COMPARISON OF SHEAR BOND STRENGTH OF ORTHODONTIC BRACKETS ON MAXILLARY TEETH USING SINGLE TIPPED LED CURING UNIT AND CLUSTER LED UNIT - AN *IN VITRO* STUDY.

By

Dr. APARNA ANAND

Dissertation submitted to the

Kerala University of Health Sciences, Thrissur

In partial fulfillment of the requirements of the degree of

MASTER OF DENTAL SURGERY

in

ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

Under the guidance of

Dr. BINNOY KURIAN

Professor & HOD

Department of Orthodontics & Dentofacial Orthopaedics

St. Gregorios Dental College,

Kothamangalam,

2018-2021

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation/thesis entitled "***Comparison of shear bond strength of orthodontic brackets on maxillary teeth using single tipped LED curing unit and cluster LED unit - an in vitro study.***" is a bonafide and genuine research work carried out by me under the guidance of ***Dr. Binnoy Kurian***, Professor & HOD, Department of Orthodontics& Dentofacial Orthopaedics, St. Gregorios dental college, Chelad, Kothamangalam.

Date: **Dr. APARNA ANAND**

Place: Kothamangalam

CERTIFICATE BY THE GUIDE

This is to certify that the dissertation entitled *"**Comparison of shear bond strength of orthodontic brackets on maxillary teeth using single tipped LED curing unit and cluster LED unit - an in vitro study.**"* is a bonafide research work done by ***Dr.Aparna Anand***, in partial fulfilment of the requirement for the Degree of ***Master of Dental Surgery.***

Dr. BINNOY KURIAN
Professor & HOD
Department of Orthodontics
St. Gregorios Dental College

Date:
Place: Kothamangalam

ENDORSEMENT BY THE HOD, PRINCIPAL/HEAD OF THE INSTITUTION

This is to certify that the dissertation entitled ***"Comparison of shear bond strength of orthodontic brackets on maxillary teeth using single tipped LED curing unit and cluster LED unit - an in vitro study."*** is a bonafide research work done by ***Dr.Aparna Anand*** under the guidance of **Dr. *Binnoy Kurian***, Professor & HOD, Department of Orthodontics & Dentofacial Orthopaedics.

Dr. BINNOY KURIAN	**Prof. Dr. JAIN MATHEW**
Professor & HOD	Principal
Date:	Date:
Place: Kothamangalam	Place: Kothamangalam

COPY RIGHT

DECLARATION BY THE CANDIDATE

Date: **Dr. APARNA ANAND**

Place: Kothamangalam

ABSTRACT

Background and Objectives: Bracket bonding is an elementary but time consuming orthodontic procedure. In a busy practice it becomes tiring for a clinician to bond every single tooth individually. Often, patients also get exhausted. Reduction in bonding time can overcome these issues to a considerable extend. Curing multiple teeth simultaneously without compromising the bond strength can be a major step forward. The objective of this study was to evaluate if the shear bond strength of multiple brackets, cured with a cluster LED unit is comparable to those cured with a standard single tip LED curing unit.

Methods: Human maxillary incisors, canines, premolars and molars (45 each) were collected and sorted into two experimental groups and a control group. Control group samples were cured with a standard, single tip LED light curing unit for 15 seconds. Samples of experimental groups were cured with cluster LED unit for 15 seconds and 30 seconds respectively. Each main group was then subdivided in to four subgroups based on the teeth type, with a sample size(n) of 15 each. After bonding the teeth were stored in distilled water at 37 °C for 24 hours before the bond test. The mechanical testing for bond strength was performed using a universal testing machine, after which the specimens were visually examined with a stereomicroscope at 10x magnification to assess the adhesive remnant index and fracture pattern.

Results: Brackets cured with cluster LED unit for 30 seconds had comparable bond strength with those brackets cured with standard single tip curing unit for 15 seconds. Although the samples cured with cluster LED unit for 15 seconds showed statistically significant reduction in bond strength compared to the other two groups, they satisfied the optimum bond strength range.

Interpretation and Conclusion: The cluster LED unit reduced the bonding time by curing orthodontic brackets on multiple teeth simultaneously and attained a shear bond strength above the optimal bond strength range. With increased curing time of 30 seconds, the bond strength of brackets cured with cluster LED unit was comparable to that of those cured with standard single tip LED light curing unit. Hence cluster LED unit can be considered as a useful adjunct for bracket bonding.

Key words: Light Emitting Diode, Light curing unit, Bracket bonding.

TABLE OF CONTENTS

Sl. No	Title	Page No.
1	Abstract	VI
2	List of tables	VII-X
3	List of figures	XI-XII
4	List of graphs	XIII
5	Introduction	1-6
6	Objectives	7-8
7	Background & Review of Literature	9-33
8	Relevance	34-35
9	Methodology	36-56
10	Results	57-74
11	Discussion	75-83
12	Conclusion	84-85
13	References	86-100
14	Annexures	101-110

LIST OF TABLES

Sl. No	Tables	Page No.
1	Table 1: Classification of light-curing units	4
2	Table 2: Light intensity and wave lengths of curing units	39
3	Table3: Control group samples	40
4	Table 4: Experimental group 1 samples	40
5	Table 5: Experiment group 2 sample	40
6	Table 6: The mean shear bond strength of 15 samples of incisors, canine, premolar and molar in the control group	58
7	Table 7: The mean shear bond strength of 15 samples of incisors, canine, premolar and molar in the Experimental group l	58
8	Table 8: The mean shear bond strength of 15 samples of incisors, canine, premolar and molar in the Experimental group 2	59
9	Table 9: Frequency distribution of Adhesive remnant index	59,60
10	Table 10: comparison of mean shear bond strength of incisors, canine, premolar and molar in the control group	61
11	Table 11: Post hoc test tukey's HSD – comparison of mean shear bond strength of incisors, canine, premolar and molar in the control group	61
12	Table 12: comparison of mean shear bond strength of incisors, canine, premolar and molar in the experimental group 1	62

13	Table 13: Post hoc test tukey’s HSD – comparison of mean shear bond strength of incisors, canine, premolar and molar in the experimental group 1	62
14	Table 14: comparison of mean shear bond strength of incisors, canine, premolar and molar in the experimental group 2	63
15	Table 15: Post hoc test tukey’s HSD – comparison of mean shear bond strength of incisors, canine, premolar and molar in the experimental group 2	63
16	Table 16: Comparison between the incisor teeth of all the three groups	64
17	Table 17: Post hoc test tukey’s hsd – comparison between the incisor teeth of all the three groups	64
18	Table18: Ccomparison between the canine teeth of all the three groups	64
19	Table 19: Post hoc test tukey’s hsd – comparison between the canine teeth of all thethree groups	65
20	Table 20: Comparison between the premolar teeth of all the three groups	65
21	Table 21: Post hoc test tukey’s hsd – comparison between the premolar teeth of all the groups	65
22	Table 22: Comparison between the molar teeth of all the three groups	65
23	Table 23: Post hoc test tukey’s hsd – comparison between the molar teeth of all the three groups	66

24	Table 24: Comparison between control and experimental group 1	66
25	Table 25: Comparison between control and experimental group 1	67
26	Table 26: Comparison Between Experimental Group 1and Experimental Group 2	68

LIST OF FIGURES

Sl. No	Figures	Page No.
Fig 1	Performing ultrasonic scaling of collected teeth sample	44
Fig 2	Making of tooth embedded acrylic blocks	44
Fig 3	Jig for placing the control group in an arch form	44
Fig 4	Control group samples mounted in acrylic blocks	45
Fig 5	Control group samples set in arch form	45
Fig 6	Samples (control group) fixed on to phantom head	45
Fig 7a	Bonding materials- Etchant, Bonding agent, Brush for applying the bonding agent and Composite	46
Fig 7b	Bonding instruments- Mouth mirror, tweezer, bracket positioner, bracket gauge, probe	46
Fig 8	Blue phase LED unit for curing control group samples	47
Fig 9	Checking the light intensity	47
Fig 10	Steps in bonding: a)Etching b)Rinsing c)Applying bonding agent d)Light curing of bonding agent e)bracket positioning d)light curing of bracket	48
Fig 11	Sinsational smile bleaching unit for curing the experimental group	49
Fig 12	Photometer to check the intensity of cluster LED curing unit	49
Fig 13	Experimental group sample set in arch form	50
Fig 14	Etching of experimental group	50

Fig 15	Rinsing of etchant	50
Fig 16	Curing after application of bonding agent	50
Fig 17	Light curing the metallic brackets	50
Fig 18	Control group after bonding(a)incisors (b)canines (c)premolars (d)molars	51
Fig 19	Experimental group 1 after bonding(a)incisors (b)canines (c)premolars (d)molars	51
Fig 20	Experimental group 2 after bonding(a)incisors (b)canines (c)premolars (d)molars	52
Fig 21	Universal testing machine for testing shear bond strength	52
Fig 22	Testing of shear bond strength	52
Fig 23	Optical stereomicroscope	53
Fig 24	Visualizing the Adhesive Remanants using Optical stereomicroscope	53
Fig 25	Adhesive remnants on tooth surface viewed at 10x magnification using an optical stereomicroscope control group(a)incisors (b)canines (c)premolars (d)molars	54
Fig 26	Adhesive remnants on tooth surface viewed at 10x magnification using an optical stereomicroscope experimental group1(a)incisors (b)canines (c)premolars (d)molars	55
Fig 27	Adhesive remnants on tooth surface viewed at 10x magnification using an optical stereomicroscope experimental group2(a)incisors (b)canines (c)premolars (d)molars	56

LIST OF GRAPHS

Sl. No	Graphs	Page No.
1	Graph 1: Comparison between the control group, experimental group 1 and experimental group 2	70
2	Graph 2: Comparison between the sub groups of control group	71
3	Graph 3: Comparison between the sub groups of Experimental group 1	72
4	Graph 4: Comparison between the sub groups of Experimental group 2	73
5	Graph 5 :Comparison of ARI scores	74

Introduction

INTRODUCTION

In the last century, Orthodontics have evolved into a unique speciality in dentistry. Scientists have been coming up with newer techniques and innovations that can make the chair-side time shorter and interesting to the practitioner and the patient as well.

From the very inception of fixed-appliance orthodontic treatment, brackets were welded either to gold or stainless-steel bands. The band encompasses the tooth all around and requires the creation of interproximal space so as to accommodate the band material. To achieve separation between teeth, wires and elastomerics were used which was time-consuming for the orthodontist and uncomfortable for the patient. These interproximal gaps had to be addressed at the conclusion of the treatment. In addition, banded appliances frequently caused gingival irritation and trauma. Decalcification under the bands sometimes occurred during the treatment course. Therefore, eliminating the need for bands and to attach the brackets directly to tooth enamel was an obvious solution to these problems.[1]

An Orthodontist, Dr George Newman, in Orange, New Jersey and Professor Fujio Miura, chair of the Department of Orthodontics at Tokyo Medical and Dental University in Japan, were the pioneers in bonding of orthodontic brackets to the enamel.[1]

Self-curing adhesives were first introduced for bonding brackets on the tooth surface. They had limitations, such as discoloration, longer working time and increased hardness and wear resistance of superficial layer. To overcome these limitations, light-activated composite resin was introduced in 1960s.[2]

These resins contain a photosensitizer, Camphor quinone [CQ] which can absorb blue light with wavelengths between 400 and 500 nm. These resin system utilizes light energy to initiate free radicals; thus, the development of the first curing light happened with the introduction of light-curing resin.

