, palladium, thodium, osmium, iridium, and ruthenium. Usually, the required 70-75% is primarily gold, with 1-5% platinum and/or palladium. A large portion of the remaining 25-30% is silver, and, to a lesser extent, copper (which plays a vitally important role in hardening the alloy). The remainder consists of traces of zinc and / or indium.[22]

There are four types of these alloys, each having a range of properties and specific composition. Type I, being the most plastic, has the highest content of gold. Type IV is the least deformable with the lowest content of gold. For a single tooth restoration, type III, or, infrequently, type II is used.

Each constituent metal will impart certain properties on the final alloy, according to its percentage composition, its alloying nature and the environment of fabricating and casting. It should be obvious that the product alloy is a very complex one, knowing that gold can alloy in different fashions with each of the previously mentioned metals in forming the alloy.[22]

Palladium and platinum, in addition to disorderly alloying with gold, can produce several ordered alloys with copper with different constituents and effects.

Silver, in addition to substitutional and ordered alloying with gold, can readily alloy with copper, producing several types of alloys, ranging from ordered to eutectic. Silver can also alloy with palladium producing a solid solution alloy.

Copper is very influential in the alloy as it can make a solid solution with gold, palladium, platinum and silver. In the amount of gold and copper used in type III and IV gold alloy, copper and gold solid solution alloys can undergo ordered solid state changes producing different intermetallic compounds that are precipitated within the solid mass. These solid-state changes affect the hardness, plasticity, and strength properties of the solid mass.

Zinc can readily alloy with gold. Indium also alloys with gold, producing some intermetallic compounds that are very influential in shaping the final microstructure of the alloy.

Thus, the properties of the cast solid alloy in the form of a restoration are easily controlled by the extent, nature, and types of the above mentioned, complex combinations. However, gold is primarily responsible for the deformability, strength, characteristic yellow colour and density (19.3 g/cm^2) of the alloy.[19]

Platinum or palladium are responsible for the rigidity, nobility, strength, hardness and whitening of the alloy, if they are present in sufficient amount. Silver mimics gold in its deformability effect, but adversely affects the nobility. A precipitated silver-gold intermetallic compound in a solid state can enter the hardening process like copper-gold compounds.

Copper, in a small percentage, is extremely important in governing the behaviour of the gold in solid state. Although it increases the hardness and strength, it also decreases the nobility of the alloy.

Zinc in small quantities is essential as a deoxidizer during casting and it should be replaced if the alloy is to be recast. Indium in trace amounts is very efficient in refining the grains of the final alloy, i.e., facilitating smaller, comparable sized, evenly distributed grains in the final product. This produces a more predictable behaviour of the restoration. Indium can also act as a scavenger for the alloy during the cast procedure.[23]

Low Gold Alloys – Gold content less than 50%

Although there is no ADA specification for such type of alloys (sometimes called "economy gold alloys"), the gold content is much lower than Class I. Palladium is usually used as a gold substitute. Copper, silver, and zinc again comprise 25-30% of the alloy composition. Some of these alloys contain up to 60% palladium and as little as 5% gold. As can be expected, the final products of casting Class II alloys will be different from those of Class I. Even though gold will still impart the same properties as in Class I alloys, they will be much more limited.[21]

Palladium will be responsible for most of the desirable physical properties, imparting strength, nobility, hardness, and the plasticity of the mass (expect less plasticity the more the palladium). The low density of palladium (as compared to gold) will show up in the final product. Copper reacts with palladium as it does with gold. forming different types and constitutions of alloys with possible solid-state precipitation of certain ordered alloys. This leads to a strengthening-hardening-brittling effect. Silver will form a continuous substitutional solid solution alloy with the palladium and the traces of gold. Zinc has the same reaction and effects as in Class I alloys.[23]

Non-Gold, Palladium based alloys

These are composed mainly of palladium and silver with indium, copper, tin and/or zinc constituting not more than l0%. As in Class II alloys, palladium is the most influential constituent in dictating the properties of the alloy, especially its colour (white), density (very light-average 11 g/cm), strength, hardness, plasticity and nobility. Understandably, the greater the percentage of palladium is, the more will be its influence on the alloy.

Silver, as mentioned before, can make substitutional alloys with palladium but the greater the amount of silver is, the less will be the nobility of the alloy, the more the plasticity, and the less the strength. Copper, as mentioned before, is very influential in the solid state of the alloy as it will react with palladium in the same way it reacts with gold. Besides, it lowers the fusing temperature of the alloy and increases its resistance to tarnish and corrosion. Zinc is used for the same reasons as in the previous two alloys. Indium and tin can alloy with both silver and palladium. In small amounts they can substantially harden the alloy. Also, indium can be a scavenger during melting, as well as serve to increase resistance to tarnish and corrosion.[19]

Nickel-chromium based alloys

These are not new to the profession as they are used extensively for partial dentures. However, their introduction for single tooth restorations is still very controversial. The basic nickel and chromium combination require numerous additions to procure the final alloy. Nickel and chromium can alloy together forming a solid solution which is the base for these alloys. For practical casting procedures, the chromium content should not exceed 30%.

Both metals impart the apparent nobility (which is actually passivity), strength. density (8 g/cm^2), plasticity (very little), hardness and colour of the alloy. Low percentages of molybdenum, tungsten and aluminium are added to increase the strength and hardness of the alloy. as all can precipitate intermetallic compounds with chromium and nickel. Beryllium can be added to lower the fusion temperature and improve castability, but its use is not advised, due to potential health hazards, especially for the technicians fabricating the castings. Gallium is the current substitute for beryllium. Silicone and iron are used in some alloys to increase their strength. They occur in trace amounts, not exceeding 2%. Most of the component metals of these alloys are carbide formers.[22]

Although carbide in trace amounts (0.2-0.4%) is essential for the potential strengthening of the alloys, more than this minimal amount will create a very brittle, dentally unusable alloy. Carbon can make complex carbides with both nickel and chromium (MC, M,C and M,C) [metal (carbide former)]. Boron can also be added in trace amounts at grain boundaries, markedly reducing the solubility of carbon, and thereby stabilizing those carbides.

Boron and silica are also used as deoxidizers and flowing agents to improve the castability of the alloy. So the properties of the final alloy are mostly dependent on the techniques used in fabricating them, as carbon is present in the alloy and surrounding atmosphere and can be incorporated in different ways forming carbides at any stage in the melting and casting of the alloy. Some alloying elements include niobium, which is helpful in open air melting of these alloys. Tin and some rare earth elements can control oxidation of the alloy during porcelain firing. Titanium and cobalt are added for strength.[21]

Castable Mouldable Ceramics

The fabricated product of these materials is a complex ceramic monolithic structure formed of 70 to 90% (by weight) crystalline material, mostly magnesium aluminate spinel and alumina, with one predominant type of space lattice arrangement. This is not the way the material begins. The original components of the material are aluminium trioxide (AlO^3), which forms the maximum percentage of the mass, at least 50%, magnesium oxide (MgO), at least 159%.

The ratio of aluminium trioxide ($Al0^3$) to magnesium oxide is 7 to 1. From 5 to 25% glass frit should be compounded to react with silica to form silicate glasses. All are in a fine particle form and are joined in a workable mass with a silicon polymer. To this mass some lubricant not exceeding 0.5% is added to improve the mouldability. It is usually a stearate or a wax. [23]

The bonding between these ingredients is absolutely secondary. When the material in this form is heated to and above the glass transition temperature of the polymer binder (30-150"), it becomes plastic, deformable and mouldable. It is at this stage that it is introduced into a gypsum mould in a place of a lost wax pattern in the desirable form.

Cooling the material to room temperature (below the glass transition temperature of the silicone polymer binder) will retain the original rigidity of the material. The formed mass is then subjected to thermal treatment for a prolonged period of time (10 to 18 hours), where the alumina and magnesia react together to the full consumption of the magnesia forming the magnesium aluminate spinel ($MgAl_20_3$). Because of the larger volume of the spinel (compared to the forming MgO and Al_2O_3), there will be substantial expansion.[20]

BIOCOMPATIBILITY OF DENTAL CASTING ALLOYS

Importance of Biocompatibility

Corrosion of alloys occurs when elements in the alloy ionize.[24] Thus, the elements that are initially uncharged inside the alloy lose electrons and become positively charged ions as they are released into solution. Corrosion is a chemical property that has consequences for other alloy properties, such as esthetics, strength, and biocompatibility. From a biocompatibility standpoint, the corrosion of an alloy indicates that some of the elements are available to affect the tissues around it.

Corrosion is measured in several ways. It may be measured visually by observing the alloy surface, by many forms of electrochemical tests that measure elemental release indirectly through the flow of the released electrons,[25] or by tests that measure the release of the elements directly by spectroscopic methods.[26] Corrosion phenomena are extremely complex, and depend on a variety of physical and chemical factors. For example, the combination of 2 different alloys in a solder joint may enhance corrosion, or the presence of pits or crevices in a single alloy may enhance corrosion.[27-29] Perhaps the most relevant measure of corrosion from the standpoint of biocompatibility is identifying and quantifying the elements that are released. Corrosion of an alloy is of fundamental importance to its biocompatibility because the release of elements from the alloy is nearly always necessary for adverse biologic effects such as toxicity, allergy, or mutagenicity. The biologic response to released elements depends on which element is released, the quantity released, the duration of exposure to tissues, and other factors.[30] Thus, corrosion is a necessary but not a sufficient condition for adverse biologic effects of dental alloys.

Systemic Toxicity of Casting Alloys

Released metals may not be inside the body. Elements released from a casting alloy into the oral cavity are not inside the body. This fact is true for both local and systemic toxicity. Elements that are released from alloys into the oral cavity may gain access to the inside of the body through the epithelium in the gut, through the gingiva or other oral tissues or, for elements that form vapours such as mercury, through the lungs. Biologic effects of metals depend on route of access into the body. The route by which an element gains access inside the body is critical to its biologic effects.[31]

A good example of the importance of route is the systemic toxicity of palladium ions. If administered orally to mice, palladium ions will have an LD_{50} (lethal dose that will kill 50% of the animals) of 1000 mg/kg.[32] If administered into the peritoneum of mice, the LD_{50} drops to 87 mg/kg.[32] The toxic dose for intravenous administration is an order of magnitude lower yet (approximately 2 mg/kg in rats).[33] Metals entering the body may be wide & distributed. Once inside the body, metal ions can be distributed to many tissues, each harbouring a characteristic amount.[34] Metal ions may be distributed by diffusion through tissues, the lymphatic system, or the bloodstream. Metallic particles (0.5 to 10.0 ~tm) may also be ingested by cells such as macrophages, which are themselves transported by the lymphatics or blood vessels.[35]

The oxidation state and chemical form of the metal will significantly influence its absorption, distribution, retention half-life, and excretion. The distribution of a metallic element is also critical to its ability to cause systemic toxicity. Ultimately, the body generally eliminates metals through the urine, faces, or lungs. The elimination of an element will depend on its route of access into the body. The rate of elimination is unique to each metallic element.[31]

There is little evidence that elements released from casting alloys contribute significantly to the systemic presence of elements in the body. This result is not surprising when the normal daily dietary intake of metals in dental alloys is considered.[37] In most situations, the amounts of elements that are released from dental alloys are tar below those taken in as a part of the diet. For example, the amount of zinc released from a dental alloy (< 0.1 µg/day)[38] is far below that eaten (14,250 µg/day). A survey of the total mass released from casting alloys shows that mass release does not approach the dietary intake. The amount of release from any alloy is directly proportional to the number of castings present in the mouth. However, nickel released from nickel-based prostheses may approach the 400 µg/day daily intake particularly if the nickel-based alloy is subjected to an acidic environmcnt.[37]

Type of alloy	ADA classification	Phases	Average mass released* (µ/cm²/day)
Au-Pt	High noble	M	0.071
Au-Pd	High noble	S	0.005
Pd-Cu-Ga	Noble	M	0.011
Pd-Ag	Noble	M	0.048
Au-Cu-Ag	High noble	S	0.152
Au-Ag-Cu	Noble	S	0.184
Ag-Pd	Noble	M	0.109
Ni-Cr	Predominately base metal	M	0.021

S = Single; *M* = multiple.
*An average dental crown would have 2 to 3 cm^2 of surface area. (Based on 10 mo of study, data adapted from reference 25.)

Release of mass from various dental casting alloys ($\mu g/cm^2/day$)

Systemic toxicity from dental casting alloys has not been demonstrated. There is evidence that released metals can and do gain access to the body, and these metals may be widely distributed. However, no studies have shown that the presence of these metals systemically causes toxicity.[39]

LOCAL TOXICITY

Metal ions can cause local toxicity. In vitro it is clear that, if metal ions are present at high enough concentrations, they will alter or totally disable cellular metabolism. The effect of silver ions on cellular mitochondrial activity is a case in point.[40]

Increased exposure time increases toxicity. Studies such as these have demonstrated that some dental alloys can cause cellular damage. It has also been possible to relate the cellular damage observed in these tests to the release of elements from the alloys into the cell-culture medium.[38]

ALLERGY TO CASTING ALLOYS

An element must be released from an alloy to cause allergy. No study has shown that allergy to alloys can occur without corrosion and release of metallic ions. At least one study has shown that, even in patients with a documented allergy to palladium, placement of palladium in the mouth did not elicit an allergic reaction.[41,42] Presumably, the lack of response was caused by a lack of corrosion of the palladium. This principle further supports the importance of knowing the corrosion properties of an alloy. Metal ions cannot be allergens by themselves. As far as is known, metal ions cannot act as allergens themselves. Rather they act as haptens, binding to resident molecules and altering these molecules such that the body "sees" the complex as foreign. Because of their ability to bind to many types of molecules in the body such as proteins, nucleic acids, or carbohydrates, the potential for many types of allergenic complexes is great. Little is known about the specific metal complexes that cause the allergic response, or whether these complexes are even similar among different allergic persons.[43-44]

The incidence of hypersensitivity with clinical dental products in general appears to be quite low.[45] In one study, only 1 in 400 prosthodontic patients experienced adverse effects to the materials. Of these, 27% were related to base metal and to noble metal alloys. Redness, swelling, pain, and lichenoid reactions were common signs and symptoms of the responders.

Studies indicate that about 15% of the general population is sensitive to nickel, 8% is sensitive to cobalt, and 8% to chromium. Documented allergies have also been reported for mercury, copper, gold, platinum, palladium, tin, and zinc.[46] However, frequencies of these allergies are not well defined. There have been reports of allergic responses to other metals, although they are less well documented. The frequency of hypersensitivity to metal ions differs considerably among the metals. The reasons for these differences are probably related to the frequency of exposure of the population to the metals, the likelihood that the metals are released as ions from alloys, and the biologic interactions of the metal ions with the tissues. For example, the high incidence of nickel allergy is probably a result of the high frequency of exposure through metallic jewellery, the releasing of nickel ions from alloys, and the biologic interactions of nickel ions with the tissues.[47] The population is also commonly exposed to gold jewellery, but the incidence of allergy to gold is rare. This lower incidence probably results from the low levels of gold that tend to be released and may result from the inability of gold ions to interact with tissues in a manner that promotes the allergic response.

MUTAGENICITY AND CARCINOGENICITY OF CASTING ALLOYS

Mutagenicity and carcinogenicity are not the same. Mutagenicity describes an alteration of the basepair sequence of DNA (a mutation). Carcinogenicity means that alterations in the DNA have caused a cell to grow and divide inappropriately. Carcinogenicity results from several mutations. Alloys must release elements for carcinogenicity or mutagenicity to occur. As with allergic responses, metal ions mediate mutagenic and carcinogenic responses.[48]

Element	Form	Mutagenic/carcinogenic status	Other comments
Beryllium			
	Be^0	Carcinogenic	Also beryllium derivatives
	Be^{2+}	Carcinogenic	Also beryllium derivatives
Cadmium			
	Cd^0	Carcinogenic	Also cadmium derivatives
	Cd^{2+}	Carcinogenic	Also cadmium derivatives
Chromium			
	Cr^{3+}	Not mutagenic	Very reactive, kills cells before reaching nucleus
	Cr^{6+}	Carcinogenic	
Cobalt			
	Co^0	Possibly carcinogenic	
	Co^{2+}	Possibly carcinogenic	
Copper			
	Cu^{1+}	Unknown	
	Cu^{2+}	Mutagenic but not carcinogenic	
Gallium	Ga^{3+}	Probably not mutagenic	Data from in vitro studies
Gold		Unknown	Low risk in dental alloys due to very low corrosion, organic, and inorganic forms probably not equivalent
Indium		Unknown	
Iron	Fe^{2+}	Mutagenic but not carcinogenic	High dietary intake
Nickel			
	Ni^0	Possibly carcinogenic	
	Ni_2S_3	Carcinogenic	Nickel subsulfide
	$NiCl_2$	Weakly mutagenic	
	$NiSo_4$	Weakly mutagenic	
Palladium	Pd^{2+}	Limited data, possibly mutagenic	Low risk in dental alloys due to very low corrosion
Platinum		Unknown	Low risk in dental alloys due to very low corrosion, organic, and inorganic forms probably not equivalent
Silver	Ag^{1+}	Limited data, probably not mutagenic	
Tin			
	Sn^{2+}	Mutagenic but not carcinogenic	
	Sn^{4+}	Unknown	
Zinc	Zn^{2+}	Not mutagenic	High daily intake

Even though an alloy may contain a metallic mutagen, the metal cannot act on the DNA if it is not released from the alloy.[48] Therefore, it is improper to state that a metal is mutagenic or carcinogenic per se, because the mutagenic activity will depend on the specific form and oxidation state of the metallic element in question. In dental laboratories, the vapour forms of elements such as beryllium are the most common mutagenic threat. These vapours are created during the casting and finishing of prostheses. Recent in vitro studies on palladium and gallium chloride indicate that the mutagenic potential of these ions is low. Overall, there is no evidence that dental casting alloys cause or contribute to neoplasia in the body. However, it may be prudent for the practitioner to avoid alloys containing elements such as cadmium, cobalt, and beryllium.[39]

MOUTH PREPARATION PRIOR TO CAST RESTORATIONS

CONTROL OF PLAQUE

Due to the vulnerability of the cast/cement/tooth structure junction, patients to receive a cast restoration should exhibit the ability, willingness and practice of control measures for their plaque. As a rule. patients should show a 10% or less plaque index prior to fabricating cast restorations for their teeth, or the result will be a futile restorative attempt.

CONTROL OF CARIES

Understandably. before planning a cast restoration, which may be m0re durable from the physical and mechanical aspects, bat not so from the cariogenic aspect, rampant or uncontrolled carious processes should be halted. Indirect pulp capping and or amalgam-composite resin restorative procedures should be employed until the patient demonstrates the ability to control plaque, and, subsequently, demonstrates little or no incidence of decay recurrence.

CONTROL OF PERIODONTAL PROBLEMS

Although cast restorations can be one of the mechano-therapies for the periodontium affected by periodontal diseases, the very nature of the clinical procedures involved in cast restorations as well as some of the final properties of the restorations themselves may be detrimental to an already pathologically affected periodontium. It is ideal to stat cast restoration fabrication with a sound periodontium, unless, of course, these restorations are part of the periodontal therapy and maintenance. In the latter case, the periodontal disease should be under control. The pockets should be eradicated, bone resorption arrested, defects connected, exposed roots and crown surfaces free from deposits, gingival tissues healed, and apparent clinical crown dimensions stable.[17]

PROPER FOUNDATION

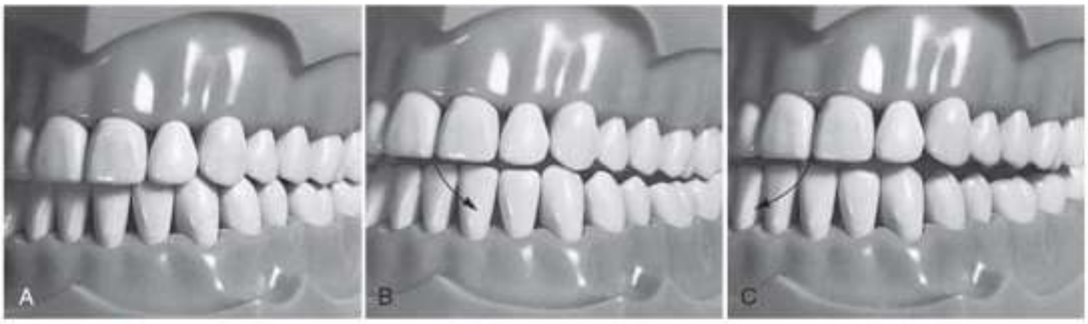
As discussed in the chapter on restoration of badly broken-down teeth, some teeth will need a substructure or a foundation before preparing them for a cast restoration. The need for such a foundation should be diagnosed and proper material and techniques should be employed before preparing the tooth for a cast restoration. Nothing is more frustrating than attempting to build up a tooth in a foundation form after unsuccessfully attempting to prepare the tooth for a cast restoration.

CONTROL OF THE PULPAL CONDITION OF THE TOOTH

Cast restorations are used for teeth with extensive defects, teeth that usually have been previously restored one or more times with amalgam or other materials. The pulp-dentin/root canal complex of these teeth has been subjected to numerous traumas which invariably affects their physiology. In many instances, these teeth, after being subjected to the additional trauma of cast restoration procedures, will undergo irreversible pathologic changes necessitating endodontic therapy. Therefore, A proper preoperative evaluation of the condition of the pulp-dentin/root-canal system is essential. If irreversible pathologic pulpal changes are present, endodontic therapy should be part of the mouth preparation prior to the cast fabrication.

OCCLUSAL EQUILIBRATION

As cast restorations will maintain the tooth shape and dimensions, any premature occluding contacts built into the restoration will create greater and longer standing disturbances in the stomato-gnathic system than if the condition were to remain in natural dentition. That is why prior to preparing teeth for cast restorations, it is vitally important to equilibrate the natural dentition. There must be no interfering or premature contacts and there should be a pattern of a reliable protective mechanism for mandibular disclusion. The pattern of occlusal contacts influences the preparation design, selection of interocclusal records and type of articulator or cast development needed.[9]



A–C, Evaluate occlusal relationships in maximum intercuspation (A) and during mandibular movements (B and C). Be alert for problems with tooth alignment and contact position. Note the amount of posterior separation provided by the guidance of anterior teeth (working side) and articular eminence (nonworking side).

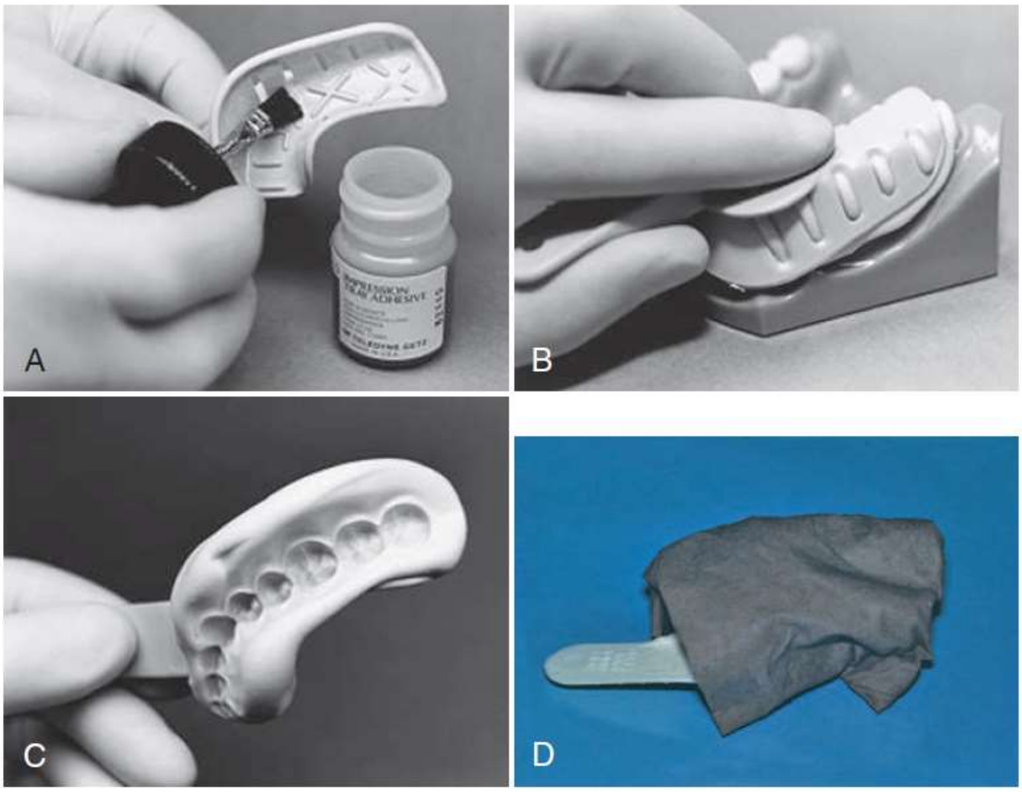
ANAESTHESIA

Local anaesthesia of the tooth to be operated on and of adjacent soft tissue usually is recommended. Anaesthesia in these areas eliminates pain and reduces salivation, resulting in a more pleasant procedure for the patient and the operator.

DIAGNOSTIC WAX-UPS AND TEMPORARY RESTORATIONS

Occasionally, cast restorations are part of the overall therapy to create a physiologically functioning stomato-gnathic system. This may involve certain changes in the anatomy of occluding surfaces, increasing the vertical dimension, or changing the axial contour of the tooth. In these cases, one or both of the following procedures should be performed.

Most temporary restoration techniques require the use of a preoperative impression to reproduce the occlusal, facial, and lingual surfaces of the temporary restoration to the preoperative contours. The technique involves making a preoperative impression with an elastic impression material. Alginate impression materials may be used and are relatively inexpensive. The preoperative impression may be made with a polyvinyl siloxane (PVS) impression material if additional accuracy, stability, and durability are required. If the tooth to be restored has large defects such as a missing cusp, an instrument can be used to carve away impression material in the area of the missing cusp or tooth structure, to simulate the desired form for the temporary restoration. Alternatively, a material such as rope wax can be added to the tooth before the impression in the area of the defect. An impression is typically made using a sectional tray. The tray filled with impression material is seated. After the impression has set, the impression is removed and examined for completeness. Alginate impressions can distort quickly if they are allowed to gain or lose moisture, so the impression is wrapped in wet paper towels to serve as a humidor. Preoperative PVS impressions do not need to be wrapped. The preoperative impression is placed aside for later use in forming the temporary restoration. Full arch study models should be made, and properly mounted on a semi-or fully adjustable articulator. The involved teeth should be reduced, and diagnostic wax-ups made in the desired occlusal shape and relationship. Duplicate stone models are then fabricated to serve as an aid in the construction of both temporary and final restorations.



A, Applying tray adhesive to stock quadrant tray. B, Making preoperative impression. C, Inspecting preoperative impression for completeness. D, When using alginate, wrap the impression with wet paper towels to serve as a humidor.

The teeth are roughly prepared and restored with temporary restorations that create the desired features that will be incorporated in the final cast restorations. These temporary restorations are usually made of reinforced resinous materials Patients should wear these temporaries and be examined periodically, Changes can then be made in the temporaries to achieve the utmost compatibility between the stomato-gnathic system and these restorations. When this is achieved and verified, the teeth arc finally prepared, and cast restorations are fabricated as replicas of the temporaries, which proved to be physiologic and therapeutic to the stomato-gnathic system.[17]

Because of the permanency of cast restorations, it is mandatory to plan the restorative treatment for the entire mouth prior to fabrication of cast restorations. Treatment may include full dentures. partial dentures, fixed bridges, etc. So, it is necessary to know in advance the location of the contemplated cast restoration, so that modifications may be made in the tooth preparation, restoration dimension and shape, etc. to satisfy the required role of the cast restoration in the restorative treatment for the entire stomato-gnathic system.[9]

PRINCIPLES OF TOOTH PREPARATION FOR CAST RESTORATIONS

The preparation of teeth to receive restorations is a complex procedure. Too much or too little tooth structure may be removed from selected areas. The purposes of giving resistance and retention features for intra-coronal restorations are:

- To bring together current concepts to reach conclusions either for present use or still to be researched
- To minimize errors common to cast restorations.

G. V. Black[49] defined the retentive quality of cavities to be such that the restoration will be firmly held in place under masticatory stress. He added that the cavity should also have such resistance form that the restoration will withstand the stress without being dislodged. Rossenstiel[50] pointed out that a preparation with good resistance form will also be retentive, but the reverse will not necessarily be true. A fundamental property of a cast restoration is that it is inserted into the preparation without deformation and that it provides a complete marginal seal. Movement into or out of the cavity implies the existence of an "insertion path." The property of retention indicates the possession of only one insertion path. Mathematically, this means that a restoration is retentive if, and only if, its movement into or out of the preparation is restricted to 1 degree of freedom. In practice two paths of insertion differing in direction by less than 5 degrees would be considered identical; so slightly tapered preparations can be used to overcome the practical difficulties encountered when preparing parallel walls that must be free of undercuts. Rosenstiel[50] defined the "rule of retention" as follows: "Of all the possible preparations of the same outline those which have maximum retention will permit one single way only of moving the restoration into the preparation and will make this way of a maximum length" (Figs. 1 and 2). Thus, in order to be retentive, it is not sufficient that a restoration have several paths of insertion, only one of which is straight: There must be only one path, straight or curved.

Craig et al.[51] described a two-dimensional photo-elastic stress analysis of inlays. The magnitude and direction of tensile and compressive stresses were determined for two-dimensional models of mesial/occlusal/distal (MOD) restorations. Slice and box preparations were compared under the same load at different sites. Shoulder less and shoulder restorations on tilted teeth were also investigated. Some conclusions were:

- Compressive stresses were reduced near the pulpal surface when the load was applied either mesially or distally
- Under similar test conditions compressive stress was relatively higher in teeth tilted away from normal occlusion
- The MOD box preparation with rounded axiopulpal line angles had lower stress concentration in comparable areas than a shoulder less slice preparation with sharp axiopulpal line angles.

Continuing these studies, El-Ebrashi et al[51] studied proximal reduction. The purpose was to investigate the difference between the slice preparation, the box preparation with parallel walls, and the box preparation with walls inclined at 45 degrees. The effects of these geometric variations on the stress distribution in the corresponding restorations were determined. Unfortunately, the study failed to include the slice preparation with proximal boxes. They drew the following conclusions:

- All three designs showed the same stress concentration factor.
- In the slice preparation, tensile stresses may be minimized by reduction of additional tooth structure at the lingual entrant (occluso-proximal) angle. This would increase the bulk of the metal at this critical surface.

- Proximal boxes with parallel walls result in concentration of stress at the junction of the parallel wall with the remainder of the restoration.

Fisher et al[52] reported similar findings. They also used two-dimensional photo-elastic models. The models represented variations of intra-coronal restorations with and without occlusal coverage. The models were loaded both centrally and at three points to represent occlusal contact. These authors found higher concentrations of stress in the inlay preparations, especially on the walls at the isthmus and cervical areas. The most favourable distribution of stress was shown by the onlay preparation with complete occlusal coverage.

Reisbick and Shillingburgs[53] tested the effect of various design features on retention for a MOD onlay. The preparations were machined on a brass die, and castings were cemented with zinc phosphate cement. They tested a basic design of occlusal reduction with mesial and distal slices, to which were added combinations of the occlusal isthmus and proximal boxes. Comparisons of the various features showed that the isthmus did not contribute to retention; the proximal boxes, however, were a significant factor. A concept for auxiliary retention was proposed by Chan and Boyer[54]. They proposed that retention can be increased by placing opposing grooves in the casting and the cavity, perpendicular to the path of withdrawal. After cementation the grooves are occupied with cement. To dislodge the casting bulk, fracture of the cement or dentin must occur. Reliance on the strength of the cement should therefore provide increased retention for casting restorations.

Auxiliary means of retention for cast restorations

- Luting cements
- Grooves
- Slots
- skirts

- Collars
- Pins
- Reverse bevel
- Internal box and external box
- Capping of cusps and marginal ridge
- Posts
- Grossly roughening, irregularising and multiple levelling the surface preparation
- Reciprocal retention
- Capping the occluso-proximo-facial and lingual corners of a preparation
- Pre cementation grooving of the casting and the adjacent tooth surface or walls
- Electrolytic etching of the tooth surface of the casting[60]

CAVITY PREPARATION DESIGNS FOR CAST RESTORATIONS

There are five general designs of tooth preparation to accommodate a cast restoration, namely:

- Inlays
- Onlays
- Cast restorations with surface extensions
- Pin-lays
- Full veneer cast or cast based restorations.

INSTRUMENTATION

The number of carbide burs and diamond stones is restricted, although alternative instruments may be selected to maximize efficiency. All carbide burs and diamond stones were manufactured by Brasseler U.S.A. Company (Savannah, Ga.). The armamentarium includes:

- Fissured carbide bur No. 558L
- Medium flat-end tapered diamond stone No. 845KR
- Fine football diamond stone No. 8368
- Fine flame-shaped diamond stone No. 8862
- Fine flat-end diamond stone No. 8847KR.[55]

TOOTH PREPARATIONS FOR INLAY CAST RESTORATIONS

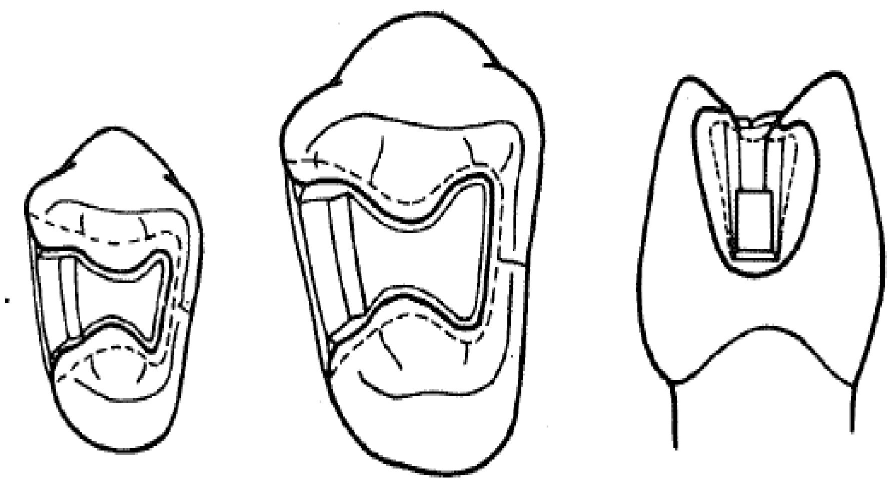
INDICATIONS

These are purely intra-coronal restorations, which have limited indications. These are:

- A cavity's width does not exceed one-third the intercuspal distance.
- Strong, self-resistant cusps remain.
- Indicated teeth have minimal or no occlusal facets and if present, are confined to the occlusal surfaces.
- The tooth is not to be an abutment for a fixed or removable prosthesis.
- Occlusion or occluding surfaces are not to be changed by the restorative procedure.

