THE EFFECT OF SURFACE SEALANT APPLICATION ON THE SURFACE ROUGHNESS AND COLOR STABILITY OF ACRYLIC DENTURE TOOTH AFTER THERMAL CYCLING– AN IN-VITRO STUDY

By

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Under the guidance of

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2020-2023

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled "**The effect of surface sealant application on the surface roughness and color stability of acrylic denture tooth after thermal cycling – An In Vitro Study**" is a bonafide and genuine research work carried out by me under the guidance of **Prof. Dr. Mathew M Alani**, Department of Prosthodontics and Crown & Bridge, St Gregorios Dental College, Chelad, Kothamangalam.

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This is to certify that the dissertation entitled **"The effect of surface sealant application on the surface roughness and color stability of acrylic denture tooth after thermal cycling – An In Vitro Study"** is a bonafide research work done by Dr. Arya Aravind, in partial fulfilment of the requirement for the degree of Master of Dental Surgery.

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ABSTRACT

Background and objectives:

Denture wearing continues to increase with the increase in the aging population; most of the edentulous people depends on complete or partial removable denture for replacing missing teeth. Denture made of PMMA is very popular today. In that the PMMA acrylic denture tooth are most commonly used. Basically polishing procedures are not much used for tooth surfaces when we compare it with the denture base. So plaque accumulation is increased due to its increased surface roughness which lead to staining. In this study our goal is to find whether there is any difference in the surface roughness and color stability of both unfilled PMMA denture tooth and microfiller reinforced PMMA denture tooth after coating with a surface sealant agent.

Methods:

A total of 104disk-shaped labial sections (6×2 mm) were prepared from the largest available A2 shade central incisors with a standardized template and trephine bur. Out of which; 52 specimens were unfilled PMMA denture tooth and the remaining 52 specimens were microfiller reinforced PMMA denture tooth. These specimens were again divided into 2 groups of 26 samples each: (i) conventionally polished and (ii) sealant coated. Half of the specimens from the four subgroups were subjected to thermal cycling procedure (n=13). Surface roughness of both thermal cycled and non-thermal cycled groups were measured using Profilometer. Likewise, colour stability of both thermal cycled and non-thermal cycled subgroups were measured using UV Spectrophotometer. Colour stability were again measured after dipping in the coffee solution for seven days.

Results and discussion

The difference in surface roughness and colour stability values were determined and evaluated statistically using 1- way ANOVA for within group comparison, followed

by Tukey test. Independent Samples t-test was used to compare the means for two groups. A paired t test was used to compare the samples at baseline and after testing. Statistical analysis was performed by using SPSS software version 21.

By analysing both before and after thermal cycling the mean surface roughness values are highest for non-coated unfilled PMMA denture teeth (0.3323 and 0.3502 respectively). In that the thermal cycling group showed the highest surface roughness values. The least values were observed by coated microfiller reinforced PMMA denture tooth, 0.129 and 0.1855 both before and after thermal cycling respectively. Color difference values also show statistically significant differences between groups. Color differences are most evident for specimen who had undergone thermal cycling. The highest mean color difference value was showed by the non-coated unfilled PMMA denture tooth with values 11.897 and 85.7679 both before thermal cycling and after staining with coffee respectively. Least color difference mean values are given by coated microfiller reinforced PMMA denture tooth both after thermal cycling and after staining with coffee solution, with values 7.5762 and 9.9908 respectively.

Conclusion:

The surface sealant coated microfiller reinforced PMMA denture tooth gave the least surface roughness and color difference values. Uncoated unfilled PMMA denture tooth showed the highest values. Thermal cycled groups show the highest surface roughness and color difference values.

Key words: unfilled PMMA denture tooth, microfiller reinforced PMMA denture tooth, surface sealant agent, thermal cycling, surface roughness, color stability

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INTRODUCTION

INTRODUCTION

Edentulism is a common manifestation among geriatric patient. The rate of edentulous patients among the elderly have been reported as relatively high. Females have high rate of edentulism than males[1]. Increasing incidence of edentulousness in the past few years has questioned the adequacy of dental treatment. Advances in medical science with continuous improvement in specialisation and treatment modalities observed in practice. So it is realized that these improvement prolongs the lifespan of humans with significant increase in the number of elderly in the past few decades.

Dental implants and dentures are the major prosthetic device for rehabilitating oral tissue of edentulous patients. But high cost of dental implants and metal base denture make the conventional dentures more popular in prosthetic dentistry. Complete denture rehabilitation still remains one of the most popular treatment modality for edentulous patient who have systemic, anatomic or financial constraints.

Denture tooth play an important role in the construction of complete denture and removable partial denture. According to GTP 9, denture tooth is a term commonly referring to an artificial tooth used in the fabrication of a resin base prosthesis[2]. For the past few decades PMMA (Poly methylmethacrylate) is the material of choice. Methacrylate polymers are capable of meeting all the features needed for use in oral cavity[3]. It has various advantages including low cost, biocompatibility, ease of processing, acceptable aesthetics, ease of polishing. However, it is not considered as an ideal material because of its inferior mechanical and physical properties[3].

The teeth of dentures are often made from various types of resin or porcelain. Porcelain tooth are always superior in their esthetic properties and wear resistance. But porcelain tooth can't be trimmed easily. Porcelain tooth causes excessive wear of the opposing natural teeth and transmit the masticatory load to the residual ridges. This

eventually accelerates the underlying residual ridge resorption[3]. Nowadays, acrylic resin is the preferred material, but sometimes porcelain is still used.

Acrylic resin has become a popular material for denture teeth for a variety of reasons. Correct bite and alignment of teeth with dentures can be crucial for comfortable wear and use of the denture. The way our teeth come together is called occlusion[3]. Acrylic adheres more securely to the denture base and is easier to adjust to achieve the correct occlusion than harder porcelain teeth. It is also significantly less expensive than porcelain, and are much lighter in weight[3]. More recently, reinforced acrylic tooth has become popularised due to its superior quality.

Acrylic denture tooth is mainly composed of polymethyl methacrylate (PMMA) and these are available in different shades, form and size[3]. Even if we consider the merits of an acrylic denture tooth in denture fabrication, there are certain disadvantages including excessive wear, staining and plaque accumulation[3]. These all are mainly due to its material properties. The material charesteristics are mainly improved by modification in the structural components.

Surface roughness and surface free energy will determine the performance of dental restorative materials. When the external surface of a dental restoration is rough, more plaque forms which accelerate tooth loss due to caries or periodontal disease and denture stomatitis[4,5,6]. In recent studies, a threshold level of surface roughness (Ra=0.2 mm) has been showed for plaque accumulation[8]. This is the borderline value. There was no reduction of plaque accumulation if the surface become smoother than this. But higher surface roughness resulted in a simultaneous increase in plaque accumulation. Furthermore, dental restorations with rough surfaces are more prone to staining and discoloration, leading to reduced esthetics and acceptability of the restoration[5].

Denture stomatitis is the most common problem in denture wearer. It is a common disease condition caused due to Candida Albicans, a fungal infection. This is the common

after effect of poor oral hygiene as well as plaque accumulation. The plaque accumulation mainly related to the surface roughness properties[10,11].

Next common problem encountered by a denture wearer is the change in the colour of the denture tooth due to the constant staining. But we frequently use acrylic denture tooth. Colour change occur due to exposure to colouring agents which often due to extrinsic accumulation of stains on the surface or in the subsurface of restorations. Overall, stain adsorption due to exposure to colouring solutions has been more commonly reported in the acrylic teeth of dentures, and dental composites and porcelain rank next[7].

Denture teeth are commonly used in complete and partial dental prostheses[12]. When the denture teeth are placed in direct contact with natural teeth or oral soft tissues, extensive plaque formation may contribute to caries or periodontal disease adjacent to the denture

Modifications of the denture tooth material include microfiller reinforced or nanofiller reinforced. Reinforcement of the tooth material will improve the surface properties of the denture tooth. This will also improve the mechanical properties of the denture tooth.

So certain studies show that there were significant differences in plaque accumulation and the surface roughness values as well as the color staining property between the normal PMMA acrylic denture tooth and the filler reinforced acrylic denture tooth. Filler reinforced acrylic denture teeth show lesser values and reduced plaque accumulation[4,11,12]. Certain microbiology studies in the denture tooth also justify the above stated data[10,11].

The polishness of the denture surface also contributed to reduced surface roughness as well as reduced plaque accumulation and improved color stability. While polishing the denture we most commonly concentrated on the denture base part. Tooth surface are not much polished. Plaque formation and discoloration can be reduced by polishing the denture teeth, which has been conventionally done in the dental laboratory with aluminium oxide

pastes or liquids [5,8]. Various chairside polishing kits and surface sealants are available if the prosthesis cannot be returned to the dental laboratory after grinding procedures[8]. Clinicians may use a surface sealant coupling technique to achieve more polished and color-stable denture tooth surfaces after chairside grinding procedures[4].

Basically sealant coupling agents were used in composite restorations. To achieve a smooth and polished surface of a denture we can employ the sealant coupling agent coating technique. The application of surface sealant agents onto the resin restoration is intended to fill in surface irregularities, increase wear resistance, and provide better staining resistance[8]. Further researches were needed to evaluate the long term performance of this sealant agent.

Thermal cycling is the process of cycling through two temperature extremes, typically at relatively high rates of change. It is an environmental stress test. Denture prosthesis are usually under thermal variations due to the ingestion of hot and cold liquids in the oral condition. A temperature ranges of 5- 55°C are found to be closest to the physiology of oral cavity. In thermal cycling, dwell time is the time period at which the specimen is immersed in the bath at a particular temperature correspond to the latency period[16,17,18]. Certain studies showed that there were increased surface roughness and staining properties of both denture bases and denture tooth material after thermal cycling[14,15].

The purpose of the study is to evaluate the effect of surface sealant application on surface roughness and color stability of unfilled PMMA denture tooth and microfiller reinforced PMMA denture tooth after thermal cycling.

AIMS AND OBJECTIVES

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To evaluate and compare the effect of surface sealant application and the thermal cycling on the surface roughness and color stability of two types of acrylic denture teeth.

a) To evaluate and compare the surface roughness of unfilled and microfilled acrylic denture teeth before thermal cycling.
b) To evaluate and compare the surface roughness of unfilled and microfilled acrylic denture teeth after thermal cycling.
c) To evaluate and compare the color stability of unfilled and microfilled acrylic denture teeth before thermal cycling.
d) To evaluate and compare the color stability of unfilled and microfilled acrylic denture teeth after thermal cycling.
e) To evaluate and compare the surface roughness of conventionally polished acrylic denture teeth and sealant coated acrylic denture teeth.
f) To evaluate and compare the color stability of conventionally polished acrylic denture teeth and sealant coated acrylic denture teeth.
g) To evaluate and compare the surface roughness of conventionally polished acrylic denture teeth and sealant coated acrylic denture teeth before and after thermal cycling.
h) To evaluate and compare the color stability of conventionally polished acrylic denture teeth and sealant coated acrylic denture teeth before and after thermal cycling.

BACKGROUND AND REVIEW OF LITERATURE

BACKGROUND AND REVIEW OF LITERATURE

- **Borchers 1999[5],** conducted a study on acrylic resins after having been polished or coated with different varnish materials. The study examined the surface roughness of acrylic resins after having been polished or coated with different varnish materials. They found that unfilled resins tended to decrease surface roughness with the increasing molecular weight of methacrylate components. All the varnish materials provide more color stable denture surface than conventional polishing technique.

- **M F Bertrand 2000[23],** conducted a study to observe the surface texture by scanning electron microscopy and measure the microhardness of the surface. The application of Fortify (Bisco, Lombard, IL), an unfilled resin, to the surface of composite resin restorations is intended to fill in defects in the surface that persist despite polishing, improve marginal integrity, and increase these materials' resistance to abrasion. The microhardness of the double layer was reduced, depending on the thickness of the glazing resin. The capacity of glaze to mask surface defects of composite resin was shown, but it was difficult to obtain a regular surface with liquid resin. The application of this product caused a decrease of the microhardness of the composite resin's surface.

- **Mutlu Sagesen 2001[24],** conducted a study related to color stability of different denture tooth and compare the color stability of commercially available porcelain, reinforced acrylic, and conventional acrylic denture teeth materials used in removable prostheses. Denture teeth were subjected to 3 staining solutions (filtered coffee, tea, and cola) and distilled water. The filtered coffee solution was found to be more chromogenic than the other 2 staining solutions, while porcelain denture teeth materials were more color stable.

- **Deniz 2002[6],** compared the surface roughness of 3 different bis-acryl composite-based and 3 different methyl methacrylate-based provisional crown and fixed partial denture resins after being polished with aluminum oxide and diamond paste. The mean of the surface characteristics of the bis-acryl composites were 1.33 micron for aluminum oxide

and 0.90 micron for diamond polishing paste; the mean of the results of the methyl methacrylate resins were 1 micron for aluminum oxide and 0.50 micron for diamond polishing paste. Within the limitations of this study, single-phase polishing of the bis-acryl composites tested and the methacrylate resins tested with diamond-based paste produced a smoother surface than when polished with aluminum oxide paste.

- **Doray 2003**[25] conducted a study on composite provisional materials. Color changes of a resin composite provisional material were measured by reflection spectrophotometry after storage in three staining solutions and water to determine stain resistance when treated with three methacrylate or urethane dimethacrylate resin surface sealants and when left untreated. Surface sealers of methacrylate or dimethacrylate resins can improve resistance of a resin composite provisional material to staining. All the three sealants provided more color stable denture tooth surface than conventional polishing technique.