By 1970s, the first dental curing- light the Nuva Light (Dentsply/Caulk) was developed, that used ultraviolet light to cure the material. Ultraviolet (UV) light used in the system was later discontinued because of its drawbacks. Furthermore, due to their shorter wavelengths, the depth of cure was limited. It was found that these lights were not very effective.[2]

By early 1980s advances in the area of visible light curing took place. Few years after the introduction of UV radiation for curing the dental restoratives, the facility of using the visible light was introduced. February 24, 1976, on that day, Dr.Mohammed Bassoiuny of Turner School of Dentistry, Manchester, did the first restoration with visible light-cured composite on Dr. John Yearn, the then head of department. This led to the development of a curing device that uses blue light. The next type of curing light that developed was the quartz-halogen bulb and it had longer wavelengths of the visible light spectrum that permitted greater penetration of curing light and light energy. The halogen curing light thus replaced the Ultra violet-curing light.[3]

The 1990s presented great improvements in light-curing equipment. Previous devices were improved and new devices developed. The focus was mainly to improve the intensity so as to cure faster and deeper. Around 1998, the plasma arc curing light was introduced, which had a high intensity light source, and a fluorescent bulb containing plasma, to cure the composite. It claimed to cure the material in 3 seconds. Yet, on an average, it took between 3seconds to 5 seconds.[4]

Light Emitting Diodes or LEDs were introduced by Mills in 1995.[5] Junctions of doped semiconductors were used to generate visible light with no requirement for light filtration. LEDs produce light within a narrow spectral range and are highly efficient light sources. Blue LED curing unit is inexpensive compared to halogen light-curing unit. The LED unit has neither any bulb nor any filter that requires maintenance. They do not require any filters because they emit light at a particular wavelength within 400–500 nm. Over time, only little degradation of light output was observed and they do not produce any heat. This was another benefit that prevented any potential gingival irritation or damage to the pulp. Its light performance degrades with time. LED curing lights are very popular among pedodontists, since less chair side time and adequate polymerization is the main aim . It has been suggested that even though the strength is inadequate, by far, it is the most reliable.[5]

Classification of light curing units

1st Generation	Ultraviolet light
2nd Generation	Visible light-curing units
3rd Generation	Plasma arc units
4th Generation	Light-emitting diodes (LEDs)
5th Generation	Lasers.

Table 1: The light-curing units are classified into the following five generations

Clinical efficiency of a light-curing unit is crucial for obtaining the optimal polymerization and a successful outcome.[6]

The main factors related to light curing that can influence the polymerization process and the strength of the material includes the intensity of the light and the curing time.[7-11]

Intensity of light

Lambert's Law–When a light beam reaches on any orthodontic adhesive surface, the penetration of light into the comparatively thin layer of material depends on many factors related to the light beam itself, the application mode, and the material properties. First, the distance of the light source from the surface and the path the incident beam that travels to reach the adhesive has a large effect on the intensity of incident light. The well-cited Lambert Law in this field describes the relation between the intensity of light and distance as:

$I = Io\ e{-}\ yd$

Where I is the light intensity at distance d, Io the intensity departing from the source, and y the absorption coefficient of the medium.

Curing time

With increase in curing time, bond strength also increases.

Depth of curing depends on the intensity of light. The light-curing unit should be able to cure the composite to the optimum bond strength. All curing lights generate heat and hence require a cooling fan. The average life of a halogen unit is restricted to 100 hours because of its heat emitting properties. [12] On the contrary minimum heat is generated by LED units.[11] Halogen lights do significantly increase the pulpal temperature compared to other light cure units. LED uses minimal energy and produces less heat, so they are marketed as cordless units with a rechargeable battery without light filaments and other cooling accessories, hence they better resist vibrations and shock. Therefore, they have a life time of more than 10,000 hours.[5,13]

Bonding of orthodontic brackets is one of the most time consuming and tedious procedure in orthodontics. Reducing the bonding time without affecting the bond strength would increase operator efficiency and patient comfort. Literature comprises so many studies conducted on the reduction of curing time, using high intensity (around 3000mW/cm^2) curing units. Perhaps a second thought should always be given to the use of high intensity light sources, as it is exposed on to living tissues. So, the prime objective should be to reduce the curing time without causing any harm to the pulpal tissue.

Marquezan conducted a study using a LED cluster unit to cure multiple teeth at single shot on bovine incisors.[14] This method of curing many teeth simultaneously using a light curing unit that does not endanger the health of pulpal tissue can be considered as an alternative and convenient method to reduce the curing time.

To achieve an adequate bond strength of 5.8–7.8 MPa as reported by Reynolds,[15] the intensity of light according to Rueggeberg should be at least 400 mW/cm^2, for an exposure time of 60 seconds.[16]

The literature supports the polymerization of orthodontic composites using Light Emitting Diode curing lights [17-20]

The advent of light-catalyzed vital dental bleaching has provided a cross-over tool which may improve the ergonomics of orthodontic appliance bonding by facilitating the simultaneous curing over an entire arch. Yoav Shapinko conducted a study in 2018 to evaluate the bond strength of orthodontic brackets cured using a bleaching unit.[21]

Most of the studies to test the shear bond strength of the teeth were either conducted on bovine teeth or on human premolars[22,23]. R.S.Hobson et al analysed the bond strength to surface enamel for different tooth types and concluded that there exists significant differences in bond strength between various tooth types. Ideally equal number of different tooth types should be included in test groups to achieve stratification.[24]

No study was found in the scientific literature that used a bleaching unit with cluster of LED units to cure four types of extracted human teeth, that is the incisor, canine, premolar and molar simultaneously.

This study was performed to compare the shear bond strength orthodontic brackets cured with the cluster LED unit with those brackets cured with a standard LED curing unit.

Objectives

AIM AND OBJECTIVES

Aim

To compare the shear bond strength of orthodontic brackets on extracted human maxillary incisor, canine, premolar and molar teeth, cured with a single tip LED curing unit and cluster LED unit.

Objectives

1. To compare the shear bond strength of orthodontic brackets on extracted human teeth, cured with a single tip LED curing unit and cluster LED unit.

2. To compare adhesive remnant index after the orthodontic brackets are debonded.

3. To compare the effect of difference in curing time between single tip LED curing unit and two different time settings of cluster LED curing uni

Background &
Review of literature

BACKGROUND OF THE STUDY

Bracket bonding is the first and foremost step during fixed appliance treatment. Light cured composites can be used for attaching the brackets on to the teeth. Various generations of light cure units were introduced in the market and LED light cure units are now well accepted by the clinicians and have a cost advantage over conventional halogen lights.

Bonding is one of the most time-consuming procedures in orthodontics. Reducing the time required for the same would make both the operator and the patient comfortable. Many studies have been conducted using high intensity curing units, around 3000mW/cm^2 with short curing time to reduce the total curing time, but using curing units of high intensity is always a point of concern as it may harm the pulpal tissue. Another safer possibility for reducing the curing time is to cure multiple teeth simultaneously.

REVIEW OF LITERATURE

Michael G. Buonocore (1955)[25] developed a simple method to increase the adhesion of acrylic filling materials to the enamel surfaces. A phosphoric acid and a phosphomolybdate oxalic acid treatment have been employed so as to alter the enamel surfaces chemically. The phosphoric acid treatment gave better results and is simpler to use.

Mills et al (1995)[26] proposed solid-state LED technology to polymerize the light-initiated resins to overcome the shortcomings of conventional halogen lights. Light-emitting diodes use junctions of doped semiconductors to generate light. They have a lifetime more than 10,000 hours and undergo little degradation of output over this time. Light-emitting diodes require no filters to produce blue light, resist the shock and vibration, and take little power to operate.

S E Bishara et al (1999)[27] conducted a study to evaluate the shear bond strengths of orthodontic brackets bonded with one of the three methods: a glass ionomer adhesive used with 20% polyacrylic acid enamel conditioner; a composite resin adhesive with 37% phosphoric acid etchant and a conventional primer; or the same composite resin and an acidic primer that combines the etchant with the primer in application. The brackets were bonded to the teeth according to one of the above mentioned three protocols. The results showed that the resin/phosphoric acid adhesive system (control group) had the strongest shear bond strength .The glass ionomer adhesive system showed a significantly lower bond strength .The least shear bond strength was observed when the acidic primer was used with an orthodontic adhesive.

M F Sfondrini et al(2001)[28] conducted a study in order to evaluate the shear bond strengths of a composite resin and a resin-modified glass ionomer cured with two different light-curing units: a conventional, visible light cure unit and a xenon arc light unit (Plasma Arc Curing [PAC] System; Two groups (1 group for each type of adhesive) were then exposed to the visible light for 20 seconds and 40 seconds, respectively and were used as the control groups. Rest of the 6 groups (3 for each adhesive) were cured with the xenon arc light for 2, 5, and 10 seconds. The findings of the study indicated that, compared to visible light-curing, the xenon arc light enables the clinician to reduce the curing time of both the bonding agents, without affecting their shear bond strengths. Therefore, xenon arc light sources can be recommended as an advantageous adjunct for curing both composite resins and resin-modified glass ionomers.

Larry J Oesterle(2002)[29] conducted a study on light curing of composite resin material underneath the brackets. Shear/peel bond strength of orthodontic brackets bonded to bovine enamel and cured using a pulsed xenon plasma arc light was compared with that of bonds cured using a conventional tungsten-quartz-halogen light and a non pulsed xenon plasma arc light. The pulsed light provided a reduced amount of light energy than that of the non pulsed lights. A small and a larger light-guide tip were used along with the pulsed xenon plasma arc light. 3 different orthodontic composite resin adhesives were verified with each light. The pulsed xenon plasma arc light resulted in either the same or reduced shear/peel bond strength when compared with that of the non pulsed lights. There seemed to be no advantage to the use of a pulsed xenon plasma arc light in bonding orthodontic brackets. Results from using either a small or a large light-guide tip changed with the adhesive that was tested.

Samir E Bishara (2003)[30] conducted a study to evaluate the effect of using a new light-curing device that uses a light-emitting diode on the shear bond strength of an orthodontic adhesive. The new light-curing device used in the study was UltraLume 2 that has an 8-mm footprint which can simultaneously cure two orthodontic brackets. The teeth were casually divided into two groups according to the curing light used. Findings of the study designated that no significant differences in the shear bond strength between the Ortholux halogen light and the UltraLume 2 LED light. So the study concluded that, the advantages of the new unit comprise the capability to cure two brackets at a time and a lesser light-emitting apparatus for the clinician to handle.

Meyer GR et al (2003)[31] analyzed the reduction in power output of a new light emitting diode curing devices with increasing distance to the filling surface and concluded that LED lights showed significant reduction in power output at 10mm from light tip compared with QTH units.

Danilo Biazzetto et al (2003)[32] in an invitro study evaluated the effect of curing tip distance on the Knoop Hardness Number (KHN) of a resin composite when using 3 different light curing devices: (1) halogen light, (2) a "softstart-polymerization" and (3) a PAC . The resin composite, Filtek Z250 (3M), was cured by these curing devices at three light-tip distances from the resin composite: 0 mm, 6 mm and 12 mm respectively. The outcomes showed that for the Elipar Trilight unit, the hardness of the resin composite reduced as the light tip distance was increased. The XL 1500 unit showed a significant decrease in hardness as the depth of cure of the resin composite increased and Apolo 95E produced a decrease in the resin composite hardness values when the depth of cure and light tip distance was increased.