GENERAL SHAPE

The outline of the occlusal portion of this preparation is dovetailed. The proximal portion is usually boxed in shape.



LOCATION OF MARGINS

In the occlusal portion, the facial, lingual, and sometimes, proximal margins are located on the inclined planes of the corresponding cusps, triangular ridges or the marginal ridges (crossing ridges). This is designed so that the bucco-lingual width of the cavity preparation (distance measured between the buccal and lingual wall proper), especially at the isthmus portion, does not exceed one-third the intercuspal distance. Gingival margins should be accomplished with the bevel and not with the wall proper.

INTERNAL ANATOMY

In the occlusal portion, the facial and lingual walls and sometimes the proximal walls (if marginal ridge is intact), will be formed of two parts:

- Parallelism

  The wall proper, constituting about the pulpal two-thirds of the facial or lingual (proximal) walls, is formed completely of dentin. These walls should taper from each other on the average of 2-50, or be parallel to each other, if necessary. As the axial walls approach parallelism, the restoration can withstand greater displacement from tensile and shearing stresses (Fig. 3).[57] Axial surface reductions, within 2 to 5 degrees of parallelism with the path of withdrawal of the preparation, provide optimal resistance and retention. This convergence facilitates technical procedures and eliminates inadvertent undercuts. Axial surface reduction approaching parallelism produces opposition to displacement that is substantially more effective than any other factor.[58] Thus, in clinical situations (i.e., short teeth), the need for maximal resistance and retention form is obvious. The prepared axial surfaces must be as close to parallel as is clinically feasible.[59]

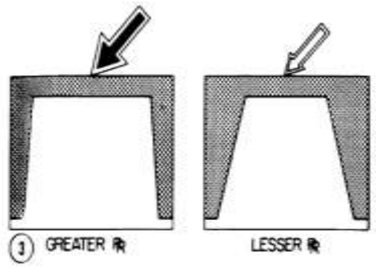


Fig. 3. Retention and resistance increase as length of axial increases.

- In the inlay cavity preparation, the pulpal floor should be flat over most of its extent. Pulpal depth should be 1-1.5 mm from the DEJ.
- In the proximal portion of the inlay cavity preparation, the axial wall should be either flat or slightly rounded in the bucco-lingual direction, and either vertical or slightly divergent (5-100) towards the pulpal floor in the gingiva-occlusal direction. Furthermore, the depth, axially, should ideally be 1-1.5 mm from the DEJ.
- Sometimes it is necessary to impose a third plane in the form of a secondary flare, placed on enamel peripherally. This serves to simplify impressions and wax pattern manipulations and for the other reasons previously mentioned.
- The gingival floor, proximally should be flat in the buccolingual direction, making a slightly obtuse angle with the buccal and lingual walls.
- The junction between the occlusal bevel and the secondary or primary flare proximally, and, the junction between the primary or secondary flares proximally and the gingival bevel should be very rounded and smooth.
- Some of the retention means previously mentioned can be used in this design, in addition to or in lieu of other means, to be described (e.g., facial, lingual and gingival grooves proximally, internal boxes or slots occlusally, capping corners of cusps, etc.).[56]

- Length

As the length of the axial walls of the preparation increases, the resistance and retention form increase (Fig. 4).6 The maximum length of the axial walls is maintained during preparation by removing minimal occlusal or incisal tooth structure to provide adequate bulk of restorative material for occlusion.

Preservation of the inclined planes of the occlusal surfaces and the incisal angles of anterior teeth is the primary factor affecting this objective. The surgical repositioning of the marginal gingiva apically becomes unnecessary when the retention and resistance form can be achieved through the effective application of the primary factors alone or in conjunction with any or all of the secondary factors.[60]

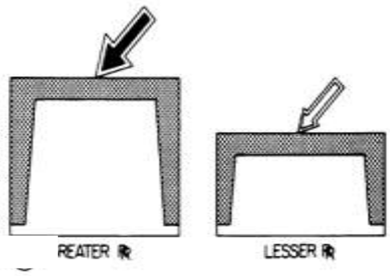


Fig. 4. Resistance and retention increase as length of axial walls increases.

- Surface area

A direct relationship exists between surface area and the retentive-resistance potential of the retainer.[6] The larger the cervical diameter of the tooth, the greater the surface area available to be included in the preparation. Thus, the greater the circumference of the tooth, the greater the potential resistance of the retainer to dislodgment. Also, by increasing circumferential involvement through the addition of axial walls, retention and resistance are increased.[60]

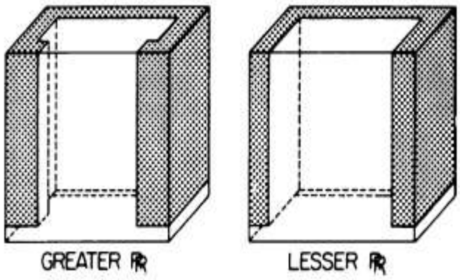


Fig. ıtion and resistance increase as circumferential involv ˙ncreases.

- Preparation features of the circumferential tie

As discussed before, the weakest link in any cast restoration is the tooth/cement/cast joint complex. Special attention should be paid to the marginal peripheries of the preparation, and every effort should be made to design and prepare these marginal peripheries to create the most favourable relationship with the restoring casting and luting cement. This peripheral marginal anatomy of the preparation is called circumferential tie, and it should have the following features. If the margin ends on enamel, enamel walls should fulfil all requirements advocated by Noy for an ideal cavity wall, namely: enamel must be supported by sound dentin; enamel rods forming the cavosurface margin should he continuous with sound dentin, enamel rods forming the cavosurface margin should be covered with the restorative material; and angular cavosurface angles should be trimmed. Cast restorations are the only restorations that can fulfil these requirements, for the simple reason that they are stronger than tooth structure.[17]

For the occlusal and gingival walls in intracoronal cavity preparations the tooth circumferential tic will be in the form of a bevel. which is a plane of a cavity wall or floor directed away from the cavity preparation.[61]

- <u>Occlusal & Gingival Bevels</u>

  According to their shapes and types of tissue involvement there are six types of bevels:

  - Partial Bevel (Fig A)

    This involves part of the enamel wall, not exceeding two thirds of its dimension. This is usually not used in cast restorations, except to trim weak enamel rods from margin peripheries.

  - Short Bevel (Fig B)

    This includes all the enamel wall and up to one-half of the dentinal wall. This is the most frequently used bevel for the first three classes of cast materials. Its major advantage is that it preserves the internal "boxed-up" resistance and retention features of the preparation.

  - Long Bevel (Fig C)

    This includes all of the enamel wall and up to one-half of the dentinal wall. This is the most frequently used bevel for the first three classes of cast materials. Its major advantage is that it preserves the internal "boxed-up" resistance and retention features of the preparation.

  - Full Bevel (Fig D)

    This includes all of the dentinal and enamel walls of the cavity wall or floor. Although it is well reproduced by all four classes of cast alloys, it deprives the preparation of its internal resistance and retention. Its use should be avoided except in cases where it is impossible to use any other form of bevel.

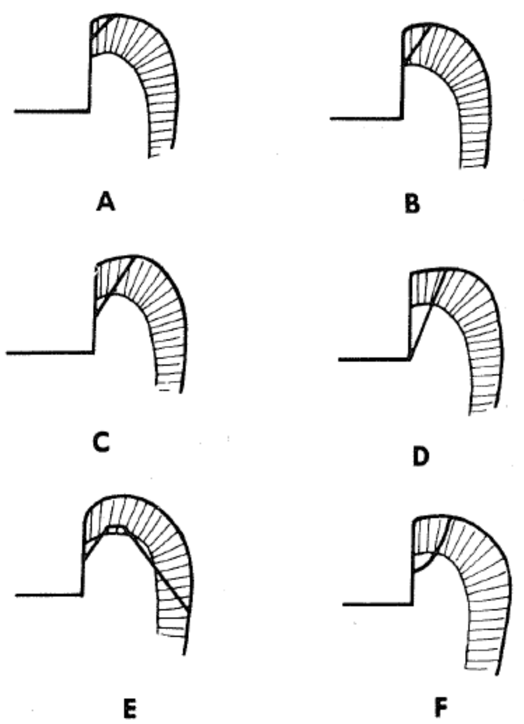
  - Counter Bevel (Fig E)

    When capping cusps to protect and support them, this type of bevel is used, opposite to an axial cavity wall, on the facial or lingual surface of the tooth, and it will have a gingival inclination facially or lingually.

- Hollow ground (concave) bevel (Fig F)

  All of the aforementioned types of bevels are in the form of a flat plane, but any of them, especially the last three, can be prepared in a concave form. This allows more space for cast material bulk, a design feature needed in special preparations to improve material's castability retention and better resistance to stresses. These bevels are ideal for Class IV and V cast materials.

  The bevel portion of the circumferential tie must have a specific angulation relative to the remaining portion of the wall (floor), the long axis of the crown, or a specific landmark Also, they should extend to certain limits. Both bevel angulation and extent are dictated by a myriad of factors that will be discussed and described with the different designs of preparations for cast restorations.[9]



Functions:

Besides satisfying the requirements of Noy for ideal cavity walls, bevels create obtuse angled marginal tooth structure, which is the bulkiest and the strongest configuration of any marginal tooth anatomy and produce an acute-angled marginal cast alloy substance which, in this configuration, will be the most amenable to burnishing for that alloy. This makes it possible to decrease or eliminate the cement line by bringing the cast alloy closer to tooth structure.

Marginal bevels reduce the error factors (space between cast and tooth substances) three or more-fold at the margins, as compared to their internal dimensions, depending on the bevel's angulation. Bevels, being part of the circumferential tie, are one of the major retention forms for a cast restoration, as it is only at the circumferential tie that there is the possibility of a direct retentive frictional component between the casting and the tooth. Some bevels, especially the hollow ground occlusal and counter bevels, are used for the resistance form of the tooth-restoration complex by encompassing cusps. They may also be used to compensate for some of the problems in the castability of alloys, thereby producing better details for retention.

Bevels arc the "flexible extensions of a cavity preparation, allowing the inclusion of surface defects, supplementary grooves, or other areas on the tooth surface. Bevels require minimum tooth involvement, and do not sacrifice the resistance and retention for the restoration. Gingival bevels, for example. can bring the gingival margins to cleansable or protected areas.[17]

- <u>Flares</u>

  There are two types of flares.

  - The primary flare is the conventional and basic part of the circumferential tie facially and lingually for an intracoronal preparation. It is very similar to a long bevel formed of enamel and part of the dentin on the facial or lingual wall. Primary flares always have a specific angulation. i.e. 45° to the inner dentinal wall proper. They may be hollow ground if they are part of the circumferential tie and the preparation is for a non-noble alloy or cast ceramics.

    Functions and indications for primary flares:

    These design features perform the same functions as bevels. In addition. they can bring the facial and lingual margins of a cavity preparation to cleansable- finishable areas, they are indicated for any facial or lingual proximal wall of an intracoronal cavity preparation. If they fulfil the objectives of a preparation circumferential tie they will be the most peripheral part of the proximal preparation; if not, a secondary fare must be placed peripheral to them.

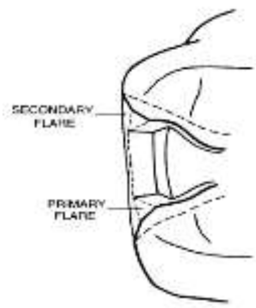
  - The secondary flare is almost always a flat plane superimposed peripherally to a primary flare. Sometimes it is prepared in a hollow ground form to accommodate materials with low castability. Usually it is prepared solely in enamel. but sometimes it may contain some dentin in all or parts of its surfaces. Unlike primary flares, secondary flares may have different angulations, involvement and extent, depending on their function.[9]

Functions and indications for secondary flares:

In addition to performing the functions mentioned for bevels, secondary flares have other specific indications. In very widely extended lesions bucco-lingually, the buccal and lingual tooth structure will be badly thinned: the primary flare will end with acute-angled marginal tooth structure. occasionally with un-supported enamel. A secondary superimposed flare at the correct angulation can create the needed obtuse angulation of the marginal tooth structure. This is done without any sacrifice in the preparation resistance and retention, because the wall proper and primary flare are maintained at their proper locations and angulations.

In very broad contact areas or malposed contact areas, the primary flare will not bring the facial and/or lingual margins to finishable-cleansable areas. However, a secondary flare placed peripheral to that primary flare will accomplish this without changing the fixed 45° angulation of the primary flare necessary for resistance and retention.[61]

- <u>Circumferential Tie Constituents for Extracoronal Preparations</u>

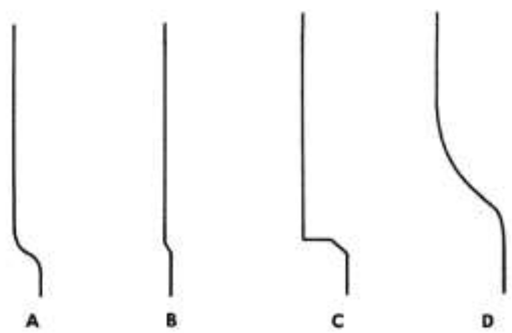


- The chamfer finishing line (Fig A) is the most universally used design for Class I, II, and III cast materials. It assures bulk and definite termination for the preparation marginally, with little tooth involvement (0.5 mm maximal depth). Its only disadvantages are the limited burnishability of the marginal cast alloy and the liability of transitional continuation of a circumferential tie and adjacent bevel ties. Chamfers can be placed gingivally on any involved axial surface provided the area is finishable-cleansable or protected. It is the most practical type of finishing line for subgingival Extracoronal preparations if anatomical considerations preclude gingival floor preparations. It is contraindicated, however, for Class IV suitable for Class IV and V cast materials.

- The knife edge (feather edge) finishing line (Fig B) is the circumferential tie constituent with the least tooth structure involvement. If the margin is on enamel, it involves part of the enamel only. It should only be used to accommodate a very castable- burnishable type of alloy (gold alloys, preferably type 1). Also, it should be located on accessible areas of the tooth surface for proper finishing It is most indicated when minimal axial depth is required for biologic or anatomic purposes. It blends easily and efficiently with bevelled constituents of the tooth circumferential tie. One of its disadvantages is the possibility of indefinite termination for the casting (technical difficulty). There is a chance of the margin not being covered with a casting made of certain alloys due to lack of bulk space to accommodate the less wetting alloys. There is also the possibility of fracturing the alloy part of the circumferential tie during burnishing-finishing-polishing, because of its very thin cross-section and he ease of over-strain-hardening it at that dimension. It is contraindicated for Class II, IV, and V cast materials.[9]

- The bevelled shoulder finishing line (Fig C) is the circumferential tie constituent with the most tooth structure involvement. Ii is exactly like a gingival floor of an intracoronal preparation, but on a smaller scale. It is indicated when a definite gingival floor, with all its components (wall proper and bevel), is needed for resistance-retention purposes. Also, it is indicated when maximum bulk of the cast is needed marginally for materials that are limited in their castability and/or are difficult or impossible to burnish. It blends very easily with bevelled constituents of the circumferential tie. Of all the finishing lines for extracoronal preparation it is the one that maximally reduces marginal problems of internal spacing. It is the ideal design for subgingivally located margins, because of the maximum predictability of the casting termination gingivally. The bevel portion extent and angulation are governed by the same factors governing gingival bevels in intracoronal preparations. It can be used for any class of cast materials. Its bevel portion could be hollow ground as this configuration is most suitable for Class IV and V cast materials.

- The hollow ground (concave) bevel (Fig D) is an exaggerated chamfer or a concave bevelled shoulder. Its tooth involvement is greater than a chamfer and less than a bevelled shoulder. its termination is not as predictable as a bevelled shoulder, but it is mechanically comparable to a bevelled shoulder and superior to a chamfer. Care must be taken to insure there is no residual frail enamel or thinned tooth structure at the periphery of this finishing design. There is good transitional continuity with the bevelled portion of the circumferential tie when using this design as part of the tie. This bevel helps the casting to seat preferentially, aids in stabilizing the casting, and is the ideal finishing line for Class IV and V cast materials. It can be used successfully for materials with limited castability. Circumferential tie constituents for extracoronal tooth preparation perform the same functions as efficiently as bevels and, to some extent, gingival doors in an intracoronal cavity preparation, except for minimizing symptoms of internal spacing marginally. This is especially true with chamfer and hollow ground bevels.[9]

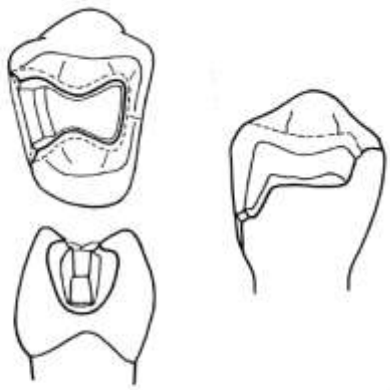


MODIFICATIONS FOR CLASS IV AND CLASS III MATERIALS

Although the general shape, location of margins, and most of the internal anatomy of preparations for cast alloys in the Class IV (and sometimes Class II) category are similar to those to be described for Class I and II alloys, certain specified modifications mast be enumerated:

- Although the preparation will still contain internal boxed portions (buccal, lingual, and proximal "wall proper") occlusally and proximally, the internal line and point angles should be more rounded.

- Surrounding walls should be more parallel to one another, i.e. less taper. This compensates for the loss of retention resulting from the rounding of internal line angles.
- All circumferential tie constituents (primary or secondary flares, occlusal or gingival bevels) should be hollow ground to improve the capability of these alloys to replicate marginal details during casting.
- Tooth preparation should be deeper axially and pulpally to compensate for the loss of retention that results from the relatively poor castability of these alloys.
- Extent and angulation of circumferential tie constituents should be dictated by the same factors that influenced them for Class I and II cast alloy cavity preparations.[17]



MODIFICATIONS FOR CLASS V CAST MATERIALS

Use of these cast materials for cast restorations dictates making the same modifications listed above for Class IV alloys. However, the internal anatomy of cavity preparations for these alloys will include the following additional changes:

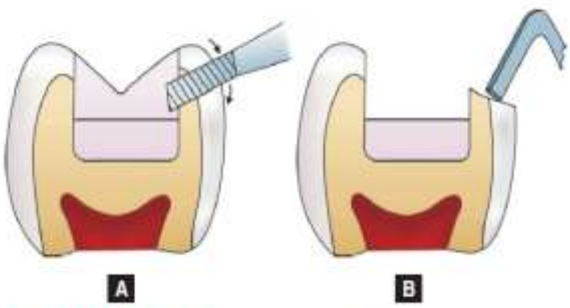
- Flat (at least peripherally) pulpal and axial walls meet surrounding walls in very rounded line angles.

- There is no decisive differentiation between surrounding walls and the circumferential tie. Both can be in the form of concave surrounding walls i.e., exaggerated hollow-ground bevels or very rounded shoulders.
- To improve retention, the preparation should be relatively deeper and with minimal or no taper (compared to that for Class I, II or III alloy). Furthermore, auxiliary retention means should be used heavily.
- The angulation of the marginal termination of the circumferential tie hollow-ground bevel (the actual wall in most cases) is dictated by the same factors that govern the angulation of the bevels und flares in cavity preparations for Class I and II alloys.
- The gingival floor, if its margins end on cementum (dentin) or at the occlusal or middle third of the anatomical crown may be made a flat, one-planed floor completely formed of dentin (after cementum removal), or enamel and dentin terminating in a 90° cavosurface margin. Although this might reduce the negating effect of bevels on internal discrepancies shown marginally, the exactness of the fit of cast ceramics would counteract this problem.[17]

TOOTH PREPARATION FOR ONLAY CAST RESTORATIONS

Cusp capping or onlays are usually indicated where one or more cusps, which are weakened by caries or trauma, are to be covered occlusally with the restorative material. The most suitable restoration is the cast restoration especially when functional cusps are to be capped. It is partly an intracoronal and partly extracoronal type of restoration. As already described, if the cavity involves more than half of the cusp inclines, cuspal coverage is mandatory.[18]

A tapering fissure bur of appropriate size is taken, and the cusp is reduced occlusally by 1.0-1.5 mm. The total height of the wall in the cavity is not included (Figs A and B). The extracoronal margins are placed at the enamel and the design of the margin can be selected depending upon the restorative material. Usually chamfer is indicated with cast gold restoration. Because of the ductility and malleability of the material, the margins can be burnished and adapted to the tooth surface. In case, functional cusps are capped, it is advisable to make contra retention on the opposing tooth surface. For example, if both the buccal cusps of mandibular molars are capped, lingual extension of the cavity is mandatory as is done in lingual complex of class I cavities.[18]



Figs 13.18A and B: **(A)** Cusp being reduced with a bur; **(B)** Margin being refined with a hand instrument

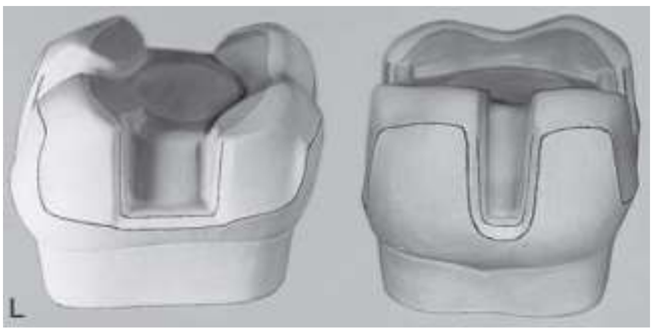
Fig. 13.19: Class II cavity preparation with distolingual cusp reduction - indicated for cast restoration

TOOTH PREPARATIONS FOR CAST RESTORATIONS WITH SURFACE EXTENSIONS

SKIRT PREPARATION

Skirts are thin extensions of the facial or lingual proximal margins of the cast-metal onlay that extend from the primary flare to a termination just past the transitional line angle of the tooth. A skirt extension is a conservative method of improving the retention and resistance forms of the preparation. It is relatively atraumatic to the tooth because it involves removing very little (if any) dentin. Usually the skirt extensions are prepared entirely in enamel.

When the proximal portion of a Class II preparation for an onlay is being prepared and the lingual wall is partially or totally missing, the retention form normally provided by this wall can be developed with a skirt extension of the facial margin. Similarly, if the facial wall is not retentive, a skirt extension of the lingual margin supplies the desired retention form. When the lingual and facial walls of a proximal box are inadequate, skirt extensions on the respective lingual and facial margins can satisfy the retention and resistance form requirements. he addition of properly prepared skirts to three of four-line angles of the tooth virtually eliminates the chance of post restorative fracture of the tooth because the skirting onlay is primarily an extracoronal restoration that encompasses and braces the tooth against forces that might otherwise split the tooth. The skirting onlay is often used successfully for many teeth that exhibit split-tooth syndrome.[43]



The addition of skirt extensions also is recommended when the proximal surface contour and contact are to be extended more than the normal dimension to develop a proximal contact. Extending these proximal margins onto the respective facial and lingual surfaces aids in recontouring the proximal surface to this increased dimension. Also, when improving the occlusal plane of a mesially tilted molar by a cusp-capping onlay, reshaping the mesial surface to a satisfactory contour and contact is facilitated when the mesiofacial and mesiolingual margins are extended generously. Skirting also is recommended when splinting posterior teeth together with onlays. he added retention and resistance forms are desirable because of the increased stress on each unit. Because the facial and lingual proximal margins are extended generously, the ease of soldering the connector and finishing of the proximal margins is increased.

A disadvantage of skirting is that it increases the display of metal on the facial and lingual surfaces of the tooth. For this reason, skirts are not placed on the mesiofacial margin of maxillary premolars and first molars. Skirting the remaining three-line angles of the tooth provides ample retention and resistance forms. he preparation of a skirt is done entirely with the slender, lame-shaped, fine-grit diamond instrument. Skirt preparations follow the completion of the proximal gingival bevel and primary flares. Experienced operators often prepare the skirt extensions while the gingival bevel is placed, however, working from the lingual toward the facial or vice versa. Maintaining the long axis of the instrument parallel to the line of draw, the operator translates the rotating instrument into the tooth to create a definite vertical margin, just beyond the line angle of the tooth, providing at the same time a 140-degree cavosurface enamel angle (40-degree metal angle). The occlusogingival length of this entrance cut varies, depending on the length of the clinical crown and the amount of extracoronal retention and resistance forms desired. Extending into the gingival third of the anatomic crown is usually necessary for an effective resistance form.

In most instances the gingival margin of the skirt extension is occlusal to the position of the gingival bevel of the proximal box.[45]

The operator should use less than half the tip diameter of the lame-shaped diamond instrument to avoid creating a ledge at the gingival margin of the skirt extension. Using high speed and maintaining the long axis of the diamond instrument parallel with the line of draw, the operator translates the instrument from the entrance cut toward the proximal box to blend the skirt into the primary flare and the proximal gingival margin. The operator must ensure that the line angle of the tooth is not over reduced when preparing skirt extensions. If the line angle of the tooth is over reduced, the bracing effect of the skirt is diminished. Holding the diamond instrument at the same angle that was used for preparing the counter bevel, the operator rounds the junction between the skirt and the counter bevel. Any sharp angles that remain after preparation of the skirt need to be rounded slightly because these angles often lead to difficulties in the subsequent steps of the restoration.[9]

COLLAR PREPARATION

To increase the retention and resistance forms when preparing a weakened tooth for a mesioocclusodistal onlay to cap all cusps, a facial or lingual "collar" or both may be provided. To reduce the display of metal, however, the facial surfaces of maxillary premolars and first molars usually are not prepared for a collar. The operator uses a No. 271 carbide bur at high speed parallel to the line of draw to prepare a 0.8-mm–deep shoulder (equivalent to the diameter of the tip end of the bur) around the lingual (or facial) surface to provide for a collar about 2 to 3 mm high occlusogingivally.

To provide for a uniform thickness of metal, the occlusal 1 mm of this reduction should be prepared to follow the original contour of the tooth, and any undesirable sharp line angle formed by the union of the prepared lingual and occlusal surfaces should be rounded. his aspect of the preparation is completed by lightly bevelling the gingival margin of the shoulder with the lame-shaped, fine-grit diamond instrument to achieve a 30-degree metal angle at the margin.[17]

SLOT PREPARATION

Occasionally the use of a slot in dentin is helpful in creating the necessary retention form. An example is the mandibular second molar that has no molar posterior to it and requires a mesioocclusal onlay restoration that caps all the cusps. The distal, facial, and lingual surfaces are free of caries or other injury, and these surfaces also are judged not to be prone to caries. After cusp reduction, the vertical walls of the occlusal step portion of the preparation have been reduced to provide very little retention form. The necessary retention can be achieved by cutting a distal slot. Such a slot is preferred over preparing a box in the distal surface because

- The former is more conserving of the tooth structure and of the strength of the tooth crown
- The linear extent of marginal outline is less.

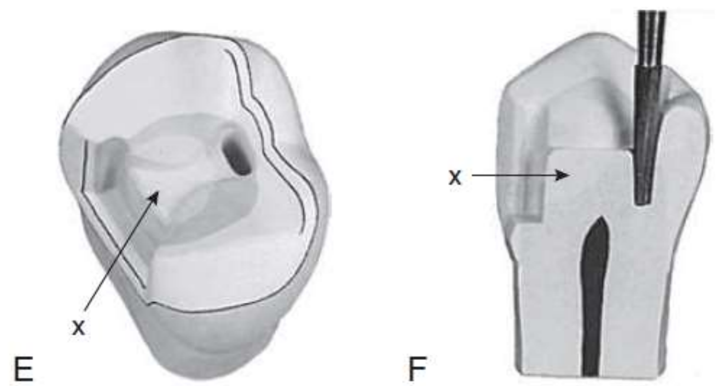
To form this slot, the dentist uses a No. 169L carbide bur with its long axis parallel to the line of draw (this must be reasonably close to a line parallel with the long axis of the tooth). The slot is cut in dentin so that it would pass midway between the pulp and the DEJ if it were to be extended gingivally. The position and direction of the slot thus avert

- The exposure of the pulp
- The removal of the dentin supporting the distal enamel
- The perforation of the distal surface of the tooth at the gingival termination of the slot.

The slot should have the following approximate dimensions:

- The width (diameter) of the bur mesiodistally
- 2 mm faciolingually
- A depth of 2 mm gingival of the normally positioned pulpal wall.

To be effective, the mesial wall of the slot must be in sound dentin; otherwise, the retention form obtained is insufficient. A comparable situation occurs occasionally: he maxillary first premolar requires a distoocclusal onlay restoration to cap the cusps, and the mesial surface is noncarious and deemed not prone to caries. To reduce the display of metal and to conserve the tooth structure, a slot similar to that described in the preceding paragraph (except that it is mesially positioned and 1.5 mm wide faciolingually) may be used for the production of adequate retention. he mesioocclusal marginal outline in this preparation should be distal of the height of the mesial marginal ridge.[9]



CROWNS AND DIFFERENT DESIGNS

FULL VENEER CROWNS:

The full veneer crown, for many years the workhorse of cast restorations, is a restoration for which there are many indications. It can be used where breakdown of tooth structure is severe, to the extent that it has been described in operative dentistry as “the final attempt to preserve a tooth”. It is also extremely useful in those situations where the tooth to be restored needs to be recontoured, since those changes can be blended into the normal contours of the tooth when all of the axial surfaces are involved.

The terms “full crown”, “full cast crown”, and “complete crown” can be used interchangeably with “full veneer crown” to describe a restoration made entirely of cast metal. The declining use of gold and its replacement by other noble or base metals, make “full gold crown”, once a common term, unacceptable as a generic description[12].

Mandibular full veneer crown preparation:

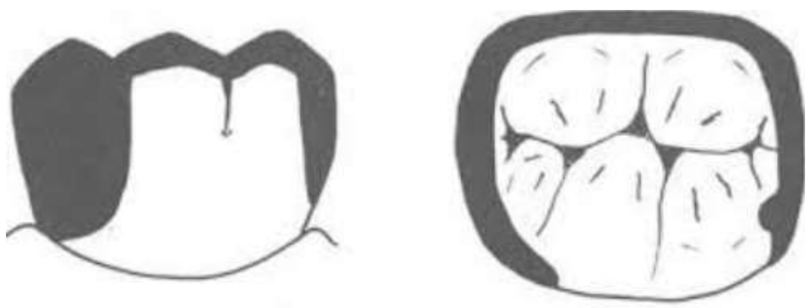
- Planar occlusal reduction is done with round –end tapered diamond and no.171 bur. Use a round-end tapered diamond to make depth orientation grooves on the triangular ridges and in the primary developmental grooves. To achieve a desired occlusal reduction of 1.0 to 1.5 mm, the depth-orientation grooves should be 1.5 mm deep on the functional cusps (maxillary lingual and mandibular facial cusps) and 1.0 mm deep on the nonfunctional cusps (maxillary facial and mandibular lingual cusps). Depth can be gauged from the diameter of the diamond used for the reduction. A 10 mm or 15 mm enamel chisel (depending on the depth of reduction desired) can also be used in the depth-orientation groove to more precisely judge the depth-orientation groove. Occlusal reduction consists of removing the tooth structure remaining between the orientation grooves. It is done in an inclined-plane pattern, which can also be described as following cuspal contours, or preserving general occlusal morphology. By using this form, adequate occlusal reduction is insured without over-reducing the tooth[15].

- Functional cusp bevel: Place depth-orientation grooves for a functional cusp bevel across the facial occlusal line angle of a mandibular premolar or molar, and across the lingual occlusal of a maxillary tooth. The functional cusp bevel should be made with the same round-end tapered diamond used in the preceding steps. It should parallel the inward facing inclines of the cusps of the opposing tooth, at a depth of 1.5 mm, usually forming a 45-degree angle with the axial wall.
- Check the occlusal clearance by having the patient close completely on a strip of red utility wax of approximately the same width as the mesiodistal dimension of the prepared tooth. Examine the imprint of the occlusal surface in the wax. Compare the translucency of the wax over portions of the preparation that have known adequate clearance with the translucency of those cusps and areas of the preparation that are too far lingual to be seen in the mouth. If the imprints of unseen segments are more translucent than those known to have adequate clearance, more reduction is needed in the unseen regions. Although the thickness of the wax can be measured with a thickness gauge, it is very difficult to do because of the softness of the wax[14].
- Facial and lingual axial reduction is done with the torpedo diamond, producing a definite chamfer finish line at the same time. The chamfer is widely preferred for the gingival finish line, because it is distinct and easy to capture in an impression, will make a slip joint between the crown margin and the preparation, and provides space for an adequate thickness of metal in the margin. If the finish line must extend subgingivally, place it supragingivally at first and then lower it after sufficient axial reduction has been accomplished, to permit entry of the diamond tip into the sulcus without excessive laceration of the gingiva.

- The facial axial reduction is carried as far as possible into interproximal embrasures without nicking the adjacent teeth. Lingual axial reduction is done with the same diamond. Because of the lingual inclination of many mandibular molars, the chamfer in this area might be less pronounced. Every effort should be made to produce a chamfer rather than a knife edge to insure sufficient space for the restoration. Inadequate reduction will usually result in over contouring of the restoration. A minimum inclination of the prepared surface in relation to the uncut facial surface of 2.5 to 6.5 degrees is preferred. The lingual axial reduction also extends as far inter proximally as can be easily accomplished.
- An occlusal view of the tooth preparation at this stage reveals isolated areas of intact tooth structure surrounding each proximal contact. The short, thin tapered diamond is placed against the facial surface of the remaining interproximal tooth structure. It is held upright and moved up and down, directing it lingually with light pressure. It may be necessary to use the tip in especially tight areas, or to lay the diamond horizontally along the marginal ridge. Don’t use the tip exclusively for any extended periods of time, because the diamond chips may be stripped from the end of the instrument.
- Once sufficient space has been produced, sweep the short thin diamond back and forth, planing the mesial surface to smoothness. Be careful not to incline the diamond toward the center of the tooth being prepared, or the preparation will be over tapered. Repeat the process on the distal surface with the short, thin, tapered diamond, working it through in short movements first. When you have gained sufficient space, make longer, sweeping strokes to smoothen the surface.
- Now go back over both proximal surfaces with the torpedo diamond. This will produce a chamfer finish line and increase the axial depth of reduction. It will also avoid the common problem of an underprepared proximal surface, which leads to over contouring of the restoration[12].