- **Rahal 2004**[26]**,** evaluated the influence of mechanical polishing (MP) and chemical polishing (CP) on surface roughness of four heat-cured denture base acrylic resins. He concluded that MP produced significantly smoother surfaces than CP and that surface roughness because of MP was not influenced by acrylic resin type, whereas this was not true of CP.

- **Milan 2005**[8]**,** compared the effects of 4 chairside polishing kits and 2 conventional laboratory techniques used for polishing 3 different acrylic denture base resins. Conventional laboratory polishing was found to produce the smoothest surface of denture base acrylic resin. Chairside silicone polishing kits produced a significantly smoother surface of acrylic resin than specimens polished with a tungsten carbide bur. The presence of large pores was characteristic for the autopolymerizing resin material.

- **Duygu Sarac 2006**[27]**,** evaluated the surface roughness and color change of a hybrid, a microhybrid, and a nanohybrid composite resin polished with the use of polishing discs, wheels, and a glaze material. The highest Ra values were obtained with hybrid composite resins due to the size of the filler particles that were exposed after polishing. Although

the smoothest surfaces were obtained with polyester strips, the use of glaze material after polishing discs or polishing wheels resulted in significantly lower Ra and DeltaE values than the use of the latter alone. The glaze appears to fill the structural microdefects and provide a more uniform, regular surface.

- **Loyaga Rendon 2007[28],** conducted a study to qualify the compositional characteristics and hardness of new commercially available types of acrylic resin and composite resin artificial teeth. Twelve brands of 3 types (2 conventional acrylic resins, 3 cross-linked acrylic resins, and 7 composite resins) of artificial teeth were examined. A significant linear correlation was observed between hardness and inorganic content**.** He found that, differences in size, shape, distribution, and content of the silica filler and the cross-linking nature of the resin matrix among the commercial brands of artificial teeth evaluated.

- **Shakeel 2007[29],** determined the effect of various food-simulating solvents on the hardness of denture teeth after varying storage times, using a Martens hardness test. Based on the results of his study, he concluded that EXP1, which is a type of a hybrid nanocomposite resin base material, is significantly harder than other polymer-based materials tested. Moreover, storage in 75% ethanol significantly reduced the hardness of all polymer based materials except EXP1 with some materials showing greater reduction than others.

- **Hahnel 2008[10],** evaluated the susceptibility of commonly used artificial teeth to adhesion of the oral bacterium *Streptococcus mutans.* Surface roughness were measured. The highest values, indicating high adhesion of streptococci, were observed for filler-supplemented teeth. Similar values were recorded for a double crosslinked resin tooth. Significantly lowest values, were found for unfilled PMMA acrylic resin teeth and acrylic resin teeth with an interpenetrating network. He concluded that the adhesion of *Streptococcus mutans* to unfilled PMMA teeth and teeth with an interpenetrating network is lower than adhesion to artificial teeth supplemented with fillers or double cross-linked acrylic resin teeth.

- **Koksal 2008**[30]evaluated the color stability of two brands of porcelain teeth and three brands of acrylic denture teeth. Samples were immersed into three staining drinks as test groups and distilled water as a control. Color measurements of teeth were performed by using a spectrophotometer. Before immersion, the initial color value of each tooth was recorded. The color stability of all teeth was significantly affected by the immersion period ($p<0.0001$). Instant coffee was found to be the most chromogenic agent among the solutions tested ($p<0.0001$). Among the materials tested, porcelain was found to be more resistant to discoloration. It was concluded that acrylic teeth showed a higher degree of color change and that the amount of color change for each group increased proportionally with time.
- **Ahmet Umut Güler 2009**[31]**,** investigated the effect of different polishing methods on color stability of posterior, universal and nanohybrid composite resin restorative materials upon exposure to a staining agent. The use of diamond polishing paste after polishing with polishing discs significantly decreased staining when compared to the groups that used polishing discs alone, for all restorative materials tested. The highest color change values were obtained for the specimens that were polished with the Biscover liquid polish system.
- **Wirley Gonçalves 2009**[14]**,** investigated the effect of polymerization methods and thermal cycling on the color change of acrylic resin denture teeth. Ten different brands of acrylic resin denture teeth were evaluated. The polymerization method did not affect the color stability of denture teeth. Although thermal cycling affects the color stability of all brands of acrylic resin denture teeth evaluated, the color differences were not clinically discernable.
- **Padiyar 2010**[32]**,** states that colour stability is the ability of materials to retain their original colour. Daily intake of food with staining ability like tea, coffee, cola etc. can compromise esthetics of restorative materials. Understanding the property of colour stability and the comparative analysis of various restorative materials will help a clinician to choose the materials as per the diet habits of the patients and ensure predictability of success. It will also enable the clinician to educate and counsel the

patient about the effects of specific chromatogenic ingredients in the diet like tea, coffee, wine etc. on the colour stability of the restorative material used.

- **Karin Neppelenbroek 2010[33],** evaluated effect of immersion in staining beverages (coffee, red wine, and orange juice) on the roughness and Vickers hardness of two layers (internal and external) of commercial cross-linked artificial teeth (Trilux and Vivodent). Hardness of both teeth was reduced after immersion in the staining beverages, with wine being the most significant. Roughness of both layers of the teeth was not affected by long-term immersion.

- **Suwannaroop 2011[34],** examined the wear resistance, hardness, elastic modulus, and the correlations between them of artificial denture teeth at the sub-enamel layer were examined. Four types of tested artificial denture teeth consisted of 3 conventional acrylic resin teeth (Cosmo HXL, Major Dent, and Yamahachi FX), 1 high cross-linked acrylic resin teeth (Trubyte Bioform IPN), 2 composite resin teeth (SR Orthosit PE, and Yamahachi PX), and 1 porcelain teeth (ACE Teeth). The two-body wear test was performed using a custom made pin on disc apparatus. Volume and weight loss were measured. Hardness and elastic modulus were also assessed by using a nanoindentation system. He concluded that wear resistance varied among the denture tooth materials. Wear resistance of high cross-linked acrylic resin teeth was the lowest. A definite relation between wear resistance and mechanical properties of materials could not be found.

- **Silva 2011[35]**,evaluated whether repeated cycles of chemical disinfectants affected the color stability of two denture tooth acrylic resins. There were statistically significant differences in ΔE* among the 5 disinfectants and water during the 90 cycles of immersion for both dentures tooth acrylic resins. Distilled water promoted the greatest color change in both dentures tooth acrylic resins, nevertheless none of tested disinfectants promoted ΔE* values higher than 1.0 on these acrylic materials during the 90 cycles of disinfection. Repeated immersion cycles in disinfecting solutions alter ΔE*

values, however these values do not compromise the color of the tested denture tooth acrylic resins because they are imperceptible to the human eye.

- **Nihan Gönülol 2012[36],** evaluated the effects of different finishing and polishing techniques on the surface roughness and color stability of nanocomposites. The composites with smaller filler size did not necessarily show low surface roughness and discoloration. Staining of composite resins was dependent on monomer structure, as well as surface irregularities.

- **Wendy 2012[37]**, assessed the color stability of high strength acrylic resin denture teeth after exposure to red wine, coffee and artificial ageing.The smallest overall color change upon staining in red wine was recorded for Vita Physiodens denture teeth. some statistically significant changes in color and color coordinates occurred upon staining and ageing.

- **Gagan Khanna 2013[38],** compared the microhardness of the different acrylic teeth since it is related to wear resistance and is the most commonly examined mechanical property indicator for synthetic artificial tooth material.

- **Seema S Patil 2013[39],** evaluated the effect of cigarette smoke on the colour stability of commercially available acrylic resin teeth. Crosslinked acrylic resin teeth was more colour stable and more resistant to the discolouration which was caused by cigarette smoke. Non-crosslinked acrylic resin teeth was least colour stable and most susceptible to discolouration which was caused by cigarette smoke.

- **Ahmad 2013[40],** determined the effect of different beverage solutions on the hardness of different acrylic denture teeth which are commercially available. The posterior teeth of each brand were placed in auto polymerizing acrylic resin and the occlusal surfaces were ground flat, then immersed in distilled water (control), Pepsi, coffee and tea solutions for 30 days and then the hardness were tested using Vickers microhardness tester. The RMH denture teeth materials showed the highest hardness than other denture teeth materials.

Pepsi was more effective than tea and coffee in reducing the hardness of different acrylic teeth materials. Pepsi reduced the hardness of different acrylic teeth materials during the 30 days' immersion. The hardness of RMH denture teeth materials was less affective by the different beverage solutions.

- **Arana-Correa 2014[41],** investigated the colour stability of acrylic resin denture teeth in beverages. A spectrophotometer measured the colour (CIE-L*a*b* system) of all specimens after storage in distilled water for 24 h at 37°C (T0). Specimens were then immersed in various beverages. After 15 days (T1) and 30 days (T2), for each material, the mean ΔE values were calculated and compared by two-way ANOVA and Tukey intervals (α=0.05). In the ΔT0T1 period, specimens stored in red wine were significantly discoloured, compared to distilled water (P=0.003). There was no difference between immersion solutions in ΔET0T2 (P=0.772) and in ΔET1T2 (P=0.058), and no difference between materials in all immersion periods.

- **Oana-Cella Andrei 2014[42],** compared the colour stability of different acrylic artificial teeth available on the market and usually used in manufacturing partial and full dentures in Romania and to find a ranking of staining ability of different solutions with which artificial teeth could come into contact lately, during function or cleaning phases. The acrylic prefabricated teeth suffered various colour changes in contact with those drinks, with magnitudes depending on the type of the liquid and the acrylic teeth chosen. He also compared colour stability of two batches of homolog teeth, first unmodified and second grinded and polished in the dental laboratory, from which the most affected were R and M where this colour change occurs in three of the four kinds of drinks in which we have made the immersion. Washing the dentures with soap and water reduced differences in colour caused by contact with any type of these drinks.

- **Freire 2014[43]**, conducted a study to evaluate the effect of different cleaning protocols and accelerated artificial aging on colour stability of denture teeth made of acrylic resin. Sixty denture teeth in dark and light shades were used, and separated according to the

treatment to which they were submitted. Results demonstrated that colour stability of artificial teeth is influenced by the cleaning solution and artificial aging, being dark teeth more susceptible to colour alteration than lighter ones.

- **Esma 2014[44],** investigated the effects of different finishing-polishing techniques on the color stability and surface roughness of various anterior restorative materials after staining. A composite, a compomer, and a resin-modified glass ionomer were used to prepare 120 specimens. Specimens were divided into subgroups: polishing discs, liquid polishing material, aluminium oxide bonded discs, and control. The specimens were stained in a coffee solution. Color parameters (*L*a*b*)* and surface roughness before and after staining were measured. The color was affected by the material type ($p<0.05$) and finishing-polishing systems ($p<0.05$). The composite showed the highest color stability; however, the color differences of all groups were visible even to the non skilled operator. The *R*a values did not significantly change after staining for any of the restorative groups ($p>0.05$). The finishing-polishing systems had an effect on color after storing in staining solution.

- **Dogu Omur 2015[45],** conducted a study to evaluate the effect of sealant agents on the surface roughness and color stability of 4 nanohybrid composite resin materials. The surface treatment technique significantly affected the Ra values of the composite resins tested The interaction between the surface treatment technique and composite resin material was also significant for DE00 values. All surface sealant agents provided less discoloration of nanohybrid composite resins after coffee staining compared with conventional polishing.

- **Sahin 2015[4]** conducted a study on different types of artificial denture teeth. The study was to evaluate the effect of three different sealant agents on the surface roughness and color stability of various denture tooth materials. The study concluded that the use of surface sealant agents decreased the surface roughness and color difference values. Color changes after the use of some sealant agents were visually perceptible but clinically

- acceptable. All the three sealants provided more color stable denture tooth surfaces than conventional polishing technique. Thermal cycling also had effect on color stability.

- **Koroglu 2015[46],** evaluated the effects of different polishing methods on the surface roughness and color stability of 4 interim crown materials. All specimens had a surface roughness higher than the plaque accumulation threshold (0.20 mm). Smoother surfaces were observed for Tempofit with Biscover when compared with theTempofit control. The color change observed with the Dentalon Plus, Tab 2000, and Tempofit control groups was clinically unacceptable. Nonperceivable color changes were seen with Protemp 4 with Optiglaze, Tempofit with Optiglaze, and Tempofit with Biscover. Perceivable but clinically acceptable color changes were observed when sealants were used for all other test groups and Protemp 4 control.

- **Karin Hermana 2015[47],** evaluated the effect of staining beverages (coffee, orange juice, and red wine) on the Vickers hardness and surface roughness of the base (BL) and enamel layers of improved artificial teeth. Hardness of the two brands of acrylic teeth was reduced by all staining beverages, mainly for red wine. Roughness of both layers of the teeth was not affected by long-term immersion in the beverages.

- **Regina 2015[48],** mapped the microhardness of artificial teeth as a function of depth and commercial brand. Knoop hardness did not present differences between layers for eight of the nine brands studied. Different hardness values were found between superficial and cervical areas for the brand SR Orthosit PE.

- **Veena Kumari 2015[49],** conducted a study on the effect of polishing procedures on the surface roughness and staining capacity of dentures**.** Polishing procedures significantly roughen the surface of the restoration compared to the unpolished Mylar controls. One-step polishing system (diamond polishing paste) produces a smoother surface compared to a multi-step system (Sof-Lex polishing disks). Turmeric solution caused maximum staining of the samples, to a visually perceptible level.