Seema K Sharma et al, (2003)[33] conducted a study to assess the effect of bracket base design on the mean shear bond strength 1 hour or 24 hours after bonding. Results showed that, Orthodontic bracket base design significantly affected mean shear bond strength. Speed (60-gauge, micro etched foil-mesh base) had the maximum bond strength at 1 hour; followed by Time (machined, integral, micro etched base with mechanical undercuts; American Orthodontics,); American Master Series (80-gauge foil-mesh base; American Orthodontics); Ovation Roth (80-gauge layered onto 150-gauge, micro etched foil-mesh base; GAC); Orthos Optimesh XRT (100-gauge micro etched foil-mesh base; Ormco); and, lastly, the nickel-free brackets (injection molded, 100-gauge, micro etched, foil-mesh base).

Timothy Swanson (2004)[34] conducted a study so as to analyse the relationship between the shear bond strength of brackets bonded to enamel and the period of photopolymerization with LEDs and conventional quartz-tungsten-halogen light-curing units. 3 LED light units (GC e-light, GC America, Alsip, Ill; Elipar FreeLight, 3M ESPE Dental Products, St Paul, Minn; and UltraLume LED 2, Ultradent Products, South Jordan, Utah) and 1 halogen-based light-curing unit (Ortholux XT, 3M Unitek, Monrovia,) were assessed in the study. Samples were sorted into 12 groups of 20 teeth each. Each group was cured using different light-curing unit for 40, 20, or 10 seconds. All experimental groups had laboratory mean shear bond strengths more than 8 MPa, even with a 10-second cure.

Nanako Oyama(2004)[35] evaluated the light intensity of different light curing units, the effect of distance of the light guide, and the rationality of a tapered light guide. Light curing units tested comprised (1) four blue light-emitting diode curing units, Lux-O-Max, LEDemetronl, Ortholux LED, and The Cure; (2) two tungsten-quartz halogen curing units, Optilux 501 and Co-bee; and (3) one plasma arc curing unit, Apollo95E. The Optilux 501 was also assessed for combinations of usual mode and boost mode and Standard tip and Turbo tip light guide. The peak value of Ortholux LED and The Cure exceeded that of Apollo95E. The light intensity significantly reduced with distance. Although The Cure presented a higher light intensity than the LEDemetron1 at zero-mm distance, the light intensity of the LEDemetron1 was more than that of The Cure at five to 20 mm, resulting in no significant difference. The boost mode improved light intensity at any distance. Although the Turbo tip boosted light intensity at zero-mm distance, decrease of light intensity by Turbo tip was demonstrated at five- to 20-mm distance.

Cornelis Johannes Kleverlaan et al (2004)[36] assessed the curing efficiency and heat production of two high-intensity halogen lamps, the Astralis 10 HIP (1100 mW cm(-2)), and Optilux 501 Boost (1000 mW cm(-2)) in curing of three resin composites (InTen-S, Tetric Ceram, and Filtek Z250). It was expected that the two lamps, having comparable irradiance would give rise to the same curing effectiveness and heat production. The curing efficiency was assessed by Vickers hardness and depth of cure measurements. No significant differences were noted in curing effectiveness between the two lamps for the three resin composites. The temperature increase in the composites during curing was between 11.2 degrees C and 16.2 degrees C. At succeeding irradiation, after the composites had been cured, the temperature rise was between 8.2 degrees C and 12.1 degrees C. The Optilux 501 generated, in all cases, a lesser amount of heat than the Astralis 10. This was not expected based on the irradiance, but can be accounted for by the differing spectra.

A Mavropoulos ,(2005)[37] conducted an in vitro study to establish the lowest essential curing time to bond stainless steel brackets using new, intensive, light-emitting diode (LED) curing units. A standard light curing adhesive was used to attach the stainless steel brackets using different lamps and curing times. Two groups were bonded with an intensive LED curing lamp for 5 and 10 seconds. Two more groups were bonded with another intensive LED curing device also for 5 and 10 seconds. Lastly, a high-output halogen lamp was used for 40 seconds to bond the final group, which served as a positive control. The Shear bond strength values attained were significantly different between groups . When used for 10 seconds, the intensive LED curing units attained adequate shear bond strength, comparable with that of the control. In contrast, 5 seconds resulted in significantly inferior SBS. The adhesive remnant index (ARI) wasn't significantly affected. A curing time of 10 seconds was noted` to be sufficient to bond metallic brackets to incisors with intensive LED curing units. These new, comparatively inexpensive, curing lamps appear to be an advantageous substitute to the conventional halogen lamps for bonding orthodontic metal brackets.

Teresa Silta,(2005)[38] evaluated the capability of the newest generation of quartz tungsten halogen and LED light-curing units to bond orthodontic brackets to teeth at reduced polymerization times. Two LED light curing units (Ortholux LED; UltraLume LED 5,) and a QTH LCU (Optilux 501) were assessed. The specimens were separated into 9 groups (3 lights and 3 curing times) of 20 teeth each. Each group was cured with one of the 3 lights for 20, 10, or 6 seconds. Thirty minutes after polymerization, the samples were taken for shear force on an instron machine until bracket failure. The maximum bond strengths were obtained with the Optilux 501 QTH LCU and the UltraLume LED 5 LCU at the longest cure time of 20 seconds. It is suggested that orthodontic brackets be photopolymerized for at least 20 seconds with the QTH or the LED LCU before the archwires are placed.

Adrian et al ,(2005) [39] investigated the curing effectiveness of a new generation high-power LED lamp (Elipar Freelight 2 [N] 3M-ESPE). The efficiency of composite cure with this new lamp was equated to conventional LED/halogen (Elipar Freelight [F], 3M-ESPE; Max [M], Dentsply-Caulk) and high-power halogen (Elipar Trilight [T], 3M-ESPE; Astralis 10 [A], Ivoclar Vivadent) lamps. Standard continuous (NS, FS, TS; MS), turbo (AT) and exponential (NE, FE, TE) curing modes of the different lights were also examined. The hardness ratio was then calculated by dividing HK (Knoops Hardness) of the bottom surface by HK of the top surface. Results of the statistical analysis were : HK top--E, FE, NE > NS and NE > AT, TS, FS; HK bottom--TE, NE > NS; Hardness ratio--NS > FE and FS, TS > NE. No significant difference in HK bottom and hardness ratio was detected between the two modes of Freelight 2 and Max. Freelight 2 cured composites as efficiently as conventional LED/halogen and high-power halogen lamps, even with a 50% decrease in cure time. The exponential modes of Freelight 2, Freelight and Trilight appear to be effective than their respective standard modes

.**Watts C and Silikas N (2005)**[40] based on their study concluded that an exceedingly high intensity, above 2000 mW/cm sq. may cause material structural defects; high rate of excitation of radicals may induce a high polymerization rate, that encapsulation of unreacted monomer takes place leading to inhomogeneous material, which are susceptible to dissolution and degradation.

A Rüya Yazici, (2006)[41] conducted a study to compare the temperature rise in a pulp chamber as a result of using different light-curing units during resin composite polymerization, and it assessed the effect of remaining dentin thickness on temperature increase. The light-curing units tested comprised two halogen lights, Spectrum 800 and Elipar Trilight (Standard and Exponential mode); a light-emitting diode (LED, Elipar Freelight) and a plasma arc (Virtuoso, Xenon Power Arc). Irradiation time was 40 seconds for the halogen and LED lights and 3 seconds for the plasma arc light . The rise in pulp chamber temperature ranged between 1.40-3.8 degrees C. The highest temperature rise was observed when using Elipar Trilight Standard mode, and the least temperature rise was detected with light emitting diode for both remaining dentin thicknesses. The only significant differences in temperature rise were observed between Elipar Trilight Standard mode and LED. No significant difference existed for the various modes of Elipar Trilight. A statistically significant higher temperature increase was observed within each curing unit at a depth of 1 mm compared to 2 mm.

Kimberly Gronberg, (2006)[42] evaluated increasing exposure times and distance among the light source and adhesive composite on the shear bond strength (SBS) of stainless steel brackets. There were significant SBS changes between exposure times; 5-second exposures were significantly less than at 20-and 40-second exposures; SBS increased in a curvilinear pattern. Significant differences were noted neither in the frequencies of ARI scores separated nor the SBS in relation to distance. Significant differences in the occurrences of ARI scores were detected when comparing the 5-second cure time to other time periods, indicating partial polymerization in the bracket base.

Maria Francesca Sfondrini (2006)[43] performed a study to evaluate the effect of distance of light-tip from tooth on the shear bond strength and the failure site of brackets cured with 3 light-curing units (high-intensity halogen, light-emitting diode, and plasma arc). Stainless steel brackets were bonded with a resin-modified glass-ionomer to the teeth, and each curing light was verified at 3 distances from the bracket: 0, 3, and 6 mm. When the effect of the light-tip distance on each light-curing unit was assessed, the halogen and light-emitting diode lights showed no significant differences between the 3 distances. However, the plasma arc light produced significantly higher shear bond strengths at a greater light-tip distance. No significant differences were observed among the adhesive remnant index scores of the various groups, except with the LED light at a distance of 3 mm. In hard-to-reach areas, the plasma arc curing light is recommended for optimal curing efficiency

Thind, B.S. in (2006)[44] investigated whether there was any differences between the debond stress and adhesive remnant index (ARI) of an adhesive cured with three different orthodontic light cure units. Sixty sound premolar teeth were sorted into three groups of 20. A standard pre-adjusted edgewise premolar bracket was attatched to each tooth using a light-cured orthodontic adhesive, Transbond X. Group 1 (control) samples were cured with an Ortholux XT (tungsten-quartz-halogen bulb) light for 20 seconds, group 2 with an Ortho lite (plasma arc) for 6 seconds and group 3 with an Ortholux LED light-emitting diode for 10 second respectively. The ARI scores for group 2 were significantly different from that of groups 1 and 3 (between which there was no significant difference). For group 2 there was a superior tendency for failure to occur at the adhesive/tooth interface than for the other two groups. There seems to be no reason why any of the three types of light source can't be used in orthodontics. Polymerization, as effective as that produced by conventional bulb light sources, was attained with the short exposure times suggested for the plasma arc or light-emitting diode sources.

Theodore Eliades (2006)[45] in a review article discoursed the fundamentals of photocuring with numerous types of lamps in orthodontics. Information on the characteristics of lamps, photopolymerization, from the viewpoint of both the material composite resin adhesive and source (lamp) were discussed, with reference to light scattering, optimum filler size, extent of polymerization, and the degree of cure of resins irradiated with various lamps. The discussion is also listed the properties of lamps and their application to orthodontic bonding as these are reflected in 4 key properties of the material, such as polymerization efficiency (degree of cure), mechanical properties (bond strength), clinical performance (failure rate), and biological properties of blue light

Vittorio Cacciafesta et al,(2006)[46] studied the effect of a 35% hydrogen peroxide bleaching gel on the shear bond strength and bond failure location of a resin-modified glass ionomer.Forty-five bovine mandibular permanent incisors were arbitrarily divided into 3 groups; each group had 15 teeth. Bleaching treatment was executed at 2 different times before the bonding procedure. Forty-five stainless steel brackets were bonded using the resin-modified glass ionomer..Group 1 (no bleaching) showed significantly higher shear bond strength values compared to group 2 (bleaching immediately before bonding) and 3 (bleaching 1 week before bonding). No significant differences were observed between groups 2 and 3. Moreover, no significant differences in debond locations were noted among the 3 groups and concluded ,Bleaching treatment before bonding significantly decreased the bond strength values of GIC.