- A common error may occur at the line angles of the preparation, where the proximal reduction and the facial or lingual axial reduction meet. This is an especially critical areas for inadequate reduction and resultant over contouring of the crown.
- Make a special effort to do more axial reduction in each transition area around a line angle, paying particular attention to creating a smooth, continuous finish line. Care is taken not to incline the torpedo diamond while doing this, or the angles of the preparation will be over tapered.
- Go over the axial walls with the torpedo bur, making sure that you also retouch the chamfer to produce a crisp, distinct finish line. Special care taken to round off the angles of the preparation and produce a smooth, continuous chamfer in this area of the preparation, too.
- A seating groove is placed on the axial surface with a large non-dentate tapered fissure bur. The groove should be cut to the full diameter of the bur, and it should extend gingivally to a point just 0.5 mm above the chamfer. This groove primarily helps to guide the crown into place during cementation. A second groove can be added elsewhere on the preparation, which, if not reproduced in the final restoration, will be an excellent cement escape vent that will permit more complete seating of the crown[15].

MAXILLARY POSTERIOR THREE-QUARTER CROWNS



The partial veneer crown represents a philosophy of practice as much as it does a form of treatment. It is generally a more conservative restoration requiring less destruction of tooth structure than most. Its use is based on the simple tenet that sound tooth structure should not be needlessly removed.

In addition to preserving sound tooth structure, the partial veneer crown permits the accuracy of fit to be evaluated at exposed margins. Cement can escape more easily, allowing more complete seating. Finally, the uncut wall serves as a guide in reproducing, natural contours in the restoration.

Partial veneer crowns are indicated in those situations where there is an intact facial surface, minimal caries, average or greater tooth length, and good hygiene. They have been demonstrated to have less retention and resistance than full veneer restorations, and therefore should be restricted to use in those situations where less than maximum retention will suffice. This type of crown can be used very successfully as a retainer for short-span bridges[13].

Maxillary posterior three-quarter crowns preparation:

- It can be very helpful for the novice to have some type of index with which to judge the reduction for the preparation. To make one, adapt one-half scoop of silicone putty over the tooth to be prepared plus one or two adjacent teeth. This can be done in the patient's mouth while waiting for anesthesia, or it can be prepared in advance on a lubricated diagnostic cast. Cut the index in half in the midsagittal plane of the tooth being prepared. Seat the distal half in the mouth to check for adaptation of the index to the unprepared tooth under it.
- Begin occlusal reduction with round-end tapered diamond and no.171 bur by making depth orientation cuts on the triangular ridges and in the major developmental grooves of the occlusal surface. The grooves should be cut to

the full diameter of the tip of the diamond, which is approximately 1.0 mm. The round-end tapered diamond used for this purpose should measure 1.6 mm at the shank end, with a diameter of 1.3 at its midpoint. The diamond will need to be buried in tooth structure to its full diameter near the tip of the lingual (functional) cusp as well. This will produce occlusal reduction in the recommended range of 1.0 to 1.5 mm, with 1.5 mm on the function cusp. The depth-orientation grooves must extend through the occluso facial line angle, but to minimize the display of metal at the occlusal margin in the restoration, the cuts will be only 0.5 mm deep at the line angle. Proceed with the occlusal reduction by removing the tooth structure remaining between the depth-orientation grooves with the round-end tapered diamond. Reduction will be 1.5 mm on the functional cusps (the lingual cusps on maxillary teeth) and 1.0 mm on the non-functional cusp (here, the facial)[12].

- Begin the functional cusp bevel with round-end tapered diamond and no.171 bur, bevel by placing three to five depth-orientation grooves approximately 1.5 mm deep on the lingual incline of the maxillary lingual cusp. Hold the diamond at an angle of approximately 45 degrees to the long axis to the preparation. The grooves will fade out at their apical ends.
- Complete the functional cusp bevel by removing the tooth structure remaining between the grooves. The bevel should extend from the central groove on the proximal surface around to the central groove on the other proximal surface. This feature provides space for the necessary bulk of metal on the outward facing incline of the functional cusp bevel to match the space on the inward facing incline, which is provided by the occlusal reduction.
- Place the midsagittal index on the teeth to check the clearance. Notice that it is greatest on the lingual cusp and becomes progressively less near the facial cusp tip.
- Plane the occlusal reduction and functional cusp bevel smooth with a no. 171 bur.

- Begin the lingual axial reduction with the torpedo diamond. Care is taken not to over-incline the lingual wall. Overinclining lingual walls is a common error, since those of maxillary molars, and especially premolars, have natural facial inclinations. Do not be concerned about having inadequate reduction in the occlusal one-third of the lingual wall if the lingual wall is kept upright. The functional cusp bevel has provided the needed space in that area[14].
- When preparing a tooth adjacent to an edentulous space, it is possible to continue from the lingual surface around the line angle and onto the proximal surface with the same torpedo diamond.
- As the axial reduction is done, a chamfer finish line is formed. This also serves as a guide to producing adequate axial reduction. The diamond must cut into tooth structure so that the instrument tip is coincident with the finish line. This ensures the removal of an amount of tooth structure at the finish line that is equal to one-half the diameter of the diamond, or 0.5 mm. It becomes progressively greater toward the occlusal surface. Make the transition from lingual to proximal surface as smooth and continuous as possible, with no sharp angles in the axial reduction nor notches in the chamfer.
- Begin the axial reduction where there is an adjacent tooth with the short-needle diamond. This type of diamond is probably most effective in this area if it is used with an up and down “sawing” motion. Continue toward the facial surface until contact with the adjacent tooth is barely broken. Where a cosmetic result is important, as it is here on the mesial surface of a maxillary first premolar, make no cuts with this instrument from the facial aspect. Overextension and an unattractive display of metal will result.
- Under extension of the proximal reduction in a facial direction can result in shortened grooves. Inadequate extension in a gingival direction on the proximal surface opposite from the pontic can lead to premature failure of a fixed bridge because of poor retention and resistance. It is important to concentrate on keeping the finish line at the same level apically throughout its

entire length, since the gingivo-facial angle has been identified as the most likely area of the three-quarter crown margin to fail[15].

- Once enough maneuvering space has been obtained with the needle diamond, a larger instrument capable of producing a chamfer finish line, as well as axial reduction, can be used. It may be necessary to use the flame diamond as an intermediate instrument before proceeding to the torpedo diamond. Although both of them have the same diameter in the body of the diamond, the flame has a longer, thinner tip that facilitates its use where there is minimal proximal clearance. The reduction is completed with a torpedo diamond to produce a good chamfer on the proximal surface.
- Go over all the axial surfaces and the entire length of the chamfer with a torpedo shaped 12-fluted carbide finishing bur
- Proximal grooves are done with no. 171 bur. Alignment and position are important aspects of groove placement. They have been described as forming a “lingual hook” or being directed to the opposite lingual corner of the tooth. **Tjan** and associates recommend the groove be cut along a line parallel with a line tangent to the outermost curvature of the tooth. Before attempting to start the grooves, draw the outline of the grooves on the occlusal surface of the preparation with a sharp pencil. The grooves should be placed as far facially as possible without undermining the facial surface. On a posterior tooth, grooves should parallel the long axis of the tooth.
- Begin the mesial groove first by cutting a “template” in the occlusal surface with the no. 170 bur. This should follow the exact outline traced with the pencil previously and should be 1.0 mm or less in depth. The final groove will be the size of a no. 171 bur, but better results will be attained by a novice if a smaller bur is used, since it allows adjustments in direction without overcutting the groove. Continue to extend the mesial groove farther apically. The distance will depend on the skill and confidence of the operator. It can be

done 0.5 mm at a time, or in 2.0-mm increments by the operator who has a better sense of what he or she is trying to accomplish[13].

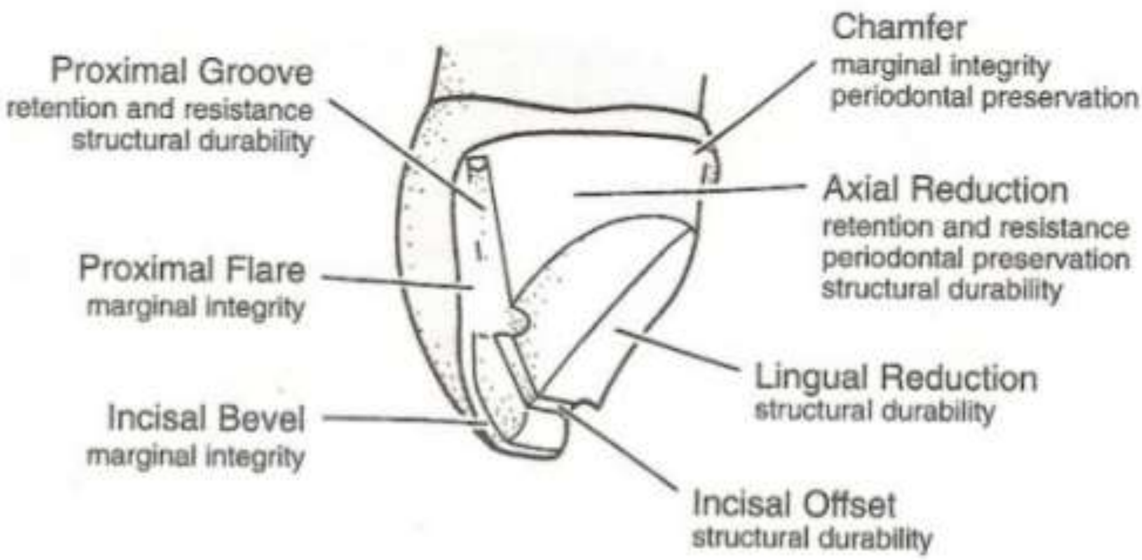
- The groove is finally extended to its full length, as far gingivally as possible, ending about 0.5 mm above the chamfer finish line. It should form a definite step, rather than fading out. Although V-shaped grooves were once widely used, they provide only 68% of the retention and 57% of the resistance of rounded or concave grooves. Grooves must be placed into the tooth at least to the full diameter of the bur used to prepare them. Since one of the groove's functions is to provide resistance to lingual tipping, it is important that it have a definite lingual wall. To prevent undermining facial enamel, and to avoid sharp unsupported "wings" of tooth structure lingual to the groove, the groove's direction towards the middle of the tooth should be at right angles to the outer surface of the tooth in the area where the groove is located.
- The distal groove is cut so that it parallels the mesial groove. It may be helpful to the novice to place a cut-off tapered fissure bur in the mesial groove to provide an easily seen indicator of that groove's direction. If the distal groove is adjacent to an edentulous space as seen in this example, it should not be necessary to cut it in small increments[16].
- Proximal flares: flame diamond and flame bur is used. The facial flare is cut from the groove outward to prevent overextension. It may not be possible to use any more than the tip of the flame diamond if the facial extension of the finish line is being kept conservative. The flare should be extended far enough to be reached by explorer and toothbrush, but not so far as to cause a noticeable display of metal. The actual distance will vary from tooth to tooth depending on the relative priority given to esthetics and cleansability. The flare is a flat geometric plane which is cut equally at the expense of the facial wall of the groove and the outer surface of the tooth.
- If a flame diamond is used for creating the flare, complete the instrumentation of that flare with a flame-shaped carbide bur with the same configuration and

1.0 mm diameter as the flame diamond. Use crisp, short strokes of the handpiece and bur in one direction only. Moving the bur back and forth is likely to round over the finish line.

- In those areas where limiting the facial extension is critical for esthetic reasons, the flare can be formed with a just-sharpened, wide enamel chisel (1.5 to 2.0 mm).
- Where access is good, a medium-grit sandpaper disk can be used to shape the flare. While this method can produce a highly desirable flat plane for the flare, it can result in a blurred or rounded finish line if the disk is used after the abrasive has worn off. Be sure to mask the lip and cheek with the fingers of the left hand to prevent injury to the patient[12].
- Begin the occlusal offset with the end of a no. 171 bur. The offset is a 1.0 mm-wide ledge or flat "terrace" on the lingual incline of the facial cusp. It connects the grooves and stays a uniform distance away from the occluso facial finish line, assuming the shape of an inverted V. This feature plays a major role in casting rigidity by tying together the proximal grooves to form a reinforcing staple.
- Go over the occlusal offset with a no. 957 end-cutting bur. This will smooth the offset, insuring that it will be a flat ledge and not a V-shaped groove. Use a no. 170 bur to round over the angle formed between the upright wall of the offset and the lingual slope of the facial cusp. The same bur can also be used to round any sharp corners between the lingual inclines of the facial cusp and the proximal flares.
- Place a narrow occlusal finish bevel along the occluso facial line angle, taking care to keep it perpendicular to the path of insertion. The bevel should be no more than 0.5 mm wide. Carry the bevel around the angle onto each proximal flare, keeping the outer edge of the bevel continuous with the outer edge of the flares. The bevel, both flares, and the chamfer should connect smoothly to form one continuous finish line without sharp angles[14].

- The silicone putty index is placed over the preparation to demonstrate the depth and form of reduction, as well as the location and relative size of features such as the occlusofacial bevel, the occlusal offset, and the functional cusp bevel.
- A common variation of the three-quarter crown preparation, employed when caries or previous restorations are present on the proximal surfaces, is one in which boxes are substituted for grooves. The three-quarter crowns with boxes is more retentive than the classic design with two grooves. However, boxes are very destructive of tooth structure, so their use can be justified only when tooth structure has already been destroyed by caries or previous restorations. The box is also used to accommodate nonrigid connectors. A less destructive alternative for augmenting retention and resistance is a three-quarter crown preparation utilizing two grooves on each proximal surface. There is no significant difference between the retention afforded by the four grooves and that available from two boxes[15].

ANTERIOR THREE-QUARTER CROWNS



Like its posterior counterpart, the anterior three-quarter crown is more likely to exhibit improved marginal integrity over a full-coverage restoration because it is open to visual inspection**. Christensen** demonstrated that clinicians are much more demanding in their assessment of visible margins than they are of those which can be evaluated by tactile sensation alone. In addition, the margins of a cemented partial veneer crown are likely to fit well. A full veneer crown acts as a closed hydraulic chamber during cementation, while the open-faced partial veneer crown will not confine the cement to produce the pressure that will prevent complete seating during cementation[12].

Maxillary canine three-quarter crown preparation:

- Before starting the preparation for a three-quarter crown, adapt one-half scoop of condensation-reaction silicone putty on the facial and lingual aspects of the tooth to be prepared and one tooth distal to it. A midsagittal index is very helpful in judging lingual reduction. Make it by cutting the index into mesial and distal segments and aligning the cut with the midline of the tooth from facio-cervical to facio-incisal to linguo-cervical. A horizontal cut is made in the putty at the inciso-gingival midpoint of the tooth to be prepared.
- Before beginning the lingual reduction, make atleast four depth-orientation cuts on the lingual surface to ensure that an adequate amount of tooth structure will be removed. Use a small round diamond with a head 1.4 mm larger in diameter than the shaft of the instrument. When buried in the enamel to the shaft, the depth of the cut will be approximately 0.7 mm. Use the small round-edged diamond wheel to create a concave surface over the lingual surface of the tooth incisal to the cingulum. A slight ridge is left on a maxillary canine, resulting in two concave depressions on the lingual surface. The lingual surfaces of incisors and mandibular canines are uninterrupted. The reduction should be made to the depth of the orientation cuts and should remove all tooth

structure remaining between them. Avoid cutting excessive tooth structure from the vertical wall of the cingulum[14].

- Make depth orientation cuts on the incisal edge. They should barely break through the facio-incisal line angle. Toward the junction between the incisal edge and the lingual surface, the depth orientation grooves should be about 0.7 mm deep. The actual incisal reduction, which parallels the inclination of the uncut incisal edge, is made with the small round-edged wheel diamond. On a canine tooth this reduction follows the natural mesial and distal inclines of the incisal edge. On an incisor the incisal reduction will be in a straight line.
- Begin the reduction of the vertical wall of the cingulum with the torpedo diamond, creating a definite chamfer finish line. Concentrate on keeping the diamond parallel with the incisal two-thirds of the tooth, which will ultimately become the path of insertion for the preparation. In conjunction with the grooves, which will be added shortly, this vertical lingual wall plays an essential role in restoration retention. If the cingulum is short, it may be necessary to make a beveled shoulder finish line on the lingual surface, in order to move the wall farther into the center of the tooth where it will be longer. To compensate for a grossly insufficient lingual wall, a pin may be added. **Lorely and Meyers** found that a cingulum pin increased the retention of an anterior three-quarter crown by 31%. The cingulum pin should be placed halfway between the outer surface of the tooth and the pulp. **Lorey et al** and **Dilts et al** found that cemented pins are most retentive when placed to a depth of 0.4 mm.
- On the proximal surface adjacent to any edentulous spaces, the axial reduction is extended with the same torpedo diamond used on the lingual surface. Bring it facially to the line angle in most circumstances.
- On the axial surface adjacent to other teeth, use the long needle diamond to produce the initial reduction. Take care to neither nick the adjacent tooth, nor lean the instrument too far over to the center of the tooth being prepared. Do

not be overly concerned with the smoothness or roughness of the prepared surface or the gingival finish line at this time. Once a little maneuvering space has been achieved, the axial surface can be smoothed.

- Only by extending the diamond facially and gingivally, while simultaneously caring the axial reduction farther into the center of the tooth, can the correct extension be achieved at the facio-gingival angle of the preparation.
- Extension in a facial direction should just barely break contact with the adjacent tooth. The preparation must be instrumented from the lingual to avoid overextension. More extension is permissible on the distal of a canine than anywhere else in the anterior portion of the mouth, because the distal aspect of maxillary canines is not visible in a normal, “conversational” view in most patients[16].
- Once space has been created with the long needle diamond, it is possible to introduce the flame diamond into the interproximal area without binding between the tooth preparation wall and the proximal surface of the adjacent tooth. After instrumenting the proximal surface with the flame diamond, switch to the torpedo diamond to insure a definite chamfer finish line interproximally.
- Now use the torpedo carbide bur to create a smooth, definite finish along the entire gingival extension of the preparation.
- To facilitate proper placement of the grooves, it is a good idea to draw their outline on the lingual incisal area of the preparation. Begin the first groove, usually on the mesial surface, with a shallow “template”. This is cut with a no. 170 bur to a depth of 1.0 mm, following exactly the outline penciled on the tooth. The groove should progress gingivally in small increments until it reaches its full length. Although the final groove will be the size of a no. 170 bur, the inexperienced operator would do well to use a no. 169L bur for the initial placement. This allows some adjustment of grooves direction without overcutting the groove. To assure maximum retention, the proximal grooves

must meet several criteria. Unlike the grooves in the posterior three-quarter crown, which parallel the long axis of the tooth, the grooves of the three-quarter crown preparation for an anterior tooth must parallel the incisal one-half to two-thirds of the facial surface. This slight lingual inclination enables a much longer groove to be made. It also decreases the likelihood of overcutting the facio-incisal corners, which would result in an unsightly display of metal[14].

Enhancement of retention:

For maximum effectiveness, the proximal grooves must be distinct, be as nearly parallel as possible, and have definite gingival seats. These grooves, which replace the facial surface of the preparation, provide a "lock" to the tooth. The locking effect of the grooves provides resistance to torquing and is accomplished by forming a definite lingual wall in the groove. This form has been described as a "lingual hook". It is made by directing the upright bur in a diagonal direction toward the opposite corner of the tooth.

The grooves should be placed as far facially as possible. This facial placement will result in the longest possible groove, and it will improve marginal integrity by allowing space for a bulk of metal near the acute edge of the margin.

Occasionally, boxes will be substituted for grooves. This is the best way of handling existing restorations or caries. Well-defined narrow boxes will also increase the retention of the preparation. However, the boxes must remain narrow to preserve resistance form, since the lingual wall of the box becomes shorter as it is moved lingually[12].

- When the groove has been extended to its full length, evaluate its direction and size. Place the bur back in the groove, and then move the handpiece facially, keeping your wrist rigid to prevent any change in the bur's angulation.

- Position the bur against the uncut proximal surface and cut the second groove. Again, the best results are obtained by cutting the grooves in increments. Refer back to the inclination of the first groove frequently. Sometimes it is helpful, especially in laboratory exercises, to secure a tapered fissure bur in the first groove with utility wax. It will serve as a benchmark against which the direction of the second groove can be checked.
- Use the flame diamond to create the flare on the facial aspect of the groove. The flare is a flat plane which is wider at the incisal that it is at the gingival end. The side of the entire instrument can be used adjacent to an edentulous space such as shown here. Where access is restricted interproximally, the thin tip of the flame diamond is used to start the flare at its gingival end. Then the diamond is brought up the line angle formed by the facial wall of the groove and the outside of the tooth[15].
- Follow up with the flame carbide bur to obtain a smooth flare and a sharp, definite finish line. Again, as with the flame diamond, it may be possible to use only the tip of this instrument on the flare adjacent to another teeth.
- In the anterior region of the mouth it is possible to use a sandpaper disk to form the flare. This technique is more certain to create a flat surface on the flare. It is possible that it may cause rounding of the actual finish line, though, and it does represent some hazard to the patient unless caution is exercised.
- Where an absolute minimal extension of the flare is desired, most commonly the case on incisors, use either a 15 mm or 20 mm wide enamel chisel (either a hatchet, a binangle chisel). Esthetically, the distal finish line of a canine is the least critical area of the anterior segment of the arch.
- The incisal offset, cut with the no. 171 bur, stays a uniform distance from the incisal edge. It is placed as close to the incisal edge as possible without undermining the enamel, providing space for the bulk of metal necessary for

the integrity of the margin of gold overlying the narrow finishing bevel placed on the incisal edge. On a canine the incisal offset forms an inverted V, but on an incisor, it follows a straight line across the incisal edge. Although some operators omit it, the incisal offset does enhance both the structural durability and the marginal integrity; it reinforces the restoration in a fragile area and completes the reinforcing staple or "truss"[13].

- Round over the sharp angle between the vertical wall of the offset and the incisal reduction with a no. 171 bur. This allows space for a little more metal near the margin, and it removes sharp angles that might prevent the casting from seating. Use the same non-dentate tapered fissure bur to round over the angle between the incisal reduction and each flare.
- The offset can be instrumented with a 1.0 mm wide enamel chisel, such as the binangle chisel. If finishing is needed on the offset, it is more often accomplished with a no. 957 end-cutting bur.
- Hold the no. 170 bur at right angles to the path of insertion of the preparation and move it lightly from one incisoproximal angle to the other, creating a finishing bevel about 0.5 mm wide. A flame diamond and bur can be used for the same purpose, but the final bevel should be done with a carbide bur to produce the sharpest finish line. Do not drop the handpiece over to the faciogingival, or this will create a "reverse bevel". An unnecessary display of metal would result[12].
- The wrap-around horizontal-cut index gives a clear view of the amount of lingual reduction accomplished in the middle of the preparation incisogingivally. The vertically cut midsagittal index shows the quantity of lingual reduction done in the middle of the preparation mesiodistally.
- A common variation of the anterior three-quarter utilizes a cingulum pin, to enhance retention in a tooth with little or no cingulum, or for a tooth which will serve as an abutment for a fixed bridge[16].

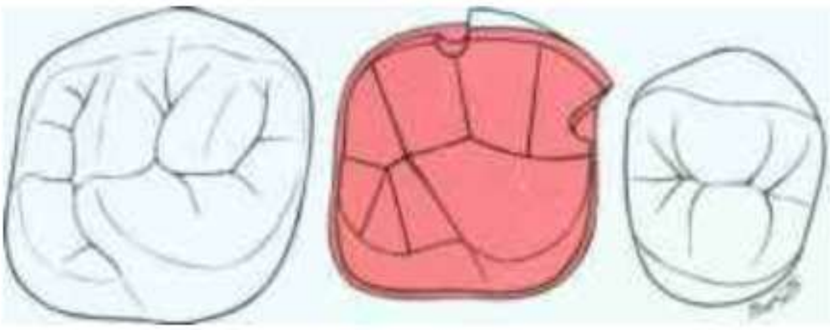
SEVEN-EIGHTHS CROWNS

The seven-eighths crown is an especially useful variation of the partial veneer crown that can be employed successfully on many maxillary and mandibular premolars and molars. It is suitable for use on teeth having an intact mesiofacial cusp but restoration, caries, decalcification, or fracture of the distofacial cusp. If conservatively prepared, it is an acceptably esthetic restoration, even on an occasional maxillary premolar.

The classic indication for its use is the maxillary first molar, in which a large distal or distofacial restoration precludes the use of three-quarter crown. If the preparation is carefully and skillfully done, the contours of the mesiofacial cusp will obscure the view of metal covering the distofacial cusp. This advantage, coupled with the fact that no porcelain-fused-to-metal restoration will duplicate the surface smoothness of unprepared enamel, makes this an excellent restoration for many patients.

Because the seven-eighths crown covers the distofacial surface of the tooth, it has significantly better retention and resistance than does the three-quarter crown. The seven-eighths crown should be considered for a bridge retainer on an abutment whose short crown length might make the retention or resistance of a three-quarter crown insufficient[12]

Preparation of Seven-Eighths Crown on Maxillary Molar



- Depth-orientation grooves are placed to a depth of 1.5 mm on the triangular ridges and in the major developmental grooves of the lingual cusps with the round-end tapered diamond. The grooves on the facial cusps are 1.0 mm deep in most areas, but they are made shallower as they approach the occlusofacial line angle of the mesiofacial cusp. The grooves on the distofacial cusp are the full diameter of the diamond at the line angle, while those on the mesial cusp make a less prominent indentation in the line angle.
- The actual occlusal reduction consists of removing the tooth structure remaining between the orientation grooves and smoothing the reduced surfaces to inclined planes. The reduction is 1.0 mm on the nonfunctional cusps, with slightly less near the occlusofacial line angle of the mesiofacial cusp. The functional cusp reduction is approximately 1.5 mm.
- Depth-orientation grooves are also made on the lingual inclines of the lingual cusps with the round-end tapered diamond. The diamond is orientated so that it parallels the inclination of the opposing cusps.
- The functional cusp bevel is produced by removing the “islands” of tooth structure isolated by the orientation grooves. It extends around to the central groove, becoming narrower as it does. Care is taken that there is ample reduction in the vicinity of the distolingual groove, or the thickness of the wax pattern will be compromised in this area. The occlusal reduction and functional cusp bevels are finished with a no. 171 bur, to remove rough areas that could impede the complete seating of the casting[15].
- Lingual axial reduction is accomplished with a parallel-sided torpedo diamond. The tip is kept surpragingival during the initial stages of reduction and is dropped gingivally, if required, as a final step. The instrument tip, with its curved point, will produce a chamfer finish line.
- When the tooth being prepared is a bridge abutment extend the axial reduction onto the mesial surface with the torpedo diamond. It should terminate in the vicinity of the mesiofacial line angle. Care is taken to keep the diamond

upright and parallel with the path of insertion of the preparation. There is a tendency to lean it mesially to place the entire length of the diamond in contact with the mesial wall starting with the very first stroke to the instrument. This should be avoided, because it will produce an undercut mesial wall.

- Perform the distofacial axial reduction with the same torpedo diamond. This reduction should end about 1.0 mm mesial to the facial groove. Extend it as far as possible into the inter-proximal area without nicking the adjacent tooth.
- An occlusal view of the tooth preparation at this point reveals an intact distal contact area, with facial and lingual axial reduction ending just short of contact with the adjacent tooth. The remaining interproximal tooth structure is removed with the tip of the short-needle diamond. Enter the facial or lingual embrasure with the instrument parallel with the path of insertion of the preparation, moving the instrument occlusally and gingivally as it is pushed through the contact area[16].
- It may prove helpful to lay the diamond horizontally, parallel with the distal surface of the tooth being prepared. Then draw the instrument across the marginal ridge. Once there is space for the diamond to enter the interproximal area, pass it lightly faciolingually, smoothing the distal wall and finish line as you do.
- If the contact extends very far gingivally, as it sometimes does between maxillary molars, it may be necessary to employ the flame diamond before the torpedo diamond. Although both instruments have the same diameter in the body, the flame diamond has a longer, thinner tip, which can be used to gain access near the interdental papilla.
- When there is sufficient space to permit it, change to the torpedo diamond to complete the axial reduction. The corners are rounded between the proximal surfaces and the facial and lingual surfaces. There is a tendency to leave them “squared off”, and inadequate reduction at the angels of the tooth is one of the

leading causes of over contouring in cast restorations. The chamfer should be smooth and without interruptions where it passes from one surface to another.

- Smooth the axial surface, and, most importantly, the chamfer finish line with the carbide finishing bur, which matches the size and configuration of the torpedo diamond.
- Align a tapered fissure bur with the long axis of the preparation. Although the grooves will be the size of a no. 171 bur, the novice may wish to begin the groove with a no. 169L bur, since it permits the groove to be realigned or repositioned slightly without over-cutting it if the initial alignment was incorrect[12].
- Make the mesial groove with the no. 171 bur. On a bridge abutment, the entire groove can be done simultaneously. When there is a tooth adjacent to the groove site, the groove should be cut in 1 or 2-mm increments, starting from the occlusal surface. The groove should be made to the full diameter of a no. 171 bur, parallel with the path of insertion of the preparation and extending to within 0.5 mm of the gingival finish fine. The bottom of the groove should have a definite, flat seat, and not fade out to the finish line.
- Use the same bur to prepare the facial groove. This groove must be correctly aligned with the path of insertion. Many novices concentrate so hard on aligning it correctly faciolingually that they forget to check it mesiodistally.
- The mesial flare is formed with a flame diamond. It will be narrow at is gingival end, becoming progressively wider occlusally. It will be prepared equally at the expense of the facial wall of the groove and the outer wall of the tooth. Because of the convexity of the mesial surface of the tooth, the difference in width should be quite noticeable.
- The flame diamond is also used to make the facial flare. Since the facial surface does not exhibit a marked convexity, this flare will be only slightly wider at the occlusal end than at the gingival end. Flame-shaped bur whose

size and shape match the flame diamond should be used to finish the flares. This will produce a smooth flare with a distinct finish line[14].

- A paper or plastic-backed abrasive disk can be used to form and finish the flares when there is adequate access. Take extreme care when using this technique in the mouth, or the patient's lip can be cut. The flare should be flat and the finish line crisp. If the flare assumes a convex shape with a "rounded" finish line, the disk has worn out. Replace it and retouch the flare.
- The occlusal offset is placed with a no. 171 bur. Its floor is perpendicular to the path of insertion and forms a level "terrace" on the lingual slope of the mesiofacial cusp. One of its functions is to provide space for a bulk of metal which will reinforce the margin. The offset should connect the lingual walls of the grooves. In this way the metal in the corresponding area of the casting will connect the bulk of metal in the grooves to provide the "truss effect" described by Willey.
- Round over the angle between the occlusal edge of the offset and the inclined planes of the mesiofacial cusp with a no. 171 bur. Continue this rounding onto the mesial and facial flares so there will be no sharp line angles between the occlusal surface of the mesiofacial cusp and its two flares. Use the no. 170 bur to blunt any sharp angles on the occlusal surface. The occlusal finishing bevel can be placed with one of several instruments. A fine girt flame diamond can be used for creating an occluso-facial finishing bevel. It will produce a coarse finish, however, and should be followed by a carbide bur[15].
- The instrument of choice, however, is the no. 170 bur or the long-flame carbide bur, since a carbide bur will produce the smoothest surface and the clearest finish line. The bevel is made at a right angle to the path of insertion and is 0.5 mm or slightly more in width.
- The bevel is rounded over the proximal occlusal line angle to blend in with the proximal flares. Be sure that the outer edge of the bevel is continuous with the edge of the flare, in order to produce a continuous finish line. Sharp corners

in the finish line of a preparation are likely to cause voids in the corresponding angle of the stone die[12].

PROXIMAL HALF-CROWNS

An especially perplexing problem for the dentist is that of the tilted mandibular molar abutment. When the prospective abutment tooth has tipped toward the edentulous space, it is no longer possible for the path of insertion of the abutment preparation to be both parallel to the long axis of the tooth and perpendicular to the plane of occlusion.

Several solutions have been offered for this problem. Whenever possible, the tooth is uprighted orthodontically to permit a favorable path of insertion with optimum preparation retention and to eliminate uncleanable periodontal defects on the mesial aspect of the root.

If orthodontic treatment is not feasible for any reason, other solutions may be used. A telescopic crown retainer on the bridge may be fitted over a cast coping on the tooth if the clinical crown of the tooth has suffered moderate to severe destruction. This approach, utilizing two crowns, telescope, and coping on the abutment, requires the destruction of considerable tooth structure and should not be used to restore minimally damaged teeth[14].

Another, less destructive retainer design for the tilted abutment is the proximal half-crown, which is a three-quarter crown variant. In concept it is a three-quarter crown which has been rotated 90 degrees so that a proximal surface, rather than the facial, is left unveneered. It can be employed if the tooth has been damaged only slightly. Two criteria must be met, however:

1) The distal surface must be caries free.
2) There should be minimal interproximal caries throughout the rest of the mouth.

There is some risk in leaving the interproximal surface of a bridge abutment unrestored. The risk can be minimized by using this retainer design only in those mouths where there is little history of interproximal caries and therefore les likelihood of future occurrence[12].