- **Matheus 2015[50],** evaluated the Knoop hardness, composition, and wear resistance of acrylic-resin artificial teeth exposed to mechanical tooth brushing. Composition analysis revealed that all of the artificial teeth analyzed contain carbon and oxygen. Trilux and Soluut PX brand teeth also contain silicon; however, the presence of filler particles did not result in increased resistance.

- **Xinyuan Xu 2016[51],** stated that most common polymer for fabricating dentures is acrylic resin and its composites with other additives like reinforcing filler, initiator, and pigment. Conventional restoration focuses on the enhancement of mechanical properties, such as the polymer shrinkage rate and fracture resistance through an admixture of new monomers (e.g., dendritic macromolecular and POSS) and reinforcing fillers (macrofiller, microfiller, nanofiller, etc.).

- **Mousavi 2016[12],** compared the colour stability of three different brands of acrylic teeth following immersion in coffee, tea and cola. Despite the significant colour change in the three groups, ΔE in Ivoclar group was within the clinically acceptable range of ≤ 3.3. A slight colour change was expected regarding the Apple and PolyDent acrylic teeth clinically.

- **Faribroz 2016[52],** assessed the effect of two flasking materials on the color stability of five brands of denture teeth that were immersed in commonly consumed beverages. Coffee caused the most color changes in the examined resin denture teeth. Tea and cola left less staining on the teeth, and distilled water caused the least discoloration. Generally, investing by heat- and cold-cured acrylic resins can significantly affect the color stability of resin denture teeth; however, heat-cured acrylic resins had fewer color changes.

- **Yuzugullu 2016[53],** compared the effects of different denture cleansers on the surface roughness and microhardness of various types of posterior denture teeth. NaOCl and Corega Tabs affected the surface roughness and microhardness of all artificial denture teeth except for the new generation nanohybrid composite teeth.

- **Derya Merve Halacoglu 2016[54],**evaluated the effect of different staining solutions and a bleaching procedure on color stability and surface roughness of a nanohybrid resin composite with or without liquid resin polishing (RP). Staining and bleaching did not change the surface roughness of the RP and P groups ($P > 0.05$). Discoloration in the red wine group was higher than for the other staining solutions for the RP ($P < 0.001$) and P groups ($P = 0.018$). Application of liquid RP did not enhance the color stability and surface roughness of the composite resin restoration.

- **Onur Sahin 2016[55],** conducted a study to evaluate the effects of different polishing methods on the surface roughness and color stability of denture base materials. A total of 120 specimens were fabricated from 2 polymethyl methacrylate (PMMA) and 1 polyamide denture base materials and divided into 4 groups (n=10 in each group) according to the applied surface treatment procedure: conventional polishing (control) and 3 surface sealant coupling methods. No statistically significant difference was found between surface roughness values of the control and those of the specimens treated using a surface sealant agent (P>.05). The highest color difference was calculated for the polyamide control group. Statistically significant differences were found between the control group and the group treated with the polyamide surface sealant agent (P<.05). All specimens had a surface roughness value higher than the plaque accumulation threshold (0.20 mm). The color changes observed were clinically unacceptable, except for conventionally polished and one type of surface sealant applied microwave polymerized PMMA denture base material.

- **Nitasha Gandhi 2017[56],** assessed the surface hardness of acrylic resin teeth of three different commercial brands (Ivoclar, Newace, Acryrock) following chemical (2% glutaraldehyde, 1% sodium hypochlorite) and microwave disinfections. It was concluded that there was no significant difference in microhardness when the teeth were subjected to chemical disinfection but three cycles of microwave disinfection produced decrease in the microhardness of different types of artificial teeth.

- **Raluca 2017[13],** analysed the colour stability of acrylic teeth, after exposure to several dietary agents (types of coffee, red wine), and the oral antiseptic chlorhexidine (0.2% mouthwash). Distilled water was used as control. The teeth colour was assessed using a spectrophotometric method. Acrylic teeth from 4 manufacturers were immersed in staining agents over a period of 11 days. Acrylic teeth showed a high susceptibility to staining, dependent on teeth manufacturer (lowest for Vita teeth), and staining agent (highest for coffee, especially espresso, and for red wine). Chlorhexidine mouthwash had a low staining potential, similar to distilled water. In conclusion, tests for staining susceptibility can be carried out by spectrophotometry before selecting teeth from one manufacturer, using specific colouring agents according to patient food preferences. Chlorhexidine, an oral antiseptic frequently prescribed, has low staining potential of acrylic teeth.

- **Mostafa 2018[57]**, conducted a study on the color stability of some denture teeth materials (acrylic &porcelain) and to evaluate some mechanical properties of these denture teeth materials. Results showing significant color changes of the different denture teeth materials upon immersion in tea, coffee, cola, or distilled water. This color change was greater in case of immersion in either tea or coffee solutions. The least color change was obtained from samples immersed in distilled water. The different materials used showed no significant statistical difference in water sorption values. Finally, the results showed that, there were significant statistical differences in surface roughness of all tested materials after immersion in any of the tested solutions. The acrylic denture teeth material is much more subjected to discoloration than the porcelain denture teeth material. Water sorption of the tested materials was of close values. Surface roughness of the denture teeth material show significant statistical difference by immersion in staining solutions.

- **Gehan G Allam 2019[58],** evaluated the effect of immersion in different beverages on the colour stability, the surface roughness and the surface hardness of the tooth-surface coating material. Tea was associated with the highest color difference followed by cola,

orange and then unionized water after 6 months. Cola was associated with the highest change in surface roughness followed by unionized distilled water, orange then tea. Cola was associated with the highest change in surface hardness followed by tea and then orange. Colour change, surface roughness and surface hardness of Beauticoat were influenced by the beverages used in this study.

- **Maranhao 2019[59],** conducted a study to evaluate the color alteration of four brands of artificial teeth (Art Plus, Tr Bionote and Biolux), after immersion in color solutions of coffee, red wine and urucum**.** The result showed that the urucum was the substance that caused the greatest staining while the coffee and the wine did not show statistical difference. Regarding trademarks, Trilux presented a statistical difference compared to the other commercial brands revealing colorimetric alteration only in the 14-day period. It was concluded that the composition of the artificial teeth, the type of pigmenting agent and the immersion time determine the color change.

- **Fabio 2019[60],** compared the surface roughness and color stability of restorations before and after application of different resin-coating agents. The Biscover surface sealant showed the lowest surface roughness and the best color stability. Surface sealants can be used to fill micro cracks and microgaps but should not be used as a substitute for polishing.

- **Lucas 2019[61],** conducted a study to evaluate coating materials regarding color and roughness changes when applied over a composite resin. ΔE00 increased with increasing storage time at red wine, until 72 hours. BF, FF, PS, SB, and CTRL presented the lowest ΔE00 after 24 hours. APS presented the highest ΔE00 (32.59; $P < .05$). Regarding roughness, initially, surface sealants and APS presented the lowest values. After 168 hours, GC presented the lowest Ra (0.60; $P < .05$). All the materials presented color and roughness changes after storage in red wine. Some coating materials can be applied over the surface of RBC restorations without changing its color stability or surface roughness.

- **Bayne 2019[62],** states that the movement has mostly come in the area of improved esthetics, marked by the gradual replacement of dental amalgam with dental composite and all-metal and porcelain-fused-to-metal indirect restorations with reinforced dental ceramics, all made possible by the rapid improvements in dental adhesive materials.

- **Eun-Sol Koh 2020[63],** evaluated color stability of Dentca 3D-printed denture teeth, in comparison to color stabilities of four conventional types of denture teeth, upon being immersed in various colorants. color change was observed in Dentca denture teeth when immersed in some colorants; however, the maximum value of ΔE for Dentca denture teeth was within the clinically acceptable range.

- **Sandro 2020[64],** evaluated the effect of four acidic beverages on the roughness (Ra) and color change (ΔEab) of two brands of artificial teeth and a heat-polymerized acrylic resin (HPAR) for use in a prosthetic base. In general, the acidic solutions changed the Ra and ΔEab of HPAR and artificial teeth after T1. The grape juice altered the roughness only of the artificial teeth, promoting a clinically acceptable color change in the materials.

- **Nick 2020[65],** investigated the possible differences in color of denture teeth of the same or different brands under different illuminations, since their metameric behavior in color under specific illumination may become unacceptable. Differences were found between and within brands under D65 illumination which increased under F2 or A illumination affected by brand type and hydration status. Executive was the most stable brand than the others under different illuminations or wet states and for this reason its difference from other brands is the lowest. In clinical practice, there should be no blending of teeth of different brands but if we must, we should select those that are more stable under different illuminations.

- **Fatma A. Sanal 2020[66],** evaluated the color stability of two different shaded acrylic denture teeth and the effectiveness of different cleansing methods on stain removal. Baseline color reading of 50 right maxillary central incisors of both A1 and A2 shaded

denture teeth were performed with a spectrophotometer. The shade of denture teeth and the denture cleansing method had a significant effect on delta E values.

- **Ann Smith 2020[11]**, investigated the association between staining of denture acrylics by different food types and subsequent *C. albicans* colonisation. This study demonstrated that staining acrylics with certain foods promoted *C. albicans* colonisation, but this was not associated with visual staining. This knowledge may then be used by dental professionals to advise patients on improving denture hygiene to improve not only denture aesthetics but also minimise *C. albicans.*

- **Ehsani 2021[67],** assessed the color change (ΔE00) of 7 brands of denture teeth (conventional acrylic and composite teeth) following immersion in staining solutions. The color stability of all teeth was significantly affected by the solutions ($P<0.001$). The type of tooth and coloring solution had significant interactions at all times ($P<0.05$). Turmeric caused the maximum color change in all teeth after 1 month. Repeated measures ANOVA showed that ΔE00 of all teeth was significantly affected by the duration of immersion in the solutions ($P<0.001$). within the limitations of this study, 1-month immersion of denture teeth in coffee, tea and cola solution altered the ΔE values; however, they were within the acceptable range, except for Beta Star. Turmeric solution caused unacceptable color change in all denture teeth even after 24 h of immersion.

- **Sule 2021[68],** evaluated the microhardness and surface roughness of four artificial teeth type against various beverages. Conventional acrylic resin, reinforced acrylic resin, microfiller composite resin, and nanofiller composite resin teeth were used. From each group, 10 maxillary first and second molars were immersed in 5 beverages (tea, filtered coffee, cola, cherry juice, and distilled water. The microhardness values significantly decreased in all beverages especially in 6thmonth. The surface roughness values significantly increased in all beverages especially in 3thmonth. There were no statistically significant differences between the beverages. Microfiller composite resin denture teeth had the highest microhardness values and the lowest surface roughness

- values. Different types of beverages consumed daily negatively affect the microhardness and surface roughness of artificial teeth. Microfiller composite resin teeth could have the ideal surface properties.

- **Hanadi A. Lamfon 2021[69],** states that denture stomatitis is increased dramatically in the recent years, particularly in denture wearers. It is a common inflammatory reaction with multifactorial etiology that usually appears in the oral cavity as an erythematous reaction on the oral mucosa extends to the limits of the maxillary denture-bearing area. Candida albicans is regarded as the primary cause of denture-associated stomatitis owing to its high capability to adhere to oral tissues and denture surfaces in addition to biofilms formation. Candida species can interact with different microorganisms within the mouth resulting in a complex and mixed biofilm formation with an organized structure which is difficult to remove. The presence of bacteria in the acrylic biofilms resulted in increased pathogenicity and virulence of Candida biofilms making them more resistance to antifungal drugs.

- **Mei Ting Tieh 2021[70],** determined the effect of various solutions on the color of denture teeth, thus answering the question in regards to which type of denture teeth has the best optical properties after exposure to various solutions. The method of measuring the color of artificial teeth was also evaluated as a secondary outcome. Color stability of CAD/CAM milled denture teeth is comparable to conventional PMMA denture teeth. There are contradictory findings in terms of color stability of 3D printed denture teeth as compared to conventional PMMA denture teeth. Staining by coffee is worst among the common beverages and solutions investigated. Denture teeth can show color changes after immersion in staining beverages as early as one week. The degree of discoloration of denture teeth after immersion is time dependent, with the larger extent in the initial phase

- **Ana Carolina Pero 2021[71],** states that brushing and consumption of dye beverages may alter the physical properties of artificial teeth. She evaluated the effect of toothbrushing

and immersion in beverages in roughness and color of two types of artificial teeth: Biotone (B) and Biotone interpenetrating polymer network (IPN). Toothbrushing had no influence on the color stability but significantly reduced the roughness, irrespective of the type of tooth.

- **Giti 2021[72],** evaluated the effect of surface sealant application on the color stability and surface roughness of two denture base materials. Surface sealant agent significantly increases the color stability in both the denture base materials, but there are not much differences seen in the surface roughness values.

- **Sevda Atalay 2021[15],** evaluated the effect of thermocycling on the water contact angle (WCA), surface roughness (SR), and microhardness (MH) of different CAD-CAM PMMA denture base materials after different surface treatments (conventional laboratory polishing, polishing kit, or surface sealant). After thermocycling, surface treatment had a significant effect on water contact angle and surface roughness. CLP or PK application resulted in hydrophobic surfaces compared with before thermocycling. CLP or SSC application on CAD-CAM PMMAs resulted in smoother surfaces. Thermocycling lowered the microhardness of all PMMAs, and the decrease was significant in CLP- or PK-applied PMMAs, except for PK-applied Poli

- **Göze Saygın 2022[73],**assessed the long-term microhardness of different artificial teeth after waiting in liquids of various pH values.Four different artificial teeth [conventional PMMA (Ivostar) as control group), double cross-linked PMMA(DCL), micro-filled composite resin(VivodentPE), nanohybrid composite resin (PhonaresiII)] were used for the study. A decrease in microhardness of the material that are immersed in liquid with different pH values for a long time was observed, and the microhardness of the materials exposed to these solutions is adversely affected.