Michael D Signorelli et al (2006)[47] assessed the in-vitro shear bond strength and in-vivo survival rate of brackets attached to the teeth with either a halogen or a plasma arc light. For the in-vivo study, no significant difference was found in bracket failure rates between the light sources . No significant differences were between ARI scores for the halogen light and the plasma arc light at either 30 minutes or 24 hours after debonding. These results specify that the plasma arc light with a 6-second curing time can produce comparable bond strength and bracket-failure rates as the halogen light that needs a longer curing time.

Akira Yamamoto et al (2006)[48] investigated the rate of bond strength progress for orthodontic adhesives in bracket bonding. Four orthodontic adhesive systems were studied. Bovine incisors were attached on self-curing acrylic resin. Orthodontic brackets were bonded according to the manufacturers' directives. Shear bond strengths were tested after storage in water for 5, 10, and 60 minutes, and 24 hours. Differences between bond strengths at 24 hours and the other test stages were statistically analysed. All materials tested had the highest bond strengths at 24 hours, and bond strength improved with storage time. The earliest time point at which there wasn’t any significant difference in bond strength compared with that at 24 hours was defined as the initial stable time. Differences in this value may have clinical implications for the assessment of orthodontic adhesives, which can incur high stresses instantly after placement. The rate of development of enamel bond strength must be considered to guarantee sufficient maturation of orthodontic adhesives before functional loading.

Aslihan Uzel et al (2006)[49] investigated the temperature variations in the pulp chamber during bracket bonding with three dissimilar light curing devices. The measurements were taken using a J-type thermocouple wire, kept in the pulp chamber and linked to a data logger. Pulp chamber temperature changes were affected by the light source, the type of tooth, and the distance from the tip of the light guide to the bracket surface. Halogen induced significantly more of intrapulpal temperature changes than light-emitting diode and Xenon Plasma Arc .The temperature increase was significantly higher when the light-guide tip was placed on the teeth at the 10-mm distance with all light-curing units. All light-curing units generated higher intra pulpal temperature increase in the mandibular incisor than in the premolar. Power PAC generated significantly higher heat changes in the incisor than in the premolar. Orthodontic bonding with different light-curing units did not surpass the critical 5.5°C value for pulpal health

Nikolaos Pandis (2007)[50] conducted a study and concluded that, high-intensity LED curing lights presented a 2.5 times higher failure rate compared to plasma lamps for nominally identical irradiation time. Mandibular teeth show almost 150% higher failure occurrence compared with maxillary teeth. No effect from the arch side (right vs left) and location (anterior vs posterior) was recognized in this study.

Hajrassie, M.K.A. (2007)[51] conducted a study to evaluate and compare in-vivo and in-vitro bond strengths of orthodontic brackets bonded to human enamel and debonded at different times. An in-vivo debonding device was confirmed and used to check the bond strengths in the oral environment. Results showed no significant differences among the in-vitro or the in-vivo groups. The in-vivo group had significantly less mean bond strength values. In addition, the probability of bond affirmed the significant difference between in-vitro and in-vivo environments. Reported bond strength values were not time dependent.

Asli Baysal (2008)[52] evaluated the influence of high-intensity light curing units (light-emitting diode and plasma arc curing) on the microleakage of flexible spiral wire retainers at the composite/enamel and composite/wire interfaces. Multistranded Penta One wire of .0215 inch size was bonded to enamel and was cured with three different light curing units: a quartz-tungsten-halogen unit and two high-intensity units. A conventional halogen light was used as the control. Very less microleakage was detected at the composite/enamel interface of the FSWR cured with three different light sources. However, at the composite/wire interface, statistically significant differences were found between the QTH and high-intensity curing units. The PAC resulted in the greatest expanse of microleakage ,whereas no statistically significant difference was noted between the PAC and the LED .High-intensity light curing units had statistically significant microleakage at the composite/wire interface and therefore is unsafe for bonding FSWRs.

Kathryn Durey (2008)[53]conducted a study evaluate the intrapulpal temperature rise occurring during polymerisation of different shades of resin-based composites ,and two light-emitting diode units. Pulp temperature rises during bonding was always greater during resin based composite (RBC) curing , and these were significant for both LED lights but not for the halogen control, irrespective of the shade . Pulp temperature rises during bonding were higher with the LED lights than with the halogen control. There was no significant difference in temperature rise between the two LED lights when bonding but there was a significant difference between the two LED lights and the halogen control(Light curing unit) LCUs. The results support the view that there is a potential threat for heat-induced pulpal injury when light-curing (resin based composite) RBCs. The risk is greater during bonding and with high energy, as compared to low-energy output systems. As the extent of tolerable thermal trauma by the pulp tissues is not known, care and consideration has be given to the choice of (Light curing unit) LCU and the exposure time when curing RBCs, and especially during bonding.

.Thaise Graciele Carrasco (2008)[54] in a study determined the temperature rise induced by the light-activated dental bleaching technique using different light sources in vitro the pulp chamber. Three groups were designed for each condition (bleach or no bleach) according to the use of 3 light sources advised for dental bleaching: a light-emitting diode (LED)laser system, a LED unit and a conventional halogen light. The light sources were placed perpendicular to the buccal aspect at a distance of 5 mm and activated for 30 s. The differences between the initial and the highest temperature readings for each sample were obtained, and, from the temperature changes. It was concluded that during light-activated tooth bleaching, with or without the bleaching agent, halogen light promoted higher pulp chamber temperature change than LED unit and LED-laser system.

Krämer, N(2008)[55] in a review accumulated information about the new technologies for state-of-the-art light curing of resin composite materials. The conclusions were: (1) curing time of 2 mm thick increments of resin composite can be reduced to 20 seconds to obtain durable results with high-power LED units of the latest generation,; (2) curing depth is mainly dependent on the distance of the resin composite to the light source, but only decisive when it exceeds 6 mm; (3) polymerization kinetics can be improved for better marginal adaptation by soft start polymerization (4) when resin composite is applied directly, adhesives should be light-cured separately for at least 10 seconds; (5) As the photocuring through indirect restorations is still a problem, both dual-cured adhesives and dual-cured composites and resin coating are recommended; and (6) heat production with high-power photopolymerization units should not be underestimated as a biological problem for both gingival and pulpal tissues.

Sibel A Antonson (2008)[56] performed a study to compare the curing efficiency of 10 new generation LED light curing units (FLASH-lite 1401, LE Demetron 1, Coltolux, Ultra-Lume 5, Mini LED, bluephase, Elipar FreeLight 2, Radii, Smartlite IQ and Allegro) for depth of cure against a high-powered halogen lighcuring t unit (Optilux 501). Depth of cure measurements were utilized as per the ANSI/ADA No 27 standard to detect differences between the lights at three time intervals (10, 20 and 40 seconds). A total of 660 samples were taken (n=10/group). Results showed that FLASH-lite 1401 performed significantly better compared to the other lights at 10- and 20-second time intervals. This study also demonstrated that an exposure time of 20 seconds or longer ensure a better depth of cure, optimal polymerization time for all of the curing light units 40 seconds being.

Gabriele Corciolani et al (2008)[57] investigated the influence of shape of the light guide on the efficacy of polymerization of a light-activated resin-based composite cured with LED units as a function of the distance between the tip and the restoration. Two different LED units, each with different light guides and shapes, were included. The ability to cure a single restorative material was evaluated. Considering the ratio (R) between the entry diameter and the exit diameter of the light guide, the tips with a higher R-value were found to be more efficient if the tip and composite distance (D) was less than 5 mm, while for D > 5 mm, the tips with a lower R-value showed better results. The tip geometry of the tested light guide had a significant effect on the depth of cure of the tested resin composites. Therefore, depending on the distance, the more suitable light guide has to be selected, based on the clinical scenario."

Davide Mirabella et al (2008)[58] tested the hypothesis that bonding with a blue light-emitting diode (LED) curing unit would result in no more failures in adhesive-precoated (APC) orthodontic brackets than bonding carried out by a conventional halogen lamp. In 34 of the randomly chosen patients, assigned group A, the APC brackets of the right maxillary and left mandibular quadrants were bonded using a halogen light, while the remaining quadrants were cured with an LED curing unit. In the other 31 patients, designated group B, halogen light was used to cure the right mandibular and left maxillary quadrants, whereas the APC brackets in the remaining quadrants were bonded with a LED curing light. The bonding date, the type of light used for curing, and the date of any bracket failures over a mean period of 8.9 months were noted for each bracket .No statistically significant difference in bond failure rate was found between the two groups. However, significantly fewer failures were noted in the maxillary arch than in the mandibular arch after each light-curing technique.

Jeffrey A Platt et al(2009)[59] evaluated the impact of curing distances using three different types of lights sources in terms microhardness of the surface of a resin composite as a function of power density. As the curing tip distance increased ,the mean Knoop microhardness values decreased significantly. Fifteen minutes after light cure, effective hardness percent values (> 80%) were attained in a few experimental groups.

Christos Rahiotis (2010)[60] evaluated the curing efficiency of 4 high-intensity light-emitting diode (LED) devices by determining the percentage of residual C=C (%RDB), surface microhardness (SM), depth of cure (DC), percentage of linear shrinkage-strain (%LS), and percentage of wall-to-wall contraction (%WWC). The light-curing units used were a QTH light, the Elipar TriLight (3M/ESPE), and 4 LED devices - the Allegro (Denmat), the Bluephase (Ivoclar/Vivadent), the FreeLight2 (3M/ESPE), and The Cure TC-01 (Spring Health Products). The %RDB was evaluated by microFTIR spectroscopy. Microhardness measurements (Vickers) were conducted at the surface (H0) and at depths of 3 mm (H3) and 5 mm (H5) of cylindrical samples. Depth of cure was defined as the ratio of microhardness at each depth, relative to the corresponding surface value (H3/H0 and H5/H0). The bonded disc method was used to assess %LS. For the %WWC measurement, cylindrical resin restorations were imaged by high resolution micro-CT and the %WWC was calculated at depths of 0 mm and 2 mm. There were no statistical differences among the LEDs in %RDB or %LS. The Bluephase and Allegro had the greatest SM values. As compared with the other LEDs, the Bluephase and The Cure TC-01 had lesser values for depth of cure at depths of 3 mm and 5 mm. There were no significant differences in %WWC among the LEDs at either depth, and the QTH had the lowest %WWC at both depths.

Madhukar Reddy Rachala,(2010)[61] conducted a study with the objectives of evaluating the shear bond strength (SBS) of orthodontic brackets bonded to teeth with a LED LCU at 10, 20 and 40 seconds and comparing them with that of 40 seconds light curing with a conventional halogen-based LCU (Hilux unit, Heraeus Kulzer comp.). Also to determine the amount of adhesive remaining on the tooth after debonding using Adhesive Remnant Index (ARI). All the recordings were assessd statistically revealed that, no statistically significant differences were seen among the shear bond strengths of 40 sec halogen, 20 sec LED and 40 sec LED cured groups; but the bond strength of 10 sec cure LED group had significantly lower than the other groups. There were no significant differences in the ARI scores between the 4 groups tested.