- Begin the occlusal reduction by placing depth-orientation grooves on the occlusal surface with the round-end tapered diamond. On the distal aspect of the occlusal surface the occlusal reduction, and therefore the depth-orientation grooves, will be the normal depth.
- The grooves and the reduction that will follow may not be as deep in the mesial portion of the occlusal surface, since this segment of the tooth has dropped below the occlusal plane. The normal occlusal reduction will be required if the tooth opposing the edentulous space has supraerupted into the space. Correction of the occlusal plane to prevent occlusal disharmony often will require placement of a restoration with occlusal coverage on that opposing tooth.[13]
- Using the round-end tapered diamond, remove the tooth structure remaining between the depth-orientation grooves to reproduce the geometric planes of the occlusal surface.
- Begin the functional cusp bevel by placing depth-orientation grooves with the round-end tapered diamond. These grooves, as well as the bevel which will follow, often will be shorter and shallower on the mesial cusp than on the

distal. There will be less need for the bevel where the tooth has tipped below the occlusal plane, providing the opposing tooth has either not supraerupted or has been restored back to the proper occlusal plane. Complete the functional cusp bevel with the round-end tapered diamond, removing the tooth structure between the depth-orientation grooves.

- Begin the axial reduction by making the path of insertion of the mesial surface parallel with the long axis of the premolar abutment. At this point the diamond instrument will make contact with only a small area of the mesial surface just apical to the marginal ridge. Do not attempt to produce a mesial gingival finish line at this point, or an undercut will be produced. Continue cutting the mesial surface with the torpedo diamond oriented with the eventual path of insertion of the preparation. Enough tooth structure will be removed so that the end of the diamond will eventually contact the tooth and produce a chamfer finish line in the gingival area of the mesial surface[15].
- Use the same diamond to produce axial reduction with a chamfer finish line on the facial surface. End the extension 1.0 mm or more mesial to the distofacial embrasure. Overextension distally will leave the vertical finish line in a position where it will be difficult to capture in the impression, hard to finish, and impossible for the patient to keep clean.
- Since mesially tipped molars also frequently exhibit some lingual inclination as well, take care to keep the diamond as upright as possible to avoid excessive facial wall inclination and resultant loss of retention.
- Often there will be a sharp angle where the facial and mesial reductions meet. Round this angle from facial to mesial, and make sure that the chamfer does not have a “scallop” or a rise occlusally at the angle.
- Repeat the process on the lingual surface, creating a definite chamfer finish line, and keeping the surface as upright as possible. Again, do not extend the vertical distal finish line tooth far into the distolingual embrasure. Go over all

three axial surfaces with a torpedo-shaped carbide finishing bur to produce a precise, well-defined chamfer finish line[12].

- Smooth the planes and angles of the occlusal surface with a no. 171 bur at this time. Now finish the functional cusp bevel with the same carbide bur. This finishing step is delayed to this time because of the large quantities of tooth structure removed during the uprighting of the mesial surface. Going over the functional cusp bevel now enables the operator to better blend it with the other occlusal and axial features of the preparation.
- The addition of an occlusal isthmus increases bulk and rigidity in the casting as well as providing much needed retention. This feature is usually "automatic" in as much as most prospective abutments will have either an old restoration or caries in the central groove. A countersink is added to the distal fossa with the no. 171 bur. This feature not only supplements retention and resistance, but it also provides greater bulk to the casting in the critical area near the distal occlusal margin.
- Place a groove on the facial surface within 1.0 mm of the vertical distal extension of the preparation. The groove should parallel the mesial surface of the tooth and the long axis of the other abutment tooth. The groove must also be upright faciolingually and should not lean to the lingual. Repeat the process on the lingual surface, paralleling that groove with the one on the facial surface. Be careful not to place it too far distally. The groove may be started with no. 170 bur and finished with the no. 171 to prevent its becoming too large[14].
- Create a V-shaped offset 0.5 to 1.0 mm from the distal occlusal finish line, connecting the lingual groove to the countersink to the facial groove. It will produce a rigid staple with the grooves to reinforce the distal marginal area of the casting.
- Place a flare distal to the facial groove with the flame diamond. The flare will be a flat plane, wider at the occlusal end than at the gingival. Repeat the

process on the lingual surface, creating a flare distal to the lingual groove, tying it in with the gingival chamfer.

- Cut a bevel along the distal marginal ridge with the flame diamond, taking care not to extend into the distal occlusal embrasure, where the compromised location of the finish line would jeopardize the success of the restoration.
- Round over the angles between the distal occlusal bevel and the facial and lingual flares. Sharp angles in these areas will cause severe problems in the restoration margin. Go over both flares with the flame carbide bur to produce the sharpest finish line possible. Redo the occlusal bevel with the flame carbide bur[16].

ANTERIOR PORCELAIN- FUSED-TO-METAL CROWNS

The porcelain-fused-to-metal restoration is a combination of an esthetic porcelain veneering material and a metal substructure. By fusing porcelain to metal, it became possible to produce a full-coverage restoration with a stable, esthetic veneer and adequate strength to be used for replacing missing teeth.

The use of porcelain-fused-to-metal restorations has grown from the development of the first commercially successful porcelain/gold alloy restoration by **Weinstein et al** in the 1950's. Unless the preparations for porcelain-fused-to-metal restorations are meticulously done, however, the restorations will not be as esthetic as sound natural tooth structure. They can often be identified by their opacity, bulkiness, exposed gingival metal collar, or by a cuff of inflamed tissue at the gingival margin. All these problems have their roots in faulty crown preparation.

Anterior porcelain-fused-to-metal crown preparation:

- Before beginning the preparation, make an index by adapting one-half scoop of condensation reaction silicone putty to the facial and lingual surfaces of the tooth to be prepared, and to a least one tooth on each side of it. A facial index can be made by cutting the adapted putty into facial and lingual halves, and then splitting the facial half. The gingivofacial segment formed in this manner is placed against the teeth to check for adaptation. A midsagittal index can be created by sectioning the silicone putty from gingivofacial to gingivolingual along the midline of the tooth to be prepared. This index gives a better indication of overall reduction, including the incisal and lingual aspects, but it does not provide any information about the facial reduction mesiodistally.
- When a tooth is being prepared to receive a crown with an esthetic veneer, the facial surface should be in two planes; one nearly parallel with the path of insertion and one parallel with the incisal two-thirds of the facial surface of the tooth. Reduction only in the plane parallel with the path of insertion may result in insufficient space for porcelain in the incisal one-third, which is a common error. One-plane reduction, which creates adequate space for the restoration in both the shoulder and incisal areas, will come dangerously close to the pulp in the midfacial area and may also produce an over tapered preparation[13].
- Failure to use biplanar facial reduction can result in a facial veneer of porcelain that is too thin. This will produce an ugly display of opaque porcelain corresponding to the inciso facial angle of the preparation.
- Depth-orientation grooves is done with flat-end tapered diamond. Make at least two vertical cuts in the incisal portion of the facial surface. These will be made to the full diameter of the diamond, fading out at the “break” where the

curvature of the facial surfaces is greatest. Sink the side of the diamond into the mesiodistal center of the facial surface, maintaining the same instrument alignment parallel to the gingival segment of the facial surface. Make sure the diamond is inserted into the tooth to its full diameter, or slightly deeper. Keep the tip of the diamond slightly supragingival at this point, even if it is ultimately to be flush with the gingival crest, or slightly subgingival. Repeat the process at least twice, placing these orientation grooves closer to the line angles of the tooth.

- Make two incisal orientation grooves that are 2.0 mm deep. The diamond should parallel the angle of the uncut incisal edge faciolingually. Reduce the incisal edge by 2.0 mm, to the level of the depth-orientation grooves. Keep the plane of the reduced surface parallel to the former incisal edge. The incisal portion of the facial surface is reduced with the flat-end tapered diamond, removing the tooth structure remaining between the orientation grooves.
- The gingival segment of the reduction should extend well into the proximal surface. Recommendations for the depth of facial axial reduction have included 1.0 mm, 1.2 mm, 1.25 mm and 1.5 mm. These are reasonable amounts if 1.2 to 1.4 mm is accepted as a desirable thickness for the veneer of porcelain and alloy. If reduction of less than 1.2 mm is done for a porcelain-fused-to- base-metal or 1.4 mm for a porcelain-fused-to-noble-metal restoration, will result in either a slightly opaque restoration or an over contoured one. The reduction interproximally is wider than the diameter of the diamond, so it is safe to favor the proximal contacts by keeping some tooth structure between the adjacent teeth and the instrument. The “lip” or undermined edge of tooth structure thus formed can be easily removed with a sharp enamel chisel, such as a hatchet or binangle chisel[14].
- If there is sound tooth structure interproximally, a vertical wall, or “wing” of it, is left standing in each interproximal area, lingual to the proximal contact. Besides preserving tooth structure, it also adds some torque resistance to the

preparation. The shoulder must be extended lingual to the contact to permit an adequate bulk of interproximal porcelain for good esthetics. If the termination of the shoulder and wings occurs at or facial to the proximal contact, the interproximal area of the restoration will have an opaque, "dead" appearance. If, as so often happens to teeth requiring porcelain-fused-to-metal crowns, the proximal surfaces have been damaged by caries or have been previously restored, the wing is deleted.

- The reduction of the lingual surface is started by using a small round diamond with a diameter 1.4 mm larger than the shaft. By sinking this instrument into lingual tooth structure until the shaft touches enamel, it is possible to produce index marks that are 0.7 mm deep. Distribute several of these "potholes" over the lingual surface of the tooth.
- Reduce the cingulum portion of the lingual surface with the small wheel diamond. Should not extend the lingual reduction so far gingivally over the cingulum that the vertical lingual wall is overshortened. Over-reduction at this point will produce a retention deficiency that will be hard to compensate for later.
- It is necessary to form the lingual surface of an anterior tooth so that there is a vertical wall on the lingual surface of the cingulum and a separate concave surface incisal to it. This provides step like resisting areas to counteract the tipping effect of forces from the lingual. The lingual concavity also creates space for a crown with proper contours and occlusion with minimum removal of tooth structure. If the lingual surface is formed into a single sloping plane, the arcs of rotation of all points in the crown will be either parallel with or directed away from the tooth, and the crown, lacking resistance form, will fail[12].
- If there is limited space between the facioproximal angle of the wing and the proximal surface of the adjacent tooth, use a long-needle diamond to reduce the axial wall lingual to the wing. In this portion of the tooth preparation where

coping will not be veneered by porcelain, the torpedo diamond is used to reduce the lingual axial surface, simultaneously forming a chamfer finish line. If the lingual axial wall is toot short, it may be possible to lengthen it by using a shoulder with a bevel to move the lingual wall farther toward the center of the tooth. The lingual axial wall should be parallel with the cervical one-third of the facial surface.

- Redefine and smooth the lingual chamfer with a torpedo carbide finishing bur. Smooth the entire facial surface with a no. 171 bur. Particular attention to the facial aspect of the proximal wings, if they are present. Make sure that they are parallel with or slightly lingually inclined to the path of insertion of the preparation. Round over any sharp angles on the incisal or along the edges of the incisal notches with the no. 171 bur. The incisal notches themselves were automatically created by placing the wings lingual to the proximal contacts. The heavier facial reduction cut through the lingual surface, creating the notches on the proximal ends of the incisal angles as it did[12].

Finishing the shoulder:

It is possible to gouge the shoulder with the bur edges when instrumenting a shoulder that is not level. The operator must be careful not to drop the shoulder at the facioproximal line angels to the same level as the facial surface midpoint while trying to eliminate nicks in the shoulder. The result will be serious damage to the interdental papilla and a vertical finish line where the facial shoulder meets the proximal finish line.

Some form of the shoulder has been widely used for the facial finish line of the preparation for the porcelain-fused-to-metal crown for many years. **McLean and Wilson** have refuted the argument that the facial finish line should be a bevel, stating that the bevel on the shoulder would have to form an angle of 160 to 170 degrees to produce a significant effect. Because a bevel on the shoulder requires a metal collar at the margin of the restoration, a 135-degree shoulder has also been proposed to allow an acute margin while minimizing the edge of metal at the actual margin[12].

- The shoulder is roughed out with the flat-end tapered diamond, is completed at this stage with an endcutting bur and hand instruments. The finish line should follow the undulating contours of the gingival tissues, rising incisally in the interproximal region.
- The shoulder is instrumented with a sharp 1.0 mm-wide chisel to produce a smooth finish line. It is not necessary to accentuate the internal angle. In fact, a rounded internal angel has been proposed by some authors because it reduced stress. It is important to make sure that there is no “lip” or reverse bevel of enamel at the finish line. Otherwise, this edge may fail to reproduce when the impression is poured, or it may fracture off the cast, resulting in ill-fitting casting. It is also susceptible to fracture on the tooth, which would cause an open margin. The shoulder should be no less than 1.0 mm in width. The enamel chisel helps to verify this dimension.
- Use the horizontal gingivofacial silicone index to check the reduction across the entire facial surface. A vertical midsagittal index can also be used for checking the amount of reduction[15].

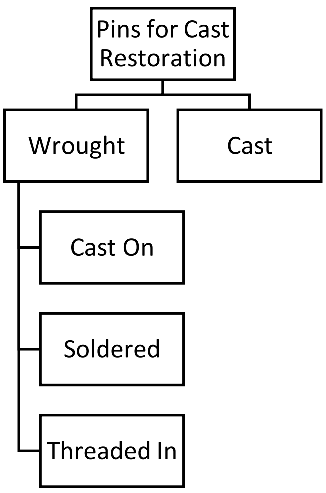
PIN RETAINED CAST RESTORATIONS

Indications

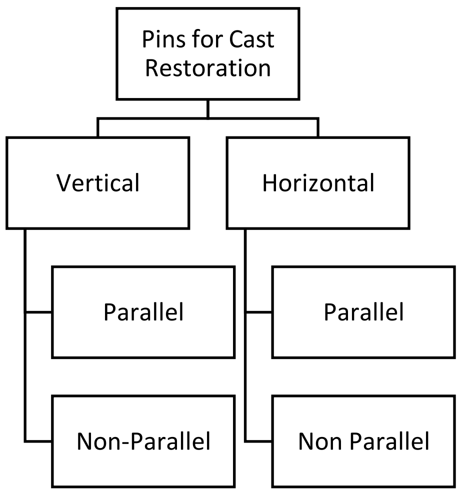
- When one wall of a proximal box is shorter than opposing proximal wall.
- When a proximal preparation is unusually long.
- In case of over tapered full crown preparations.
- Full crown preparations with one wall very short and opposite wall very long.
- Attritioned or abraded teeth where occlusogingival height is excessively reduced.
- Large occlusal inlays and cuspal fractures.

Types:

According to the modes incorporating them in a casting, pins can be divided into:



According to their relationship to the long axis of the tooth, pins can be divided into:



Methods

The pin channels are slightly wider in cast pin restorations and a depth of 3.0 mm is required with such pins. In case, two or more pins are required to be inserted, the parallelism between the pins is to be maintained. The wax pattern can be drawn by two methods:

1. Direct: In direct method, the wax pattern is made in the oral cavity itself. After making necessary pinholes, nylon bristle of the size of the pinhole is seated in each pinhole and wax pattern is made, incorporating the external part of the bristle. The outer end of the bristle is flattened to enable the end to be incorporated into the pattern. This wax pattern along with the incorporated bristle is invested, and casting is completed.
2. Indirect: In indirect method, a stainless-steel pin ground to the size of pin channel, is inserted and stabilized using inlay wax. An impression is taken using rubber base impression materials.

Figs 13.20A to I: Occlusal rehabilitation using cast pins on maxillary right first molar: **(A)** Pre-operative photograph (facial view); **(B)** Pre-operative photograph (occlusal view); **(C)** Pins placed in pin-channel preparation; **(D)** Casting obtained; **(E)** Casting in place. Occlusal rehabilitation using cast pins mandibular right first molar; **(F)** Pre-operative photograph; **(G)** Pins placed in pin channels; **(H)** Casting obtained; **(I)** Casting in place

This impression is used to make a die and, on this die, wax pattern is made using plastic pins as in the direct method. This wax pattern is invested, and casting is completed with the requisite alloy. A case of occlusal rehabilitation with cast pins is shown in Figs A to I.[17]

TOOTH PREPARATION FOR FULL VENEER CAST OR CAST ALLOY BASED RESTORATIONS

INDICATIONS

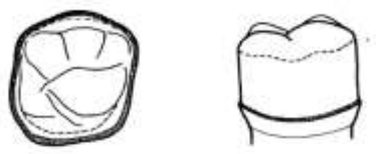
Besides the general indications, full veneer castings are indicated in the following situations:

- They are required where extensive involvement of the tooth precludes the use of other forms of cast restorations due to resistance-retention problems.
- These restorations, when completely made of cast ceramic or veneered with porcelain or tooth-coloured resin, can be the most esthetic type of single-tooth restoration. For this reason, the porcelain-fused-to-metal crown is presently the most used single-tooth restoration for badly broken down or otherwise disfigured anterior teeth.
- Full veneer restorations are indicated when substantial changes in the contact, contour, or occluding anatomy of the tooth is to be created by a cast restoration, beyond the capabilities of onlays, even with surface extensions.
- Full veneer castings are indicated as a superstructure on a tooth with an amalgam or cast alloy 1oundation to reinforce t and/or change its alignment

- The full veneer casting is the most resistant type of extracoronal cast restoration to displacing forces. Therefore, it is the last resort for restoring a single tooth.
- Teeth preparation, precementation and post-cementation adjustment for such type of cast restorations (cast based) are the easiest and most feasible. Therefore, it is the restoration of choice in areas with difficult access.[18]

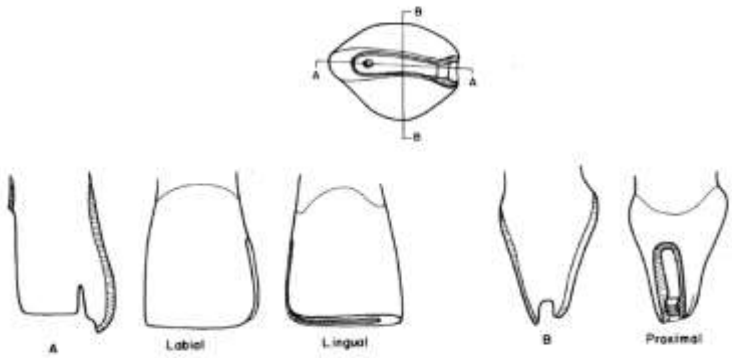
FEATURES

The chamfer finish line is the most frequently used for Classes I, II, and, sometimes, II cast alloy full veneer restorations.

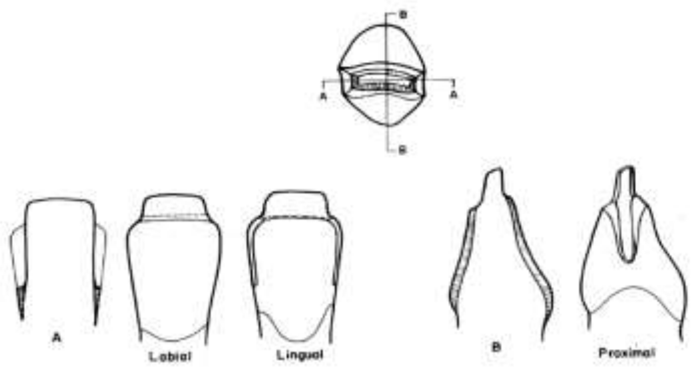


The hollow-ground bevel is the most universal for alloys with low castability (i.e., Class IV and some Class III alloys). The bevelled shoulder is regularly used for cast-based porcelain (tooth-coloured resin) restorations. The bevelled portion of the shoulder should be hollow ground if the alloy for the substructure is Class III or IV.[7]

For cast ceramics, whenever possible the finishing line should be a very rounded shoulder exaggerated hollow-ground bevel); an unbevelled shoulder may be used as a finishing line when the preparation is deficient in resistance (at floors) und generally has short axial length. But these shouldered margins should end on the occlusal % of the anatomical crown or on the anatomical root surface.[7]



Class IV for cast ceramics with incisal shoulder

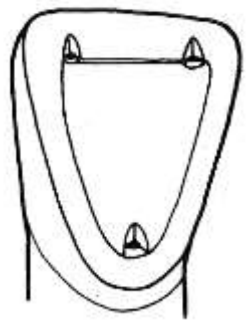


Class IV for cast ceramics with incisal step

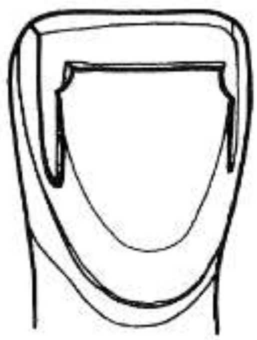
Proximal box with lingual skirt

Pin-Ledge Cavity and Tooth Preparation

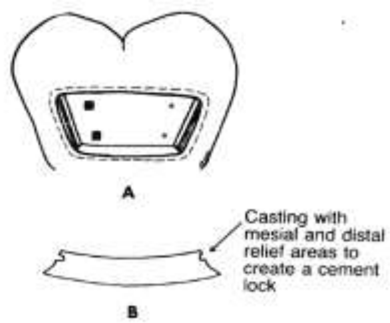
This design is indicated for cast alloys only. It is in the form of full veneer axial reduction of the lingual surface, short of the incisal ridge and the lingual proximal axial angles. Proximally, the lingual reduction could join a proximal box or a plane proximal reduction, ending gingivally like the lingual reduction, i.e. in a chamfer or hollow-ground bevel. At least three steps (ledges), each accommodating a pin channel, should be prepared in the lingually reduced arca, paralleling the incisal or inciso-lingual insertion path and strategically located to avoid the pulp, and to be reciprocally retentive.[17]



Three Quarter Crown



This design is indicated for all types of cast materials. The proximal parts may be in a groove or box form. The lingual reduction should be like a preparation for a full veneer restoration, following the lingual surface anatomy. The incisal ridge should be minimally reduced, with a little bevel (skirt for cast ceramics) inclining labially and paralleling the incisal ridge or slopes. The circumferential tie constit0uents of the tooth preparation for cast alloys are composed of proximal labial flares and gingival chamfers proximally and lingually. They can be shoulders only for cast ceramics (see Section on inlays). [17]



Class V Cavity Preparation

CHOICE OF LUTING AGENT FOR CAST RESTORATIONS

Luting cements play an important role in retaining the restorations with prepared tooth structure. Most often, improper and inadequate cementation causes failures. The marginal adaptation of the restoration is another critical factor to prevent or minimize the marginal leakage. Film thickness of the luting agent is one of the vital factors for the complete seating of the restoration.[63] Normally the luting cement is selected according to clinical situations combined with the physical, biologic and handling properties.

Luting materials play a central role in indirect dentistry by aiding the retention of restorations and in the prevention of leakage at their margins. These may be classified:

(i) According to the material from which they are formed

(ii) More generally, as active or passive.

- **Active luting materials:** By being bonded both tot tooth and restoration, make the restoration and tooth synergistic, and thereby play a role in the retention of the restoration, as well as sealing its margins and filling the space between restoration and tooth.
- **Passive luting materials:** Merely fill the gap between the indirect restoration and the tooth, with no chemical adhesion at the restoration/lute and/or tooth/lute interfaces.

Ideal requirements for luting materials:

- Be biocompatible with the tissue that it contacts, i.e., tooth and periodontal tissues.
- Adhere to tooth substance and restoration, either chemically, mechanically, or both.
- Prevent leakage by producing a good marginal seal.

- Have sufficient mechanical properties to resist the forces transmitted to the lute through the restoration. This should include high tensile and compressive strengths, high fracture toughness and fatigue strength, and a modulus of elasticity which is appropriate for stress absorption.
- Be cariostatic.
- Be insoluble in the dilute organic acids found in plaque-which may collect at the gingival margins of poorly contoured/poorly fitting indirect restorations or in patients with suboptimal oral hygiene.
- Resist water sorption.
- Be available in a sufficient range of shades if the luting material contributes to the overall shade of the restoration.
- Achieve optimal physical properties as quickly as possible.
- Allow easy removal of excess and cleanup.
- Have sufficiently low film thickness so that the restoration may seat fully.
- Have radio-opacity similar to or greater than dentine.

Additionally, the luting material should be technique insensitive and capable of easy and accurate proportioning if presented in powder/ liquid form, although encapsulation may be considered ideal from the aspect of producing a reproducible mix.

The principal functions of a luting material are the retention of the restoration onto or into the preparation and the sealing and filling of the gap between the preparation and the restoration.

The three major cementing agents are zine phosphate cement, polycarboxylate cement and ASPA. Z0E cements are used for temporary cementation as it is considered non-irritant in any effective depth. ASPA, although not yet properly tested, can be used in the same circumstances with Similar effects as poly-carboxylate cement.[63]

CEMENTING WITH ZINC PHOSPHATE CEMENT

- If the effective depth is 3.5 mm or more, only varnish is used on all enamel and dentinal walls prior to cementation.
- If the effective depth is 2-3.5 men, a base of polycarboxylate cement, or varnish and zine phosphate cement, is required before taking the impression or the direct wax pattern. Both cements should be inserted in a base consistency (thick and properly locked. Prior to cementation, varnish all dentinal and enamel walls.
- If the effective depth is less than 2 mm, before taking the impression or direct wax pattern, use a subbase of calcium hydroxide or unmodified ZOE (according to location and condition of the P-D organ), followed by varnish and a base of zinc phosphate cement. A base of polycarboxylate cement can be used only over a calcium hydroxide subbase with no varnish. Before cementation, use varnish overall all dentin and enamel walls.[63]

CEMENTING WITH POLYCARBOXYLATE OR A.S.P.A. CEMENT

- If there is an effective depth of 2 mm or more, cement directly, i.e., use no intervening varnish.
- If the effective depth is 1-2 mm, before taking the impression or the direct wax pattern, use a base of polycarboxylate cement (ASPA) (base consistency). Then, when the cast is ready, cement directly.
- If the effective depth is less than mm, before taking the impression or the direct wax pattern, use a subbase of calcium hydroxide or unmodified ZOE. The calcium hydroxide subbase can be covered with A.S.P.A base, but the ZOE sub-base must be covered with varnish and a zinc phosphate cement base. When the cast is ready, cement directly A.S.P.A can replace Z.P.C. in situations indicated for its use, but Z.P.C. cannot replace A.S.P.A. in situations indicated for their use.[64]

The marginal adaptation of the restoration is a critical factor to prevent or minimize the marginal leakage. Film thickness of the luting agent is one of the vital factors for the complete seating of the restoration. The retentivity of the luting cements were assessed by their adhesive capacity of the tooth surface over the metal surface. Glass Ionomer cements were introduced in early 1970 and they exhibit higher compressive strengths than zinc phosphate cement.[64]

White S.N. et al. investigated the ability to seat restorations with the resin cements and noticed the increased film thickness when compared to other luting agents. Also have reported that the glass ionomer cement possesses low film thickness and maintain relatively constant viscosity after mixing.[65] This result in improved seating of cast metal restorations compared with zinc phosphate cement.

Zinc phosphate cement has historically been the cement of choice for cementation of indirect cast restorations. The phosphoric acid and zinc oxide react ionically to form a low pH amorphous mass. However, the cement does not bond to dentin and due to its solubility, chemical dissolution occurs leading to higher microleakage scores than other cements.[66,67] In order to overcome this problem, glass-ionomer cements, resin modified glass ionomer cements and resin composite cements were developed in recent last decades.[68]

More recently, new improved self-adhesive resin-based or resin-modified glass ionomer cements were introduced and are currently being used by the dental profession. Resin-based luting cements can penetrate into the dentin tubules and exposed collagen network and bond to dentin through micro-mechanical interlocking.[69]

Resin modified glass-ionomer cements are hybrid formulas and composed of fluoroaluminosilicate glasses, polyacrylic acid and resin composites and contain photo or chemical initiators and methacrylate monomers.[70] They bond to dentin through a combined ionic bond between polyacrylic acid and hydroxyapatite and a micro-mechanical interlocking with collagen and dentin tubules.

Previous studies have shown that resin-based and resin modified glass-ionomer luting materials possess superior mechanical properties over conventional zinc phosphate cements,[71-73] which may be a factor in sealing capacity as well as in resistance to displacement.[71,72]

The increased film thickness of resin cement could be attributed to the factors which influence the film thickness of luting material, the size or shape of filler particles, viscosity of unset material and its rate of set. Resin cement possesses good marginal fit when compared with other luting agents. Glass Ionomer cement had the better tensile bond strength and low film thickness, with its adhesive ability makes it a good luting agent. The resin cement has the higher bond strength and better marginal fit, when compared to other luting agents.

Post cementation sensitivity with glass-ionomer cements is comparable to or even less than that with zinc phosphate cement.[74]

Type of luting material	Advantages	Disadvantages
Zinc phosphate	▪ Anecdotal reliability ▪ Ease of use ▪ Ease of clean-up ▪ Adequate compressive strength ▪ Adjustable working time	▪ High solubility in oral fluids ▪ Potential for leakage ▪ Potential for pulp irritation ▪ No adhesion to restorations ▪ Difficult mixing technique
Zinc polycarboxylate	▪ Low potential for pulpal irritation ▪ Some adhesion to tooth	▪ High solubility in oral fluids ▪ Low compressive strength ▪ High potential for leakage ▪ Difficult clean-up/clean-up time is critical ▪ No adhesion to restorations
Glass ionomer	▪ Adhesion to tooth ▪ Fluoride release during early life ▪ Adequate compressive and tensile strengths ▪ Easy to mix	▪ Moisture intolerance during setting ▪ Potential for pulpal irritation/history of post-operative sensitivity ▪ Difficulty clean-up ▪ Low fracture toughness ▪ No adhesion to restorations
Reins-modified glass ionomer (RMG)	▪ Good biocompatibility ▪ Fluoride release ▪ Improved adhesion to tooth ▪ Improved physical properties, particularly tensile strength ▪ Easy clean-up ▪ Low solubility in oral fluids	▪ Expansion of some cements under moist conditions, causing fracture of all-ceramic crowns ▪ No adhesion to restorations
Resin-composite	▪ Excellent physical properties ▪ Low solubility in oral fluids ▪ Potential for adhesion to tooth ▪ Tooth-coloured, so may form part of an esthetic restoration ▪ Capable of being bonded to restorations	▪ Need to etch and bond to tooth, therefore may be technique sensitive ▪ Bonding takes extra time ▪ Need to finish restoration margins ▪ Moisture control is critical ▪ Clean-up time is critical

Self-adhesive resin luting materials:

It could be conjectured that the reasons for the slow acceptance of resin luting materials, is possibly because of the technique sensitive nature of their use, which involves etching with phosphoric acid and the use of a dentine bonding agent.

A material that overcomes the technique problems could therefore be of value to the clinician. Material is **RelyX Unicem.** This newly developed auto polymerizing or dual-cure resin-based material consists of phosphoric acid modified (meth) acrylate resins which when mixed, have a pH of 1. This then results in the etching of the dentine surface, resulting in the formation of a thin hybrid layer.

In addition to the bond strengths to enamel and dentine reported laboratory physical properties of RelyX Unicem have been assessed in a variety of studies and have been found to be satisfactory in terms of compressive strength, surface hardness, flexural strength and flexural modulus[73].

TECHNIQUES & RATIONALE FOR CONTROL OF THE PERIODONTIUM PREPARATORY TO CAST FABRICATION

The various methods for the soft tissue retraction in the crown and bridge procedures are as follows:

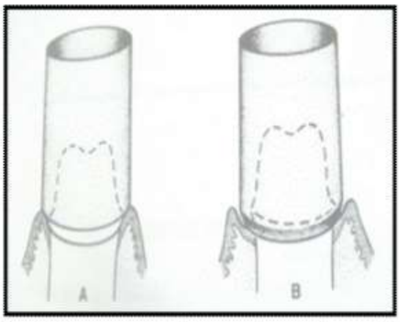
- Mechanical
- Mechanical-Chemical Method
- Surgical

MECHANICAL METHOD

Physical displacing of the gingival tissue was one of the first methods for insuring adequate reproduction of the prepared finish line.

i. Rubber dam is not only an asset in the preparation of the tooth, but also when the impression is made. With this technique, wax must be used to block out the clamp and prevent its displacement. Excellent impressions are obtainable when the prepared teeth are in a clean and dry environment. However, it is not feasible to make complete arch impressions and the rubber dam should only be used on relatively simple preparations with minimal Sub-gingival extension.[77]

ii. A copper band or tube can serve as a means of carrying the impression material as well as a mechanism for displacing the gingiva to ensure that the gingival finish line is captured in the impression. It has been used with impression compound and elastomeric materials. The use of copper bands can cause incision injuries of gingival tissues, but recession following their use is 0.3mm in a general clinic population. Copper bands are especially useful for situations in which several teeth have been prepared. This is also known as matrix method.[78]



iii. Cotton fibres, cord, string, or unwaxed floss are the products most used to displace gingival tissue. Plain cotton cord is poor in its ability to adequately displace gingiva when compared with chemically impregnated cords. Tissue recovery, on the other hand, is excellent. Over packing can traumatize the tissue; the cord must be placed firmly but gently. Wetting cord with water before removal from the sulcus to prevent injury to delicate epithelial attachment.

iv. Zinc oxide Eugenol cement placed on cotton is a technique recommended for deep cervically involved teeth. The advantages are acceptable tissue tolerance and extended working time to finish the preparation and make the impression. The disadvantage is the time necessary to make this technique work adequately.

v. A temporary crown filled with thermoplastic stopping material or gutta-percha can cause prolonged or lasting recession if left in place for more than twelve hours. The resulting uncovered neck of the tooth may be sensitive and susceptible to caries. Impressions cannot be made at the same appointment as the tooth preparation. Based on wound healing and gingival recession, the metal band with modelling compound was better than either surgery or retraction cords (with or without chemicals). The disadvantages of this technique include the amount of time necessary to fit and adapt the band, the difficulty in removing the modelling compound and trauma to the tissue caused by the band.

CHEMO MECHANICAL METHOD

Mechanical chemical dilation consists of cords impregnated with chemicals that are eased into the intracrevicular space beneath the cavity margin without force. A cord is used for mechanically separating the tissue from the cavity margin and is impregnated with a chemical for hemostasis as impressions are made. The area must be kept dry but not desiccated if the haemostatic chemical in the cord is to have 3 maximum effectiveness[79]. The impregnated string does injure the gingival sulcus epithelium. The injuries are temporary and heal within 7 to 10 days (except those caused by zinc chloride concentration above 8%). After 5 to 10 minutes the cord is gently removed and the sulcus surrounding the cavity margin is exposed and homeostasis maintained. If the bleeding is evident the crevice is repacked for another 5 minutes. Sub gingival packing instrument is directed towards the area where the cord is already secure pushing away from the area dislodge the cord. The cord is pushed into the sulcus which mechanically stretches the circumferential periodontal fibres. Placement is often easier if a braided (e.g. Gingibraid) or a knitted (e.g. Ultrapak) cord is used. In areas where very narrow sulcus precludes placement of smaller size of twisted or braided cord, wool-like cord that can be flattened are preferable for initial displacement of tissue.