- **Sreelakshmy K. S. Kammath 2022[74],** conducted a study on staining the artificial tooth with beverages.During clinical use, artificial teeth are exposed to saliva, beverages, and cleaning agents and such materials are prone to the absorptionand adsorption processes.

Certain foods can promote discoloration, surface degradation, and changes in other properties of artificial teeth. The results show changes in the color of acrylic teeth.Beverages causes significant color changes to the acrylic tooth material**.**

- **Fahmi Yunisa 2022[75],** evaluated the surface roughness of denture tooth that had been exposed to coffee and then cleaned mechanically and chemically. Surface roughness of artificial teeth increases after immersion in coffee solution. The denture cleaning method did not give negative result on the surface roughness of artificial tooth that had been exposed to coffee solution.

- **Tayseer Maaly 2022[76],** conducted a study to evaluate the effect of different staining solutions on color stability and surface roughness (SR) of Nano hybrid composite and acrylic denture teeth. Results showed significant color changes of both types of artificial teeth materials upon immersion in tea, coffee, cola, licorice or distilled water. This color change was greater in case of tea and coffee solutions. The least color change values were obtained from specimens immersed in distilled water. SR values were increased for acrylic teeth compared with composite teeth and there were significant statistical differences in surface roughness of all tested materials after immersion in any of the tested solutions. The acrylic denture teeth material is much more subjected to discoloration than the composite denture teeth material. Surface roughness of all tested teeth of both types recorded statistically significant decrease by immersion in staining solutions.

RELEVANCE OF THE STUDY

RELEVANCE OF THE STUDY

Dental esthetics and beauty of the smile are of prime importance in today's society Denture tooth plays the more esthetic role in a denture wearer patient. There are four esthetic harmonies that must be considered to produce a denture which will satisfy the patient's esthetic demands. These esthetic harmonies are tooth size, form, tooth color, tooth position, and background[9]. The color of the denture tooth can get stained in the time period. These properties are determined by the surface properties of the denture tooth and denture itself, which includes surface roughness and color stability of the denture.

Surface roughness is mainly associated with the plaque accumulation. Surface irregularities cause an increase in surface roughness which leads to accumulation of plaque. A threshold level of surface roughness (Ra=0.2 μm) has effect on plaque accumulation. Above this level will definitely cause plaque accumulation[5,8]. This eventually lead to staining of the denture surface. Common after effect of this scenario was the occurrence of denture stomatitis. Growth of *Candida Albicans* causes this oral health condition.

Various studies show that there is a high correlation with the increased colonization of *Candida Albicans* species and surface roughness. It shows an exponential growth pattern[10,11]. So while giving a denture before educating the patient with oral hygiene maintenance, we should first deliver a polished denture. Denture should not be a medium for this bacterial growth.

Artificial teeth are a significant part of the overall esthetical outcome in a removable denture. Color stability is the one major factor which maintains this esthetic outcome. PMMA denture tooth are inferior in maintaining this esthetic outcome due to wear and discoloration[30]. Color stability of a denture tooth is determined by the surface irregularities. Smooth even surfaces reduce plaque accumulation and staining. This will contribute to the color stability[4].

Polishing the denture is an unavoidable step in the fabrication of a denture. Polishing improves the surface properties and reduces complication such as denture stomatitis. Various polishing protocols were employed by the clinician to do the polishing which includes laboratory polishing, chairside polishing and chemical polishing. These all procedures gave a smooth even surfaces for the denture[19]. Our concern is regarding the polishing and the effect of polishing in the surface roughness and color stability of denture tooth.

Denture tooth are already supplied in a polished smooth surface. In the course of polishing the denture there was an increased chance of occurrence of surface irregularities in the artificial denture tooth surface. This increase in surface roughness were least observed or managed, since finishing and polishing were mostly concentrated on the denture base surfaces. Some studies show adding filler to the tooth material will reduce surface roughness values as well as color staining properties[4,12,13], so we had taken two different materials for the study, one is the unfilled PMMA and the other one is the microfilled PMMA.

Even after improving the material quality the problem of plaque accumulation and color fading still occurs. So our aim is to find whether the surface sealant agents used in composite restorations for the surface polishness can be incorporated in denture tooth surface to form a more polished sealed surface and whether this application will reduce the surface roughness as well as improves the color stability.

Improving the surface properties will be a boon to the dental society for achieving a more polished denture surfaces in the near future. Color stability and surface roughness are important properties of a denture. Denture tooth get stained and loss its property with time period more often than a denture base. Methods to extend the life of the dentures are necessary. It will be more beneficial in esthetic concern. The significance of this study was to evaluate the effect of sealant agents and thermal cycling on the surface roughness and color stability of different denture teeth.

METHODOLOGY

METHODOLOGY

This in-vitro study was conducted in the Department of Prosthodontics, Crown and Bridge and Implantology, St. Gregorios Dental College, Chelad, Kothamangalam, Kerala.Testing of the samples were carried out in the Mechanical engineering branch, CUSAT, Eranakulam, CSIR, Trivandrum and Bio Medical Technology Wing, Sree Chitra Thirunal Institute of Technology, Trivandrum, Kerala.

MATERIALS AND METHODS:

Table 1: List of materials used for the study

SI NO	Materials used	Brand name and company
1	Unfilled PMMA denture tooth	Acryrock Teeth Set (A2 shade)- Ruthinium- Amritsar (Punjab, India)
2	Microfilled PMMA denture tooth	SR Vivodent DCL- Ivoclar Vivadent- Switzerland
3	Surface sealant agent	GC-G Coat Plus- GC Corporations, Tokyo, Japan

Table 2: List of Equipments used for the study

SI NO	Equipments used	Specifications
1	Profilometer	SURFCOM FLEX 50A
2	UV Spectrophotometer	SHIMADZU UV-3600 - UV-VIS-NIR
3	Thermal cycling unit	WILEYTEC THERMOCYCLER WITH COOLING SYSTEM HAAKE EK 30

Table 3: List of armamentarium used for the study

SI NO	Armamentarium used	Specifications
1	Trephine bur	Osung- dental technologies- Pune – ISO: 20569
2	Silicon Carbide polishing paper (400 grit)	Warrior plus-local dealer
3	Denture polishing cake	Samit- local dealer
4	Polishing lathe	Jaypee Dental lathe, Delhi
5	Coffee powder	NESCAFE CLASSIC INSTANT 7.5gm
6	Distilled water	Pharmaceutical institute of India Pvt limited
7	Light curing unit	Woodpecker
8	Stainless steel tumbler	Local dealer
9	Incubator (33-37°C)	Laboratory incubator

SAMPLING

a) Sample size

Sample size was calculated G*power software Version 3.1.9.4.

Input:

- Effect size f = .4
- α err prob = 0.05
- Power (1-β err prob) = 0.8
- Number of groups = 8

Output:

- Noncentrality parameter λ = 16.6400000
- Critical F = 2.1064654
- Numerator df = 7
- Denominator df = 96
- Actual power = 0.8346628
- Minimum sample size per group = 13
- Total sample size = 104

b) Inclusion criteria

Not applicable

c) Exclusion criteria

Not applicable

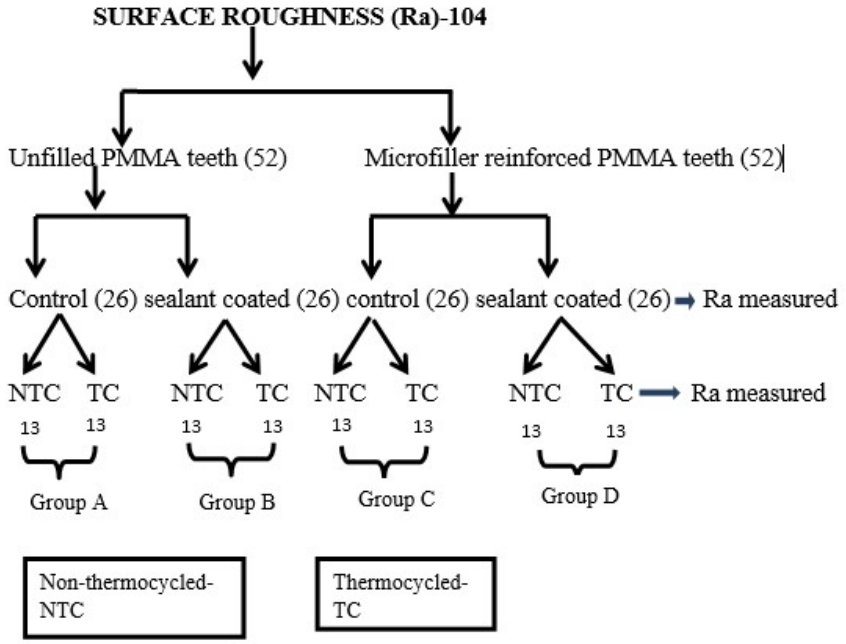
A total of 104 specimens were fabricated, out of which; 52 specimens were unfilled PMMA tooth and the remaining 52 specimens were microfiller reinforced PMMA tooth.

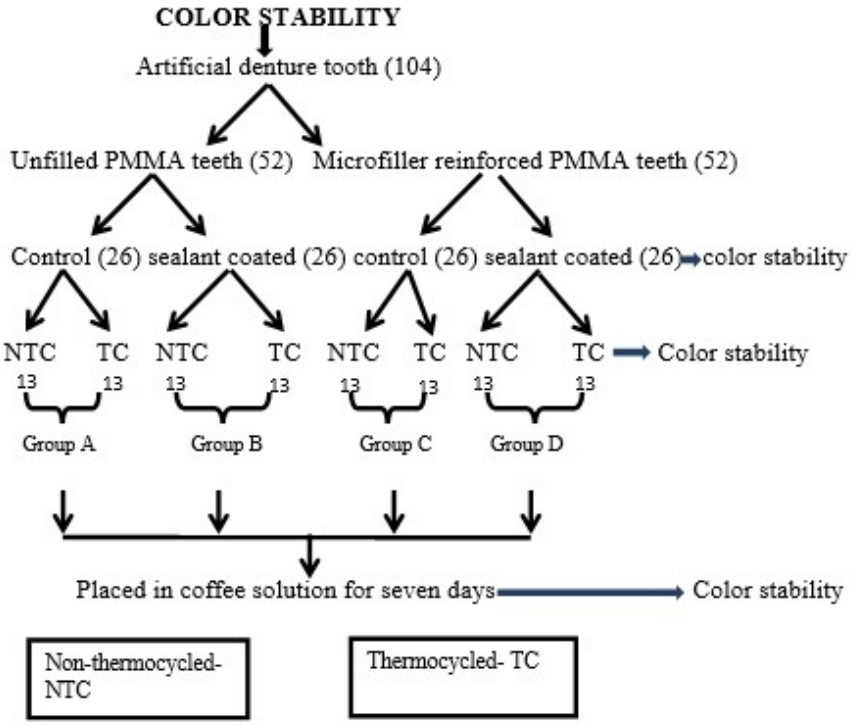
SELECTION AND FABRICATION OF THE TEST SPECIMENS

Two commonly used denture tooth type were selected for this study. All the materials were purchased from local market through regular commercial channels. The materials used for this study were divided into four groups (Group A, Group B, Group C, Group D) and again it was divided into 8 subgroups based on whether it was thermal cycled or not. These groups and the corresponding specimens used were listed below (Table 4):

Table 4: Description of sample groups

Group	Description
Group A (Control)	PMMA acrylic tooth conventionally polished
Group B	PMMA acrylic tooth coated with surface sealant
Group C (Control)	Microfiller reinforced PMMA acrylic tooth conventionally polished
Group D	Microfiller reinforced PMMA acrylic tooth coated with surface sealant


SURFACE ROUGHNESS (Ra)-104
Unfilled PMMA teeth (52)
Microfiller reinforced PMMA teeth (52)
Control (26) sealant coated (26) control (26) sealant coated (26)
Ra measured
NTC TC NTC TC NTC TC NTC TC
Ra measured
13 13 13 13 13 13 13 13
Group A
Group B
Group C
Group D
Non-thermocycled-NTC
Thermocycled-TC


COLOR STABILITY
Artificial denture tooth (104)
Unfilled PMMA teeth (52)
Microfiller reinforced PMMA teeth (52)
Control (26) sealant coated (26) control (26) sealant coated (26)
color stability
NTC TC NTC TC NTC TC NTC TC
Color stability
13 13 13 13 13 13 13 13
Group A
Group B
Group C
Group D
Placed in coffee solution for seven days
Color stability
Non-thermocycled-NTC
Thermocycled- TC

SAMPLE PREPARATION

Disk-shaped labial sections (6×2 mm) were prepared from the largest available A2 shade central incisors with a standardized template and trephine bur (Hager & Meisinger GmbH)[4].Before the polishing procedures, the specimens were ground-finished with 400-grit silicon carbide abrasive paper on a machine under water cooling. Sealant agent were applied with a soft brush in an even, thin layer in 1 direction without any agitation to avoid air bubble formation. Half of the specimen was applied with the sealant. Sealant agent applied on the tooth surface was cured using light curing instrument as per the manufactures instructions. Surface roughness of each specimen were measured using Profilometer. The color difference measurements were done using UV Spectrophotometer.

The group was divided again into 8 subgroups based on thermal cycling. The specimens were subjected to thermal cycling between 5℃ and 55 ℃ for 3000 cycles at 30 seconds in distilled water[16,17,18]. After thermal cycling the surface roughness and color stability were measured again. The CIE (Commission International de l'Eclairage)L*a*b* color parameters of each specimen were measured with a digital spectrophotometer. The initial color measurements were repeated 3 times for each specimen, and the means were recorded as L0*, a0*, b0*.