Erion Cerekja (2011)[62] in a study concluded that Curing time can be shorten to 6 seconds with high-power halogen light and to 10 seconds with high-intensity LED without compromising the in vitro SBS of metal brackets.

Carine Maccarini Dall'Igna (2011)[63]conducted a study to evaluate the impact of two light units, a light-emitting diode and a plasma arc light , on the shear bond strength of brackets bonded to enamel. In the LED group, the specimens were cured for 5, 10, and 15 seconds and in the PAC group, the samples were light cured for 3, 6, and 9 seconds. The highest mean SBS was attained with the LED at 15 seconds, which did not significantly differ from the LED 10 or 5 second groups. The LED 10 and 5 second groups were not significantly different from the PAC 9 second group or from the PAC 6 second group .The least mean SBS was obtained with the PAC 3 second group, which did not differ significantly from the PAC 6 second group. The method of light curing did not have any influence the ARI, with score 3 predominant. The LED at 5 seconds and the PAC at 3 seconds provided the required mean SBS to oppose either orthodontic or masticatory forces.

Mohammed A Wahbi, (2012)[64] evaluated the heat emissions produced by light-curing units of different intensities during their operation. Five commercially available light curing units were checked: a "Flipo" plasma arc, "Cromalux 100" quartz-tungsten-halogen, "L.E. Demetron 1" second-generation light-emitting diode (LED), and "Blue Phase C5" and "UltraLume 5" third-generation LED light curing units. Temperature changes were monitored in continues 10 and 20 s intervals up to 300 s. The Flipo light source had the highest mean heat emission while the L.E. Demetron 1 LED showed the least mean value at 10 and 20 s exposure times. Moreover, Cromalux (QTH) showed the second highest value for all intervals of heat emission than Blue Phase C5 (LED) , at 20 s illumination for all intervals the highest results were also recorded with Flipo (PAC) LCU, and the lowest with L.E. Demetron 1 LED, while Blue Phase C5 (LED) showed the second highest value at the 1st and 2nd 20 s intervals of heat emission than Cromalux (QTH) . The rate of temperature or heat rise during the 10 and 20 s depends on light intensity of emitted light. However, the QTH LCU resulted in a higher temperature rise than LED curing units of the same power density.The PAC curing unit induced a significantly higher heat emission and temperature rise in all periods, and data were statistically different than the other tested groups . LED (Blue Phase C5) was not statistically significant (at 10 s) than QTH units, also LED (Blue Phase C5, UltraLume 5) produced obvious heat emission and temperature rises than QTH units (at 20 s) except for those which have lower power density of LED curing units (first generation).

Sergio Luiz Mota Júnior(2013)[65] developed a new equipment to be coupled to light-curing units for bonding orthodontic brackets and accessories, and checked its efficacy in an in vitro mechanical trial. The inner surface of the device is mirrored and is based on physical concepts of refraction and reflection light. The main advantage of such an equipment is the reduced clinical time required for bonding and the least possibility of contamination during the process. The shear bond strength and adhesive Remnant Index (ARI) was assessed. The tests of mechanical trials and the ARI analysis showed that the new device fulfilled the requirements for bonding , and that the time for bonding was lowered to half, being necessary only one light exposure.

Murilo Gaby Neves (2013) [66] assessed thhe shear bond strength and ahdesive remnant index (ARI) of self-curing (ConciseTM - 3M and Alpha Plast - DFL) and light-curing composites (TransbondTM XT - 3M and Natural Ortho - DFL), bonded to Morelli metal brackets. These samples were sorted in to four groups: G1 group, the brackets were bonded with ConciseTM - 3M composite; in G2 group, Alpha Plast - DFL composite was used; in G3 group, TransbondTM XT - 3M; in G4 group, Natural Ortho - DFL composite was used. These groups were subjected to shear strength tests using universal testing machine, at 0.5 mm per minute speed.

Shear bond strength was satisfactory and were similar between the composites, however Natural Ortho - DFL showed the best comparing to TransbondTM XT - 3M.

Anika Braun et al, (2013)[67] evaluated if bovine teeth are appropriate substitutes for the respective human hard tooth tissues to test shear bond strength (SBS) and fracture analysis. Study concluded that solely conducted SBS on bovine substrate are not enough to judge the perfomance of adhesives, thus bovine teeth are questionable as a substitute for human teeth for shear bond testing.

Kenan Cantekin et al (2014)[68] conducted a study to evaluate the temperature rises in the pulp chamber caused by halogen, plasma arc, and conventional light-emitting diode (LED) curing units with that induced via a new generation LED-curing unit (VALO) in extra power mode. The greatest rise in temperature were observed during polymerization of composite resin with a halogen curing unit (3.2 degrees Celsius), followed by plasma arc curing (2.07 degrees Celsius) and VALO curing (1.44 degrees Celsius); the lowest temperature rise was observed with conventional LED curing (1.01 degrees Celsius).

Sertac Aksakalli (2014)[69] assessed the effects of different curing units and light-tip tooth surface distances on the temperature increase produced during orthodontic bonding, using an infrared camera (IR) and artificial neural networks (ANN). The LED unit caused significantly higher temperature changes than did the high intensity qurtz tungsten halogen.The temperature increase during orthodontic bonding was increased with increase in exposure time. A shorter light-tip tooth surface distance leads to more increase in temperature.

Gomes P (2014)[70] evaluated the impact of light exposure time on the adhesive strength and the failure mode of orthodontic brackets bonded to human teeth.The study concluded that both the SBS and the failure mode were statistically related to the exposure time. Reduction in the exposure time less than 10s, decreases the bracket bond strength. The bracket-adhesive interface had the weakest adhesive link .

Justin D Ward(2015)[71] conducted a study to determine the performance of brackets cured with a high-intensity, light-emitting diode with a shorter curing time. The teeth in the maxillary right and mandibular left quadrants were cured for 6 seconds with a high-intensity LED light and the maxillary left and mandibular right quadrant teeth were cured for 20 seconds with a standard-intensity LED light. No difference was seen in bond failure rates between the two curing methods. Both methods had bond failure rates low enough to be considered clinically sufficient. The high-intensity LED light used with reduced curing time may be considered an advantage due to the reduced chair time.

Sabri Ilhan Ramoglu (2015)[72] conducted a study to assess and compare intra pulpal temperature increase with three different light-curing units by using a study model replicating pulpal blood micro circulation. A J-type thermocouple wire was inserted into the pulp chamber through a access drilled on the palatal aspect of the teeth. Four measurements were made using each tooth for four different modes: group 1, 1000 mW/cm^2 for 15 seconds; group 2, 1200 mW/cm^2 for 10 seconds; group 3, 1400 mW/cm^2 for 8 seconds; and group 4, 3200 mW/cm^2 for 3 seconds. The tip of the light source was placed at 2 mm to the incisor's labial aspect.The highest temperature rise was seen in group 1, followed by group 2 and group 3. The lowest temperature rise value was recorded in group 4; this value indicated significantly lower ΔT values when compared to group 1 and group 2.The lowest intra pulpal temperature rise was produced by 3200 mW/cm^2 for 3 seconds of irradiation. Inspite of the significant differences among the groups, the temperature increases recorded for all groups were below the critical value of 5.6°C.

E Armellin (2016)[73] conducted an in vitro study to determine thermal changes on tooth tissues during light exposure using two different LED curing units. The hypothesis was that irrespective of the use of a composite resin or a light-curing unit, no temperature increase could be detected within the dental pulp during polymerization. Polymerization data assessment showed that in the pulp chamber temperature increase was higher than that without resin. Starlight PRO, in the equivalent condition of Valo lamp, showed less temperature increase in pre- and intra polymerization. Temperature elevation during resin curing is a function of the rate of polymerization, due to the exothermic polymerization reaction, the energy from the light unit, and time of exposure.

Jang et al (2016)[74] examined the influence of insufficient light exposure on the polymerization of conventional and self-adhesive dual-cure resin cements under ceramic restorations. Conventional dual-cure resin cements and two self-adhesive resin cements were polymerized using different curing modes (dual-cure or self-cure), curing times (20 and 120 seconds), and thickness of the ceramic overlay (2 and 4 mm). Polymerization kinetics was measured using a Fourier transform infrared spectroscopy for the initial 10 minutes and after 24 hours. When light-curing time was set to 20 seconds, the presence of the ceramic block significantly influenced the degree of conversion (DC) of all resin cements. Especially, the DC of the groups with 20 seconds of light-curing time under 4 mm of ceramic thickness was lower compared to the self-cured groups at 24 hours after polymerization. However, when light-curing time was set to 120 seconds, a similar DC compared with the group with direct light exposure was obtained in all dual-cure groups except Maxcem Elite, at 24 hours after polymerization. For both conventional and self-adhesive dual-cure resin cements, inadequate light exposure (20 seconds of light-curing time) through thick ceramic restoration (4 mm thick) resulted in a DC even lower than that of self-curing alone

Rafael Francisco Lia Mondelli (2016)[75] conducted a study with the aim to measure the increase in intra pulpal temperature induced by different light-activated bleaching procedures with and without the use of a bleaching gel. A human maxillary central incisor was cut 2 mm below the cementoenamel junctionThere were statistically significant differences in temperature increases between the different light curing units used and between the same light sources with and without the application of bleaching gel. The presence of a bleaching gel produced an increase in intra-pulpal temperature in groups activated with halogen light, hybrid light, and high intensity LED. Compared to the other light sources, the conventional halogen lamp source of light over the bleaching gel induced a significant increase in temperature (3.83±0.41°C). The green LED unit with and without gel application did not generate any significant intra pulpal temperature differences.

Javad Chalipa(2016)[76] conducted a study to determine the impact of conventional and high-power light emitting diode (LED) light curing units on shear bond strength (SBS) of metal and ceramic brackets to tooth surface. The study concluded that, type of LED unit did not affect SBS. But the type of bracket significantly affected SBS. ARI score was not significantly influenced by the interaction between the type of LED unit and bracket type. The obtained SBS for both bracket types by use of high-power and conventional LED light curing units were the same. Regardless of the type of LED unit, SBS of ceramic brackets was significantly lower compared to the metal brackets.

Abdullah Alper Oz(2016)[77] performed a study to compare the clinical failure rates and the in-vitro bond strengths of metal brackets bonded with different light-emitting diode (LED) devices and curing times. A split-mouth design was used, with the adhesive in group 1 cured with an LED unit (Elipar S10)for 10 seconds, and the adhesive in group 2 cured with another LED unit (VALO Ortho;) for 3 seconds. Bond failures for 12 months of orthodontic treatment were recorded. In-vitro performance of the brackets was also assessed by bonding brackets to extracted premolars and using the same light units and curing times . The adhesive remnant index was used to evaluate the bond failure interface. Bond failure rates were 2.90% for the Elipar and 3.16% for the VALO curing units. The difference in bracket failure rates between the 2 LED devices was not significant statistically. In-vitro bond strengths between groups did not show any statistically significant difference. The findings regarding long-term clinical survival rates and in-vitro bond strengths denotes that bracket bonding can be safely accomplished in 10 seconds of light-curing with an Elipar LED and 3 seconds of light-curing with a valo LED.