Better sulcus enlargement can be attributed to a chemically impregnated cord or by dipping the cord in an astringent. The soaking time ensured for the liquid uptake of retraction cords is a crucial factor in successful gingival retraction procedure. Three criteria for gingival retraction material are:

- Effectiveness in gingival displacement and homeostasis.
- Absence of irreversible damage to gingival
- Paucity of untoward systemic effects.

Donovan et al, Benson et al[79,80] stated that in many patients it produces an epinephrine syndrome that may include tachycardia, increased respiratory rate, hypotension, nervousness, and feelings of weakness in the extremities, frank apprehension and post-operative depression. Therefore, epinephrine is not recommended in patients with cardiovascular disorders, diabetics, hyperthyroidism or hypertension and known hypersensitivity to epinephrine.

[81] Nemetz and Seibly reviewed the use of chemical agents for gingival retraction. There is no ideal agent for gingival retraction and therefore it is considered worthwhile to explore new chemical agents. There are several vasoactive substances which when used topically have relatively few side effects. These substances are the active ingredients in various over the contour nasal or epinephric decongestant tetrahydrizoline HCl 0.25%. They are sympathomimetic and act as alpha agonists.

Tissue retraction must be done gently but with enough firmness to place the cord just apical to the margin. Over packing should be avoided because it will tear the gingival attachment leading to irreversible recession. Prior to the removal of the cord it should be moistened to avoid stripping of sulcular epithelium. The cord must be saturated with solution prior to the insertion or place dry and then the solution is applied onto it. Some cords are previously impregnated by manufacturer and do not require additional application of chemicals. Alum in 100 % concentration has been shown to be only slightly less effective than epinephrine in shrinking the gingival tissue. Cord saturated with 100% alum can be left in the sulcus for as long as 20 minutes without adverse effects and shows good tissue recovery. A 0.1mm permanent loss of crestal gingival usually occurs. Alum has been used because it is safer and fewer systemic effects[82]

Aluminium chloride solution (15% and 25 %): It is one of the most commonly used chemical. A 10 min. application is usually sufficient. The 25 % solution has been advocated for use with other chemical agents because it approximately doubled the haemostatic success of each other chemicals. It has been observed that 25% aluminum chloride was significantly more aggressive than 0.05% tetrahydrozoline. [81]

Ferric sulfate (Monsel's solution): It is advocated for use in gingival displacement. It is slightly more effective than epinephrine in gingival displacement. The recommended time of use is 3 minutes. Tissue recovery is good, but the solution is messy to use. It is highly acidic and hence corrosive hence it is injurious to the soft tissue and enamel. However ferric sulfate (13.3%) does not traumatize the tissue and the healing is more rapid with aluminium chloride. Ferric sulfate is compatible with aluminium chloride but not with epinephrine, it will result in the development of a massive blue precipitate.

Zinc chloride (8% and 40%): Effective gingival displacement by 8% zinc chloride is like epinephrine while 40% Zinc chloride is slightly more effective.

As there are very caustic, they cause a chemical cautery and hence not recommended.

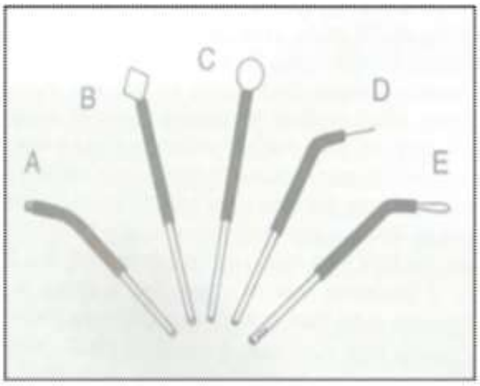
Tannic Acid (20%-40%): It is less effective then epinephrine, but it shows good tissue recovery whereas the haemostatic effectiveness is minimal.

Negatol solution: It is 45% condensation product of metacresol sulphonic acid and formaldehyde. It provides better retraction than epinephrine, but tissue recovery is poor. It is highly acidic and decalcifies teeth in both 10% and 100% solutions. It is classified as chemical cautery agent and is not recommended for gingival displacement.[83,84,85,86]

Surgical Tissue Dilation:

Surgical resection of the gingiva is the preferred method for providing access to the margin of the preparation. A ribbon of gingival tissue is removed from the sulcus around margin with dental electro surgery. Continuous visualization of the sub epithelial margin is difficult for the dentist. Cords, chemicals, rubber or leather ring, copper, stainless steel and aluminium bands with other materials have been suggested for this purpose. Under local anaesthesia, the gingiva is excised apical to the margin of the preparation with periodontal knives or no.11 Bard-parker blade. The gingiva regenerates and is restored to its normal position provided it was healthy when the preparation was started. When the tooth is prepared, resection of the gingiva or inadvertent removal of plaque and calculus during the preparation results in shrinkage of the pocket wall and leads to exposure of the tooth surface beyond margin of the preparation[83,87,89]

Electrosurgery[89]



An electrosurgical instrumentation and technique have been well known for nearly a century, it was not until the late 1960s that the principles of electro surgery became understood and improved equipment became available. Electro surgery has been used in dentistry for more than half a century. Two general types of electrosurgical units (ESU) are monopolar and bipolar. Both types are used extensively in medicine, but only monopolar systems have been established in dentistry (except for the use of bipolar units by oral surgeons). Electro surgery unit may be used for minor tissue removal before making the impression. In one technique, the inner epithelial lining of the gingival sulcus is removed, thus improving access for a sub gingival crown margin, and effectively controlling postsurgical haemorrhage (provided that the tissue are not inflamed). Unfortunately, there is potential gingival tissue recession after treatment.

The depth of tissue removal is determined by the morphology of the tissue and the biologic width. Electro surgery requires profound local anaesthesia and all the armamentarium should be made of plastic. The passive or insufficient plate is positioned under the shoulder for bi-terminal application. The selection of electrode varies depend upon the tooth, and its arch position. The tissue through extend about 0.3 to 0.5 mm below the margin of the cast restoration for definite margin detection in the impression and on master dies.

Ordinary alternating current electric energy is passed through a certain apparatus to substantially increase its frequency (from 6 to 120 to a million and more per second). The current at this extremely high velocity will pass through human bodies without inducing shocks. The idea is to concentrate this energy al tiny electrodes, producing extremely localized changes in the tissues, changes which can be confined to as little as 2-3 cell layers.

Four types of actions can be produced at the electrode end:

a. Cutting

This is extremely precise, bloodless, with minimal tissue involvement and after-effects, if properly controlled and executed.

b. Coagulation

This creates surface coagulation of tissues, their fluids and oozed blood; the effect is due to the thermal energy introduced. If overdone, it will be accompanied by carbonization.

c. Fulgeration

Because of the greater energy used, fulgeration has deeper tissue involvement. It is always accompanied by carbonization, and is less limited in its after-effect than cutting and coagulation

d. Desiccation

It includes massive tissue involvement both in terms of depth and surface area. It is the most unlimited and uncontrolled of all four actions. Tissue reactions are unpredictable mast of the time. For fulgeration and desiccation bi-polar electrodes are required, while cutting and coagulation require a uni-polar electrode.

Advantages of Electrosurgery[89]:

- It controls any degree of haemorrhage.
- It prevents seeding of bacteria into the incision site.
- The active electrodes are flexible wires that can he bent or shaped easily to fit any requirement, never need sharpening are self- sterilizing; and require no pressure to function.
- It permits planning of soft tissues, a procedure unique to electro surgery.
- It provides a clear or at least a better view of the operative site.
- It increases operative efficiency and reduces chair time.
- It improves the quality restorations and eliminates scar formation.

Disadvantages of Electrosurgery:[89]

- It may be contraindicated in patients with a non-compatible or poorly shielded cardiac pacemaker patient.
- It produces an unpleasant odour and sometimes an unpleasant taste.

Gilmore et al[90] summarized the problems associated with tissue displacement.

- Laceration of tissue during preparations.
- Debris left in the preparation because the area was not completely dried.
- Inadequate control of haemorrhage.
- Irreversible tissue damage caused by prolonged contact of the displacement string (chemical and mechanical) with the sulcus.
- Alteration of the periodontal attachment when the preparation was extended too far into the gingival sulcus and
- Lack of knowledge and understanding of the use of chemical and tissue reaction.

It should be recommended that regardless of the method or technique used, irreversible tissue damage can occur if proper care and concern are not shown. Restorative Dentist possesses high degree of artistic sculpturing skills that can be effectively utilized to harmonize restorative and soft tissue contours. The longevity and the function of the restoration depend on the optimal health and biocompatibility of the surrounding tissue. Sulcus damage with electro surgery was reported to vary depending on the type of unit used. Electrosection causes dehydration and volatization only along the line of incision.

Electro coagulation causes tissue necrosis over a moderately localized area. Electro dissection or electrocautery produces coagulative necrosis over a wide area, extending into underlying tissues.

Wilhelmanet et al reported the following:

- Burn marks on root surfaces where contact was made with electrode.
- Cemental destruction with subsequent unpaired cementogenesis
- Lack of epithelial and connective tissue reattachment
- Significant recession of the free gingival margin
- Apical positioning of the sulcular epithelium and
- Slight loss of crestal alveolar bone

Rotary Gingival Curettage

The technique of using rotary diamond instrument to enlarge the sulcus has been termed as “Gingitage”. It involves preparation of the tooth subgingivally while simultaneously curetting the inner lining of the gingival sulcus with rotary[91] diamond instrument. Definitive tissue removal allows room for placement of retraction cord and impression material. This technique has been described for removal of healthy or inflamed gingival tissue during tooth preparation.

Kamansky et al reported less change in gingival height with rotary curettage than with lateral displacement using retraction cord. With curettage there was apparent disruption of the apical sulcular and attachment epithelium, resulting in apical positioning of the junctional epithelium and increase in sulcus depth. The changes were quite small, and not regarded as clinically significant. Thick palatal tissue responded better to the technique than the tissues on the facial aspect of maxillary anterior teeth.

Tupac and Neacy found no significant difference between retraction cord and rotary curettage. The goal is to eliminate the trauma of pressure packing and necessity of electrosurgical procedures. Using air and water coolant, the subgingival margin placed on the tooth with diamond burs. No attempt was made to retract the gingival margin or shield it from the diamond while the finish line is being prepared. The gingitage technique is followed by non-pressure placement of retraction cord rather than packing into sulcus and without causing permanent damage to the soft tissue.[85,91]

Expa-syl Injectable Retraction Method[92]: Expa–syl is a unique paste system (Company-Pierre Roland, France) specifically designed for gingival retraction that ensures suppression of gingival margin and drying of the sulcus. It displaces the tissue similar to traditional retraction cord. The aim of this system is to detach the marginal gingivae without injuring the epithelial attachment. The system consists of an injectable material that contains a haemostatic agent, specially designed gun and tips. This injectable material is repacked in a dispenser. This dispenser is specially prepared to extrude the paste at a 2 pressure of $0.1N/mm^2$; it is the maximum amount of pressure to prevent damage to the epithelial attachment. The force exhibited by the Expa-syl is still nearly 50 times less than that of single and the double cord technique. Expa-syl is injected into the sulcus at approximately 2mm/second. It is left in place for approximately 1 to 2 minutes.

Composition: **Micronized Kaolin, Aluminum**

Chloride and Water

Kaolin is an organic binder, clay like material responsible for the body or rigidity of the material. Aluminium chloride is the haemostatic agent that controls haemorrhage of the tissue. Thus EXPA-SYL is a painless tissue retraction procedure offering many removed, the clinician can obtain a clean clinical site that is ideal for a perfect impression. EXPA-SYL can change the way clinicians manage tissue in variety of restorative procedures, providing a good satisfaction to both clinician and the patient. Several studies have suggested that gingival retraction cords containing epinephrine may not be better than cord containing aluminium sulfate. Dentists should carefully consider the benefits and disadvantages of gingival retraction cords containing epinephrine in the light of the potential risk of adverse effects and apparent lack of significant improved clinical performance. Knitted gingival retraction cords are ranked better that the twined cords.

There is no consensus cited in the literature regarding criteria for evaluation of the clinical efficacy with gingival retraction cord. In the period of global harmonization, this appears peculiar because kilometres of retraction cords are used daily by thousands of dentists.

The following interpretations can be made related to use of retraction cords:

1. Effect in vivo crown margin: An increase in marginal discrepancy between the casting and the prepared tooth resulted in an increase of gingival inflammation measured by gingival index and crevicular fluid volume.

2. Kinetic study of absorbency of retraction cords. The soaking time ensured for the liquid uptake of retraction cords was of crucial factor in successful gingival retraction procedure. The results of this study indicated that prior to clinical use, 20 minutes of soaking in the medicament solution was necessary and air bubbles are removed from the liquid before soaking the cord. The rate of liquid uptake depends on the thickness of the cords as well. The thinner cords exhibit faster absorption rates than the thicker cords. The saturation time however did not correlate with the thickness of the cords, as the time also depends on the maximum of the fluid absorption capacity.

3. The effect of the amount of time a cord remains in the gingival sulcus was investigated using one type of cord and hemodent solution.

Within limits of the investigation design the following conclusions may be made:

I. At both the mesiobuccal and the transitional line angle areas, tissues displaced for 2 minutes resulted in the gingival crevice significantly

II. Smaller at 20 seconds than those when displacement time was 4, 6 or 8 minutes.

III. No significant difference in crevicular width was found at any time period for tissues displaced for 4, 6 and 8 minutes.

IV. At the transitional line angle, crevicular widths were significantly smaller than the mesiobuccal angle at 20seconds for all periods of displacement and remained so up to 180 seconds.

V. To achieve a crevicular width of 0.20mm, cord should remain in for an optimum time of 4minutes prior to impression making.

Soft tissue laser like the diode laser and the carbon dioxide laser can also be used for gingival retraction. Cryosurgery using nitrous oxide under pressure may also be used. Cryosurgery has an advantage over other surgical procedures as there is no need of anaesthesia.[93,94]

IMPRESSIONS FOR CAST RESTORATIONS

Impression materials are used to record intraoral structures for the fabrication of definitive restorations. The accuracy of final restorations depends greatly on the impression materials and techniques. Diagnostic casts are used to aid in treatment planning. Master casts are used for producing complete dentures, removable partial dentures, crowns, fixed partial dentures, and implant prostheses. Accurate impressions depend on identifying the applications that do or do not fit each material's characteristics. Materials used without adequate knowledge of their characteristics can impair a successful outcome. Often, the choice of impression materials depends on the subjective choice of the operator based on personal preferences and past experience with particular materials.

Ideal characteristics of impression materials

- Safety
- Accuracy
- Easy handling
- Capacity to be poured multiple times
- Tolerable taste
- Dimensionally stable
- Non irritating to human tissue
- Reproduction of details
- Cost

Common impression materials used in restorative dentistry

Impression materials that are currently popular include hydrocolloids, addition silicones, polyethers, and polysulfides. Some of the older impression materials (e.g., zinc oxide eugenol impression paste, impression plaster, and impression compound) are still used in certain applications but are limited in use because they cannot be removed past undercuts without distorting or fracturing the impression[95].

Disinfection of impression materials

Impressions should be rinsed with water and then disinfected[97]. Diluted sodium hypochlorite (bleach 5.25%, 1:10 dilution, 10 minutes at 20°C) provides American Dental Association– accepted disinfection but not sterilization for all materials, except zinc-oxide eugenol paste. Glutaraldehydes are the disinfectant of choice for zinc oxide eugenol impression pastes.[96]

Types and characteristics of specific impression materials

REVERSIBLE AGAR-AGAR HYDROCOLLOID

These materials are formed mostly of water (80-87%), which is the dispersion phase of the colloidal system of the material. The dispersed phase is agar-agar. This occurs naturally as metabolite of seaweed; chemically, it is a sulfuric acid ester of a linear polymer of the polysaccharide galactose. It comprises 8-15%. A sol state of the material is produced by heating. It occurs as a result of thermally vibrating the polymer molecules of the agar, increasing their kinking activity and breaking the weak secondary bonding holding them together. A gel state is produced by cooling, which creates a fairly solid mass. In the gel state the poorly joined agar molecules will create a porous meshwork, into which the dispersion phase (water) will be absorbed. This is the set mass. The material is introduced and brought in contact with the details to be duplicated in a sol state, then gelled by cooling. After a specified period, it is removed in the gel state. The agar and water relation play the major role in dictating the behaviour of the material.

IRREVERSIBLE HYDROCOLLOIDS

When alginic acid (prepared from a marine plant) reacts with a calcium salt (calcium sulfate), it produces an insoluble elastic gel called calcium alginate. When mixed with water, the alginate material first forms a sol. The following chemical reaction forms a gel to create the set impression material. In an alginate impression compound, calcium sulfate dehydrate, soluble alginate, and sodium phosphate are in the powder. When water is added, calcium ions from the calcium sulfate dehydrate react preferentially with phosphate ions from the sodium phosphate and pyrophosphate to form insoluble calcium phosphate. [96]

Calcium phosphate is formed because it has a lower solubility; thus, the sodium phosphate is called a retarder and provides working time for the mixed alginate. After the phosphate ions are depleted, the calcium ions react with the soluble alginate to form insoluble calcium alginate, which with water forms the irreversible calcium alginate gel. It is insoluble in water and its formation causes the material to gel[97].

POLYETHERS

Polyethers consist of a base paste that is composed of a long-chain polyether copolymer with alternating oxygen atoms and methylene groups ($O-[CH2]_n$) and reactive terminal groups. Also present are fillers, plasticizers, and triglycerides. The catalyst paste has a cross-linking agent (aliphatic cationic starter) and filler and plasticizers. Polyethers involve the reaction of impression materials. The polyether-containing imine ringed side chains with a reactant that opens the rings and causes chain lengthening and cross-linking to form a polyether rubber[97].

POLYVINYL SILOXANES

Addition silicones (which are the most popular because no reaction by-products are formed) involve the linking of a vinyl siloxane in the base material with a hydrogen siloxane via a platinum catalyst[20,98]. The reaction produces hydrogen, which is scavenged by the platinum. Viscosity is altered by changing the amount of silica filler, which produces either a putty or less viscous wash material. Vinyl polysiloxane silicones (also called addition silicones, polyvinyls, vinyls, and polyvinyl siloxane) are considered state-of-the-art for fixed partial denture impressions. They constitute the most widespread use of impression materials for fixed prosthetics[98].

They are virtually inert after set, and they can be trimmed and poured in any die material. Before they set, however, they are susceptible to contamination. Because the addition silicones require a small amount of catalyst (platinum compound) to initiate the setting reaction, anything that interferes with 636 RUBEL the catalyst (preventing cross-linking of the material) causes the surface of the impression to remain tacky[20]. Polyvinyl siloxane contamination is usually a result of sulfur or sulfur compounds[98]. This is usually seen in the dental office in the form of latex gloves or rubber dams. Small amounts of sulfur interfere with setting of the critical surface next to the tooth and produce major distortion[95]. The preparation and adjacent soft tissues can be cleaned with 2% chlorhexidine to remove contaminants[20]. If wearing latex gloves, one should avoid touching the unset impression material, the teeth and adjacent gingiva, the interior of the tray, the mixing spatula or mixing pad, the end of a mixing tip, and the retraction cord. The way to avoid latex contamination is to wear polyethylene gloves over the latex gloves or not wear latex gloves during the impression procedures.[96]

Some vinyl gloves also may have the same effect because of the sulfur-containing stabilizer used in the manufacturing procesS[95]. Sulfur compounds can poison the platinum-containing catalyst in addition silicone impression materials and result in retarded or no polymerization in the contaminated area of the impression[20]. It has been reported that vapor given off by polysulfide impression material may cause contamination. It is a good idea not to store polyvinylsiloxane impression material close to polysulfide impression materials. Another source of contamination is the oxygen-inhibited layer on the surface of resin materials that appears immediately after curing. This thin layer causes impressions to remain tacky around new composite placed restorations[98].

POLYSULFIDES

Polysulfide impression materials are supplied as two paste systems. The base consists of a polysulfide polymer (terminal/side chain SH groups), titanium dioxide, zinc sulfate, copper carbonate, or silica. The accelerator 638 RUBEL (catalyst) has primarily lead dioxide with other substances, such as dibutyl or dioctyl phthalate, sulfur, and magnesium stearate and deodorants. The viscosity is altered by adding different amounts of titanium dioxide powder to the base. It sets by oxidation of the SH groups, which results in chain lengthening and cross-linking and gives it elastomeric properties[97]

The polyvinyls (addition silicones) and the polyethers account for a major portion of the market used as impression materials in fabricating fixed partial dentures, removable appliances, and implant prostheses. The hydrophilic addition silicones and polyethers flow easily, result in fewer retakes, and produce more bubble-free casts when used under appropriate guidelines. The polyvinyl siloxane materials are intrinsically hydrophobic (water repellent) by nature, so they must be made hydrophilic by adding surfactants. When these surfactants come in contact with moisture, it has to migrate to the surface, which prevents the hydrophilicity from fully developing during working and setting times and can result in voids and inaccurate impressions. A dry field is critical for their use.

Polyether is hydrophilic by nature of its chemical makeup, and moisture does not interfere as much with achieving void-free impressions. The condensation silicones, polysulfides, and irreversible hydrocolloids have qualities that make them more sensitive with respect to handling considerations and mix-and-pour techniques because they exhibit more changes over time after setting, which may affect accuracy in detail reproduction. The polyvinyls and polyethers are more stable to deformation after setting has occurred.[96]

ACCURACY

According to American Dental Association specification #19, elastomeric impression materials used to fabricate precision castings must be able to reproduce fine detail of 25 µm or less.[99] PVS impression materials can reproduce details of 1 to 2 µm.[100] The various viscosities also play a role in the accuracy of detail reproduction. In fact, the lower the viscosity, the better it records fine detail. Putty materials cannot reproduce fine detail at the 25 µm level and are required only to record details of 75 µm.[101]

DIMENSIONAL STABILITY

Ideally, the dimensional stability of an impression material reflects its ability to maintain the accuracy of the impression over time,[20] thus giving the opportunity to pour it at the convenience of the operator. In reality, it is usually a time-dependent procedure, with greater dimensional accuracy occurring immediately upon polymerization completion, declining as the impression is stored for extended periods of time.[98,95,102] This is why these materials should have a low shrinkage upon polymerizing and remain stable. PVS materials possess almost ideal dimensional stability and can be poured within 1 to 2 weeks after making the impression.[20, 95, 98,103]They are followed by polyethers, but these can absorb water from the atmosphere and swell.[104, 105] For maximum accuracy, it is recommended to pour them within 1 hour of removal from the mouth. Other impression materials, such as condensation silicone and polysulfides, should be poured no more than 30 minutes after removal from the mouth. The volatile ethyl alcohol and water produced as by-products of the setting reaction with condensation silicone and polysulfide rubber, respectively, tend to evaporate from the surface of the set impression, resulting in distortion.[106] All types of elastomeric impression materials undergo shrinkage caused by polymerization, and materials with reaction by-products undergo additional contraction. In numbers, the polysulfides and condensation silicones have the largest dimensional change during setting, in the range of −0.4% to −0.6%. PVS has the smallest change (−0.15%), followed by polyether (−0.2%).

DEFORMATION AND TEAR ENERGY

According to Chai et al, three mechanical properties of elastomeric impression materials are clinically relevant: the yield strength, the strain at yield point, and the tear energy[107]. The yield strength determines the ability of the impression to withstand stress without permanent deformation. The strain at yield point indicates the amount of undercut an impression material can overcome without permanent elastic deformation, and the tear energy indicates the resistance to tear of the material after setting.[95,108] Where subgingival margins are concerned, this can be an important criterion. A performing material should display high tear energy and adequate elastic recovery and should require the expenditure of large amounts of energy to initiate and propagate tearing. Polysulfides display higher tear energy, but permanently deform after being stretched to 0.4%, which is the critical point of permanent deformation, and do not recover completely elastically.[20,105] PVS and polyethers tear before the limit of permanent deformation and are considered to have the highest tear strengths.10 Therefore, their clinical use is more suitable, as they will deform in the range of their yield strength.[109]

ELASTIC RECOVERY

Elastic recovery of an impression is defined as the ability of a material to return to its original dimensions without significant distortion upon removal from the mouth.10 No impression material has 100% elastic recovery, and for all impression materials the greater the depth of undercut, the greater its permanent distortion.[98] Thus, the minimum thickness of the material in the tray should be three to four times more than the largest undercut. An excellent procedure to maximize the elastic recovery of the impression material is to eliminate or block out any undercuts in the tooth preparation. PVS showed the best elastic behaviour, with over 99% elastic recovery, followed by polyethers and polysulfides.[20] Once mixed, PVS develops elasticity rapidly and should be used as soon as possible, especially in high temperatures. On the contrary, polyethers remain plastic for a longer period after being mixed,[110] but their final stiffness is still more than that of PVS, which may affect the ease of removal from the mouth.

COMPATIBILITY WITH GYPSUM AND RESIN DIE MATERIALS DURING SETTING

Except for hydrocolloid impression materials, all previously mentioned impression materials have no effect on the setting of gypsum or resin die materials used for the pour. Hydrocolloid materials tend to retard the setting of the adjacent hemihydrate of calcium sulfate to a dihydrated one, resulting in a stone surface that is soft, chalky, easily abraded and does not replicate all the details of the impression. This should be obvious recalling that colloidal materials in general are retarders to gypsum setting. Additionally, the presence of borax in the mass aggravates the situation. Also, water in the mass tends to dilute the gypsum, thus locally delaying its setting and weakening the product. To counteract this, immersing the impression for 5-10 min. in 3% solution of potassium sulfate can accelerate the setting of the gypsum sufficiently to neutralize the retarding effect of hydrocolloid and its contents. Also, proper washing of the impression of saliva and blood will enhance the hardening of the contacting gypsum.[96]

Even with the elastomeric impression materials, incomplete details or an unworkable die surface may be produced if excessive moisture in the form of saliva, blood, or water is present in the impression during pouring, or if the die material is not vibrated sufficiently into the impression to counteract the hydrophobic nature of rubber base materials. If treated and handled properly, all impression materials will produce a workable die surface and detail.[17]

WORKABILITY

Using these materials necessitates the following steps

- <u>Choosing the material</u>

  Several types of impression materials are available and considered accurate enough for use in the fabrication of cast restorations. The choice is based on ease of manipulation, dimensional stability and to some extent the cost of material. Most of newly available materials have excellent accuracy and can be used without doubt. The impression can be taken on prefabricated tray or the tray can be fabricated outside the oral cavity.[25]

- <u>Constructing or customizing a tray</u>

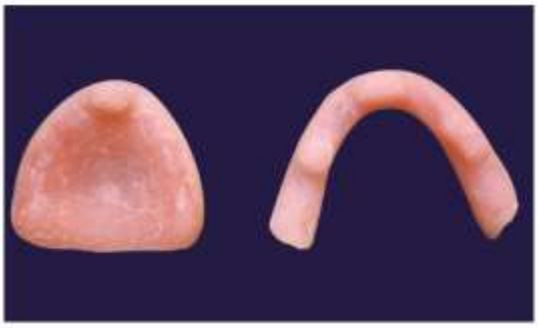
Selection of Impression Tray

For reversible hydrocolloid, a water-cooled stock metal tray is used. For polysulfide and polyether material, a custom tray is used. Condensation and addition silicones can be used with stock or custom trays. Custom trays are usually preferred because they allow a more uniform, thin layer of 2.0-3.0 mm of the impression material. A uniform thickness of impression material will lead to less distortion. Elastomeric impression materials in thicknesses greater than 3.0 mm show greater shrinkage and distortion. Thickness of less than 2.0 mm would either tear or distort easily. It has been reported that the mean difference in material thickness between custom and stock trays is less than 1.0 mm and that variations from uniform thickness of impression material exist in both custom and stock trays. It has been established that there is no significant difference in the marginal fit of single tooth restorations on casts made from polyvinyl siloxane impressions in custom and stock trays. Thus, for single tooth restorations, stock trays serve the purpose adequately. However, for long span fixed partial dentures inter-preparation and cross-arch discrepancies may occur with these trays. Some authors have described a technique of making a custom tray by lining a stock-tray with modelling compound. But this is not an effective method because plasticizer in the elastomeric material can soften the compound and distort the impression.[110]

Fabrication of Custom Tray

Acrylic resin is used to form a custom tray. A study model provides the basis for forming the tray. To provide space within the completed tray for the impression material, the study model is covered with base plate wax. A sheet of base plate wax is heated over a flame to soften it. It is then folded in half and placed on the diagnostic cast. It is trimmed so that it extends 2.0-3.0 mm beyond the necks of the teeth. A horseshoe shaped form is used for both arches, palatal coverage is not required for the maxillary arch. The diagnostic cast must be covered with tin foil before the wax is adapted. A 3.0 × 3.0 mm hole is cut through the wax over the posterior teeth on both sides and in the incisor area. The tray resin will touch the teeth in these areas to form tray stops. This will prevent the tray from being seated inaccurately. On the side of the prepared tooth, the stop is placed distal to the prepared tooth.[111]

Before the resin tray is made, the wax is covered by a layer of tin foil to prevent the wax from impregnating the surface of the tray during the exothermic polymerization of the resin. The waxy layer on the tray will diminish bonding action to the tray adhesive. The cold cure acrylic resin is mixed and allowed to stand till the dough stage is reached. It is then rolled to form a horseshoe shape and flattened. Some extra bulk is left in the middle. The acrylic is adapted over the wax. The bulk in the middle is used to make a handle. Two lateral extensions in the posterior region may be placed to aid in removal of the tray from the mouth. When the tray is hard, but still warm to touch, it is removed from the cast and the tin foil is peeled off. The tray undergoes polymerization shrinkage for at least 40 minutes after fabrication and minor changes continue to occur for up to six hours. Thus, it should be prepared at least six hours prior to making the final impression. The tray is then coated with the tray adhesive. Different tray adhesives are available. The adhesive must be painted and allowed to dry for at least 15 minutes before the material is loaded. The bonding strength of the adhesives used with polyvinyl siloxane can be improved nearly 50% by adding perforations to the tray and approximately 40% by roughening the inner surface of the tray. When plastic perforated impression trays are used with polyvinyl siloxane impression material the adhesion is usually adequate but can be improved when a tray adhesive is used.[17]



- Preparing the mouth, the teeth, and the preparation

Interocclual Record

Before preparation of the tooth, the occlusal contacts in maximum intercuspation and in all lateral and protrusive movements should have been carefully evaluated. If the patient has sufficient canine guidance to provide disocclusion of posterior teeth, the necessary registration of the opposing teeth can be obtained by

(1) making a maximum intercuspation interocclusal record with commercially available bite registration pastes or

(2) making full-arch impressions and mounting the casts made from these impressions on a simple hinge articulator. he interocclusal record works well when preparing one tooth; the full-arch casts are preferred when two or more prepared teeth are involved.[111]

The maximum intercuspation interocclusal record can be made from one of several commercially available bite registration pastes. The most used bite registration pastes are composed of heavily filled PVS impression materials. Several materials are available in cartridge systems that automatically mix the base and accelerator pastes together as they are expressed through a special disposable mixing tip. The mixed impression material is dispensed directly onto the prepared teeth and their opponents, then the patient closes completely. The dentist observes teeth not covered by the bite registration paste to verify that teeth are in maximum intercuspation. When the material has set, the dentist removes the interocclusal record and inspects it for completeness. When held up to a light, areas where the adjacent unprepared teeth have penetrated through the material should be seen. The interocclusal record is set aside for later use in the laboratory.[111]

- Preparing the material

  A thickness of impression material greater than 3 mm increases shrinkage and the chance of voids; a thickness less than 2 mm may lead to distortion or tear of the impression material or to breakage of narrow or isolated teeth on the cast during withdrawal from the impression. Adequate bonding of impression material to the tray is accomplished with the application of a special adhesive to the tray.[17]

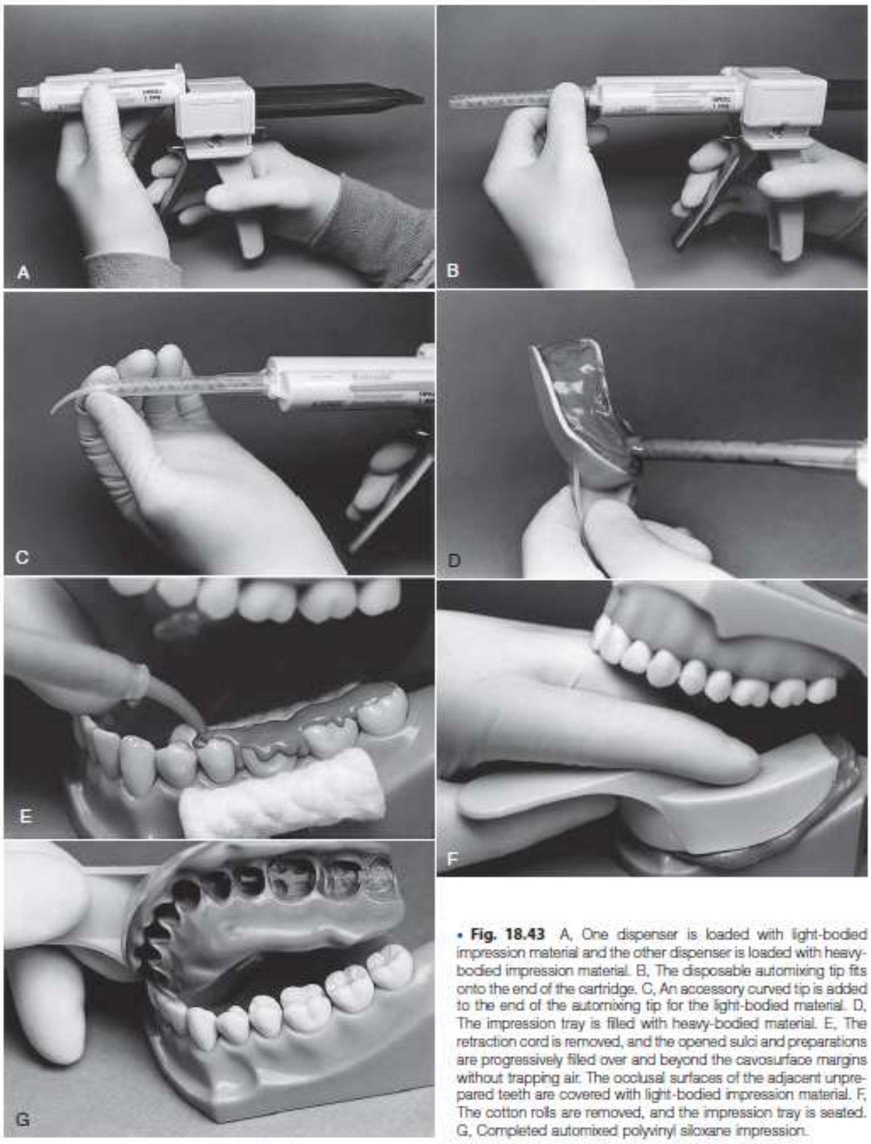
- Loading the syringe and tray

Impression Technique

Most dental manufacturers offer their PVS impression materials in automix dispensing systems. The auto mixing systems have many advantages, including (1) speed, (2) consistent and complete mixing of accelerator and base pastes, and (3) incorporation of very few air voids during mixing and delivery to teeth. The technique demonstrated illustrates the use of two viscosities of impression material, a light-bodied material to inject around the preparation and a heavy-bodied material to Fill the tray. Two dispensing guns are needed. The dispensers are loaded with cartridges that contain the accelerator and base pastes. A disposable automixing tip it's onto the end of each cartridge. The light-bodied mixing tip has an accessory curved tip that is small enough to gain access to the smallest, most remote areas of the preparation. [17]

The first dispenser is used to mix and fill the impression tray with the heavy-bodied impression material. The dispensing tip should be kept embedded in the impression material as it is expressed into the tray so that the chance of trapping air is decreased. he second dispenser is then used to mix and inject the light-bodied impression material on the prepared teeth. Teeth should be examined to ensure that the field is still clean and dry. Any visible moisture on teeth is removed with compressed air. he retraction cord is gently removed with operative pliers. All preparation surfaces should be clean, dry, and exposed to view. Next the opened gingival sulci and preparations are deliberately and progressively (moving from distal to mesial) filled over and beyond the margins with material from the syringe.[111]

To avoid trapping air, the tip is kept directly on the gingival and pulpal walls, filling the preparations from the gingival to the occlusal aspect, and the low is regulated so that the material is not extruded too fast ahead of the tip. Light-bodied material also is injected on the occlusal surfaces of the unprepared adjacent teeth to eliminate the trapping of air on the occlusal grooves. After filling and covering teeth with material from the syringe, the cotton rolls are immediately removed, and the loaded tray seated over the region. The manufacturer's product instructions should be followed about how long the material should be allowed to set before removal. As an additional safeguard, the operator should test the set of the impression material wherever it is accessible at the periphery of the tray. When it recovers elastically from an indentation made by the tips of the operative pliers, it is ready for removal.[112]



• **Fig. 18.43** A, One dispenser is loaded with light-bodied impression material and the other dispenser is loaded with heavy-bodied impression material. B, The disposable automixing tip fits onto the end of the cartridge. C, An accessory curved tip is added to the end of the automixing tip for the light-bodied material. D, The impression tray is filled with heavy-bodied material. E, The retraction cord is removed, and the opened sulci and preparations are progressively filled over and beyond the cavosurface margins without trapping air. The occlusal surfaces of the adjacent unprepared teeth are covered with light-bodied impression material. F, The cotton rolls are removed, and the impression tray is seated. G, Completed automixed polyvinyl siloxane impression.