Both thermal cycled (TC) and non-thermal cycled (NT) specimens were then embedded into wax plates to cover the unpolished surfaces. The staining solution was prepared by adding 7.5 g of coffee (Nescafé Classic; Nestlé) to 500 mL of boiling distilled water[4,30,45]. All specimens on the wax plates were immersed in the coffee solution in a stainless steel container and stored at 37℃ in a dark environment for 7 days to simulate intraoral conditions. After the staining procedure, each specimen were washed under water andair-spray dried, and color measurements were made. Data were recorded as L1*, a1*, b1*.The color change values of TC and NT denture teeth after different surface treatments were calculated with the following CIEDE 2000 (DE00) color difference formula:

$$\Delta E_{00}=\sqrt{\left(\frac{\Delta L*}{KLSL}\right)^2+\left(\frac{\Delta C*}{KcSc}\right)^2+\left(\frac{\Delta H*}{KHSH}\right)^2+RT\left(\frac{\Delta C*}{KCSL}\right)\left(\frac{\Delta H*}{KHSH}\right)}$$

where DL*, DC*, and DH* are the differences in lightness, chroma, and hue for a pair of specimens in DE00, and where RT is a function that accounts for the interaction between chroma and hue differences in the blue region

EXPERIMENTAL TEST

Measuring the surface roughness before thermal cycling

Surface roughness of all the 104 specimens were measured before thermal cycling using profilometer.

Measuring the surface roughness after thermal cycling

13 thermal cycled specimens from each group were selected and surface roughness were measured using profilometer.

Measuring the color stability before thermal cycling

Color stability of all the 104 samples were measured before thermal cycling using digital UV spectrophotometer

Measuring the color stability after thermal cycling

13 specimens from each group were subjected to thermal cycling and the color difference were measured using digital UV spectrophotometer.

Measuring the color stability after dipping the samples in coffee for 7 days

After thermal cycling all the specimens were dipped in coffee for seven days at 37℃ using an incubator for continues seven days. After staining color differences were calculated using digital UV spectrophotometer.

Statistical analysis

The difference in surface roughness and colour stability values were determined and evaluated statistically using 1- way ANOVA for within group comparison, followed by Tukey test. Independent Samples t-test was used to compare the means for two groups. A paired t test was used to compare the samples at baseline and after testing. Statistical analysis was performed by using SPSS software version 21.

Figure 1: Unfilled PMMA tooth (Acryrock)

Figure 2: Microfiller reinforced PMMA tooth (Vivodent)

Figure 3: Surface sealant agent (GC G-Coat Plus)

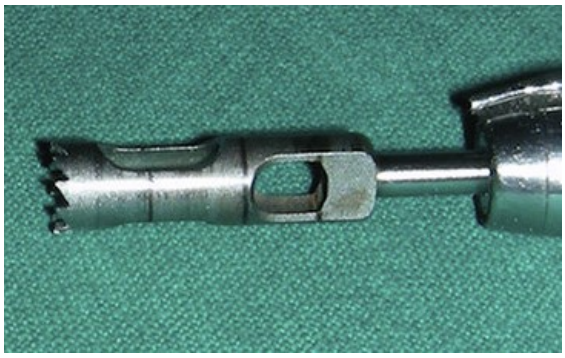


Figure 4: Trephine bur

Figure 5: Denture polishing cake

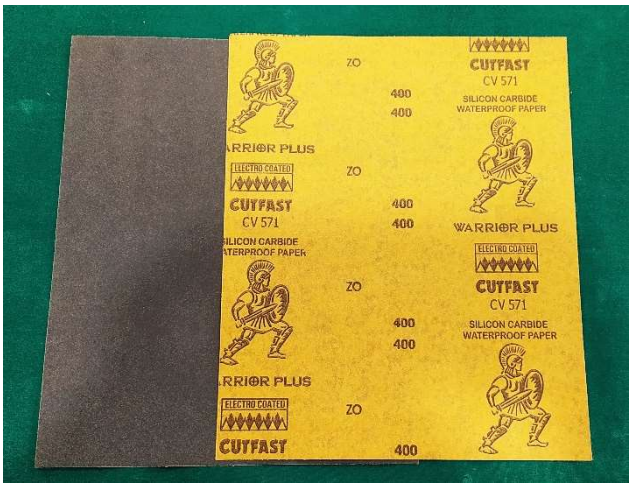


Figure 6: 400 grit silicon carbide abrasive paper

Figure 7: Acrylic polisher

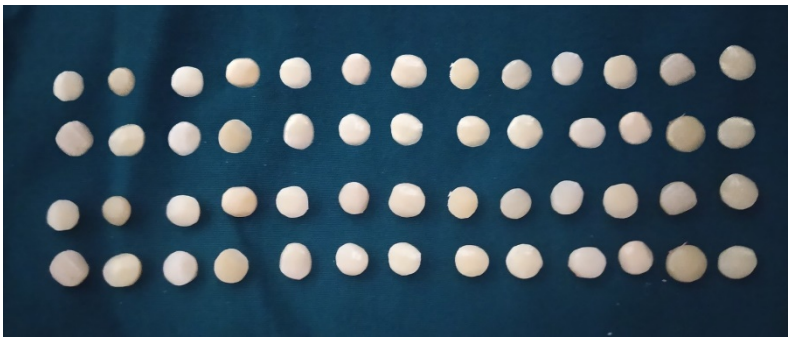


Figure 8: Unfilled PMMA tooth

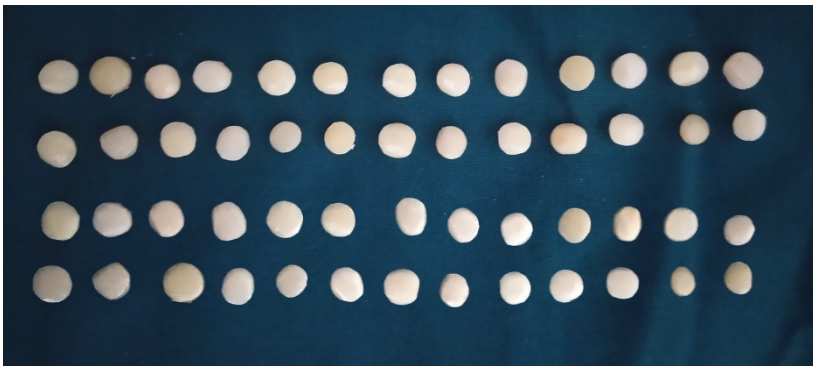


Figure 9– Microfiller reinforced PMMA tooth

Figure 10: Surface sealant coated unfilled PMMA tooth

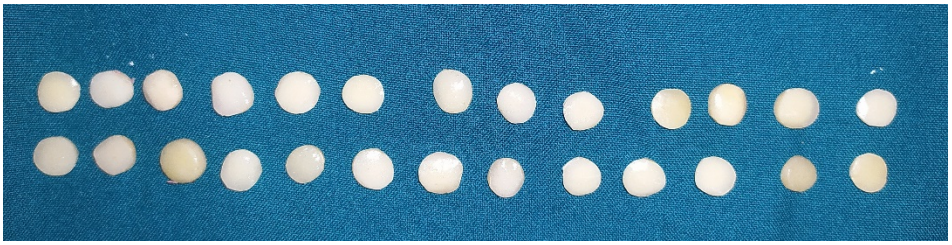


Figure 11: Surface sealant coated microfiller reinforced PMMA

Figure 12: Uncoated unfilled PMMA

Figure 13: Uncoated Microfiller reinforced PMMA

Figure 14: Coffee and distilled water

Figure 15: PMMA specimens dipped in coffee in an incubator

Figure 16: Thermal cycler

Figure 17: Spectrophotometer for measuring color stability

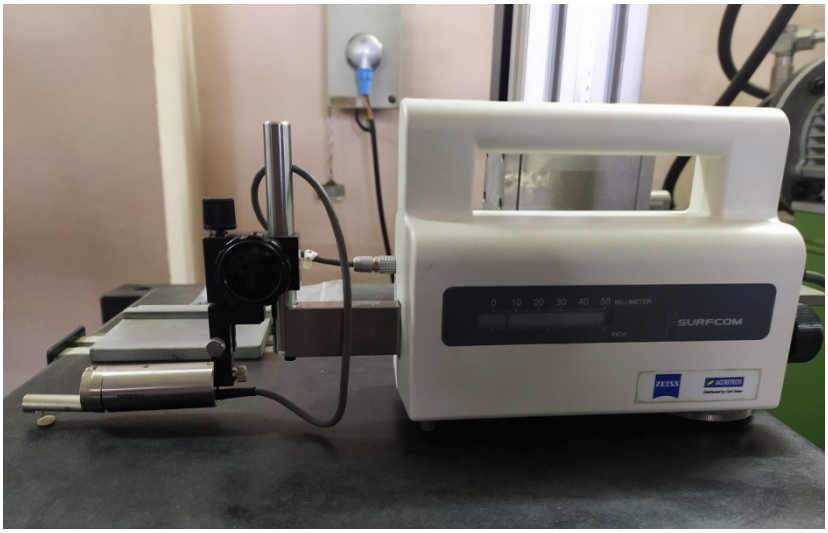


Figure 18: Profilometer for measuring surface roughness

Figure 19: Performing thermal cycling

Figure 20: Measuring the color stability

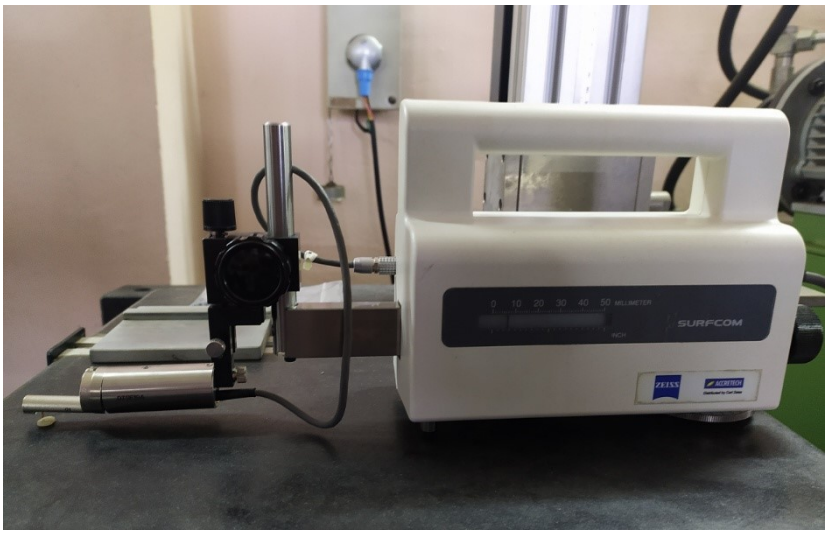


Figure 21: Measuring the surface roughness

RESULTS

RESULTS

The surface roughness of 4 different groups before thermal cycling were evaluated and calculated values were listed in table 5:

TABLE 5 :SURFACE ROUGHNESS BEFORE THERMAL CYCLING (µm)

SL NO	GROUP A	GROUP B	GROUP C	GROUP D
1	0.287	0.222	0.201	0.186
2	0.263	0.210	0.210	0.175
3	0.345	0.213	0.197	0.183
4	0.293	0.205	0.200	0.191
5	0.355	0.220	0.216	0.173
6	0.581	0.240	0.208	0.184
7	0.431	0.243	0.203	0.185
8	0.263	0.231	0.195	0.191
9	0.287	0.233	0.197	0.185
10	0.290	0.196	0.204	0.199
11	0.287	0.222	0.208	0.184
12	0.263	0.210	0.203	0.185
13	0.345	0.213	0.195	0.191
14	0.293	0.205	0.208	0.185
15	0.355	0.220	0.201	0.199
16	0.581	0.240	0.210	0.184
17	0.431	0.243	0.197	0.186
18	0.263	0.231	0.200	0.175
19	0.287	0.233	0.216	0.183

20	0.290	0.196	0.208	0.191
21	0.287	0.222	0.203	0.173
22	0.263	0.210	0.195	0.184
23	0.345	0.213	0.197	0.185
24	0.293	0.205	0.204	0.191
25	0.355	0.220	0.208	0.185
26	0.581	0.240	0.203	0.199

The surface roughness of 8 different sub groups after thermal cycling were evaluated and calculated values were listed in table 6:

TABLE 6: SURFACE ROUGHNESS AFTER THERMAL CYCLING (µm)

SL NO	GROUP A-TC	GROUP A-NTC	GROUP B-TC	GROUP B- NTC	GROUP C- TC	GROUP C- NTC	GROUP D- TC	GROUP D- NTC
1	0.293	0.287	0.265	0.222	0.221	0.201	0.201	0.186
2	0.341	0.263	0.278	0.210	0.230	0.210	0.210	0.175
3	0.332	0.345	0.289	0.213	0.215	0.197	0.207	0.183
4	0.298	0.293	0.254	0.205	0.232	0.200	0.215	0.191
5	0.313	0.581	0.265	0.220	0.228	0.216	0.216	0.173
6	0.543	0.355	0.263	0.240	0.225	0.208	0.207	0.184
7	0.437	0.431	0.254	0.243	0.226	0.203	0.209	0.185
8	0.353	0.263	0.255	0.231	0.219	0.195	0.216	0.185
9	0.383	0.287	0.263	0.233	0.215	0.197	0.224	0.191