Anil Tiwari et al (2016)[78] in an in vitro study determined the effect of the dental chair light on the bond strength of light cured composite resinLight cure bonding with dental chair light switched on produced greater bond strength .In both the groups ARI score were similar. It is suggested that the inexperienced orthodontist should always switch off the dental chair light while bonding for enough working time during the bracket placement.

Mustafa M. Al-Khatieeb et al (2017)[79] assssed the influence of different curing time of LED light cure on the shear bond strength of stainless steel orthodontic brackets fixed to human teeth in comparison with light exposure of 40 seconds from a conventional halogen-based light-curing device which was used as a control. The brackets were bonded using Halogen light cure for 40 seconds in the first group. Brackets were bonded using Woodpecker i-Led light cure for 3 seconds in the second group, while in the third group, the brackets were fixed using Woodpecker i-Led light cure for one second. The shear bond strengths of both groups of LED unit were higher compared to halogen one, with a statistically significant difference. Predominant scores for the adhesive remnant index were score 2 and 3, with a non-significant difference among groups tested. Both of the LED units groups showed clinically acceptable shear bond strength in comparison to that of halogen, so the time of bonding reduced without affecting the shear bond strength or enamel surface after debonding.

Vasudevamurthy Akshatha (2019)[80] conducted a study to test the FlashCure unit. The mean shear bond strength of the brackets cured with the FlashCure unit was 8.88mPA (± .57), compared with 8.40mPA (± .57) for the conventionally cured brackets. The difference was statistically significant

Ines Dallel(2019)[81] compared fourth, fifth and seventh generation adhesive systems performance (GASs) and the effect of two different light curing units on shear bond strength (SBS). Bonds were then evaluated as following: group 1 using 4th GAS, group 2 using 5th GAS, group 3 and 4 using 7th GAS with two different light curing units (1500 and 800mw/cm2). Group 1 and 2 had similar SBSs which were significantly higher than group 3. Group 4 displayed significantly the weakest SBS. Applying shear forces below 15MPa on group 3 bonds led to the dislodgment of almost all of the of brackets. Whereas, applying the same forces on group 2 bonds leads to the debonding of 66.7% of brackets. Notably, only 40% of brackets in group 1 got debonded. Group 4 brackets were completely debonded when applying shear forces below 10MPa. While ARI=0 was the more frequent in group 1, ARI=3 was the most frequent in group 3. Fourth and fifth GASs showed similar SBS higher than seventh GAS. Fourth GAS bonds resisted longer against traction forces than those set up by fifth generation. Seventh GAS bonds offered the least effective resistance. ARI=0 was the highest in group 1.Group 4 had the highest ARI=1 and ARI=2 revealing cohesive failure. Study also identified that the adhesive power is proportional to the power of the lamp used and concluded that 1500 mw/cm2 units light curing during 30seconds generated an ideal energy to reinforce orthodontic bracket adhesion.

Shadwa H. Kabil,et al (2019)[82] conducted a study on comparison of teeth sensitivity and shade with decreasing different light intensities after bleaching protocol versus bleaching protocol with the same high light intensity. Decreasing light intensities protocol showed a lower teeth sensitivity compared to high light intensity protocol after 1 and 2 days. There was no sensitivity of teeth reported at 1-week post-bleaching. Regarding the teeth shade, decreasing light intensities protocol had a higher effect on colour change in shade guide units (SGU) than high light intensity protocol effect. Both bleaching protocols showed there was not any significant difference in ∆SGU recorded after bleaching between high and descending light intensities protocols. A lower teeth sensitivity was seen with descending different light intensities protocol than high same light intensity protocol. Descending light intensities protocol also had a little higher effect on colour change in shade guide units (SGU) compared to high light intensity protocol effect

Anna-Lena Groddeck et al(2020)[83] in an vitro pilot study measured the temperatures in the pulpal cavity with non pulpal circulation approaches. In the study four groups of lower and upper incisors, premolars and molars were included by dividing 60 extracted teeth equally. The temperature rise was calculated for the first series on each tooth without a bracket, without and with the recommended hygienic barrier case for the LED light curing device, and exposure to light once versus twice starting at 37 °C (body temperature) as the reference. A metal bracket was also bonded to each tooth in the second test sequence. The light exposure distance was increased to 4 mm in the third series. Significant changes in the intrapulpal temperature were seen in all three test series: the highest temperatures were identified once after light exposure without the hygienic barrier case. This method revealed temperatures even higher than 42.5 °C in the lower incisors and premolars in the first set of studies. According to the manufacturer's recommendation for an LED light curing device with in vitro non-pulpal circulation approaches, significant increases in the temperature of the pulp cavity (up to 42.5 °C) can occur during bonding brackets.

Relevance

RELEVANCE

Bonding of brackets on teeth forms the footing of fixed orthodontic treatment. It is also one of the most time consuming procedure. Bonding the upper and the lower arch on the same day makes the patient feel exhausted as he or she have to keep the mouth open throughout the entire process. Splitting the appointment would increase the number of patient visits. Protocols and methods that can reduce the time required for bonding procedure without compromising the quality of treatment can address this problem effectively.

Many studies were done on reduction of curing time using high intensity curing units which advocates time as less as 1 to 3 seconds to cure a tooth. Though the curing time is reduced with these devices, the protection of pulpal tissue is not always guaranteed. Another alternative to reduce the curing time without causing any injury to the pulpal tissue is to use a curing unit that can cure multiple teeth in one shot, with an intensity not above the range that causes any pulpal damage.

Methodology

METHODOLOGY

MATERIALS USED:

1. Alginate impression material (Septodont Mariflex)
2. Wax blocks (Mdm)
3. Cold cure acrylic polymer (DPI -RR)
4. Cold cure acrylic monomer(DPI - RR)
5. Putty material(3M Dental Express XT VPS Impression Material)
6. 37 % phosphoric acid gel (3M)
7. Transbond XT Primer (3M Unitek)
8. Transbond XT composite resin(3M Unitek)
9. MBT bracket kit (Modern *Sapphire* Metal *Brackets)*

EQUIPMENTS USED

1. BLUE PHASE N R MC light cure unit
2. SINSATIONAL SMILE bleaching unit
3. Universal testing machine (AG 1 AUTOGRAPH)
4. Light stereomicroscope(MagnUs)
5. Lightmeter(Blue phase meter II)
6. Photometer(Spectra physics)

STUDY SETTING

- Department of Orthodontics and Dentofacial Orthopaedics ,St.Gregorios Dental College, Kothamangalam**.**

- Cochin University of Science and Technology, Kochi.

Sample Size calculation

Sample size calculated is 179. 180 samples will be considered for the study which will be distributed among 12 groups.

$$n_A = \kappa n_B \text{ and } n_B = \left(1 + \frac{1}{\kappa}\right)\left(\sigma \frac{z_{1-\alpha/2} + z_{1-\beta}}{\mu_A - \mu_B}\right)^2$$

$$1 - \beta = \Phi\left(z - z_{1-\alpha/2}\right) + \Phi\left(-z - z_{1-\alpha/2}\right) \quad , \quad z = \frac{\mu_A - \mu_B}{\sigma\sqrt{\frac{1}{n_A} + \frac{1}{n_B}}}$$

- κ=nA/nBκ=nA/nB is the matching ratio
- σσ is standard deviation
- ΦΦ is the standard Normal distribution function
- Φ−1Φ−1 is the standard Normal quantile function
- αα is Type I error
- ββ is Type II error, meaning 1−β1−β is power

Inclusion Criteria

- Extracted human maxillary incisors, canine, premolar, molar teeth
- Non carious teeth
- Teeth with no enamel defects on buccal aspect

Exclusion Criteria

- Carious teeth
- Teeth with enamel defects on buccal aspect
- Teeth with altered morphology

SORTING OF SAMPLES

The samples were divided in to three groups:

1. The control group in which the samples were cured with a standardized single tip LED curing unit (BLUE PHASE N R MC).

2. Experimental group 1 in which the samples were cured with cluster LED unit (SINSATIONAL SMILE bleaching unit) for 15 seconds and

3. Experimental group 2 in which the samples were cured with cluster LED unit (SINSATIONAL SMILE bleaching unit**)** for 30 seconds.

CURING UNITS USED

Curing unit	Light intensity	Wave lengths
Control group: (BLUE PHASE N ^{R} MC)	*800mW/cm^2	*430 – 490 nm
	**850mW/cm^2	
Experimental group: (SINSATIONAL SMILE)	*2000mW/cm^2	* 430 - 490 nm
	**800mw/cm^2	

Table 2: Light intensity and wave lengths of curing units

*manufacturer's value

**value obtained after checking with photometer

Samples were grouped as given in the following tables:

CONTROL GROUP: SINGLE TIP LED UNIT (15 SEC CURING)

GROUP	TEETH	CURING TIME	SAMPLE SIZE (n)
GROUP 1	MAX INCISORS	15 sec	15
GROUP 2	MAX CANINE	15 sec	15
GROUP 3	MAX PREMOLAR	15 sec	15
GROUP 4	MAX MOLAR	15 sec	15

Table 3: Control group samples

EXPERIMENTAL GROUP 1:CLUSTER LED UNIT (15 SEC CURING)

GROUP	TEETH	CURING TIME	SAMPLE SIZE (n)
GROUP 5	MAX INCISORS	15 sec	15
GROUP 6	MAX CANINE	15 sec	15
GROUP 7	MAX PREMOLAR	15 sec	15
GROUP 8	MAX MOLAR	15 sec	15

Table 4 : Experimental group 1 samples

EXPERIMENTAL GROUP 2: CLUSTER LED UNIT (30 SEC CURING)

GROUP	TEETH	CURING TIME	SAMPLE SIZE (n)
GROUP 9	MAX INCISORS	30 sec	15
GROUP 10	MAX CANINE	30 sec	15
GROUP 11	MAX PREMOLAR	30 sec	15
GROUP 12	MAX MOLAR	30 sec	15

Table 5: Experiment group 2 sample

PREPARATION OF SAMPLE

Collection and storage of specimens

A total of 180 extracted human maxillary teeth without any visible enamel defects on the labial/buccal surface i.e; maxillary incisors (45), canines(45) , premolars (45) and molars(45) were collected and stored in 0.1 % thymol solution at 4^{0}c, until the start of the study. Ultrasonic scaling was performed on all the teeth(fig 1). Teeth were then polished for 10 sec with a prophy cup and pumice and rinsed with water. Specimens were then sorted in to the control and experimental groups.

Making of specimens

Control group

To prepare tooth embedded acrylic blocks, alginate impression material was used to make the impressions of wax blocks of dimensions 1.5cm x 2.5 cm. The wax blocks were removed and the mould spaces were filled with cold cure acrylic. Teeth were then embedded in the acrylic block, before it was set(fig 2). To distinguish between different groups, dyes were added. Pink colour was used for the control group, Once the acrylic was set, the blocks were taken out, trimmed and polished (fig 4).

Making of Jig

To simulate patient's oral cavity, teeth belonging to the control group were arranged in an arch form. Putty impression material was used to make the mould spaces to receive the acrylic blocks, which was then fixed on to the metallic rim attached plastic articulator (fig 3,5,6). And finally, the whole set up was secured on to a phantom head.

Experimental group

Before bonding the teeth belonging to the experimental groups were arranged in an arch form on an occlusal rim which was made up of wax(fig 13). It was then fixed on to the articulator with the metallic jaw. Finally the model was positioned on the phantom head for bonding(fig 14, 15).