Removing and Inspecting the Impression

After the PVS impression has properly polymerized, it is removed from the mouth by a quick, firm pull that is directed as much as possible in line with the draw of the preparation. Removal is aided by inserting a fingertip at the junction of the facial border of the impression and the vestibule fornix, disrupting the vacuum that occasionally occurs during withdrawal, especially with full-arch impressions. It should register every detail of the teeth and the preparation Introducing the material to the tooth preparation and the mouth.[111]

WORKING DIE & MODEL CONSTRUCTION

Various materials have been used for construction of dies. Some of the basic requirements for such materials are:

- It should be compatible with the impression material.
- It should be dimensionally stable.
- It should have a smooth, non-abradable surface.
- It should be able to accommodate auxiliary restoration retention (e.g. pins).
- It should be able to receive a spacer in selected areas to create space for the luting agent of the casting.[112]

The materials used for construction of dies are:

GYPSUM

The materials used to fabricate the die and working models are usually gypsum products. There are several variables chat can affect the behaviour of these gypsum products. In their powder form they are primarily calcium sulfate hemihydrate in the alpha form. This signifies only that their crystals are very regular and have smooth surfaces that can be readily wetted with the least amount of water, as compared to the other types of hemihydrates (beta hemihydrate). Some contain silica (for divesting investment). When mixed with distilled water, the setting reaction starts. The setting reaction is a process of dissolution and hydration followed by supersaturation and precipitation of dihydrate crystals of the calcium sulfate. When the crystals are in enough and dimensions, they intermesh, collide, and harden the mass. The collision of these formed and growing crystals, if in sufficient impact, can create stresses at their interfaces. If conditions allow (nonconfinement), the outward release of these stresses will be in the form of expansion of the plastic mass. This situation is not desirable at this stage of the cast fabrication.[111]

ELECTROFORMED DIES

Certain metals having high strength, hardness and abrasion resistance can be electroplated on the impression forming electroformed dies. Electroplating is the result of electrolysis. When electric field is superimposed on the electrolytic solution, the ions in this solution are attracted and begin to move to oppositely charged electrodes. The
positively charged ions (cations) move to the negative electrodes (cathodes), the negatively charged ions (anions) move to the positive electrode (anode). The anode is a bar of pure metal, supplying metal cations continuously. The deposition takes place on the cathode (impression). The impression must be made electrically conducting and it acts like cathode.[111]

- Copper Plating

  This method is usually used with impressions of impression compound or addition silicone rubber base material.

The two methods frequently used are:

- The cavity surface may be lightly oiled and coated with a thin film of colloidal metal.
- The cavity surface may be coated with a film of graphite.

The graphite is mixed with water to a concentrated consistency, painted onto the cavity surface of the impression and dried under the blast of a chip blower. Application of graphite is the method of choice because it is more readily wetted by the copper sulfate solution. A thin copper wire, 28-gauge, is wrapped around the copper tube and twisted. A sheet of tacky casting wax is cut into strips. One of the strips is open for a short distance at its midpoint. The strip is passed through the flame of a Bunsen burner, the slit of the wax accommodates the circuit wire, while the wax is wrapped around the copper tube and tucked over its bottom edges. A second strip of wire is wrapped around the circuit wire. Wax is melted and used to seal all joints and to cover any remaining exposed metallic surfaces. The wax wrapping the circuit wire is bent and acts as a handle and permits ready visibility during the electrodeposition. The manufacturer provides a 'holder' for the impression. The impression is wrapped in wax and then held in a stream of cold water. The force of stream will flush out the pattern and force any pocket of air before it. Any pocket of air will result in a failure of electrodeposition in the area.[112]

The water-filled impression is then submerged in the electronic bath, and the circuit wire is twisted about the contact bar of the impression holder. A cathode 'tapping' wire is placed in the bath. This taps some of current to reduce the rate of deposition.

The electroformer apparatus are merely devices, which step down the line voltage, rectify the alternating current, and provide rheostatic control to regulate the rate of electrodeposition.[112]

Electroforming must begin at a very low amperage, otherwise the initial deposit of copper is granulated and since this deposit will be along the margins of the preparation such dies are worthless. When copper deposition has begun satisfactorily, the tapping wire may be removed. After the entire cavity surface is coated with copper, the amperage may be stepped up to accelerate the electroforming. The composition of the solution for copper plating is:

Copper sulfate	-	200 gm
Sulphuric acid	-	30 ml
Phenol Sulphuric acid	-	2 ml
Distilled water	-	100 ml

Plating proceeds for 12-15 hours. After electroforming, the impressions are washed off the elctroforming solution. Acrylic resin or dental stone can be poured.[113]

- Silver Plating

These dies are restricted to polysulfide, polyether and silicone rubber base materials; however, some silicone rubber impression materials might not produce acceptable silver-plated dies. Same apparatus as copper plating is used, but small current is required. The surface of the impression is metallized with a fine silver powder. A silver cyanide bath is preferred over an acid copper bath. The reliability of silver cyanide bath is better, and polysulfide is more dimensionally stable in the alkaline cyanide bath than in the acid copper bath.

An anode of pure silver at least twice the area to be plated is used. Electroplating is carried out for approximately 10 hours.[112]

The composition of the silver-plating bath solution is

Silver cyanide	-	36 gm
Potassium cyanide	-	60 gm
Potassium carbonate	-	45 gm
Distilled water	-	100 ml

Precautions

- The silver-plating solution is poisonous so care should be taken that hands, workbench area or clothes are not contaminated.
- Silver-plating solution should be kept as a basic solution. Addition of acid will cause formation of hydrogen cyanide gas, which is poisonous.
- Copper plating shouldn't be done in the same area where silver plating is done because of risk of contaminating the basic silver solution with acidic copper solution.
- The silver-plating solution should be covered always to control evaporation and dissipation of fumes.[113]

- Low Fusing Alloy Such as Bismuth, Lead, tin and Cadmium

Low fusing alloy such as bismuth, lead, tin and cadmium have also been used. They are usually used to form extensions on electroformed dies.

AMALGAM DIES

Conventional amalgam is also used to make dies like silver amalgam which is used to restore teeth.

Technique

An impression is made in a copper band with modelling compound. A thin piece of boxing wax, 28 to 30 gauge, is wrapped around the impression and band matrix and extended about 3/8 inch beyond and along the gingival margins of the band and its contained impression. The boxed impression is embedded with the open end showing the cavity facing up, in a mix of plaster, which has been previously placed in a small rubber ring to hold it steady and prevent it from spreading during setting. After the plaster base has hardened, a plastic mass of amalgam alloy is mixed. The amalgam is condensed into the impression as is done in making a good restoration.[112]

After it has thoroughly set, the rubber ring and plaster is removed; the die is then immersed in warm water to remove the impression compound and wax. The die is trimmed and tapered so that it simulates the shape of a tooth root. An impression of the upper and lower arches is made. The amalgam die is placed in the impression of the prepared tooth and the cast is poured. Amalgam dies and all metal dies are good conductors of heat and so softened wax applied to them cools rapidly. This rapid cooling of the wax may produce internal stress, which can cause distortion of the wax pattern.[113]

The sudden cooling of the liquid wax when applied to a metal die may also result in the contraction of wax away from the die and discrepancies may arise because of imperfect adaptation of the wax pattern to the die. These problems can be avoided by:

- Warming the metal die to mouth temperature or slightly below.
- Some operators prefer to place an electric heating pad on the bench which serves to keep the die and all carving instruments at a suitable temperature to avoid sudden cooling of the inlay wax.

In case of amalgam dies, the die should be lubricated with oil prior to fabrication of the wax pattern. After the inlay is tried on the amalgam die it must be pickled to remove any traces of amalgam.[17]

SILICOPHOSPHATE CEMENT DIES

These are sometimes used to make dies in compound impressions. They give harder dies than dental stone. One disadvantage of these materials is that they shrink on setting and the surface of the cement has a tendency to lose water upon standing making it friable. Therefore, the cement dies are stored in water or glycerine.

EPOXY RESIN DIES

Epoxy resins are supplied in two or three parts that are mixed before insertion into the impression. The first part contains 50–60% epoxy polymer, 30–40% vinyl cyclo-hexene diepoxide and the rest are copolymers. The second part consists of partially hydrolyzed benzophene tetra-carboxylic acid dianhydride. The third part is a tertiary amine catalyst.

The material is mixed in vacuum and then poured into the impression. It is compatible with all impression materials except hydrocolloids. The resin cures in about half an hour at room temperature.[113]

During this curing it shrinks about 0.02 to 0.6% depending on configuration and bulk of the die. This shrinkage can be compensated for by thermal treatment of the die. It is heated in steps of 10o per minute to 160oC and then held at 160°C for one hour. The temperature should not exceed 200°C. It is then rapidly cooled to room temperature. The exact mechanism of this expansion of the material is not known. One hypothesis is that further cross-linking of the polymer occurs which generates water causing expansion.[25]

Epoxy dies are stronger and more abrasion resistant than gypsum dies and their reproduction of detail is much better than with gypsum dies.

DIVESTMENT

Divestment is a combination of die material and investing material. Divestment is mixed with a colloidal silica liquid, then a die is prepared from the mix and a wax pattern is made on it. After this, the wax pattern with die is invested in divestment. This is highly accurate technique for extracoronal cast gold restorations.[112]

CONSTRUCTION OF THE DIE AND THE WORKING MODEL

A ‘Die’ is the positive replica of one tooth. Usually the prepared tooth is separated from the cast (die making) and the rest of the procedures are carried out on the die.

The ‘dies’ can be constructed in two ways.

- Techniques utilizing two sets of pours
- Techniques utilizing one set of pour

Techniques Utilizing two Sets of Pours

- Two pours can be had if elastomeric impression materials are used
- Two separate impressions are required if reversible hydrocolloid is used.

Dies are prepared from the first pour. These dies are not incorporated into the working model. Working models are poured from the second impression or are obtained from second pour of the same impression depending upon the impression material[17].

Advantages

- The mounted casts are not subjected to distortion since mechanical removal and insertion of the die may induce stresses and may interfere with its relationship with the master cast.
- There is complete immobilization of the prepared tooth replica, during building the anatomy, contact and contour of the wax pattern.

Disadvantages

• Moving the wax pattern from the working model to the die and vice-versa can induce stresses in the wax.

• The two replicas of the tooth may not have the same exact dimension and shape, thus inducing stresses in the wax pattern.

A pre-measured amount of water is placed in a plastic bowl and a measured amount of die stone is added to the water. Die can be poured with approximately 50–70 gms. of stone. Full arch impressions require approximately 200 gms. The water and powder is vacuum mixed. Excessive water is blown from the surface of the hydrocolloid impression material without desiccating it[19].

In case of elastomeric impression material, a surface wetting agent may be sprayed on it. A small amount of stone is then carried on the side of the impression above the preparation and then vibrated until stone reaches the 'bottom' of the preparation. Small increments are continually added till the impression is filled completely. After the preparation is filled, stone is poured into the tooth on either side of the impression. Stone is built to approximately one-inch height to allow adequate bulk for preparation of a handle on the die. After this pour is hardened, the impression is poured again (for elastomers); second impression can be used for hydrocolloids to obtain full arch working models. Hydrocolloid impressions are placed in a humidor while the stone hardens, while elastomeric impressions are kept open.

The cast from which die is poured is trimmed. Wet it slightly prior to trimming. All excess stone around the prepared tooth is removed. A handle is cut for the die. The handle should be slightly larger in diameter than the preparation and octagonal in cross section. Its sides ought to be parallel or slightly tapered toward the base. The handle should be parallel to the long axis of the tooth preparation. It should be approximately 1 inch long. The die is trimmed 'apical' to the finish line. There should be adequate access to rest a burnisher on this part of the stone die when the margins are finished. The contour of the die apical to the finish line should approximate that of the root to facilitate good axial contours in the finished restoration. The full arch models are articulated. The wax pattern contacts, contours and occlusal morphology is built on the working casts. The dies are reserved for final margination, detail adjustments, surface treatment and spruing of the wax pattern[9].

Techniques Utilizing one set of Pour (Cast)

In these techniques, the die will be part of the working cast, where it can be used to build occlusion, contact and contour of the wax pattern. The die can be removed from the working cast to marginate, adjust and treat the wax pattern.

Advantages

- It saves time and effort by using only one cast.
- It eliminates dimensional discrepancies between dies.
- There is less distortion of the wax pattern since it is not moved from one die to another.

Disadvantages

- Mobility in one or more directions is not completely prohibited, especially with the loss of interproximal gypsum of adjacent teeth.
- Necessity for additional tools and equipment[18].

Dowel Pin System

In this system, a dowel pin is positioned over the prepared tooth in the impression after partially pouring the cast. The accurate positioning of the dowel pin is a must. Inaccurate placement might cause them to interfere with the margins, weaken the die or prevent the die from being easily removed from the cast. After initial setting, the pin, which is visible, is coated with some lubricant and then the final pouring is done[114].

Alternatively, it is advised to preposition and stabilize the dowel pin before stone is poured into the impression. There are devices made specifically for precise positioning of dowels before the pouring of an impression. One such device uses a moveable base to hold an impression in an exact, repeatable position, while pins are suspended above the impression from magnets on a larger immoveable base. Anaesthetic needles, bobby pins, paper clips and paper matches have been used to orient dowel pins. A technique using bobby pins is common. A straight pin is pushed between the arms of the bobby pin and into the impression material on both the buccal and lingual surfaces of the impression of the prepared tooth. Dowel pin is stabilized in the bobby pin, the round side of the dowel in one of the corrugations and the flat side of the dowel against the flat arm of the bobby pin. The bobby pin is then stabilized against the straight pins with sticky wax. The dowel pin should be parallel to the long axis of the preparation and must not touch the impression. Die stone is poured into the impression. Paper clips can be set in the partially set stone to provide retention for the base that will be added later. When the stone has set, the straight pins and bobby pins are removed from the impression. A small ball of soft utility wax is applied to the tip of each dowel[115].

A U-shaped buccolingually orientation groove or a round dimple on each die is cut to aid in reseating the die completely and accurately during use. Then the stone around each die is lubricated with a separating medium. Stone is then poured to form the base of the cast.

When the stone is hard and dry, use a saw frame with a thin blade to cut through the layer of die stone. Mechanical die cutters are also available. A cut is made on the mesial and distal side of each die. The cuts should taper slightly toward each other from occlusal to gingival. The end of the dowel is tapped lightly to loosen the die. The die is then trimmed[116].

Strip Technique

Stainless steel strips are cut from ribbon material that is 8 mm wide and 0.05 mm thick. Two strips for each tooth are required. The gingival end is trimmed to follow the proximal gingival outline. The strips are trimmed so that they follow but do not touch the facial, lingual and gingival contours of the impression. The strips are positioned so that they converge slightly away from the impression. However, they must not converge so much that they interfere with head of the dowel placed subsequently. When the gingival margin is adjacent to an edentulous region, the strip is positioned 1.0-2.0 mm away from the impression of the gingival margin. After the strips have been adequately trimmed, they are placed aside. Utility wax 1.0-2.0 mm is poured on the facial and lingual flange area of the impression.

Now each strip is heated in an open flame, held in a tweezers. The strips are heated so that they will readily enter and move into the wax. The strips are positioned adequately in the wax and sealed with the help of a heated spatula. Now dowel pins are checked for correct positioning in the impression and placed aside. A mix of high strength die stone is made using vacuum mixing and poured with the help of a vibrator. The die stone is poured so that 1.0 mm of the strips is left exposed. Gently the head positions of the tapered brass dowel pins are inserted into the stone. The dowel pins are aligned vertically so that they are parallel to one another and to the long axis of the tooth. After the die stone has set, a separating medium is poured on the stone and the boxed impression is poured. The base of the cast must be at least 10 mm for adequate strength with 2.0 mm of the dowel pins are left exposed. After the stone has hardened the boxing wax is removed and the ends of the dowel pins are tapped lightly with the end of an instrument handle until a different 'ring' is heard. This indicates that the die has moved slightly from its seating. The dies are then gently pushed out.

The metal strips and the v-shaped wedges that are between the adjacent dies are removed[117].

Advantages

• Offers more control resulting in fewer difficulties, especially in the separation of those dies, which are extremely close to each other.

• It provides landmarks so that dowel pins are positioned precisely in the centre of the die base.

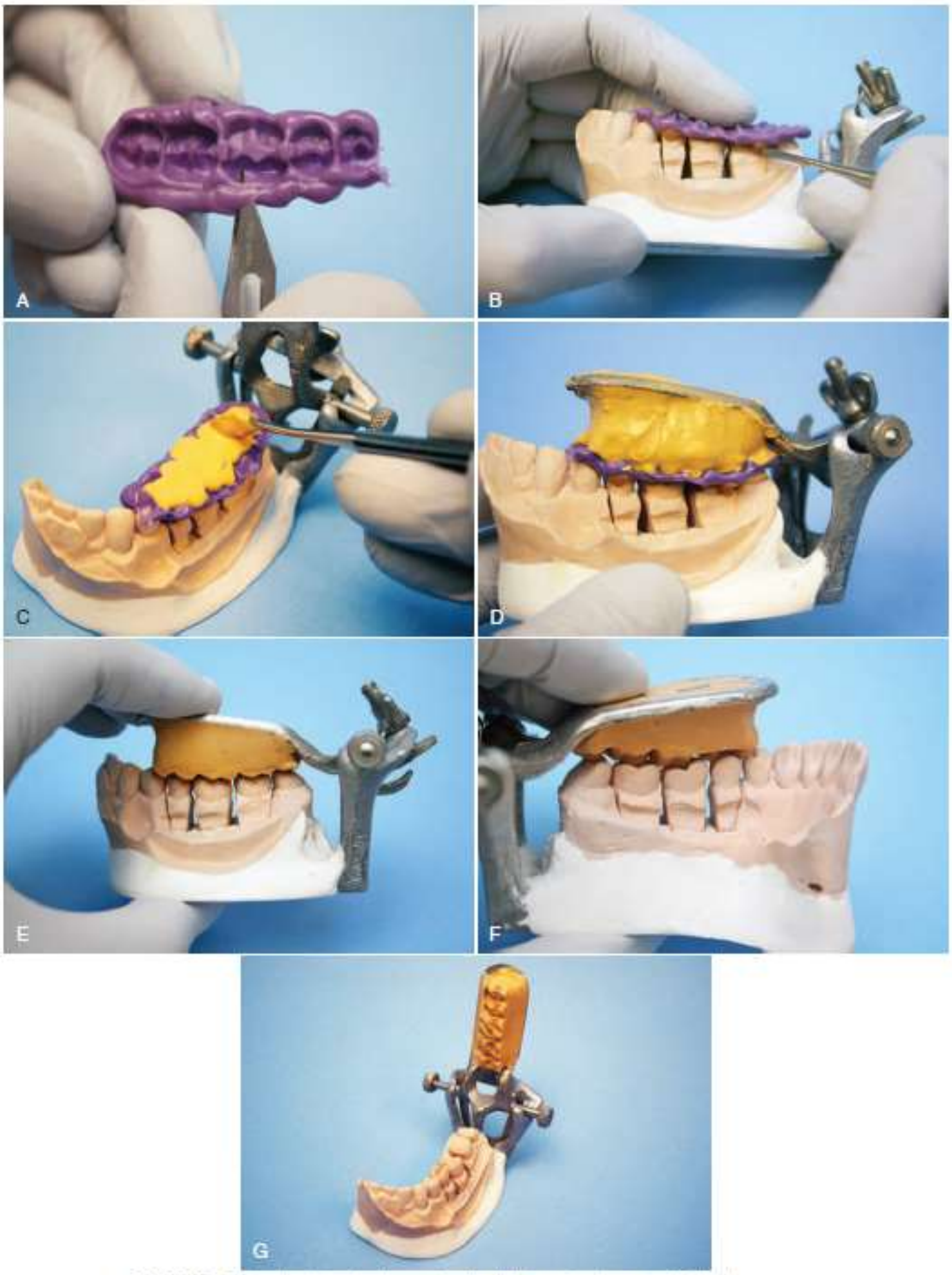
• It provides a concave die base that helps index the die on the cast.

• Allows speedy separation of dies without the use of rotary instruments or saws[118].

USE OF INTEROCCLUSAL RECORDS

A maximum intercuspation interocclusal record is made before making the final impression. From this interocclusal record, a gypsum cast of the opposing teeth is made; this cast can be related accurately to the working cast, when forming the occlusal surface of the wax pattern. his step can be omitted if full-arch casts are to be used in waxing.

When using this type of interocclusal record, the working cast is mounted on a simple hinge articulator. the working cast is attached to one member of the articulator with fast-setting plaster. The interocclusal record is carefully fitted on the dies of the working cast. The interocclusal record should seat completely without rocking. Interocclusal bite records must never touch the registrations of soft tissue areas on the cast because these contacts usually interfere with complete seating. Such areas of contact on the interocclusal record can be trimmed away easily with a sharp knife. After ensuring that the interocclusal record is completely seated, lute the record adjacent to the unprepared teeth with sticky wax to prevent dislodgment when dental stone is poured into the record. Dental stone is then poured into the record. This gypsum is attached to the opposite arm of the hinge articulator and allowed to set after which the interocclusal record is removed[114].



• **Fig. 18.47** Pouring the interocclusal record made with bite registration paste. A, Trimming away some of the interocclusal record (on the preparation side) with a sharp knife is often necessary to allow complete seating on the working cast. B, Fastening the seated interocclusal record to the working cast of preparations first shown in Fig. 18.33A with small amounts of sticky wax. C, Pouring stone into the interocclusal record. D, Attaching gypsum to the upper member of the hinge articulator. E–G, Three views of the completed mounting.

PROVISIONAL RESTORATIONS

MORE THAN JUST A TEMPORARY

Provisional restorations are an integral part of indirect restorative dentistry. They are placed following tooth preparation and should remain in situ until the definitive restoration or prosthesis is placed. They are also known as 'interim restorations', with an interim prosthesis defined as 'a fixed or removable prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive prosthesis.

The potential functions of a provisional restoration are essentially the same as for the definitive restoration, with the exception of longevity[117].

Functions of Provisional Restoration:

Biologic:

- Protect pulp from adverse effects of microleakage / cover prepared tooth to prevent sensitivity.
- Maintain periodontal health by producing cleansable contours, correct emergence profile and smooth, well-fitting, well-finished margins which do not impinge on the periodontal tissues.
- Prevent tooth or core fracture.

Mechanical:

- Resist functional loads without excessive wear, fracture or displacement.
- Maintain the stability of inter-and-intra-arch relationships through the establishment of optimal proximal and occlusal contacts.
- Maintain positional stability of prepared teeth thereby maintaining contact points in single tooth prostheses and abutment positions in bridgework.

- Maintain occlusal function of anterior provisional restorations by providing appropriate protrusive and lateral guidance.
- Resist forces of removal[119].

Esthetic:

- Maintain appearance of prepared tooth by mimicking the prepared tooth or the final restoration.

Provisional restorations may be categorized according to the role for which they are used:

- Removable prosthodontics, for example, immediate dentures.
- Access cavity seals in root canal therapy, since it is important to maintain the integrity of the coronal seal for successful endodontic treatment as coronal microleakage may lead to contamination of the root canal system. This applies not only to the definitive restoration but to seals placed between visits prior to the completion of root canal therapy.
- Operative dentistry: Zinc oxide eugenol-based cements may be used in the treatment of dental emergencies, such as lost restorations, while glass ionomer cements may be used in the treatment of fractured cusps.
- Crown and bridge work.

In addition, some specific types of restoration may be considered as provisional:

- Diagnostic and therapeutic splints.
- Fluoride-releasing materials placed in highly caries active patients during a stabilization phase[120].

Provisional Restorations for Veneers, Inlays, Crowns:

Inlays:

- Following the preparation of a cavity for an inlay, the dentist may face the challenge of provisionally restoring a non-retentive cavity with a restoration that will be retained in the cavity in function but easily removed at the fit appointment, leaving a clean and unaltered surface.

- Conventional zinc phosphate cements are strong, durable and can be removed from the cavity leaving a clean, uncontaminated surface by sectioning with a bur at high speed and excavating the fragments of material. As a result, they are undergoing a revival in this situation.
- Although adhesive cements, such as glass ionomer, may readily remain in situ between appointments, they will be extremely difficult, if not impossible, to remove successfully without alteration to the cavity.
- Zinc polycarboxylate cements are an alternative as they are less adhesive than glass ionomer cements: cement remnants may be removed with the assistance of an air scaler[121].

Crowns:

Pre-formed crowns:

These crowns are manufactured in a variety of shapes and sized, but generally require considerable adjustment to fit a given tooth. Plastic, tooth-coloured, pre-formed crowns are manufactured in polycarbonate or acrylic. After adjustment for marginal fit and occlusion, they are filled with self-cured acrylic resin to provide a close fit.

Metal pre-formed crowns for posterior teeth may be provided in aluminum, stainless steel or nickel-chromium. Aluminum shells generally require crimping and burnishing to produce a reasonable marginal fit and, as these crowns deform readily, they are therefore only appropriate for short-term use. Metal crowns of various types may be trimmed for size, and their occlusion adjusted. These also may be lined with self-curing acrylic to improve their fit, but a thick mix of resin-reinforced zinc-oxide eugenol cement may be sufficient to retain the restoration in place. The major drawback of techniques using pre-formed crowns forms is that occlusal and proximal stability may be difficult to establish, owing to the preexisting contours of the shell[122].

Custom-made provisional restoration-the '*Replica*' technique:

While pre-formed crowns may be the only option possible if there is no existing crown to use as a template, the custom-made crown holds a number of advantages. These include:

- The ability to replicate pre-operative occlusal contacts.
- The ability to replicate the pre-operative shape of the tooth being prepared.
- The ability to make a provisional crown of close fit.

The technique involves taking a pre-preparation impression of the tooth to be prepared and those adjacent to it, in alginate, silicone putty or monophase silicone, in order to form a matrix for the provisional restoration. This may be taken while the local anaesthetic is taking effect[123].

A broken-down tooth maybe built up in soft red wax in the mouth before this pre-preparation impression is taken. In this respect, **Wassell** and **Colleagues** have suggested that the adhesion of the soft red wax to the broken-down tooth is enhanced by first painting the tooth with copal ether varnish and allowing this to dry. The pre-preparation impression is then stored appropriately for use following tooth preparation. Regarding the material of choice for the matrix impression, elastomeric materials have the advantage of being reusable –they can be disinfected and stored until the fit appointment, in case the provisional restoration requires remaking before the delivery of the definitive restoration. However, alginate has the advantage of good absorption of the exotherm produced in polymerization of resin provisional materials[124].

Following tooth reduction, the stored impression is loaded with provisional material. The impression, which should be trimmed to allow easy re-insertion, is re-seated in the mouth until the resin is set. The temporary crown is then removed from the impression and trimmed to remove excess material at its margins, as necessary. Following finishing and polishing, a layer of unfilled resin, such as Biscover, a recently-introduced resin which does not have an oxygen-inhibited layer, may be painted on to the labial surface of the provisional crown in order to provide a shiny, light-reflective surface.

A similar technique uses a stent, most often vacuum-formed polythene, manufactured from a pre-operative study cast, to hold the resin material in position around the prepared tooth. If it is necessary to alter the shape of the tooth being prepared because of loss of tooth substance, then a stent made from a duplicate cast of diagnostic wax-up may be used. In addition to providing a temporary restoration, the use of a clear stent enables the dentist to examine the extent of tooth reduction by directly observing the prepared tooth or abutment. This may be of value in avoiding over-contouring of the definitive restoration as a result of insufficient tooth reduction. Retaining the stent after the preparation appointment ensures that the provisional can be relatively easily replaced if breakage occurs[121].

Materials for the Replica Technique:

Polymethylmethacrylate (PMMA) has the greatest strength of the methacrylate resins and has good esthetics, its polymerization contraction may compromise the fit of restorations formed in these materials (and use additional chairside time as additions to the crowns are made at the chairside) and the polymerization exotherm has the potential for pulpal damage. By comparison, polymethylmethacrylate has the advantages of reduced polymerization and less exotherm on polymerization, but strength, wear resistance and colour stability are not as good. Surface finish may also contribute to colour stability, as unpolished surfaces will darken more readily than highly polished ones. In this respect, a coating of unfilled resin on the provisional restoration surface, as described above, enhances the appearance.

Bis-acrylate composites have the advantages of less exotherm, less potential for pulpal irritation and less shrinkage than other provisional resins. Their physical properties are reasonable, but early versions of these materials were brittle in thin sections. Bis-acrylate resins exhibit better microhardness, and potentially better resistance to wear than traditional PMMA materials. The material is easily added to, if required. Latest versions are available in a range of shades.

In summary, for single-unit restorations bis-acrylate materials therefore offer many advantages, including low polymerization shrinkage and good marginal fit, minimal odour and taste, quick setting and ease of trimming. Cartridge delivery systems simplify and make mixing more consistent. Disadvantages include brittleness and increased cost.

Light-cured provisional materials are also available. While these give the operator control over working time, they require the additional time or expense in construction of a stent through which the material is cured[123].

Direct/indirect technique:

Less frequently used is a direct/indirect, chairside technique to make provisional crowns. In this technique, an impression is taken before the tooth is prepared and this is stored. Immediately following tooth preparation an alginate impression is taken and poured in quick-setting plaster. Once this is set, the original impression is filled with resin, placed on the cast of the prepared tooth / teeth and the provisional restoration is constructed.

A major advantage of this technique is that, when using acrylic type resins, it avoids the exposure of the patient to the heat, smell and taste of the setting material. The major drawback of the technique is the additional cost in terms of time, although this may be minimized by using the setting and curing time to make the working master impression of the teeth[124].

Laboratory-made provisional restorations:

Despite the additional cost involved in laboratory charges for laboratory made provisional restorations, these may present advantages in cases where long-term temporization is indicated. In general, the appearance of laboratory-made provisional restorations will be better, and materials which can be heat or heat / light cured in the laboratory may offer improved durability compared with those constructed at the chairside. This also allows assessment of proposed shape, eg. tooth position, appearance.

VENEERS:

The placement of provisional restorations to cover veneer preparations is generally necessary because the prepared tooth/teeth may be sensitive and of less than ideal appearance. Additionally, the placement of veneer provisional restorations will prevent approximal movement of the prepared teeth. While it is possible to produce provisional veneer restorations using the replica technique, such restorations are generally thin and present difficulties in cementation to the prepared teeth[118].

When to make provisional restorations:

Provisional restorations should not be constructed in a rush at the end of a preparation appointment – it has previously been considered, by **Wassell** and **Colleagues**, that the time taken to construct a provisional restoration should be the same as the time spent on its preparation. Ideally, provisional restorations should be made following preparation and prior to taking the final impression.