10	0.332	0.290	0.231	0.196	0.238	0.204	0.227	0.199
11	0.341	0.287	0.245	0.231	0.240	0.197	0.204	0.182
12	0.293	0.345	0.253	0.224	0.219	0.193	0.215	0.190
13	0.294	0.293	0.249	0.238	0.222	0.210	0.217	0.188

The color difference of 4 different groups before thermal cycling were evaluated and calculated values were listed in table 7:

TABLE 7 :COLOR DIFFERENCE VALUES BEFORE THERMAL CYCLING (DE)

SL NO	GROUP A	GROUP B	GROUP C	GROUP D
1	3,791.14	3,750.23	3,669.08	3,499.41
2	3,817.89	3,743.87	3,672.57	3,504.17
3	3,730.64	3,792.33	3,673.59	3,500.10
4	3,753.78	3,730.85	3,674.06	3,504.40
5	3,806.23	3,750.27	3,669.90	3,497.43
6	3,715.48	3,742.05	3,666.15	3,497.44
7	3,810.52	3,795.98	3,664.99	3,502.95
8	3,815.65	3,733.96	3,676.77	3,499.79
9	3,819.56	3,751.35	3,669.11	3,499.31
10	3,821.27	3,751.95	3,667.94	3,503.46
11	3,790.32	3,751.29	3,669.08	3,499.41
12	3,817.54	3,745.47	3,672.57	3,504.17

13	3,731.49	3,793.40	3,673.59	3,500.10
14	3,791.14	3,731.65	3,674.06	3,504.08
15	3,817.89	3,750.86	3,669.90	3,498.37
16	3,730.64	3,753.58	3,666.02	3,502.74
17	3,753.78	3,750.42	3,665.39	3,501.70
18	3,806.23	3,743.99	3,676.19	3,504.55
19	3,715.48	3,792.26	3,668.89	3,498.24
20	3,810.52	3,730.78	3,668.12	3,496.82
21	3,815.65	3,752.15	3,665.92	3,501.86
22	3,819.56	3,753.77	3,664.75	3,501.76
23	3,821.27	3,736.43	3,677.47	3,499.12
24	3,791.14	3,734.59	3,669.34	3,503.28
25	3,817.89	3,757.75	3,667.25	3,498.37
26	3,730.64	3,758.70	3,669.31	3,499.77

The color differences of eight different sub group after thermal cycling were evaluated and calculated values are listed in table 8:

TABLE 8: COLOR DIFFERENCES VALUES AFTER THERMAL CYCLING (DE)

SL NO	GROUP A-TC	GROUP A-NTC	GROUP B-TC	GROUP B- NTC	GROUP C- TC	GROUP C- NTC	GROUP D- TC	GROUP D- NTC
1	10.03	3.79	37.70	3.75	7.14	3.69	7.49	3.49
2	9.86	3.81	38.01	3.74	7.29	3.67	7.67	3.50
3	10.43	3.73	38.93	3.79	7.26	3.67	7.82	3.50

4	9.97	3.75	36.47	3.73	7.03	3.67	7.66	3.50
5	9.29	3.80	37.64	3.75	7.16	3.66	7.35	3.49
6	11.50	3.75	37.78	3.74	7.12	3.66	7.52	3.49
7	10.31	3.81	40.21	3.79	6.97	3.66	7.37	3.50
8	10.49	3.81	37.77	3.73	7.46	3.67	7.24	3.49
9	6.34	3.81	37.42	3.75	7.12	3.66	7.50	3.49
10	10.63	3.82	37.35	3.75	7.22	3.66	7.60	3.50
11	9.79	3.79	37.86	3.75	7.25	3.66	7.53	3.49
12	9.66	3.87	38.58	3.74	7.32	3.67	7.89	3.50
13	10.54	3.73	39.32	3.79	7.27	3.67	7.85	3.50

The color difference values of eight different sub groups after dipping in coffee for seven days were evaluated and calculated values are listed in table 9:

TABLE 9: COLOR DIFFERENCES AFTER THERMAL CYCLING AND AFTER DIPPING IN COFFEE (DE)

SL NO	GROUP A-TC	GROUP A-NTC	GROUP B-TC	GROUP B- NTC	GROUP C- TC	GROUP C- NTC	GROUP D- TC	GROUP D- NTC
1	91.35	89.71	18.82	18.76	12.51	12.51	9.93	9.97
2	91.35	90.49	18.93	19.00	12.70	12.70	9.95	9.90
3	92.18	90.56	19.14	18.77	12.50	12.50	10.17	10.05
4	91.56	91.56	18.62	18.71	12.23	12.23	10.12	9.59
5	91.90	91.90	18.36	18.96	12.67	12.67	10.09	9.97
6	89.66	89.66	18.96	18.86	12.51	12.70	10.05	9.90
7	91.39	91.39	18.83	18.83	12.70	12.50	9.59	10.05
8	92.28	92.28	18.76	18.82	12.50	12.23	9.97	9.97
9	90.39	91.35	19.00	18.93	12.23	12.67	9.90	10.08
10	90.01	91.35	18.77	19.14	12.67	12.70	10.05	10.01
11	89.71	92.18	18.71	18.62	12.51	12.50	9.97	9.97
12	90.49	91.56	18.96	18.36	12.70	12.23	10.08	9.90
13	90.56	91.90	18.86	18.96	12.50	12.67	10.01	10.05

STATISTICAL ANALYSIS

The analysis was performed by 1- way ANOVA for within group comparison, followed by Tukey test (alpha = 0.05) if statistical significance is found. Independent Samples t-test was used to compare the means for two groups. A paired t test was used to compare the samples at baseline and after testing. Statistical analysis was performed by using SPSS software version 21.

DESCRIPTIVE STATISTICS

The surface roughness of all the group before thermal cycling were compared and the mean and standard deviation of each group were evaluated.

Table 10: Mean values and standard deviation of surface roughness values

	N	Minimum	Maximum	Mean	Std. Deviation
GROUPA	26	.263	.581	.34285	.099330
GROUPB	26	.196	.243	.22062	.014303
GROUPC	26	.195	.216	.20335	.006073
GROUPD	26	.173	.199	.18585	.007075
Valid N (listwise)	26				

RESULT OF ONE WAY ANOVA

Table 11: Results of one way ANOVA for surface roughness						
		Sum of Squares	df	Mean Square	F	Sig.
A	Between Groups	250.722	3	83.574	1388.465	.000
	Within Groups	6.019	100	.060		
	Total	256.741	103			

The surface roughness difference was statistically significant between the groups

Table 12: Multiple Comparisons of surface roughness values between group						
Dependent Variable: baseline Tukey HSD						
(I) VAR	(J) VAR	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group A	Group B	.122231*	.013977	.000	.08571	.15875
	Group C	.139500*	.013977	.000	.10298	.17602
	Group D	.157000*	.013977	.000	.12048	.19352

Group B	Group A	-.122231*	.013977	.000	-.15875	-.08571
	Group C	.017269	.013977	.606	-.01925	.05379
	Group D	.034769	.013977	.068	-.00175	.07129
Group C	Group A	-.139500*	.013977	.000	-.17602	-.10298
	Group B	-.017269	.013977	.606	-.05379	.01925
	Group D	.017500	.013977	.595	-.01902	.05402
Group D	Group A	-.157000*	.013977	.000	-.19352	-.12048
	Group B	-.034769	.013977	.068	-.07129	.00175
	Group C	-.017500	.013977	.595	-.05402	.01902

*. **The mean difference is significant at the 0.05 level**.

Results of the Multiple Comparisons using Tuckey's test showing the difference between the four groups showed that there is statistically significant difference when groups A (non-coated unfilled PMMA) was compared with the other groups. Groups B (coated unfilled PMMA)showed no significant difference with the groups C and D (non-coated and coated microfiller reinforced PMMA respectively). Similarly, group C showed no significant difference with group D.

The mean and standard deviation values after thermal cycling was evaluated and listed in table 13:

Table 13: mean and standard deviation of surface roughness values after thermal cycling

	N	Minimum	Maximum	Mean	Std. Deviation
GROUP A TC	13	.29	.54	.3502	.07096
GROUP A NTC	13	.26	.58	.3323	.08807
GROUP B TC	13	.23	.29	.2588	.01457
GROUP B NTC	13	.20	.24	.2235	.01435
GROUP C TC	13	.22	.24	.2254	.00803
GROUP C NTC	13	.19	.22	.2024	.00691
GROUP D TC	13	.20	.23	.2129	.00753
GROUP D NTC	13	.17	.20	.1855	.00681
Valid N (listwise)	13				

Table 14: Paired Samples Test for surface roughness between each groups

		Paired Differences					T	Df	P value
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	GROUP A TC GROUP A NTC	.01792	.10569	.02931	-.04594	.08179	.611	12	.552
Pair 2	GROUP B TC GROUP B NTC	.03523	.02051	.00569	.02284	.04763	6.193	12	.000
Pair 3	GROUP C TC GROUP C NTC	.02300	.00893	.00248	.01760	.02840	9.281	12	.000
Pair 4	GROUP D TC GROUP D NTC	.02738	.00702	.00195	.02314	.03163	14.068	12	.000

Results showed that there is no statistically significant difference for Group A (non-coated unfilled PMMA) after inter group comparison P=0.552

But, groups B, C, D (coated unfilled PMMA, non-coated microfiller reinforced PMMA and coated microfiller reinforced PMMA respectively) showed significant difference by which surface roughness increased with thermal cycling.

The mean values of DEand its comparison between each group and within groups are listed in table 15

Table 15: Comparison of four different groups

COLOR COORDINATES BEFORE THERMALCYCLING using ANOVA

DeltaE afterTC

	Sum of Squares	Df	Mean Square	F	P value.
Between Groups	8027.046	3	2675.682	172.111	.000
Within Groups	746.223	48	15.546		
Total	8773.268	51			

Results of the One-way ANOVA showing the difference before thermal cycling of the four different groups shows a significant difference with a *p*-value less than 0.05

Multiple comparison of four different groups using Tukey's test listed in table 16:

Table 16: Multiple Comparisons of the four different group

COLOR COORDINATES BEFORE THERMALCYCLING using Tukey's test

Dependent Variable: DeltaEafterTC

Tukey HSD

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P valu e.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group A	Group B	-26.21595*	1.55112	.000	-30.3441	-22.0878
	Group C	4.69495*	1.51866	.017	.6532	8.7367
	Group D	4.31956*	1.51866	.032	.2778	8.3613
Group B	Group A	26.21595*	1.55112	.000	22.0878	30.3441
	Group C	30.91090*	1.57842	.000	26.7101	35.1116
	Group D	30.53551*	1.57842	.000	26.3348	34.7363
Group C	Group A	-4.69495*	1.51866	.017	-8.7367	-.6532
	Group B	-30.91090*	1.57842	.000	-35.1116	-26.7101

	Group D	-.37538	1.54652	.995	-4.4913	3.7405
Group D	Group A	-4.31956*	1.51866	.032	-8.3613	-.2778
	Group B	-30.53551*	1.57842	.000	-34.7363	-26.3348
	Group C	.37538	1.54652	.995	-3.7405	4.4913
*. The mean difference is significant at the 0.05 level.						

Results of the Multiple Comparisons using Tuckey's test showing the difference between the four groups showed that there is statistically significant difference when groups A(non-coated unfilled PMMA) was compared with the other groups. Similarly, groups B (non-coated unfilled PMMA) also showed a significant difference with the other groups. whereas group C (non-coated microfiller reinforced PMMA) showed no significant difference with group D (coated microfiller reinforced PMMA).

Table 17 shows the mean and standard deviation values of DE after thermal cycling and after dipping in coffee of different groups

Table 17: mean and standard deviation of DE after thermal cycling and after dipping in coffee

Groups		Delta E after TC	Coffee
Group A	Mean	11.8957	85.7679
	N	14	14
	Std. Deviation	7.51674	19.28870
Group B	Mean	38.1117	18.8250
	N	12	12

	Std. Deviation	1.00130	.20389
Group C	Mean	7.2008	12.5215
	N	13	13
	Std. Deviation	.12952	.22850
Group D	Mean	7.5762	9.9908
	N	13	13
	Std. Deviation	.19885	.14408
Total	Mean	15.6919	33.0637
	N	52	52
	Std. Deviation	13.11583	33.88722

The comparison of eight different subgroups after thermal cycling are listed in table 18

Table 18: Comparison of the four different group

COLOR COORDINATES after THERMALCYCLING using ANOVA

Coffee

	Sum of Squares	Df	Mean Square	F	P value.
Between Groups	53727.508	3	17909.169	177.684	.000

Within Groups	4838.034	48	100.792		
Total	58565.542	51			

Results of the One-way ANOVA showing the difference after dipping in coffee and thermal cycling of the four different groups shows a significant difference with a *p*-value less than 0.05

Multiple comparison of different groups after thermal cycling and after dipping in coffee are listed in table: 19