Checking the Light intensity

Before bonding, the light intensity of both the single tip (fig 9) and cluster LED units were checked using a photometer (fig 12).

Single tip LED unit was placed as close as to the photometer similar to the bonding position of the teeth to check the intensity. And in the cluster LED unit the LED series were moved forward with in the light housing in such a manner that it is within a range of 10 mm from the photometer.

Bonding of brackets (control group)

Teeth were then acid etched for 15 seconds, as per manufacturer's instructions with 37 % phosphoric acid ; rinsed with water for 15 seconds and air dried for 5 seconds to produce a chalky enamel surface. Adhesive primer was applied and polymerized using single tip LED curing unit. Trans bond XT composite resin was applied to the base of the bracket by a single operator, and was cured with single tip curing unit for 15 seconds.(fig 10)

Bonding of brackets (experimental group)

Acid etching, rinsing and drying done,(fig 14,15) similar to the control group. Half of the arch was then blocked with a partitioner to ensure that the light does not pass on to the covered portion. Rest of the arch was then applied with the adhesive primer and cured with cluster LED unit for 15 seconds. Brackets were positioned on the teeth using a bracket positioner with the help of a bracket gauge and then lightly pressed. Excess adhesive was then removed. Samples of experiment group1 were then cured with cluster LED unit for 15 seconds. Same procedures were repeated for experimental group 2 except that bracket curing was done for 30 seconds instead of 15 seconds. The other half of the arch was then bonded blocking, the bonded half-arch from light exposure. While curing with cluster LED unit, precautions were taken to ensure that the LED light source was positioned with in a range of 10 mm from the bonding surface.(fig 16,17)

Preparation of experimental group before testing

After bonding, the teeth in the experimental groups were set in the acrylic blocks similar to the control group. Light purple coloured dye was used for experimental group 1(fig 19) and light bluish green colour was used for experimental group 2(fig 20).

Testing the sample

After bonding, the specimens were kept in distilled water for 24hrs before testing the shear bond . The mechanical testing was performed using a universal testing machine (UTM) (fig 21). Each specimen was stressed at the junction of the bracket and adhesive in an occluso gingival direction (parallel to long axis of tooth) with a 50 kg load cell of 0.5 mm/ min until the brackets were debonded (fig 22). After bond strength testing, all specimens were visually examined with a stereomicroscope at 10x magnification(fig 23,24) by a single examiner to assess the adhesive remnant scores and enamel fracture pattern.

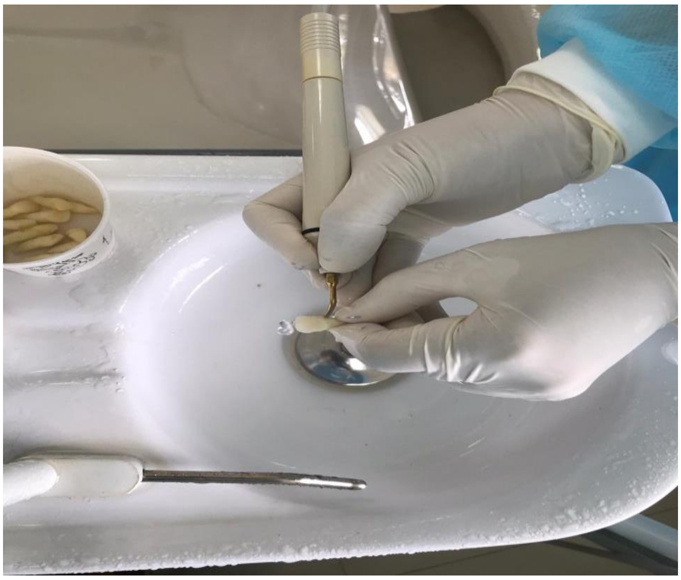


FIG 1: Performing ultrasonic scaling of collected teeth sample

FIG 2 : Making of tooth embedded acrylic blocks

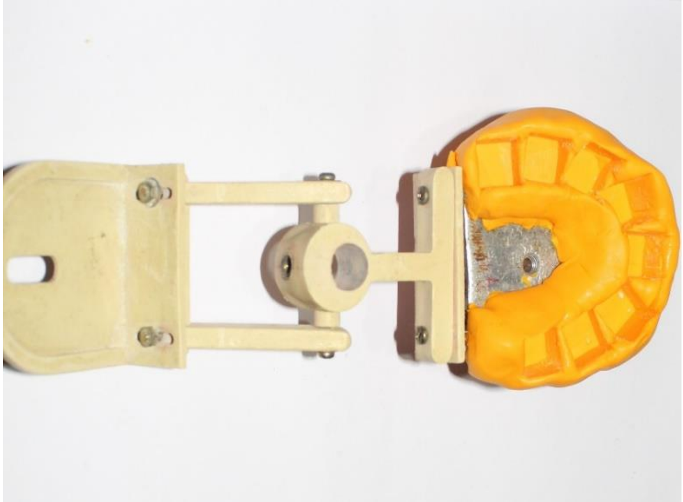


FIG 3: Jig for placing the control group in an arch form

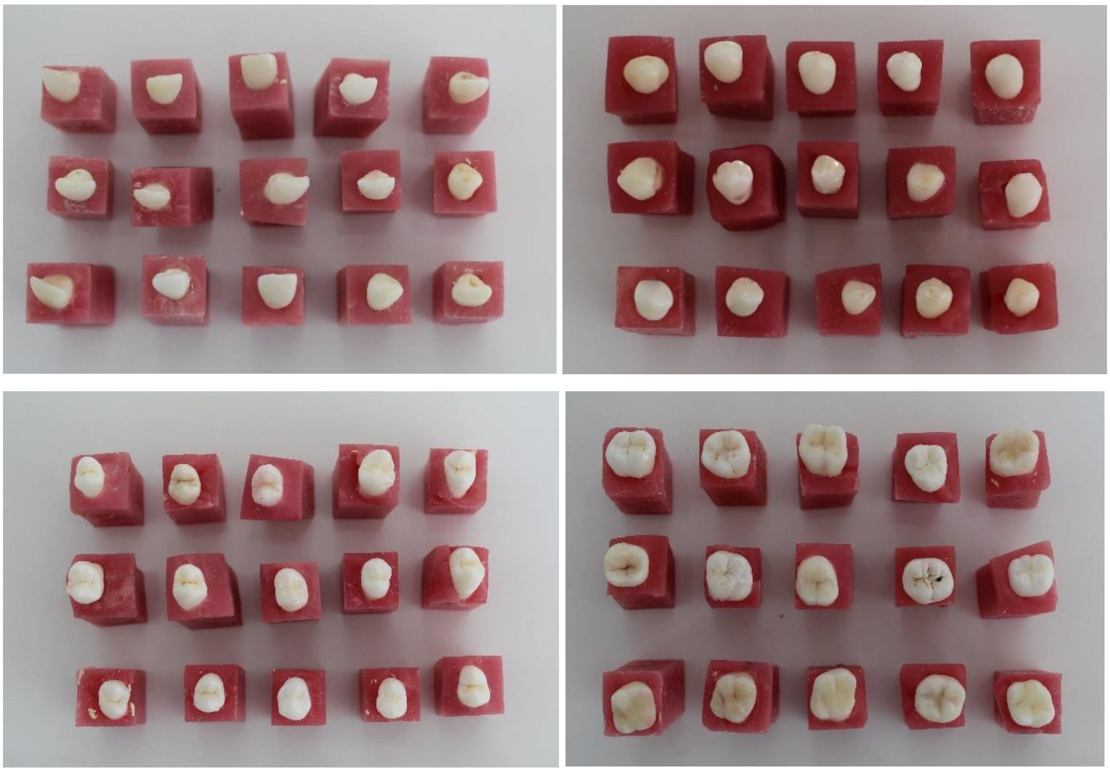


FIG 4 : Control group samples mounted in acrylic blocks

FIG 5 :Control group samples set in arch form

FIG 6 :Samples (control) fixed on to phantom head

FIG 7a: Bonding materials- Etchant, Brush for applying the bonding agent Bonding agent and Composite

FIG 7b: Bonding instruments- Mouth mirror, tweezer, bracket positioner, bracket gauge, probe

FIG 8: Blue phase LED unit for curing control group samples

FIG 9: Checking the light intensity

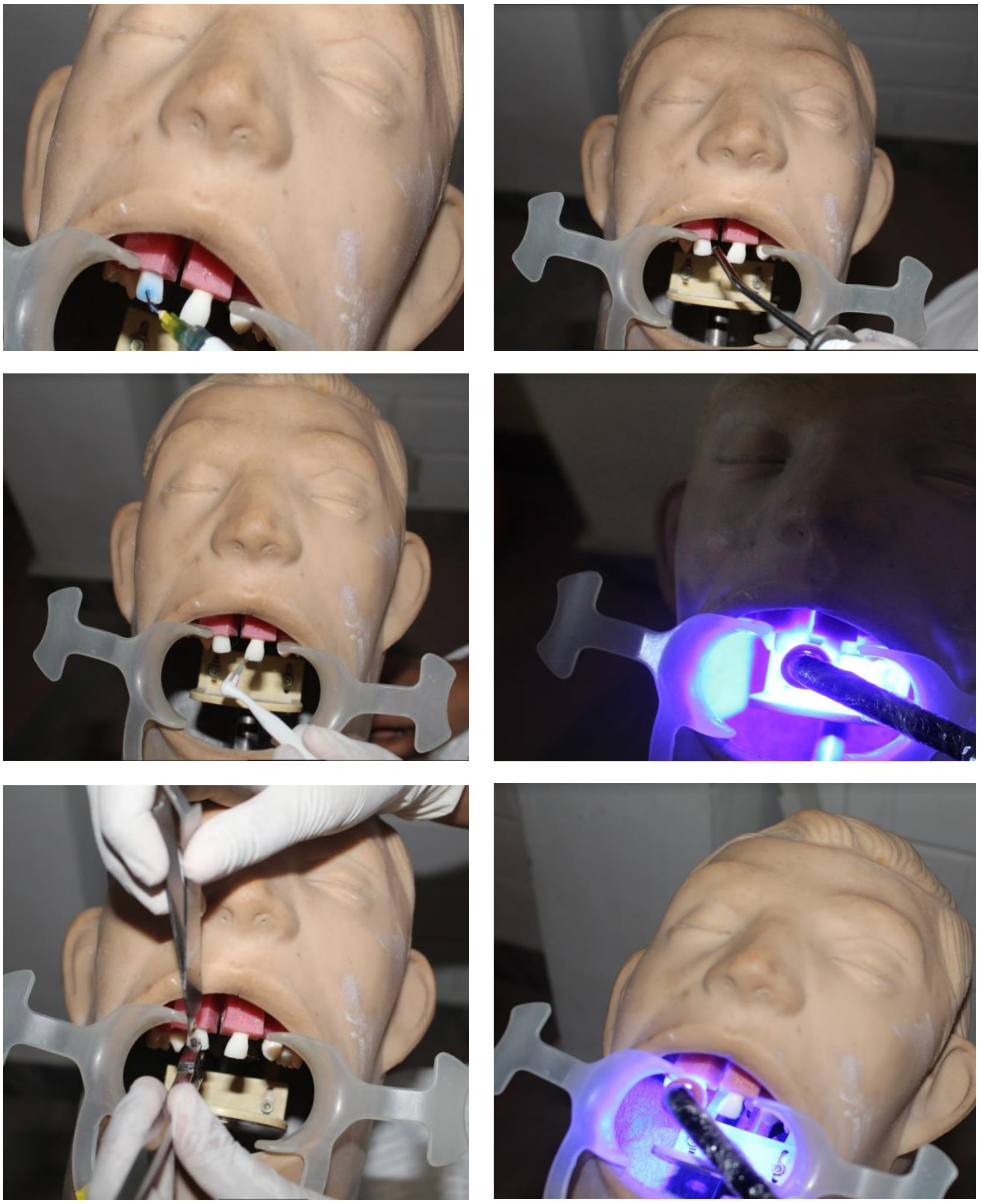


FIG 10: Steps in bonding, a)Etching b)Rinsing c)Applying bonding agent d)Light curing of bonding agent e)bracket positioning d)light curing of bracket.