This will permit the measurement of the thickness of the provisional restoration, thereby providing the clinician with a measure of the amount of tooth reduction, which (s) he may then assess as being sufficient, or not[124].

Magne, in a recent literature review, has suggested the concept of **'Immediate Dentine Sealing'**. In this concept, he recommends the sealing of freshly cut dentine with a dentin-bonding agent (DBA) immediately after tooth preparation, before the impression is taken. By sealing the dentine, patients experience less sensitivity during provisionalization and limited need for anesthesia during insertion of the definitive restoration[125]. This technique, also termed the dual-bonding technique by **Paul** and **Scherrer**, also avoids the potential problems of imperfect seating of adhesively-luted restorations owing to the pooling of DBAs, because the impression is taken after placement of the DBA.

Care is taken when using this technique, the clinician should construct the provisional restoration prior to placement of the DBA because, if the DBA is placed first, the (resin-based) provisional will bond to the DBA and will be difficult, or impossible, to remove[126].

Transferring information on provisional restorations to the laboratory:

This step can be challenging but, if not carried out effectively, may lead to occlusal, esthetic or phonetic failure in the final restoration.
The following procedure has been suggested:

- Double pour of the final master cast. The first pour cast is kept for final fabrication of the bridgework.
- The provisional restorations are removed from the patient's mouth and placed on the second master cast.
- A silicone putty impression is recorded of the cast/provisional assembly.

- Wax is poured into the silicone putty template and, while still fluid, the putty/wax is seated on the second master cast.
- This wax analogue of the provisional restoration (s) is refined if required but forms a replica of the provisional restoration which the patient was using.

Lingual and labial indices of the wax analogue may be made for use in the final porcelain or wax build-ups. It will be apparent to readers that this technique involves extra clinician time, but it should ensure that the technician receives the information needed to proceed in the laboratory with the final casting and porcelain work[119].

Along with the master impression and provisional analogue, adequate occlusal records must be sent from the clinic to the laboratory to allow the technician to locate the models accurately. In the last case the following records must be sent with the final impression:

- An impression of the opposing teeth.
- A face bow record with which to mount the upper cast on the articulator.
- An interocclusal record with which to mount the lower to the upper cast, or a record of the maxillo-manidublar relationship in the retruded or desired position.
- Protrusive and lateral records to set the condylar angles on the articulator.

Many of the commonly used registration materials, especially uncorrected waxes, distort significantly during recording and transfer. It is advisable to use a registration material[123].

Luting materials for provisional restorations:

Provisional cements should be easily removed without causing damage or alteration to the prepared surface. In general, provisional luting materials are supplied with a softener that facilitates removal of the restoration at the fit appointment. However, if a provisional restoration is required to remain in place for an extended period of time, a permanent cement, such as zinc phosphate, may be considered: glass ionomer materials are contra-indicated in such circumstances as these will adhere to the prepared tooth.

Causes of failure of provisional restoration:

- Provisional restoration in hyperocclusion, in intercuspal position or lateral excursions.
- Insufficient tooth preparation – will lead to thin provisional restoration, which may then fracture.
- Inadequate tooth preparation – preparations lacking adequate resistance and retention form will be more likely to fail.
- Unacceptable esthetics.
- Incorrect choice of material or luting cement[126]

CASTING FABRICATIONS

WAX PATTERN

There are two methods of making a wax pattern for an inlay; the direct method (fashioned on the tooth) and the indirect method (fashioned on a die).

Direct Method

Indications

• A tooth is in an area of easy accessibility, i.e. the tooth should be clearly visible and easy to work on. The second and third molars are usually not suitable.

• Cavity preparations with minimal proximal extensions, i.e. relatively small cavity preparations which leave a good deal of supporting tooth structure to help stabilize the pattern during carving.

• Cavity preparation where the walls are flat, internal line angles are sharp and gingival bevel is definite.

Advantages

• The pattern is carved on the tooth and not on a model which may not be a perfect replica of the tooth because of possible inaccuracies during each stage of preparation of the model.

• Little laboratory work has to be done compared with the indirect method.

• Time saving: Although chairside time is increased but the overall time required for fabrication is decreased.

Disadvantages

• Great skill and patience is required to carve patterns in the mouth.

• When wax is carved by indirect vision in a mirror, manipulation becomes difficult and fatiguing.

• Discrepancies of the pattern at the gingival margin are difficult to detect until the pattern has been carved and withdrawn.

• As most of the adjusting and polishing has to be done on the tooth, valuable chairside time is lost.

• If the casting fails, the patient has to be recalled thereby wasting time and energy[9].

Manipulation of the Inlay Wax

The stick of inlay wax can be softened in hot water or using dry heat. Softening in a water bath can result in inclusion of droplets of water that could splatter on flaming, smear the wax surface during polishing and distortion of the pattern due to thermal changes. When wax is softened directly over a flame, care must be exercised to ensure thorough heating of the wax stick. The wax should be kept moving till it becomes shiny and then removed from the flame. It should then be compressed between the fingers and again warmed. The process is repeated until the wax is warm throughout. It is kneaded using the thumb and first finger which are lubricated with vaseline to avoid sticking of the wax. The wax stick can be flattened to expose more wax surface to the flame and thereby obtain a uniform softened texture. A wax annealer, which maintains a constant temperature of 65°C can also been employed It has been observed that higher the temperature of the wax during manipulation, the lesser the internal strain and distortion upon storage. Plastic mass should be inserted into the prepared cavity at as high a temperature as can be tolerated and held under pressure. The surface is cooled in running water. The pattern should be prepared in such a manner that no addition of wax would be required, as wax, which is added after the initial cooling introduces stresses which will distort the pattern. The wax pattern by direct method can be prepared with and without the application of matrix band.

Wax Pattern Prepared with a Matrix Band

The retainer and band are tried loosely on the tooth, making certain that the gingival margins are covered by the band before fitting and applying a wedge. The internal surfaces of the band are lightly lubricated with a separating medium such as castor oil. With the finger used as a plunger to confine the occlusal portion of the wax, the band is tightened until a snug fit is obtained. Finger pressure is maintained while the wax is cooled and hardened. The bulk of excess wax is then trimmed. The matrix retainer is loosened and removed. The wax is held firmly in place and the band is removed. Excess wax is trimmed from the cavosurface margins. Trial removal of the pattern is attempted at this stage. A narrow strip of copper ribbon is bent into a 'V' or 'U' shape, heated over the flame and quickly inserted as a staple into the marginal ridge areas of the wax pattern. The staple is kept stable for 2-3 minutes so as to let it cool down. An instrument is inserted under the staple to lift the pattern out of the cavity in an occlusal direction[17].

The pattern is carefully inspected for:

• Sharp internal details.

• Good reproduction of the cavosurface and gingival margins.

If either is lacking it is better to start again rather than attempt to repair the same. The gingival flash, if any, is removed with a sharp scalpel. The pattern is again seated in the cavity. A heated instrument is held lightly against the copper staple, thus, facilitating its removal. The pattern is then carved with the help of plastic instruments. To test the occlusion, the tooth is carefully isolated and dried with cotton rolls. The opposing tooth is also dried. With a camel hairbrush, talcum powder is dusted on the occlusal surface of the wax and the patient is instructed to close the teeth lightly. Cuspal contact with the wax pattern is indicated by a shiny burnished spot on the pattern. The spots of hyperocclusion are carved away using warm carvers. The occlusal surface may be polished by rubbing a wet pledget of cotton over the area. The pledget of cotton can be warmed over a flame for better results. Proximal surfaces are polished by wrapping a smooth linen strip tightly around the tooth and clinching it upon the buccal side. Copper bands can also be used instead of matrix bands[18].

Wax Pattern Prepared Without a Matrix Band Attempts have been made to prepare wax patterns without the use of a matrix band. Here the inlay wax stick is softened to form a pointed end. The softened pointed end is forced into the cavity, the harder end acting as a plunger so as to confine the wax to the approximal part of the cavity; the thumb and forefinger of the free hand are pressed into the buccal and lingual embrasures. Excess wax is cut off occlusally and an egg shaped burnisher is used to press the wax further into the cavity until it ceases to move under pressure. It is now bathed with several syringes of water at 110–115°F. The patient is asked to close his teeth to force the wax further into the cavity and to locate the occluding cusps. The wax is again bathed in warm water. The occlusal surface is carved with a wax carver. Wax in the embrasures is rimmed. The remaining wax in the approximal space is removed with curved probes. At this stage a piece of silk thread is passed through the contact point to make sure all the wax has been removed. The thread is held just below where the contact point will be and then moved gingivally under pressure against the approximal surface of the wax pattern. In this way the thread cuts the approximal excess leaving a triangular section of wax in the approximal space which can be removed with plastic instruments. Finally, the approximal surface is burnished with a smooth linen strip. Care should be exercised to hold the strip so that it does not burnish the wax away from the cavity margin. Hence when it is being withdrawn against the buccal part of the pattern it must be held away from the lingual margin.[17]

Wax pattern fabrication without band applied on tooth

The proximal contour and contact of the pattern deserve special attention. It is important that contacts be of proper form as in the right position. In order to evaluate the contact, form the ligature (dental floss) is first passed to the gingival of the contact; the two ends are then held parallel in the occlusal direction as shown for the contact between the premolars. This measures the faciolingual width of the contact or very near approach of the two surfaces[9].

Without removing the ligature, the two ends should be held parallel in the facial direction as shown for the contact between the two premolars. This measures the occlusogingival width of the contact. In either position of the parallel strands are more than 1½ or 2 mm apart the contact is too broad.

Indirect Method

After the preparation of the die, a lubricant is applied to facilitate the withdrawal of the pattern from the die.

Various lubricants used are castor oil, machine oil, petroleum jelly, cocoa butter, etc. The time for the application of the lubricant depends upon the wetness of the die, the humid die will take less time and vice versa. Few authors are however, not in favor of using lubricants since, these may lead to change characteristics of the inner side of the wax pattern. In case of large patterns, mostly with full crowns and fixed partial dentures, die spacer is used to compensate the solidification shrinkage of the casting alloy

Die spacer and thinner

The blue inlay wax is softened, moulded and pushed into the cavity as in direct pattern technique. The rest of the finishing and carving is carried out as in direct pattern[18].

Removing the Pattern from the Cavity

The pattern must be removed without distortion and maintaining the path of removal parallel with the direction of the cavity walls. The sprue former should be attached to the pattern while it is still on the tooth to minimize distortion of pattern due to heat and mechanical induction of stresses. The sprue former of exact size and shape is selected, keeping in mind the size of wax pattern, casting machine to be used and the metal to be cast. Sticky wax is applied to one end of the sprue and attached to the pattern site. A little wax can be added, if need be, at the joining of the sprue and the pattern. After keeping the sprue for 2-3 minutes, trial removal can be carried out. If the pattern cannot be freely sprued on the tooth, indirect procedure can be used (the same procedure as used for trial removal of the pattern). A copper staple or a 24-gauge twisted brass wire is inserted into the occlusal part of the pattern. For MOD patterns, the prongs of the wire are placed near the marginal ridges and for disto-occlusal or mesio-occlusal patterns, the prongs are inserted at an angle of 45° near the marginal ridge[17].

Fig. 13.31: Copper staple for removing wax impression of MOD cavity

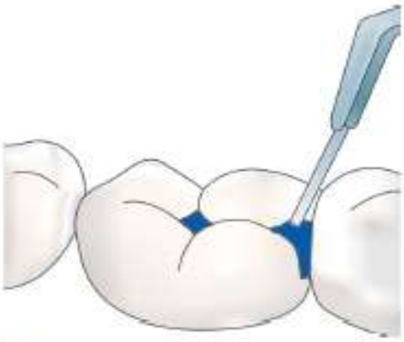


Fig. 13.32: Staple inserted at 45° for mesiocclusal or distoocclusal preparation

Using the staple, the pattern is lifted out of the cavity with a direct pull parallel to the cavity walls. The sprue is then inserted into the wax pattern and the staple removed by holding it with warm pliers to melt the wax holding the staple[9].

Removal of pattern from the tooth

A heated blunt explorer is used to fill in the holes left from the staple. If the staple is made of the same alloy or one of the component metals of the alloy used for casting, then it can be left in the pattern and cut off after casting. The purpose of the sprue former is to provide a channel through which molten alloy can reach the mould in an invested ring after the wax has been eliminated. Low fusing inlay wax is flown over the contact area and flushed with the proximal surface to build the contact[19].

Building of the contact area

SPRUE FORMER

Sprue Former Material

The sprue former can be made of wax, resin or metal. Wax and resin sprue formers have the advantage of being burnable and so do not need to be mechanically removed. Further, the wax or resin have a fusion temperature lower or almost same as that of the pattern wax. However, disadvantage of wax sprue formers is that they lack rigidity. Metal sprue formers can be solid or hollow. Hollow sprue formers are preferred since they hold less heat than a solid sprue former and so will cause less heat transfer to wax pattern resulting in less distortion. Besides, their retention to the wax pattern is better. To further improve retention and reduce thermal conductivity, the sprue former can be filled with sticky wax. The metal sprue former must be mechanically removed prior to burnout. This could cause investment to loosen from the walls. To avoid this, metal sprue formers are uniformly coated with wax before investing so that at the time of burn out, the sprue former comes out on its own because of melting of wax. This way the loosening or breaking of investment can be avoided[9].

Inlay wax for making sprue former

Sprue Former Diameter

The diameter of the sprue former will depend on the size of the wax pattern, the quality of casting machine, and the ring, which is used to form the mould.

In general, a sprue former with a larger diameter is preferred to one with a smaller diameter, because the greater the diameter the less likely is the molten alloy to solidify before the mould is filled. On the other hand, since the sprue former is attached to the wax pattern by heat, the heat from a large sprue former might cause distortion or actual melting of the pattern if a very small wax pattern is involved. Preferably the diameter of the sprue former should not be more than 1/4th of the total area of the wax pattern[127].

Suggested Sprue Former Diameters

Gauge no.	Diameter (cm)
06	0.4115
08	0.3264
10	0.2588
12	0.2053
14	0.1628

16	0.1291
18	0.1024

Tabulation of sprue sizes and their application		
Sprue size	Approximate diameter (mm)	Comments
16	1.3	Thin inlay onlay; may need reservoir
14	1.7	Largest size for air pressure casting
12	2.1	Best for most inlays
10	2.6	Use on heavy crown only

The diameter of the sprue is the most important factor in determining the speed with which the molten metal enters and fills the mould. Melt velocity is directly proportional to sprue diameter. If gold is to be melted immediately above the entrance (air pressure technique) the sprue former must be small in diameter so that the molten gold will not be able to flow into the sprue hole before the pressure of the casting is applied.

Sprue Former Length

The length of the sprue former depends upon the length of the casting ring. The length should be adjusted so that the wax pattern is within 6.5 mm (1/ 4 inch) of the open end of the ring for gypsum-bonded investments and 3.25 mm (1/8 inch) for phosphate bonded investments. If the pattern is too close to the end of the ring, the molten alloy may blast through the investment during casting; if it is too far away, gases may not escape rapidly enough to allow metal to fill the mould space. The sprue former should not be too long so that the gold will begin to solidify in the sprue and cause porosity in the casting[128].

Location of Sprue Former

The sprue former should be attached to the bulkiest part of the wax pattern because of the following reasons.

- This will minimize the effect of released residual stresses by the heat of attaching the sprue.
- It will ensure that the thinner cross-section of the mould will be filled completely.
- The melt will always be fluid enough and available until all lesser dimension sections are adequately filled.

The general rule is to attach the sprue former in a position so that the molten metal will reach the mould areas farthest from the attachment of the sprue former at the same time.

Sprue formers should be attached to the least anatomical area of the wax pattern.

Angulation of the Sprue Former It should not be attached at right angle to a broad surface because the melt may impinge the mould surface and produce a so-called 'hot spot' producing suck back porosity.

An angle of 45° is usually adequate. The sprue former should be directed away from any thin or delicate parts of the pattern, since molten metal may abrade or fracture investment in this area and result in casting failure.

Number of Sprues

If the wax pattern is designed such that attachment of the sprue former at the bulkiest portion allows the metal to flow uninterrupted from the sprue to the farthest end of the mould then a single sprue is adequate. However, should the wax pattern have a thin area between the sprue and the periphery of the pattern, the melt will solidify at the reduced cross-sectional area preventing complete filling of the mould. Here two sprues can be used. If multiple sprues are used, they should join together at the crucible former level in a reservoir larger in diameter than all the sprues combined.

Sprue Former Attachment

The sprue pattern joint must be smooth and uninterrupted. If high velocity ingress of the melt into the mould is required, the junction should be flared. If low velocity ingress is required, a constricted junction is made. To minimize stress release while joining a sprue former to a wax pattern, a drop of sticky wax should be applied to the wax pattern. Then the sprue also, with a bead of sticky wax is brought in contact with the sticky wax on the wax pattern and held immobile until the sticky wax is solidified. Patterns can be sprued directly or indirectly. In direct spruing, the sprue former provides direct connection between the pattern area and the crucible former[129].

Reservoir

In case, the diameter of the sprue is smaller than the average cross-sectional area of the pattern, a reservoir is attached with the sprue as near as possible to the pattern sprue junction. The diameter of the reservoir should be more than the average cross-sectional area of the pattern. The rationale of adding reservoir to sprue is to provide molten metal to prevent localized shrinkage porosity.

When molten metal strikes against the mould wall at 90-degree angle and if the mould-metal temperature differential is more, it creates a hot-spot, the molten metal in this area will solidify last, leading to localized shrinkage porosity, if there is no continuous supply of molten metal. The reservoir provides the molten metal to compensate for this localized shrinkage porosity at the casting sprue junction. If we use a sprue former, the diameter of which is greater than the diameter of the cross-sectional area of the pattern, there is no need for providing reservoir. The sprue will itself provide the molten metal.

Forming the Crucible and Attaching the Pattern

The crucible part of the investment assembly is cone shaped. The sprue is attached to the crucible in the same way as the sprue is attached to the mould, i.e. it should be bulkiest in cross-section, flared and smooth. The depth of the crucible and the inclination of its walls towards the sprue are dictated by factors similar to those governing the diameter of sprue, i.e. alloy density, casting machine energy, melt viscosity, size of a pattern, porosity of investment, etc. The deeper the crucible is and the more inclined its walls are, more velocity will be imparted to the melt on its way to the mould[130].

Venting

In some situations, there is some doubt about the speed with which the mould gases will escape relative to the speed at which the molten metal is entering. A wax rod is added to the farthest, or close to the farthest part of the pattern, which will stop short of the ring (investment) surface. In most cases, they are curved towards the sprue. Gases that will not escape fast enough ahead of the ingressing melt will be
compressed and trapped in these vents.

Preparation of the Ring for Casting

In the past, several metals have been used for making casting rings. The metal used in the construction of a ring should be non-corrodible, hard and with a thermal expansion similar to the investment used. Stainless steel has been found to produce the most acceptable rings. The thermal expansion of stainless steel is 12% at 700°C, which is compatible with the expansion of investments, provided a liner is used. The dimensions of the ring may vary according to the desire of the operator, but the average dimensions are approximately 29 mm (11/8 inch) in diameter and 38 mm (1½ inches) in height[125].

Need for Liner

A resilient liner is placed inside the ring to provide a buffer of pliable material against which the investment can expand to enlarge the mould. If there is no liner present, the investment is in direct contact with the walls of the mould and will not be able to expand outward (because of the resisting action of the walls of the ring) and so will expand in the direction providing less restriction, i.e. towards the centre of the mould thus resulting in distortion of the casting. The liner if wetted allows for semi-hygroscopic expansion of the investment. It becomes easier to remove the investment and casting from the ring, if a liner is used.

Liner Material

For many years, asbestos was used to line casting rings, but now its use has decreased because of concern over its carcinogenic properties. It has been proved that asbestos fibres can cause asbestosis, bronchogenic lung cancer, mesothelioma, etc. The currently accepted threshold limit value for asbestos fibres ranges from 2 × 105–20 × 105 fibres/m3. This limit is considerably exceeded when dental castings are recovered from asbestos lined rings.

Alternatives to asbestos liners have been introduced, these include absorbent cellulose and nonabsorbent ceramic materials. Cellulose liners readily absorb water when immersed and therefore must be wetted before use. Ceramic liners are virtually nonabsorbent and can be used dry[9].

It has recently been suggested that fibres from ceramic lining material can be of similar dimensions to those from asbestos liners, and so may also be a potential health risk. But other studies claim that these fibres dissolve quickly in lung tissues and so have little harmful effect. Most studies carried out to determine suitability of these alternative liners have concluded that both cellulose and ceramic liners could produce satisfactory castings provided some alterations were made to the investing technique, which is routinely used with asbestos. When using ceramic liners, one should not use vacuum investing technique. A dry ceramic liner produces very inconsistent castings, which are clinically unacceptable. So, one can saturate the liner with a dilute wetting agent prior to investing. An investment with an increased potential expansion should be used.

The relative incompressibility and the high-water sorption of cellulose liners must be considered and also the fact that they burn out of the ring at temperatures over 600°C. A study comparing asbestos and ceramic liners showed that asbestos could be compressed 10 percent of its original thickness when dry and 30 percent when wet. Ceramic liner could be compressed 50% of its original thickness when dry or wet. Thus, ceramic material is not only an adequate substitute for the traditional asbestos liner, but an improvement as regard the requisites of the liner[17].

How to use a Liner?

A liner can be used dry or wet. A dry liner will allow greater normal setting expansion in the investment. Theoretically, a wet liner will allow greater normal setting expansion and semi-hygroscopic expansion, but it also reduces the powder-water ratio, which in turn will reduce the thermal expansion of the investment. As a result, the net expansion with a dry liner will be slightly greater than with a wet liner. However, because the effect of a dry liner depends on its volume relative to that of the investment, which varies with the diameter of the ring, a damp liner is preferred for the sake of consistency.

The maximum thickness of a liner is 1.0 mm. A thicker liner or two layers of liner can also be used. The liner is cut to fit the inside diameter of the ring with no overlap. The length of the liner is a controversy. Few authors are of the view that when a liner is placed 1/8th to 1/4th inch short at each end of the ring, the investment cannot expand laterally at the ends of the ring. In the central portion of the ring it does expand laterally to a limited extent. Thus, the mould cavity is distorted. Many others feel that expansion of the investment is always greater in the unrestricted direction (longitudinal) rather than in the lateral direction (towards the ring itself). Thus, it is important to reduce expansion in the longitudinal direction. Liner should be placed 1/8 inch short at the ends to get less distortion of the mould. Others believe that placing the liner flush with the open end of the ring gives maximum expansion. When cellulose liners are used, they burn out before the casting is made. This deprives the investment of support by the ring and may result in cracking of the investment. Thus 3.0 mm of the ring is left unlined at each end to support the investment. After the liner has been placed in the ring, the ring is dipped in water for 10 seconds (in case of asbestos or cellulose liners) and then gently shaken to remove excess. Squeezing the liner would result in removal of excess and variable amounts of water[9].

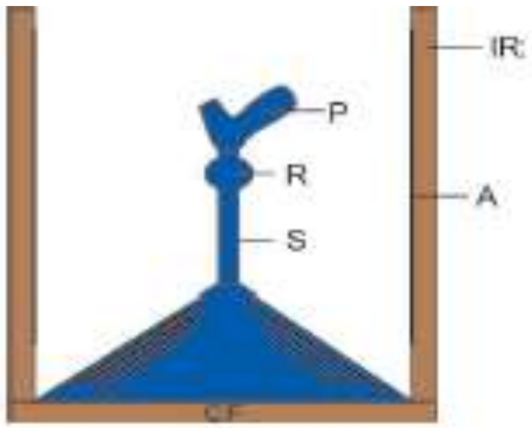


Fig. 13.36: The length of the sprue is so adjusted to bring the wax pattern(P) to 6 mm from the top of the ring. Crucible former (CF), investment ring (IR) lined with wet asbestos (A) kept short of the ring on both sides and reservoir (R) added to the sprue (S).

Preparing the Wax Pattern for Investment

The wax pattern should be cleaned of any debris, grease or oils before it is positioned in the ring. This will decrease the surface tension and improve the wettability of the wax pattern. Gentle washing with liquid soap using no. 2 paint brush is effective. The soap should be thoroughly rinsed off with water at room temperature and the pattern dried with a stream of clean air. A debubblizing solution provided by the manufacturer may also be painted on the surface of the pattern, taking care to avoid pooling around the internal line angles[18].

INVESTMENT OF THE PATTERN

Investment Materials

An investment can be described as a ceramic material which is suitable for forming a mould into which molten metal or alloy is cast. The procedure for forming the mould is described as investing. These materials can withstand high temperatures. Therefore, also known as refractory materials.

There are three types of investment materials:

- Gypsum bonded investments
- Phosphate bonded investments
- Silica bonded investments

General composition

All investment materials contain:

- Refractory
- Binder
- Modifiers

Gypsum Bonded Investment

Composition

Refractory – silica (Quartz or cristobalite)	60–65%
Binder – Alpha-hemihydrate	30–35%
Modifiers – Carbon, Boric acid or sodium chloride	5%

Silica is a refractory material which withstand high temperature, it regulates thermal expansion and increases setting expansion. Alpha-hemihydrate binds and holds the silica particles together, contributes to mould expansion. Carbon provides reducing atmosphere in the mould, it reduces any oxide formed on the metal. Boric acid or sodium chloride regulate setting expansion and setting time[131].

Setting Reaction

$CaSO_4 \frac{1}{2} H_2O + 1\frac{1}{2} H_2O \longrightarrow CaSO_4.2H_2O$

Properties

1. Thermal behavior of gypsum – When gypsum is heated to high temperature, it shrinks and fractures. At 700°C it shows slight expansion and then great amount of contraction.
2. Thermal behavior of silica – when heated quartz and crystoballite changes its crystalline form. The α (alpha) form converted into β (beta) form, which is table only above transition temperature. Density decreases as a change to β (beta) form, with resulting increase in volume and rapid increase in linear expansion.
3. Normal setting expansion – A mixture of silica and dental stone results in greater setting expansion than gypsum product alone. Silica particles interfere with the intermeshing of the crystals as they form.
4. Hygrosopic setting expansion – When gypsum products are allowed to set in contact with water, the amount of expansion exhibited is much greater than normal setting expansion. The increased amount of expansion is because, water helps in the outward growth of crystals.

<u>Phosphate Bonded Investment</u>

The metal ceramic alloys and cobalt chromium alloys have high melting temperatures. They are cast in moulds at 850 to 1100°C. At high temperatures, gypsum bonded investment disintegrates. Hence investment which can withstand higher temperature are required. The investment used for this purpose are phosphate bonded and silica bonded.

Composition

• Powder

• Refractory – Silica

• Binder – Ammonium diacid phosphate

• Magnesium oxide – reacts with phosphate ions, liberated by ammonium diacid phosphate

• Liquid – Silica solution in water

Setting Reaction

$NH4H2PO4 + MgO + H2O \longrightarrow NH4MgPO4 + H2O$

At room temperature, ammonium diacid phosphate reacts with magnesium oxide to give the investment green strength. At high temperature, a superficial reaction between P2O5 and SiO2 to form silicophosphate, which increases the strength of investment at higher temperature.

Silica Bonded Investment

In silica bonded investment, the silica is used as binder. It is derived from ethyl silicate or aqueous dispersion of colloidal silica or sodium silicate.

Ethyl silicate as a binder – Silica bonded investment bonded by hydrolysis of ethyl silicate in the presence of hydrochloric acid. The product of hydrolysis in the colloidal solution of silicic acid and ethyl alcohol.

$$Si(OC_2H5)_4 + 4H_2O \xrightarrow{HCl} Si(OH)_4 + 4C_2H_5OH$$

Ethyl silicate has the disadvantage of containing inflammable components which are required for manufacture. Sodium silicate and colloidal silica are more commonly used as binders.

Methods of Investment

Two methods of investing may be used.

• Manual investing

• Vacuum investing

Manual Investing

Water and powder may be incorporated in the appropriate ratio (indicated by manufacturer) in a rubber bowl with a hand spatula using a rubbing motion and slowly rotating the bowl during the mixing period. Mixing is carried for one minute. The mix is placed on a vibrating table and stirred very slowly for 30 seconds to remove any entrapped air. The investment is then carefully applied to the pattern, using a small sable brush, starting in one place and carrying the investment forward until the pattern is completely covered. The investment is allowed to set partially. The rest of the lined ring is then filled with investment[132].

Vacuum Investing

In this technique, the investment is mixed, and the pattern is invested under vacuum. Several types of vacuum investing equipment are available in the market.

The basic method used is as follows:

The investment and water are measured as usual. The mix is placed in a specially constructed mixing unit. The unit is motor driven, and the air evacuated by means of a tube attached to the mixing unit from a vacuum pump. During mixing, air is evacuated, and the possibility of bubble formation is thereby reduced.

Also, while under vacuum, the investment is vibrated into the casting ring and over the wax pattern. Although good results can be obtained both with hand and vacuum investing, the latter technique is preferred because it is more likely that the casting will be smooth and free of nodules with this technique[133].

CASTING OF THE PATTERN

Time Allowable for Casting

The investment contracts as it cools because of the liner and the low thermal conductivity of the investment. A short period can elapse before the temperature of the mould is appreciably affected. Approximately one minute can pass without a noticeable change in dimension.

Casting Machines

Casting machines are divided into three groups depending upon the technique by which gold is pushed into the mould.

- Those which exert pressure on the gold, as by air, nitrous oxide gas or steam.
- Machines which draw the gold into the mould by a vacuum.
- Machines which revolve, and gold is carried into the mould by centrifugal force.

Air Pressure Casting Machine

The alloy is melted in the hollow left by crucible former and then air pressure is applied through a piston, which is pushed downward into contact with the top of the ring, enclosing the molten gold alloy. A pressure of 10-15 psi is usually applied the pressure gradient along the sprue axis and casting is nil, the thinner the section the faster it solidifies. The button is the thickest portion and so it solidifies last. Carbon dioxide, carbon monoxide or nitrogen gas can be used.[132]

Vacuum Casting Machine

Here a vacuum is applied through the base beneath the casting ring and the molten alloy can be drawn into the mould by suction. It cannot work alone in filling the mould, even if gravitational forces are used in driving the melt. Therefore, machines are employed that use a combination of centrifugal pressure and a vacuum, gas pressure and a vacuum or centrifugal and gas pressure with the vacuum to create the driving force.

Centrifugal Casting Machine

Various designs of the centrifugal casting machines are now available. The most commonly used design of casting machine is shown in the. The machine basically has a strong spring encased in the base of the casting machine, which can be wound into tension by rotating the arms with the weights at one end and the casting ring at the other. In front of the ring is a separate crucible in which the gold alloy is melted. When the spring is released the two arms rotate rapidly, and the molten metal is forced into the mould by centrifugal force. If a ‘broken arm’ principle is incorporated in the machine it further accelerates the effective initial rotational speed of the crucible and casting ring, thus increasing the linear speed of the liquid casting alloy as it moves into the mould. A pressure gradient, which is parabolic in shape is created so that a pressure of 30-40 psi (highest) is created at the tip of the casting and zero at the button surface. The gradient of heat transfer is such that heat transfer is maximum at higher pressure end thus this further ensures that the tip solidifies first[9].

Time required to cast gold alloy by centrifugal force depends on the cross-sectional area of the sprue and the number of winds of the machine. When the size of the sprue is increased, the casting time is reduced. When the number of winds is increased and therefore the force is increased, the casting time is reduced. It is observed that the cross-sectional area has a greater influence on casting time than does the number of winds of the machine. Time required to cast gold through 11-gauge, 14 gauge and 17-gauge sprues by centrifugal force produced with 5, 4 and 3 winds of the machine is given in Table[18]

	5 wind	*4 wind*	*3 wind*
11 gauge sprue	0.38 min.	0.39 min.	0.46 min.
14 gauge sprue	0.42 min.	0.44 min.	0.54 min.
17 gauge sprue	0.51 min.	0.54 min.	0.67 min.

It is concluded that:

• Centrifugal force is directly proportional to the square of the speed of the machine in revolutions per second.

• Centrifugal force varies directly with the radius of the circular path. Doubling the length of the arm of machine doubles the force.

• Centrifugal force is directly proportional to the weight of the metal directly over the sprue.

When a larger sprue is used the weight of the effective mass of metal is increased thus large sprues are used. More speed of the machine is required[17].

Casting Procedure Using Centrifugal Casting Machine

The counterweight of the casting machine is grabbed in the right hand and wound clockwise 2-5 times. The pin is raised from the base so that it rests in front of the crucible assembly, preventing the spring from unwinding.

Casting alloy is placed in the crucible. Enough bulk of the metal must be used in casting to fill the mould, the sprue and part of the crucible former. This metal is melted using one of the methods described earlier.

The oxygen gas along with blowpipe is commonly used. A small multiorifice tip is ideal. Single orifice tips may be used if they are large enough. The small soldering tips should not be used for melting the alloy. Before any torch is lit each knob must be checked. The oxygen valve should be opened slowly to prevent sudden high pressure from hitting the regulator and producing high recompression heat. Gas is ignited first and extinguished last.

A conical flame about 40 mm long is obtained by adjusting the torch. The parts of the flame are identified. The first long cone emanating directly from the nozzle is the zone in which the gas and oxygen are mixed before combustion. No heat is present in this zone. The next cone, which is green in colour is the combustion zone. Here the gas and air are partially burned. This is an oxidizing zone. The next zone, dimly blue is the reducing zone. It is the hottest part of the flame and is just beyond the tip of the green combustion zone. This area of the flame should be used to melt the metal. Beyond this is an outer oxidizing zone where combustion occurs with oxygen in the air. Contact with the oxidizing zone will cause copper and other metals in the alloy to form oxides and thus alter the properties of the alloy.

A small amount of flux should be sprinkled onto the warm metal. Borax when used as a flux will help to exclude oxygen from the surface of the alloy and dissolve any oxides that are formed.

Reducing flux, which contains carbon in addition to borax, will also reduce any oxides that happen to form. When the reducing zone of the flame is in contact with the metal the surface will be bright and mirror like. As the alloy melts it first appears spongy, and finally it assumes a spheroidal shape and moves with the flame[9].