Table 19: Multiple Comparisons of the four different group

COLOR COORDINATES after THERMAL CYCLING and coffee

Dependent Variable: coffee

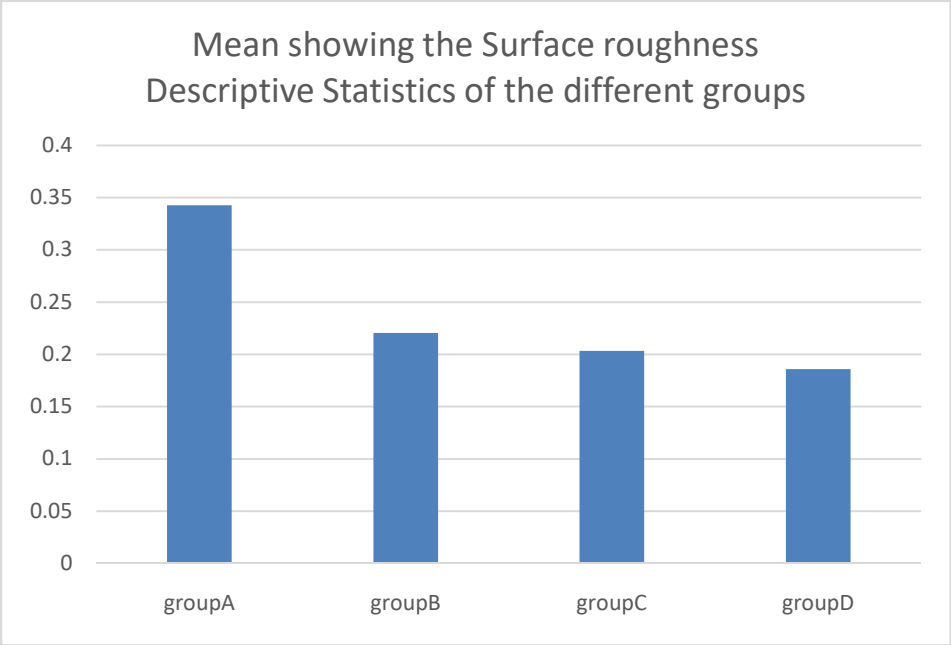
Tukey HSD

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P value.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group A	Group B	66.94286*	3.94953	.000	56.4317	77.4540
	Group C	73.24632*	3.86687	.000	62.9551	83.5375
	Group D	75.77709*	3.86687	.000	65.4859	86.0683
Group B	Group A	-66.94286*	3.94953	.000	-77.4540	-56.4317

	Group C	6.30346	4.01903	.406	-4.3927	16.9996
	Group D	8.83423	4.01903	.138	-1.8619	19.5304
Group C	Group A	-73.24632*	3.86687	.000	-83.5375	-62.9551
	Group B	-6.30346	4.01903	.406	-16.9996	4.3927
	Group D	2.53077	3.93783	.918	-7.9493	13.0108
Group D	Group A	-75.77709*	3.86687	.000	-86.0683	-65.4859
	Group B	-8.83423	4.01903	.138	-19.5304	1.8619
	Group C	-2.53077	3.93783	.918	-13.0108	7.9493
***. The mean difference is significant at the 0.05 level.**						

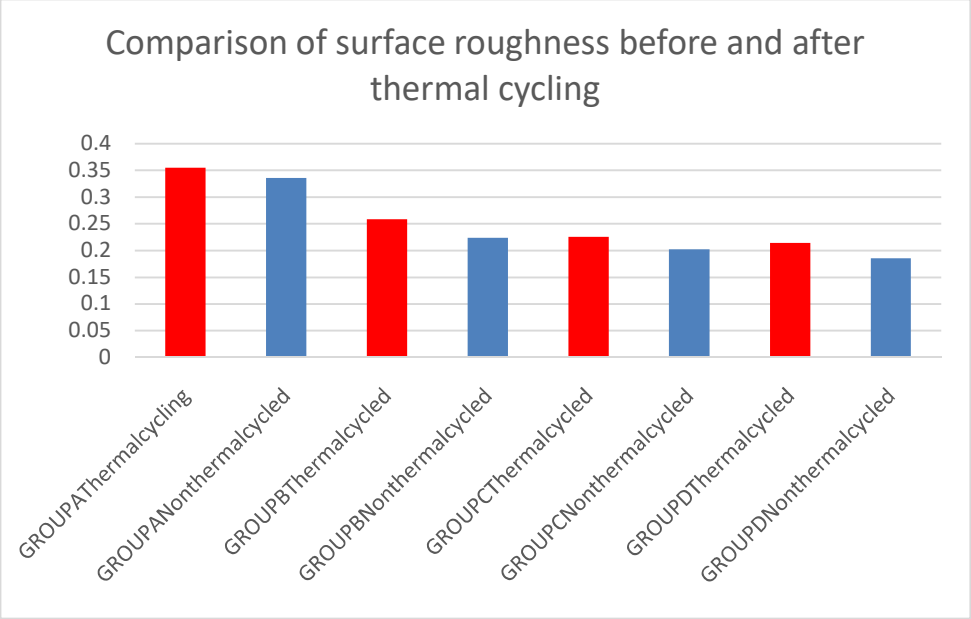
Results of the Multiple Comparisons using Tuckey's test showing the difference between the four groups showed that there is statistically significant difference when groups A (non-coated unfilled PMMA) was compared with the other groups. Groups B (coated unfilled PMMA) also showed no significant difference with the groups C and D (non-coated microfiller reinforced PMMA and coated microfiller reinforced PMMA respectively). Similarly, group C showed no significant difference with group D.

GRAPH 1- MEAN SHOWING THE SURFACE ROUGHNESS- DESCRIPTIVE STATISTICS OF DIFFERENT GROUP



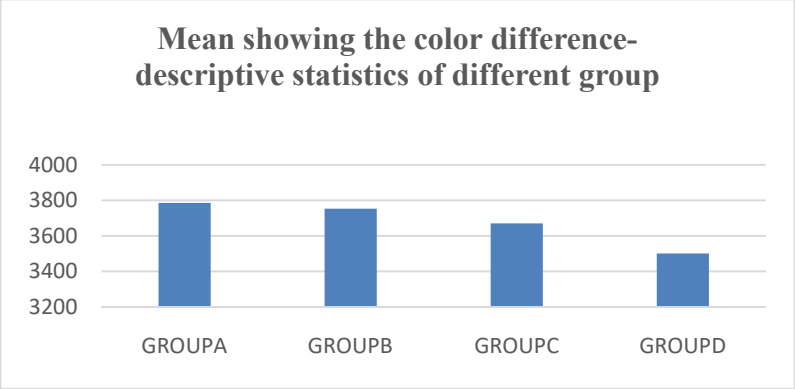
Descriptive statistics of different groups showing the highest surface roughness values in Group A (non-coated unfilled PMMA denture tooth) and the lowest surface roughness values in Group D (coated microfiller reinforced PMMA denture tooth).

GRAPH 2- COMPARISON OF SURFACE ROUGHNESS BEFORE AND AFTER THERMAL CYCLING



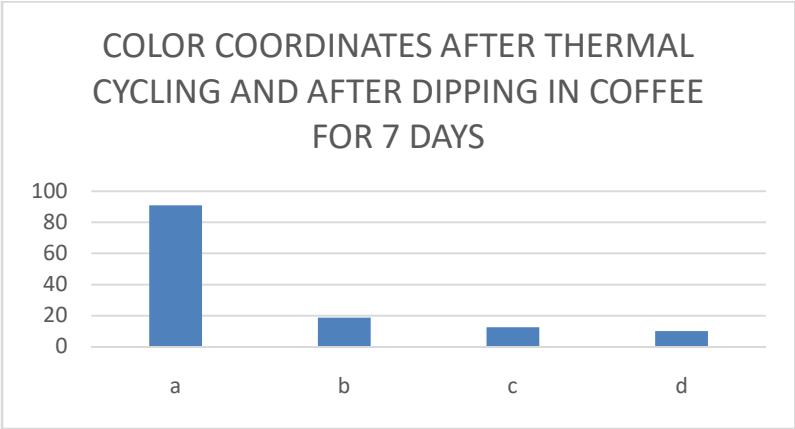
Comparing the surface roughness values before and after thermal cycling shows significant difference within groups. The non-thermal cycled specimens show least surface roughness values.

GRAPH 3: MEAN SHOWING THE COLOR DIFFERENCE- DESCRIPTIVE STATISTICS OF DIFFERENT GROUP



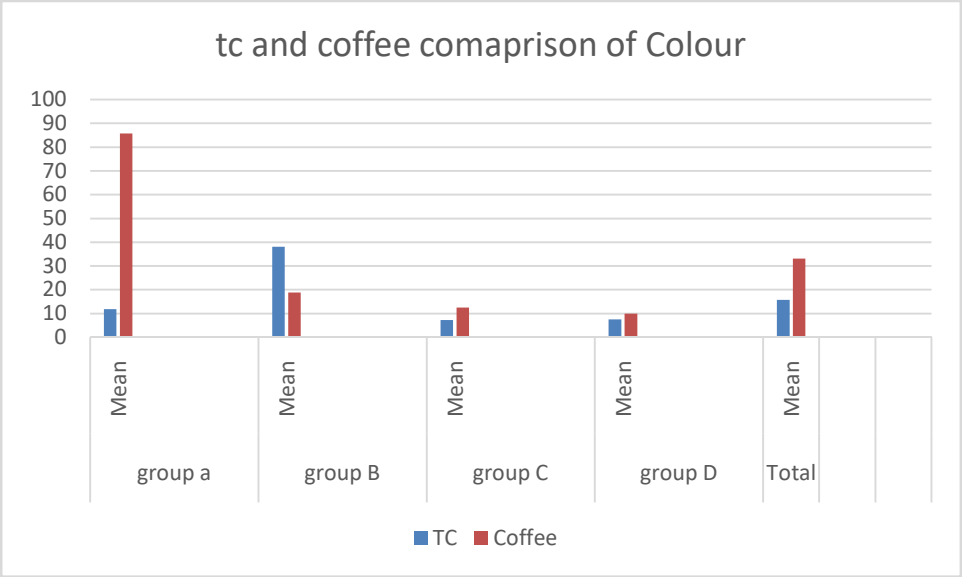
Descriptive statistics of different groups showing the highest color difference values in Group A (non-coated unfilled PMMA denture tooth) and the lowest color difference values in Group D (coated microfiller reinforced PMMA denture tooth).

GRAPH 4: COLOR COORDINATES AFTER THERMAL CYCLING AND AFTER DIPPING IN COFFEE FOR SEVEN DAYS



Mean values of color difference after thermal cycling and after dipping in coffee for seven days' shows highest color difference in Group A (non-coated unfilled PMMA denture tooth) and the lowest values were observed in Group D (coated microfiller reinforced PMMA denture tooth)

GRAPH 5: COMPARISON OF COLOR DIFFERENCE AFTER THERMAL CYCLING AND DIPPING IN COFFEE



Comparison colour difference between each group shows least color difference was given by Group D (coated microfiller reinforced PMMA denture tooth) and highest difference was given by Group A (non-coated unfilled PMMA denture tooth). Irrespective of the group, all group shows an increased color change after thermal cycling as well as after immersion in coffee. In that Group D (coated microfiller reinforced PMMA denture tooth) shows the least color change.

DISCUSSION

DISCUSSION

Edentulism is a debilitating and irreversible condition affecting the oral health. According to GPT-9, edentulism is the state of being edentulous; without natural teeth and edentulous means without teeth or lacking of teeth[2]. Edentulism can lead to functional impairment, physical, psychological, and social disability. It has a direct effect on general health of an individual and has a direct correlation with the socio-economic status of people. Denture wearing continues to increase with the increase in the aging population; most of the edentulous people rely on complete or partial removable denture for replacement of teeth[1].

Rehabilitation of edentulous patients were done either by fixed prosthesis like implant and FPD or by removable partial or complete dentures[1,21]. Dental implants and metal base denture are highly expensive and to some extent patient can't afford the expenses. Such scenario makes the conventional dentures more popular in prosthetic dentistry. Complete denture rehabilitation remains as the acceptable treatment modality for edentulous patient who have systemic, anatomic or financial constraints[1].

Denture esthetics is defined as the effect produced by a dental prosthesis that affect the beauty and attractiveness of the person (GPT 9)[2]. Denture polishing is a mandatory step in the fabrication of a denture[19]. Dentures in the unpolished state causes easy adhesion of plaque and leads to bacterial colonization. Eventually colonization of microbes leads to denture stomatitis. Another problem was accumulation of food debris challenging the hygienic standards of the denture. Heavy deposits cause staining and compromise the esthetics. Polishing is the process of making the denture surface smooth and glossy without causing major changes to the contour[19]. Various polishing protocols are employed to obtain a smooth surface. Laboratory polishing, chair- side polishing and the chemical polishing are the different polishing methods. Normally a denture is delivered from the laboratory in a polished manner. Any denture correction during insertion should need application of a chair-side polishing kit for proper polishing[19]. Armamentarium used for polishing includes[19]:

1. Lab micro-motor with straight handpiece
2. Tungsten carbide acrylic trimmimg burs
3. Dental lathe
4. Cloth or rag wheel
5. Wool buff
6. Stone burs
7. Sand paper
8. Pumice
9. Polishing cake
10. Chair-side polishing kit

The esthetic harmonies which determine the final outcome of a denture include tooth size and form, tooth color, tooth position, and background[9].

Denture tooth play an important role in construction of complete denture and removable partial denture. According to GTP 9, denture tooth is a term commonly referring to an artificial tooth used in the fabrication of a resin base prosthesis[2].

Material used for artificial denture teeth can be classified as:

1. Resin:
    i. Acrylic resin
        a. Monolithic
        b. Cross-linked
        c. IPN linked
    ii. Composite resin
2. Porcelain

Resin and the porcelain are the materials used for fabricating preformed artificial denture teeth. Porcelain teeth are rarely used, only when aesthetics are paramount. As they cannot be trimmed easily, they are used only when adequate interarch space is available[3,20].

The advantages of resin teeth over the porcelain tooth includes easy to grind and adjust, it does not abrade the opposing natural teeth and restorations, it will chemically bond to the denture base since porcelain teeth are mechanically bonded using pins or diatoric holes, soft impact sound, no leakage and a good impact resistance. But the main disadvantages regarding the resin teeth is color instability and also it wears easily with loss of vertical dimension. Due to its advantages and less harmful to the natural teeth and supporting structures, dentist always opted for a resin tooth[3,20].

The majority of resin teeth are made of acrylic resin- PMMA- polymethyl methacrylate. Composite resin tooth is not commonly used due to greater wear than newer acrylics. Main disadvantage of the traditional monolithic acrylic teeth was poor wear resistance. So to improve the properties cross linked and IPN linked acrylic teeth were introduced. These materials have high strength with good wear resistance than porcelain tooth. But the main problem is color stability. These materials stains very easily[3,20].

Due to the staining properties of the denture tooth the denture esthetics will deteriorate when years passed due to the constant contact of the irritant. Here the newer material introduced are microfillers and nanofillers incorporated denture tooth material. This will improve the surface properties of the denture tooth and become more color stable.

The mechanical properties and surface roughness of resin materials depend on the filler particle size, hardness, and percentage content[2,4,9]. Silicon dioxide, glass, and ceramic are the preferred inorganic filler materials. Denture teeth made of a synthetic polymer based on PMMA with a double cross-linked (DCL) polymer and matrix, which reportedly is solvent resistant (SR) and provides shade stability and resistance to mechanical wear[37]. Microfiller reinforced polyacrylic material is comprised of a triple cross-linked PMMA, a cross-linked monomer, and inorganic microparticle filler that are polymerised into a polymer network. It has a homogenous structure that is abrasion and craze resistant with a lifelike surface anatomy[37]. This property gives the superior quality of the denture teeth. So here the

surface roughness and color stability of cross linked PMMA denture tooth and microfiller reinforced PMMA denture tooth were compared.

Koroglu et al evaluated the effects of polishing methods on the surface properties and showed that polishing increased the opening of pores and also increased the surface irregularities in denture tooth[46]. Certain studies showed that polishing of the filler resins and cross linked resin tooth causes the higher fraction of the inorganic components in the surface layer and this causes an increase in the surface roughness and surface free energy[10].

Coating the polished denture tooth surface with a sealant or glaze material improves the surface property[4,75]. Different glaze agents are available in the dentistry field. These are more commonly used in the composite restoration. Sealant coating reduces the surface irregularities and defects and this enhances the surface smoothness. These account for the superiority of the sealant agent in providing improved stain resistance[75]. Based on the content there are different sealant agents. The composition mainly include methacrylate or dimethacrylate containing glaze material, ethoxylatedbisphenol-A dimethacrylate, dipentaerythritolpentaacrylate etc[4,5]. Surface sealants are able to seal the micro-cracks or pores generated during the polishing[4]. So the sealant application provides a more even surface and reduces the surface roughness and surface free energy. To check the efficiency of this sealant application, sealant coated and non-coated acrylic denture teeth were compared.

Doray et al conducted a study on the sealant agents and stated that the methacrylate- or dimethacrylate containing glaze material shows the highest stain resistance[25]. This is mainly due to its content. This is the reason for the selection of methacrylate based light curing sealant in this study.

According to the temperature variations in the food we consumed the oral environment temperature also changes. While measuring the surface properties like surface roughness and stainability, it was necessary to simulate the conditions of the oral

environment. These changes in temperatures affects the surface properties. For simulating the oral condition thermal cycling were done in the study. In this study thermal cycled group and non-thermal cycled group were compared.

The majority of studies reported that temperatures of 5 ◦C and 55 ◦C to test dental materials, considering these values as the closest to the physiology of the oral cavity based on the ISO standard (ISO 11405)[18]. Therefore, in the study 5 ◦C-55 ◦C were used for thermal cycling. Dwell time is the period of time that the specimen is immersed in a bath of a particular temperature to correspond to a latency period. The choice of dwell time showed a great variability in different studies and suggested that the direct contact of a vital tooth with extremely hot or cold substances for extended period of time was not tolerated by patients[21]. Certain studies used 30s as dwell time and this temperature simulates more faithfully the abrupt changes occuring in the oral cavity. The number of cycles used in experimental studies published in the last 15 years, have ranged between 100 cycles and 100.000 cycles[18]. Sahin et al in his study used 3000 cycles which will simulate 3 years of use[4], which was adopted in the present study.

Discoloration of the denture tooth is a complex phenomenon and is mainly associated with several mechanisms including surface roughness, chemical and physical interactions[25,31,36]. Obtaining a precise relationship between surface roughness and staining is not usually possible, but surface roughness has been shown to be the main reason for the absorption of stains[25,31]. Certain studies shows conventional polishing of the denture tooth surface causes increased surface irregularities, since the inorganic filler content get exposed and this contribute to the increase in surface roughness[5]. This inferences supported the study, where the surface roughness was highest in the conventionally polished groups.

Borcher's et.al conducted a similar study and found that unfilled resins tended to decrease surface roughness with the increasing molecular weight of methacrylate components[5]. In another study, although low bacterial adhesion and fluorescence values were found for PMMA resin teeth, the highest surface roughness values and the highest

adhesion of bacteria were observed for filler-supplemented resin teeth[10]. This was mainly due to the polishing effect. Veena Kumari et al also stated in her study that polishing procedure significantly roughen the surface compared to unpolished surface[49]. This substantiates that polishing increases the surface roughness.

Various studies show the effect of sealant application in the surface properties. Dogu Omar et al, in his study stated that the application of the surface sealant decreases the surface irregularities and stainability of nanohybrid composite[45]. Based on the study, Sahin et al also conducted a study on both artificial teeth and denture base resin. In both the cases the sealant application gave a positive result as surface roughness and color changes were reduced[4,55]. Koroglu et al also stated the same in his study using artificial denture teeth[46].

Bacterial adhesion shows a positive correlation with the surface irregularities. Ann Smith et al in her study showed that the surface irregularities cause color changes and thus increases the chance of plaque accumulation. In polished surface colonization process is rapid and in order to achieve a smoother uniform surface, sealant coating application were done which seals the surface[11].

The adsorption and absorption of a colorant into the organic phase of resin materials and the high surface reactivity of poorly polymerized surfaces which causes staining[25,31,36]. In this study, the color changes for specimens treated with conventional polishing technique were higher than the sealant coupling techniques. Reducing surface irregularities and defects and enhancing surface smoothness accounts for the superior quality of sealants in providing improved resistance to stain.

The present study shows that the surface roughness values increases with the increase in surface irregularities. The unfilled PMMA shows the highest surface roughness values and the sealant coated microfiller reinforced PMMA shows the least value. In both types of denture tooth sealant coated group shows the least values than the uncoated one. While evaluating the color stability of each tooth, sealant coated group show the least color change

than the uncoated one. Among the sealant coated group microfiller reinforced group were more color stable.

Various studies evaluated the staining effects of different acrylic tooth. Seema et al conducted a study on the effect of cigarette smoking in the denture teeth and showed that cross linked acrylic teeth resin are more color stable[39]. Mousavi et al in his study concluded that staining was significant for all the commercially available acrylic denture tooth material and Ivoclar showed better colour stability[12]. Raluca et al[13] and Wendy et al[37] supported the same result.

Allam et al, Fabio et al and Sahin et al in their study stated that the sealant agent application made the denture tooth more color stable. This results in reduction of surface irregularities, thus reduced surface roughness and reduced stainability[4,58,60]. Giti et al conducted a study on the denture base resins with application of surface sealant and concluded that surface sealant coated denture base resins shows the least surface roughness and color changes in the group[72].

Thermal cycling caused a drastic change in the surface properties. Thermal cycling increases the surface irregularities and increases the stainability. In the present study thermal cycled group shows highest surface roughness values and the highest color changes. While evaluating the tooth that are subjected to thermal cycling shows more surface roughness irrespective of the coating. Wirley Gonclaves et al investigated the effect of thermal cycling on the color change of acrylic resin denture teeth and found that thermal cycling affects the color stability[14]. Freire et al. found that accelerated ageing will influence the color stability[43]. Sevda et al evaluated the correlation between surface roughness and the thermal cycling and found that thermal cycling causes an increased surface roughness values[15].

The color change of denture tooth specimens was substantially associated with the sealant agent's intrinsic and extrinsic staining factors, whereas conventionally polished specimens were affected by the chemical and physical factors of the denture teeth. The color

change of resin materials after thermal cycling may be associated with the absorption and adsorption of the discolorant. Increasing the hydrophobic content of denture teeth may reduce the susceptibility to water sorption and staining[14,30].

Stainability of the denture teeth were measured, after putting the denture tooth in coffee solution for seven days. Commonly used staining solutions include tea, coffee, coke, turmeric powder and food colours. Most potent staining solution include tea, coffee and coke. Among these three solutions, coffee wasthe most chromogenic agent. This finding was consistent with a study performed by Mutlu-Sagesen et.al[24]. Karin et al, Faribroz et al, Raluca et al and Mei Ting et al also supported the same[31,37,42,57]. In the present study coffee solution were used due to its high staining property. Ehsani et al found in his study that turmeric were the most chromogenic agent[67]. But in the day to day life the consumption of turmeric concentration was very limited and coffee concentration is more. This was the reason why we conducted the study in coffee solution.

Koksal et al found that instant coffee was the most chromogenic agent among the beverages[30]. He used 20gm of Nescafe coffee powder in 1000ml of distilled water. Sahin et al, Omur et al and Giti et al used 7.5gm of Nescafe in 500ml of distilled water for 7 days[4,45,72]. Lee et al stated that minimum of one week was needed to visualize a color change[91]. Moore et al reported that sublingual temperature is routinely used as an indicator of oral temperature for most of the individuals and it measured as 37℃ under specific conditions[16]. Using an incubator 37℃ of the coffee solution was maintained for seven days. Hence, color stability were measured using coffee solution at 37℃ for seven days.

The study concluded that the surface roughness will affect the stainability of the denture tooth. The conventionally polished unfilled PMMA denture tooth shows the highest surface roughness and color difference values between the coated and uncoated group. Coated microfilled PMMA tooth shows superior properties. Color difference are above the threshold level but are clinically acceptable. Surface sealant agent coating will be more beneficial for achieving an even more color stable denture tooth as well as denture resin

surface.Staining shows much less effect on surface roughness. So, in this study surface roughness was not evaluated after staining. Karin et al in his study found that roughness of the denture tooth was not affected by the long term immersion in the beverages[47].

According to this study, surface sealant coated non-thermal cycled denture tooth showed the least surface roughness and color stainability values. The difference in surface roughness and colour stability were more statistically significant with P-value < 0.05. Thus microfiller reinforced PMMA denture tooth with surface sealant coating will improve the surface properties and colour stability.

CONCLUSION

CONCLUSION

Within the limitations of the study, the following conclusions are drawn:

1. The type of denture tooth material, surface treatment technique and the thermal cycling were significant for both surface roughness and color stability.
2. The use of surface sealant agents decreased the surface roughness and increased the color stability than for the teeth in the conventionally polished groups.
3. Conventionally polished teeth showed the highest color changes, which were clinically unacceptable.
4. Unfilled PMMA teeth shows the highest surface roughness as well as the highest color change.
5. Surface sealant coated microfiller reinforced PMMA shows the least surface roughness as well as the least color change.
6. Thermal cycling increases the surface roughness and color stainability irrespective of the denture tooth type and the sealant application

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ANNEXURES

ST. GREGORIOS DENTAL COLLEGE

UNDER THE MANAGEMENT OF MJSCE TRUST, PUTHENCRUZ

CHELAD , KOTHAMANGALAM, ERNAKULAM DIST, KERALA - 686681

SGDC/152/2021/4013 17/02/2021

ETHICAL CLEARANCE CERTIFICATE

To,

Dr. Arya Aravind
St. Gregorios Dental College
Chelad, Kothamangalam

Dear Dr. Arya Aravind

Subject: Ethics Committee Clearance-reg

Protocol: The effect of surface sealant application on the surface roughness and color stability of acrylic denture tooth after thermal cycling -An in-vitro study.

At the Institutional Ethics Committee (IEC) held on 15th of January 2021, this study was examined and discussed. After consideration, the committee has decided to approve and grant clearance for the aforementioned study.

The members who attended the meeting at which the protocol was discussed were:

1) Dr .C.K.K Nair - Former BARC Scientist
2) Dr.Cinu Thomas A - Scientist, Vice Principal, Caritas College of Pharmacy.
3) Dr. Lissy Jose – Former member of Women's welfare Association.
4) Adv. Jose Aranjani – Advocate.
5) Dr. Sauganth Paul – Reader, Department of Biochemistry, St. Gregorios Dental College.
6) Dr. Eapen Cherian – Secretary, Professor, St. Gregorios Dental College
7) Dr. Jain Mathew – Principal and Head of the Department, Department of Conservative Dentistry and Endodontics.
8) Dr. George Francis – Head of the Department, Department of Prosthodontics and Crown and Bridge.
9) Dr. Binoy Kurian – Head of the Department, Department of Orthodontics and Dentofacial Orthopaedics.

Dr. C.K.K Nair
Chairman Institutional Ethics Committee
St Gregorios Dental College, Chelad

St. Gregorios Dental College Chelad - 686 681

Dr. Eapen Cherian
Secretary

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LIST OF ABBREVIATIONS USED

PMMA	Polymethylmethacrylate
UV	Ultraviolet
Ra	Surface roughness
DE	Delta E- color difference
µm	Micrometer
GPT	Glossary of Prosthodontic terms
℃	Degree Celsius
NTC	Non-thermal cycled
TC	Thermal cycled
Gm	Gram
mL	Millilitre
s	Seconds
P-value	Probability value