Keeping the flame on the gold, the casting ring is removed from the oven and carefully placed in the cradle of the casting machine. When the metal is a light orange in colour and tends to spin or follow the flame when moved, it is ready to be cast. At this juncture it is approximately 38° to 66°C above the liquidus temperature. Gentle clockwise pressure is applied on the counterweight so that the pin drops. The weight is released allowing the machine to spin. The metal will be thrust into the mould space. The amount of driving energy used is a matter of judgement but is dictated by the following factors.

a. The density of the cast metal: the lower the density, the higher the energy needed.
b. The porosity of the investment: the more the porosity, the less the energy needed.
c. The number of sprues: the more the number of sprues, the more the driving energy needed to force the melt into them.
d. The length of the sprue: the longer the sprue, the more the energy needed.

e. The size of the sprue: the larger the diameter of the sprue, the less the energy needed.

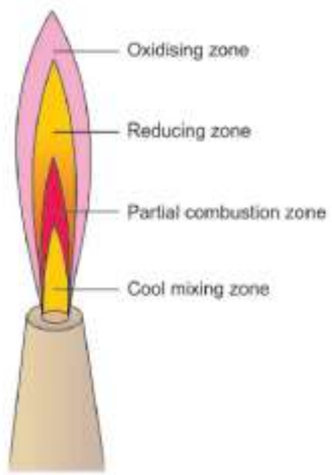
f. The size of the pattern: larger the size, more the energy needed.

g. The amount of the melt: greater the amount of melt, relative to mould size, less the energy used.

h. The angulation and funneling of the sprue: the more the sprue is oriented for immediate and fast filling of the mould, less the energy used.

i. The differential temperature between the melt and mould: the more the lag between the two temperatures, the less the energy required within a limit.

j. The configuration and details of the pattern: the more the details, the more the energy required.



Casting Techniques

There are two casting techniques usually being used.

• Thermal expansion technique (high heat technique)

• Hygroscopic expansion technique (low heat technique).

Thermal Expansion Casting Technique

The investment is allowed to harden for a minimum of 45 minutes. The excess investment is levelled off the surface of the ring before it sets. Scraping of the investment at a later stage will fill in the pores, decreasing the porosity of the investment.

After the investment has thoroughly set, the crucible former is removed. At this stage any loose particles of investment should be removed and prevented from blocking the ingate formed by the sprue former. The metal sprue former is warmed slightly over a gas flame and carefully removed with pliers. With the ring inverted, a dry brush is used to remove any loose particles of investment remaining around the edges of the sprue hole. The inverted ring is then tapped lightly on the laboratory bench to remove any loose particles, which may have fallen into the mould space.

If the burnout and casting procedure are to be delayed for several hours or overnight, it is advisable to place the invested pattern in humid environment to prevent excessive drying. Excessive drying of the investment prior to burnout will cause the molten wax produced during burnout to be absorbed into the investment[17].

Burnout Procedure

The casting ring should be placed in an oven preheated to approximately 900oF (480°C), held at that temperature for 20 minutes, and then the temperature is slowly raised to 1290oF (700°C) and held for 30 minutes.

A cold furnace may be used to start the burnout and the temperature is raised slowly and uniformly till 1290°F. The ring is held at this temperature for an adequate period of time to assure complete wax elimination.

Care should be taken to avoid heating gypsum bonded investment above 1290°F. This is because above 1290°F (700°C) calcium sulfate is reduced by carbon molecules releasing sulphur dioxide gas. The sulphur dioxide gas thus released may contaminate the gold alloy as it enters the mould. It is advisable to burnout with the sprue hole facing downward, since this will allow the wax to run from the mould and carry investment inclusions out of the mould cavity.

The mould should be protected from variations in temperature by placing it in the centre of the furnace away from the heating coils and the door of the furnace[18].

Melting Gold Inlays

The gold alloy is melted in one of the following ways.

A. Using a torch flame

a. Natural gas (mainly propane) and air: This supplies the lowest temperature of all sources and is very efficient for small inlays and Type I and Type II alloys.

b. Natural gas and oxygen: This supplies a higher temperature and can be used for extensive alloys.

c. Acetylene and oxygen mixture: This is the hottest of all gas fuels. It may be too hot for cast gold alloys. It is used for melting base metal alloys.

B. Using electric energy

Induction heat is the most efficient and popular method of melting an alloy. The metal is melted by an induction field that develops within a crucible surrounded by water-cooled metal tubing. The metal can be melted in a separate crucible and then pushed into the mould space or in the same crucible.

Generally, three types of casting crucibles are available- clay (ceramic), carbon and quartz. For gold alloy, clay or carbon crucibles are used. Clay crucibles are more popular. They are lined with asbestos or kaolin, which after casting insures non-contamination of the crucibles, hence may be re-used[9].

Hygroscopic Expansion Technique

This technique involves the immersion of the metal ring with investment into a warm water bath set at 37°C or 100°F. The technique compensates shrinkage by three mechanisms.

• 37°C water bath expands the wax pattern.

• Water entering the investment provides greater volume into which gypsum crystals can grow and hence provides some hygroscopic expansion.

• Thermal expansion at 468°C (burn out temperature for hygroscopic setting expansion).

The amount of hygroscopic expansion can be controlled by:

• Water / Powder ratio: The higher the water/powder ratio, the lower the amount of expansion.

• Time of immersion in the water bath: The longer the delay before the investment is immersed in the water bath, the less is the hygroscopic expansion.

• Controlling the amount of water added during the setting.

Hygroscopic expansion can be achieved by two ways:

• Immersing the filled casting ring in a water bath.

• By addition of a known quantity of water to the exposed surface of unset investment in the casting ring (controlled water technique).

I. Water Bath Technique

The essential features of water bath technique are:

• The pattern is washed with soap and water.

• Definite proportions of water and investment are used.

• Investment must be slow setting (from twenty to thirty minutes) to allow sufficient time to expand.

• The wax pattern is invested.

• Both ends of the ring are sealed and it is placed in the water bath at 43°C for inlays and at 44°C to 45°C for crowns until the investment has completely set.

In actual practice, these temperatures are governed by prevailing conditions and the exact temperature to be used must be worked out by the practitioner.

• The wax is then burned out and the metal is casted[17].

II. Controlled Water Technique

It has been shown that the amount of hygroscopic expansion is directly related to the amount of water available to the setting investment and that by adding a specific amount of water to the setting investment, a specific amount of expansion results. The controlled water added technique is based on this principle.

Equipment Required

The equipment consists of a rubber sprue former, around which a rubber ring is placed. A thin metal ring is placed around the rubber ring, to prevent its collapse during vacuum investing or for convenience during hand investing. It is removed after the rubber ring is filled. A syringe of 200 ml capacity is used to add controlled amounts of water with an accuracy of 0.1 ml.

Procedure

In all techniques involving setting expansion of the investment, the expansion takes place in the presence of the wax pattern. The wax pattern can restrict expansion of the investment. To soften the wax, the ring can be immersed in water held at a temperature of 37°C. But care is taken to see that the level of water is below the top of the rubber ring and no water is allowed to come in contact with the investment.

The investment used for this technique is an investment especially compounded to provide high hygroscopic expansion.

The investment is mixed and poured into the rubber ring with supporting metal ring in place. Immediately after investing, the metal ring is removed so as to avoid restriction of the expansion of investment. The investment is flushed with the top of the rubber ring and the reservoir collar inserted.

The syringe is filled with water and the water is carefully dispersed into the reservoir collar. For an inlay, generally 1.1 ml of water is added. If a warm water bath is used, then some expansion of wax has already occurred so about 0.6 ml water is added.

Before burn out, the investment is allowed to set for a minimum of 45 minutes. After the investment has set, the rubber ring is removed and the investment mould without the support of a metal ring is subjected to burn out and the alloy is cast into the mould. The purpose of the rubber ring is to eliminate the asbestos liner, which would absorb the added water, thereby mitigating the accuracy of the water addition.

In the hygroscopic technique the ring is heated not higher than 468°C because thermal expansion of the investment is not desired. The mould should be held at this temperature for 60 to 90 minutes because the chances of a carbonaceous residue are very high[18].

Cleaning the Casting

After the casting has been completed, the ring is removed and quenched in water as soon as the button emits a dull red glow.

Advantages of quenching are:

• The noble metal alloy is left in an annealed condition for burnishing, polishing, etc.

• When water contacts the investment, it is absorbed into the investment pores. It undergoes immediate vapourizing within the hot mass.

Steam in large amounts produces cracking of the investment into small pieces. This simplifies cleaning the casting.

Sandblast technique is also used to remove the remaining investment material on the casting[9].

FINISHING AND POLISHING OF CAST RESTORATIONS

Finishing and polishing of restorative dental materials are important steps in the fabrication of clinically successful restorations. The techniques employed for these procedures are meant not only for the removal of excess material but also to smoothen the rough surfaces.

Chemical

After casting the gold alloys become discoloured or dark due to contamination and due to the presence of sulphide in the investment material. To remove these discolourations, pickling procedure is done. The solutions used for pickling are 50% hydrochloric acid or 50% sulphuric acid. The best pickling solution for gypsum bonded investment is 50% HCl acid solution. The disadvantage of hydrochloric acid is that fumes from acids are likely to corrode laboratory equipments and can cause health hazards. A similar solution of sulphuric acid is more advantageous in this respect[135].

Its action is enhanced by addition of potassium dichromate. However, sulphuric acid solution also proves dangerous. The best method of pickling is to place the casting in a test tube or dish and pour the acid over it. It may be necessary to heat the acid but boiling should be avoided. After pickling, the acid is poured off and the casting is removed. The pickling solution should be renewed frequently because it is likely to become contaminated. Casting should not be held with steel instruments as this may contaminate the pickling solution and casting. This is because the pickling solution usually contains small amounts of copper dissolved from previous castings. When the steel tongs contact this electrolyte, a galvanic cell is created, and copper is deposited on the casting at the point where tongs grip it[136].

Another procedure to be avoided is heating the casting and then dropping it in the pickling solution. This may cause delicate margins of the casting to melt or the casting may be distorted by sudden thermal shock when plunged into the acid. After pickling, the casting should be washed in running water to remove the acid.

Mechanical

The casting that is retrieved from the investment possesses a surface that is too rough to be used in the mouth. To remove the roughness of the casting surface, different abrasives are used. There are coarse materials, which help in removing the surface irregularities and impregnation. Different abrasives used are diamond, silicon carbide, emery, aluminium oxide, garnet, sand, tripoli, rouge, etc. The outer surface of the casting is smoothened with these abrasives using consecutive and progressive small particle sizes. The finishing process not only removes the surface blemishes and imperfections but also it gives the casting a shape to an ideal form or a desired state.

Polishing

Finishing procedures tend to leave microscopic scratches on the casting. During the final polishing stage these scratches are eliminated or reduced to a microscopic size which results in a microcrystalline surface layer known as Bielby layer.

Polishing can be accomplished with the help of rubber abrasive points, fine particle disks, strips, flexible paper backed disks finishing burs and polishing paste used with rotary instrument.

Polishing paste is applied with soft felt points, muslin wheels, prophy cups or buffy wheels. Therefore, polishing is one of the more refined finishing processes which should be done to keep the casting restoration clean as it also aids in corrosion resistance[136].

Try in

Remove the temporary restoration, making sure that all the temporary cement has been dislodged from the preparation walls and cleared away. Now confirm the fit of the casting. A gauze sponge should be placed as a 'throat screen' to catch the casting, if it is accidently dropped. Try the casting on the tooth using light pressure. Do not force the casting on the tooth.

If the casting does not seat properly, most likely cause is an over contoured proximal surface. Using the mouth mirror, judge where the proximal contour needs adjustment to allow final seating of the casting, producing the correct position and form to the contact.

Passing the dental floss through the contact will indicate tightness and position of the contact. If the floss will not enter or tears on entering the contact is excessive. To adjust the proximal contour and to correct contact relationship several trials on the tooth are required but it is best not to remove too much at a time. This contact should be passive. If contact is open, a new contact area must be soldered to the casting. An open contact is best detected by visual inspection with the aid of the mouth mirror. The soldering can be done by cleaning the contact area using a mild acid. Cut a small piece about 2.0 to 3.0 mm of solder out of solder strip. Apply borax type flux on the contact area of the casting and on the both surfaces of the piece of solder. Place the solder on contact area requiring build-up and direct the pinpoint flame of Bunsen burner to the solder with the help of blow pipe so that the solder melts and flows[137].

When the proximal contacts have been adjusted and the casting is satisfactorily seated on the tooth occlusion is verified. Occlusion is verified both in centric occlusion and during lateral excursive movements. Any high points and areas of heavy occlusal contacts are reduced with suitable abrasive stones.

CEMENTATION

Before cementation, the tooth is isolated with the air syringe, dry the preparation walls but do not dessicate them. Now mix the cement following manufacturer's instructions. Cement mix is generously applied to the preparation side of the casting, start the casting to place with fingers. Place the ball burnisher in the pit area to exert firm pressure to seat the casting. Ask the patient to close and exert biting force, several seconds of this pressure is sufficient. Complete seating of the casting is verified by inspection after wiping the excess cement away from the margins[138].

After the cement has hardened, excess is cleared off with an explorer and air water spray. Dental floss should be passed through the contact and clean the gingival embrasure.

Burnishing of the margins depends on the cement used. Burnishing of the margins was done after 24 hours, if zinc phosphate cement was used, as zinc phosphate cement is soluble in oral fluids whereas burnishing can be done after 15–20 minutes if resin cements were used because they are very less soluble in the oral cavity[139].

CASTING DEFECTS

Various casting defects, their probable causes and solutions are given in Table Porosity is a major defect in casting, so is discussed separately here. Porosities in noble metal alloy castings can be classified as:

Those Caused by Solidification Shrinkage

a. Localized shrinkage porosity: When the alloy solidifies from liquid state, a shrinkage of at least 1.25% occurs. Thus during solidification of metal in mould, if additional molten metal is not available to compensate for shrinkage then porosity occurs. It can occur if the metal freezes in the sprue before it does in the mould. It generally occurs at the sprue casting junction[140].

It could also be the result of formation of a hot spot when metal impinges on a mould surface so that here the metal remains molten whilst it solidifies everywhere else[141].

This kind of porosity is avoided by:

- Flaring the point of sprue attachment.
- Placing sprue in such a way so that a hot spot formation is avoided.
- Not using an excessively long sprue.
- Using a reservoir.
- Reducing the mould-melt temperature differential (i.e. lowering the casting temperature by about 30°C).

b. Micro porosity: It occurs due to premature solidification of the metal and is the result of solidification shrinkage. The voids produced are irregular in shape. This defect is discovered only if the casting is sectioned[142].

It occurs due to unduly rapid solidification of the metal or casting temperature is too low[9].

Porosities Caused by Gas

a. Pinhole porosity.

b. Gas inclusion porosity.

Both produce spherical defects; the defects in case of gas inclusion porosity are larger.

The metal absorbs gases when it is in molten state. Upon solidification, the absorbed gases are expelled and pinhole porosity results. Larger spherical porosities are caused by gas occluded from a poorly adjusted blowpipe flame or if the reducing zone of the flame is not used.

Subsurface Porosity

The exact reason for this has not been established. It may be due to the simultaneous nucleation of solid grains and gas bubbles at the first moment that the metal freezes at the mould walls. This can be diminished by controlling the rate at which the molten metal enters the mould.

Back Pressure Porosity

Porosity produced due to air entrapped on the inner surface of the casting. Usually occurs if for some reason gas is not vented from the mould. To prevent this the burnout should be adequate so that carbonaceous residues do not decrease porosity of investment. Mould and casting temperature should not be too low so as to allow metal to solidify rapidly. The water/powder ratio of the investment should be correct. The casting pressure should be adequate[18].

Repair

The weak link of most cast-metal inlays and onlays is the cement seal. At times, the operator may find discrepancies at margins that require replacement or repair. If the restoration is intact and retentive and if the defective margin area is small and accessible, small repairs can be attempted with amalgam or composite. If cement loss is found in one area of the restoration, however, other areas are usually suspect. When defects are found, the most common procedure is to remove the defective restoration and replace it[135].

POST AND CORE RESTORATIONS

The original post-retained restoration was described by **Pierre Fauchard** in 1746. Roots of anterior maxillary teeth were selected and gold or silver pivots (posts) were retained with an adhesive called mastic, softened by heat. Crown replacements made from bone, ivory, animal teeth and sound natural teeth were then cemented to the pivots.

Today, the post is a universally accepted treatment modality when insufficient tooth substance exists to retain a coronal restoration.

The last decade has seen fundamental changes in the restoration of the root-filled tooth, including the development of the fibre-based post systems and techniques of bonding to the prepared post-space.

Modern post and core techniques embrace a sound understanding of both biological and mechanical principles. No definitive guidelines are, however, available on best clinical practice. There is, in addition, a bewildering array of posts available and numerous techniques described for their placement[143].

CASE SELECTION:

Patient assessment:

Careful case selection is important if treatment with an endodontic post is to be successful. There are very few absolute medical contra-indications to carrying out indirect restorations. It is essential, however, that a comprehensive medical history is taken prior to any treatment. Careful planning should be instituted if a patient requires antibiotic prophylaxis for certain stages of treatment as the frequency of antibiotic doses should be reduced to a minimum. Certain conditions may necessitate the referral of the patient to a center for specialist care or require that the treatment be carried out following consultation with the medical practitioner[144].

Tooth Assessment:

A post should only be considered where there is insufficient substance to retain a coronal restoration. Most root-filled anterior teeth for which crowns are planned will require a post. Posterior teeth, in contrast, very rarely require a post, as the pulp chamber coronal root canal space can be used successfully to retain a core. The tooth should be well obturated and free from signs and symptoms of periradicular disease.

Radiographic Assessment:

An up-to-date radiograph is mandatory and should be good quality of paralleling periapical view. Of particular importance is an assessment of root caries and quality of root canal treatment including tooth length, density and the root canal filing, presence of periradicular disease and periodontal support.

Clinical Examination:

The clinician should percuss tooth and palpate soft tissues around the root for tenderness. This palpation also provides clues for the clinician on root evaluation within the alveolus and may prevent inadvertent perforation during post preparation[145].

Clinical techniques:

Post selection:

- Post selection is complicated and a bewildering array of commercially available post systems and techniques.

- These can be classified in a number of different ways but, in general, will be either prefabricated or custom-made. Posts can also be classified as follows:

  2) Active or passive.
  3) Parallel or tapered.
  4) By their material composition.

Custom-made Posts:

- Custom-cast posts have enjoyed widespread use and were regarded as the 'gold standard" for many years. However, fallen from favour as they incur additional clinical and laboratory stages. and require the provision of a temporary post restoration. Impression errors and insults in laboratory processing may render these posts ill-fitting.
- In addition, clinical data would suggest that custom-cast posts do not perform as well as prefabricated parallel-sided posts. Nonetheless, such posts are of value in situations where direct post placement is impractical. These include cases where correction of unfavourable crown-root angulation is anticipated.
- Multiple post and core restorations may make direct placement and build-up inefficient.
- Where short clinical crown height will render a core build-up unretentive for a subsequent crown, a one-piece cast post, core and crown may represent the best treatment option.
- Custom posts are most often constructed on a model poured from an impression of the teeth and the prepared root canal. These custom posts can be tapered to conform to the anatomic irregularities of the root canal and the core shaped by the technician for ideal retention and resistance form.
- Impression systems for constructing custom-made parallel posts are also widely available. These include matched reamers, impression posts and burn-out posts[146].

Prefabricated Posts:

- Prefabricated posts offer a number of distinct advantages over custom-cast posts.
- Post preparation, cementation and core build-up can be completed at the same appointment.
- This obviates the need for a temporary post crown and the extra time and cost associated with a custom-cast post and core.

Active Posts vs. Passive Posts:

- Active posts (screw-type posts) are threaded and are designed to engage the walls of the canal.
- These have been shown to be more retentive than passive posts which are designed to be retained solely by the luting agent.
- Stress concentration with active posts may, however, predispose to root fracture.
- Clinicians should only consider use of active posts in short roots where a passive post would be unretentive[147].

Parallel Post vs. Tapered Posts:

- Laboratory-based studies have shown better retention for parallel-sided posts when compared to tapered post designs.
- Clinical trials have also shown the superiority of traditional metal-based, parallel-sides posts when compared to tapered posts.
- Root canal anatomy generally presents a tapered shape and, accordingly, preparation for a parallel-sided post may necessitate over preparation of the apical post-space to maintain good post adaptation coronally.
- Modern endodontic rotary preparation techniques create canals with a tapered shape from crown to apex and greater degrees of taper than traditional hand instrumentation techniques.

- This has been shown to have a significant effect on post retention in lab-based trials. Root canal anatomy therefore plays an important role in selection of post shape and the operator should assess this carefully[14]

Fibre-based Posts:

- In 1990, **Duret et al,** reported a non-metallic material for the fabrication of posts based on the principle of carbon-fibre reinforcement.
- Have a high tensile strength and a modulus of elasticity similar to that of dentine.
- Rigid metal posts resisted lateral forces without distortion and hence this stress was transferred to the less rigid dentine, which could lead to root fracture.
- These posts are cemented with resin cements which are bonded to the root canal dentine and a core is built up directly with composite resin.
- Thus, the root dentine, luting cement, post and core form a unified structure which is thought to allow even distribution of stresses between the post, core and the dentine.
- Fibre-based posts are generally epoxy resin-based, with fibres running along the long axis of the post.
- A wide variety of posts shapes are available and include parallel-sided, tapered, smooth and serrated forms.
- Carbon-fibre posts are black in colour and do not lend themselves to esthetic restorations with all-ceramic units.
- This has led to the introduction of the quartz-fibre posts which are translucent and more tooth-coloured.
- These posts are also called glass-fibre and silica-fibre.
- A Technique has been described for the chair-side construction of custom-shaped composite/fibre-based posts, which is useful for restoration of teeth with irregular and wide canals. These might include teeth with immature root anatomy, post treatment or with caries in root canal dentine.

- A fibre-based post is place into a prepared canal along with a dual-curing resin cement without etching or bonding procedures. This is cured and the post subsequently removed.
- Further curing the relined post takes place and the subsequently cemented with a dual resin cement after etching and bonding to the canal dentine[149].

Timing of Post Placement:

- The ideal time to place within the root canal of a tooth is as soon as the obturation of the tooth has been completed and verified radiographically. This coronal seal will prevent potential bacterial contamination of the root canal system which may lead to endodontic failure.
- Thus, it should be possible to place the root canal filling and the definitive post without removing the rubber dam.
- It should be noted that the fibre-based post used to restore the tooth has a similar radio-density as gutta-percha.

Coronal Tooth Preparation:

- Before post placement and core build-up, the tooth should be prepared for the definitive coronal restoration, maintaining as much coronal dentine as possible.
- Straight line access will help prevent inadvertent root perforation and ensure meticulous removal of gutta-percha and root canal sealer[150].

Isolation:

- Rubber dam placement prevents ingress of saliva in the post-space and allows greater predictability when bonding to root dentine. In addition, rubber dam prevents aspiration or contamination of the post, allows improved vision and protects the patient from chemical agents used to prepare root dentine.

Post-space Preparation:

Length assessment should be made from a radiograph before canal preparation begins. Determining post length is often relatively subjective and much depends on root canal anatomy.

- The clinician should be guided by the need to leave at least 4-5 mm of apical gutta-percha.
- In this respect, in a recent study, **Abramovitz et al**, have shown that 3 mm of apical root filing provides an unreliable apical seal[151].
- Another study has suggested a 97% success where post length is at least equal to crown height.
- The operator must also be mindful to avoid canal perforation in the thinner apical dentine.
- The post-space should be made no wider than is necessary to place a post of adequate diameter.
- In general, when size-matched post reamers are used and apical resistance is initially felt, there is no need to increase post diameter.
- Most prefabricated post systems include a radiographic guide which can be placed on periapical radiographs and are helpful in assessing width and length of potential posts.
- Gutta-percha removal is most easily carried out with rotary instruments. If the root canal is being obturated at the same visit as post-space preparation, the use of an apical warm vertical condensation technique, greatly simplifies this process.
- For post-space preparation, when using post preparation reamers, start with the smallest bur first and gradually increase the size in sequence. A careful technique at a slow speed or using reamers by hand means that there is less risk of perforation[147].

- Use of sodium hypochlorite is useful between each instrument to remove debris and is mandatory in cases where coronal canal contamination is suspected.
- After the final reamer has been used, a spiral interdental brush dipped in alcohol may be useful to remove any small particles of sealer and gutta-percha, thus leaving a clean dentinal surface.
- Any remaining gutta-percha or sealer on dentinal walls should be identified at this stage and carefully removed with an endodotnic explorer. Such debris has been shown to occlude dentinal tubules and inhibit dentine bonding.
- It is not normally necessary to prepare an anti-rotational notch as any irregularities in the root will prevent rotation of the post and core. An anti-rotation notch may weaken the coronal dentine and predispose to root fracture[148].

Indirect technique of Post and Core Preparation:

- A custom dowel core can also be fabricated by making a wax or resin pattern on a cast of the prepared tooth.
- An impression of the prepared canal (elastomeric impression material) can be made by injecting impression material into the canal.
- In order to prevent distortion / displacement of impression material, during removal from the mouth and pouring of the cast, the impression is reinforced with some type of rigid dowel. These include paper clips, orthodontic wire. Plastic post and root canal instruments.
- Only use plastic posts when they are totally passive and do not bind on any tooth structure.
- When a safety pin or orthodontic wire is selected the coronal portion of wire should be bent over to form a handled to help retain it in the impression material.
- Notch the wire and coat it with adhesive.

- Fill the prepared canal with impression material using a slowly rotating lentulospiral instrument accompanied by up and down motion to reduce voids and uniform coating.
- Alternatively, an anesthetic needle can be placed to the full depth of the canal. Syringe additional impression material around the post as well as the prepared tooth and seat the impression tray.
- Remove the impression, evaluate it and pour a cast.
- Lightly lubricate the canal of the working cast with die lubricant.
- Place notches on the side of a plastic post that seats to the full depth of the canal preparation.
- Apply a very thin layer of sticky wax to the plastic post and then add soft inlay wax (Type II) in small increments, fully seating the plastic post after each increment of wax is added (Also beading wax can be used because it is soft and can be easily removed from irregularities and undercuts in canals).
- After the post pattern has been fabricated, the wax core is added and shaped and then the pattern is removed from the cast, inverted and cast in metal.
- The cast post core is then cemented in the tooth and the definite tooth preparation completed[145].

Post Adjustment:

- Parallel-sided posts are normally adjusted apically, leaving a retentive coronal portion ideally placed to support the core build-up.
- Tapered post is adjusted coronally.
- Fibre-based post should be cut with high speed diameter instruments. Wire cutters should not be used as these may weaken the post.
- The post should be tried in the clean and confirmed as fitting at the approximate working length[150].

Dentin Preparation:

Conventional cements:

- The post-space should be cleaned carefully with alcohol and an interdental brush. Drying with the air syringe is unpredictable at removal of moisture in the canal and paper points should be used.
- The conventional cement selected should be mixed to a luting consistency and placed in the canal with lentulospiral. This allows an even distribution of cement within the post-space.
- The surface of the posts should be lightly coated with the cement and the post pumped firmly to the tooth, taking care to prevent any trapped bubbles. The post should be maintained in working length till the cement has set, at which stage any excess can be removed.

Resin –based cements:

- Resin-based cements have number of physical advantages over conventional cements that have made them popular for cementing posts.
- These cement bond to dentine when a dentine bonding agent is applied and exhibit improved agent is applied and exhibit improved retention, and less microleakage than conventional cements.
- Bonding to root dentine is technique sensitive and more time consuming than conventional cementation techniques[140].
- Phosphoric acid etch should be placed with a syringe to fill the deepest part of the post-space. It can be difficult clinically to wash etch from the post-space and the use of a syringe with an irrigating needle is recommended.
- Drying of the dentine with paper points is recommended as this will prevent desiccation, which may in turn compromise the bonding surface.

- Bonding agent should be placed with a brush. The use of tapered microbrushes, which conform well to root canal anatomy, have been recommended for this purpose.
- Bonding resin should be blotted apically with paper points as pooling and subsequent cure of the resin may impede fit of post to length.
- **Ferrari and Mannocci** have shown that a one-step bonding agent does not perform as effectively as a traditional three-step bonding agent in preparing root dentine[147].
- It is difficult to ensure that all of the bonding agent is cured within the canal, unless self-cure materials are used. Self-cure or dual-cure resin cements should be used for luting because of limited light penetration into the root, even with translucent posts.
- A newly introduced one-step, self-etching, resin-based luting cement has been introduced which reduces the techniques sensitivity of bonding posts.
- Some resin-based cements may set prematurely if a lentulospiral is used, so this is not advisable. Luting must be performed quickly and carefully to ensure that the post is completely seated prior to cement setting. The post should abut the apical gutta-percha; empty canal space may predispose to endodontic failure.

Temporary Post Crowns:

- A direct post obviates the need for a temporary post-crown.

  Indirect techniques will normally make these a necessity in areas of esthetic importance. These restorations are, however, prone to failure and are associated with significant microleakage.
- Where possible, therefore, an apical barrier should be placed against gutta-percha after post-space preparation prior to cementation of the temporary post, and the definitive post and core cemented as soon as possible[143].

Core build-up:

- The purpose of the post is to retain the core, which in turn helps retain the crown.
- With cast post and cores, the core is formed on the post directly on the tooth or indirectly on a cast.
- The general shape and orientation of the core is developed during fabrication.
- Prefabricated posts are used in combination with a restorative build-up material which is formed after cementation of the post.
- The core should be designed to offer optimal retention and resistance form for the subsequent crown to be placed on the tooth.
- The choices are glass-ionomer materials, amalgam or composite resin.
- Glass-ionomer materials, including resin-modified glass ionomer, do not possess sufficient strength as a build-up material and should not be used in teeth with extensive loss of tooth structure[145].
- Amalgam has been used as a build-up material, with well-recognized strengths and limitations. It has good physical and mechanical properties and works well in high stress areas. In many cases, it may require the addition of pins or other methods to provide retention and resistance to rotation. Placement may be difficult where there is minimal coronal tooth structure. In addition, crown preparation must be delayed to allow time for the material to set. Esthetic problems may occur with amalgam where ceramic crowns are planned. There is also a risk of tattooing the cervical gingival with amalgam particles during the crown preparation. Amalgam does not have any intrinsic properties of adhesion and a bonding system should therefore be used for build-up.
- Core build-up for direct posts it most conveniently carried out with a direct placement of resin-bonded composite. Composite is esthetic and will not adversely affect the shade of translucent all-ceramic restorations. It has high tensile strength and the tooth can be prepared for a crown immediately after

polymerization. Composite can be bonded to many of the current posts and to the remaining tooth structure to increase retention[147].

- On the negative side, composite shrinks during polymerization, causing gap formation in the areas in which adhesion is weakest. It undergoes plastic deformation under repeated loads. Adhesion to dentine on the pulpal floor is generally not as strong or reliable as to coronal dentin. If the dentine surface is contaminated with blood or saliva during bonding procedures, the adhesion is greatly reduced. Although composite resin is far from ideal, it is currently the most widely used build-up material[151].

SUMMARY

Cast-metal inlays and onlays offer excellent restorations that may be underused in dentistry. The technique requires multiple patient visits and excellent laboratory support, but the resulting restorations have the potential to last for decades. High noble alloys are desirable for patients concerned with allergy or sensitivity to other restorative materials. Cast-metal onlays, in particular, can be designed to strengthen the restored tooth while conserving more tooth structure than does a full crown. Disadvantages such as high cost and esthetics limit their use, but when indicated, cast-metal inlays and onlays provide a restorative option that is less damaging to pulpal and periodontal tissues compared with a full crown.

Principal conclusions which may be drawn include:

- Good patient assessment and treatment planning is essential, even where minimal intervention techniques are employed.
- Recent evidence on the performance of fibre posts is very positive. Although the volume of studies is comparatively small, there are several studies of over 4 years duration with large numbers of crowns in the studies. The results indicate very low incidence of root fracture associated with fibre posts, possibly because their elastic modulus is similar to that of dentine, in contrast to metal posts which are often implicated in root fracture. In addition, fibre posts are relatively easily removed, again in contrast to fractured metal posts.
- Conventional acid base luting materials have inferior physical properties compared with resin-based luting materials. In addition, acid-base materials have high solubility in lactic acid erosion testing, the relevance being that lactic acid is one of the dilute organic acids found in plaque. If plaque is present, this may be in contact with the luting material at the gingival margin of an indirect restoration.

- Of non-resin luting materials, resin modified glass ionomer luting materials have the best physical properties. In addition, these materials release fluoride and adhere to tooth substance.
- Self-adhesive luting material remove much of the technique sensitivity associated with the use of the preliminary etching and bonding steps which were required to gain adhesion with conventional resin based luting materials. This new group of materials, which includes Rely X Unicem (3M ESPE) and Maxcem (Kerr Mfg Co.) have a low pH on mixing, similar to self-etch dentine adhesives.
- A wide variety of indirect restorative techniques which use contemporary adhesive technology are now available. These invariably require less tooth destruction than conventional non-adhesive techniques.
- Success rates of adhesive indirect techniques show promise, even if some do not appear to perform as well as traditional techniques when measured in terms of debond / loss of the restoration. However, the reduced tooth substance which is destroyed during preparation of adhesive restorations should reap benefit in terms of reduced pulp death, but the incidence of this may be difficult to determine in the literature.
- Dentin-bonded crowns, in which porcelain is bonded to tooth substance using a resin based luting material and with the bond being mediated by a dentine bonding agent and a micromechanically retentive crown fitting surface, provide a minimally invasive full coverage restorative treatment which has low incidence of pulp death and good esthetics.
- Success rates for porcelain veneers is not 100%, so these restorations should not be used for instant orthodontics in cases where orthodontic treatment is a realistic, albeit more time-consuming, option.
- Good laboratory communication is essential for successful indirect dentistry.
- A well-fitting provisional restoration is essential to avoid drifting of adjacent teeth and eruption of opposing teeth, notwithstanding pulp damage which may

occur when a large number of dentinal tubules are opened. Ideally, also, for patient satisfaction, the provisional crown should be of good esthetics: unfilled resins may be of value in producing a shiny surface.

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