FIG 11:Sinsational smile bleaching unit for curing the experimental group.

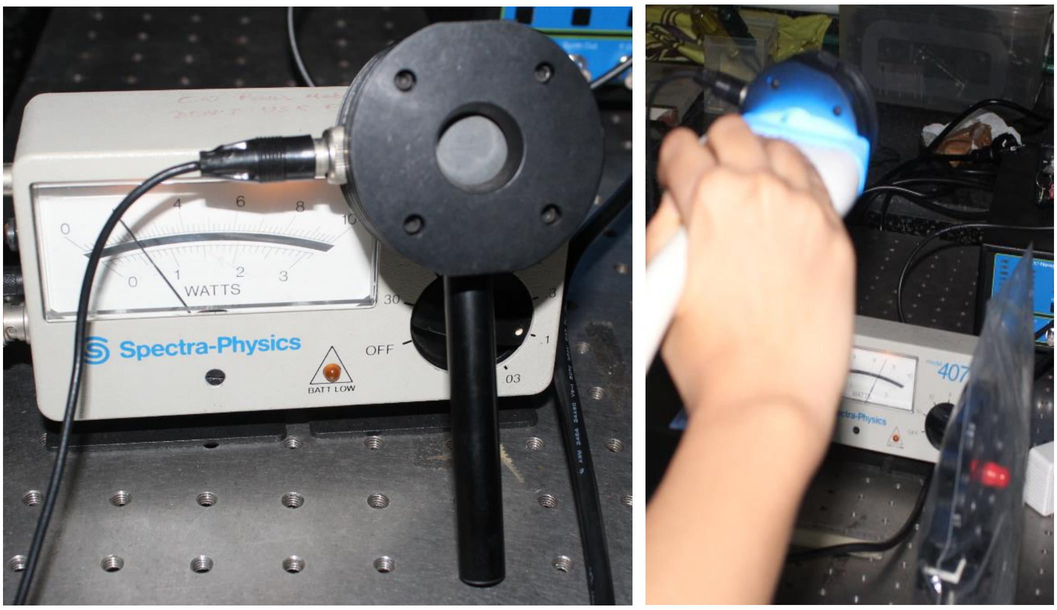


FIG 12: Photometer to check the intensity of cluster LED curing unit

FIG 13: Experiment group sample set in arch form

FIG 14 : Etching of experimental group

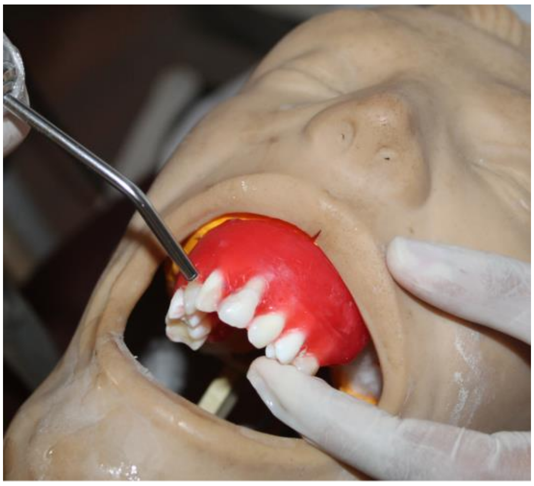


FIG 15: Rinsing of etchant

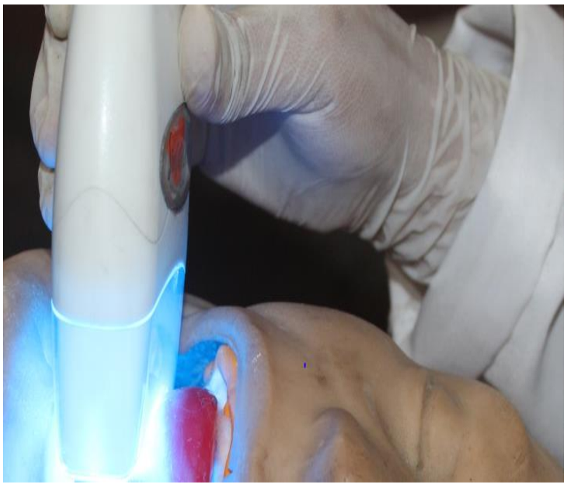


FIG 16: Curing after application of bonding agent

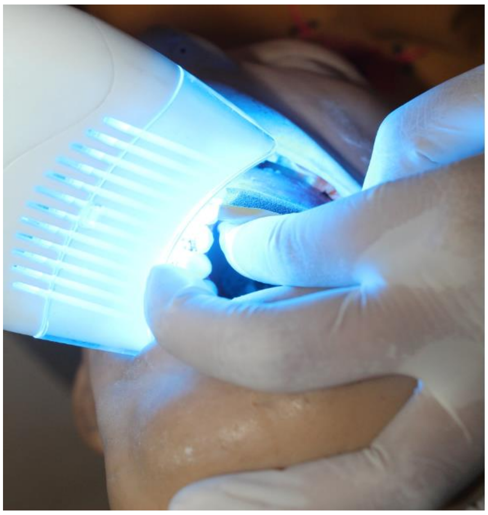
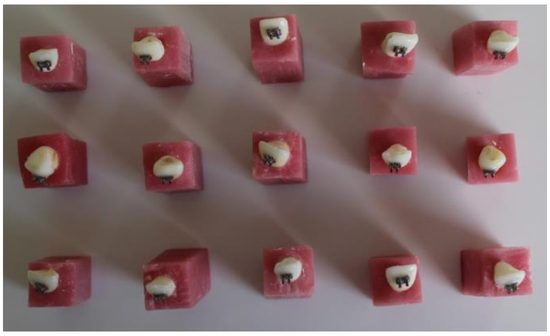
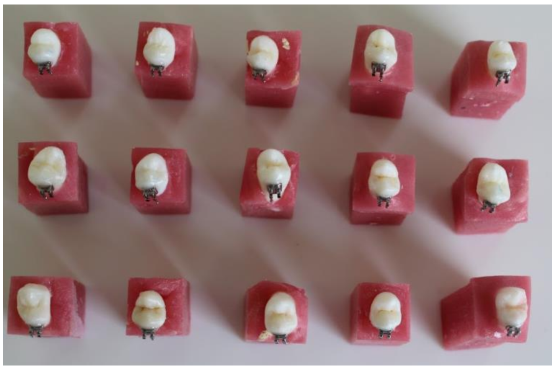


FIG 17: Light curing the metallic brackets



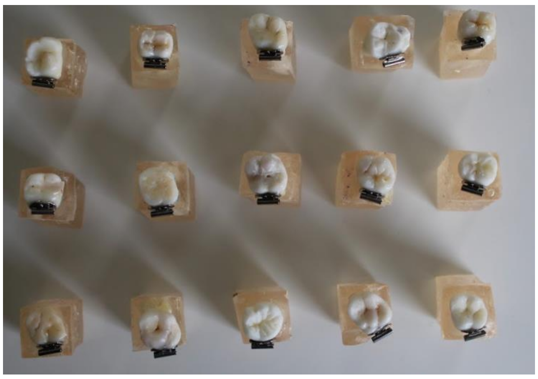

A B




C D

FIG 18: control group after bonding(a)incisors (b)canines (c)premolars (d)molars


A B

C D

FIG 19: Experimental group 1 after bonding(a)incisors (b)canines (c)premolars (d)molars

A **B**

C D

FIG 20 : Experimental group 2 after bonding(a)incisors (b)canines (c)premolars (d)molars

FIG 21: universal testing machine

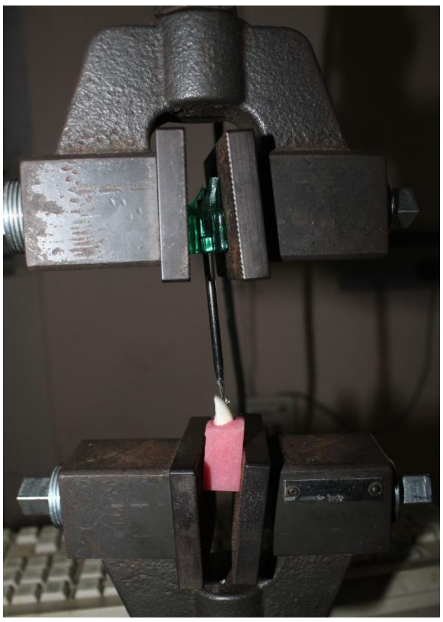


FIG 22: Testing of shear bond strength

FIG 23: Optical stereomicroscope

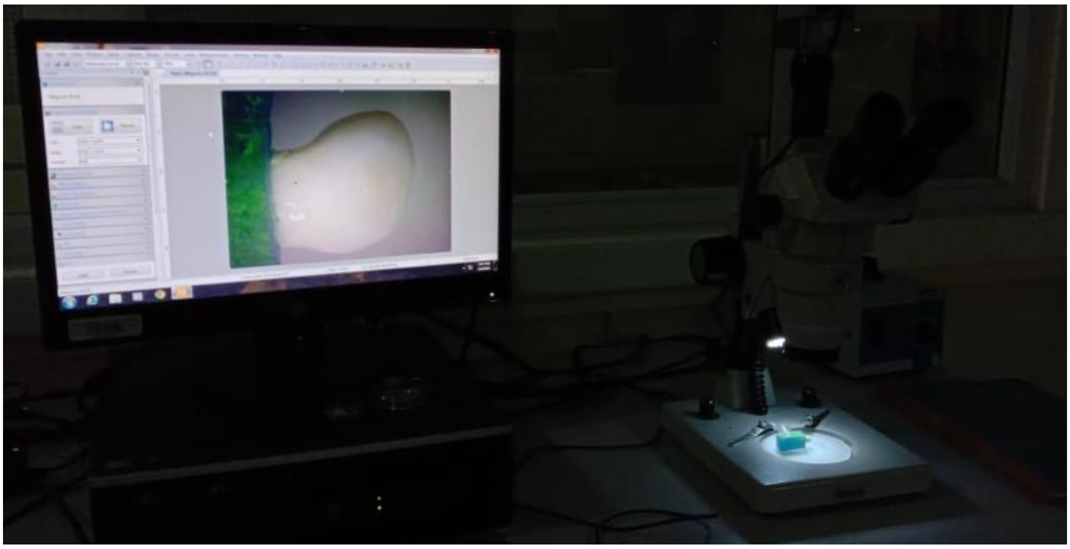
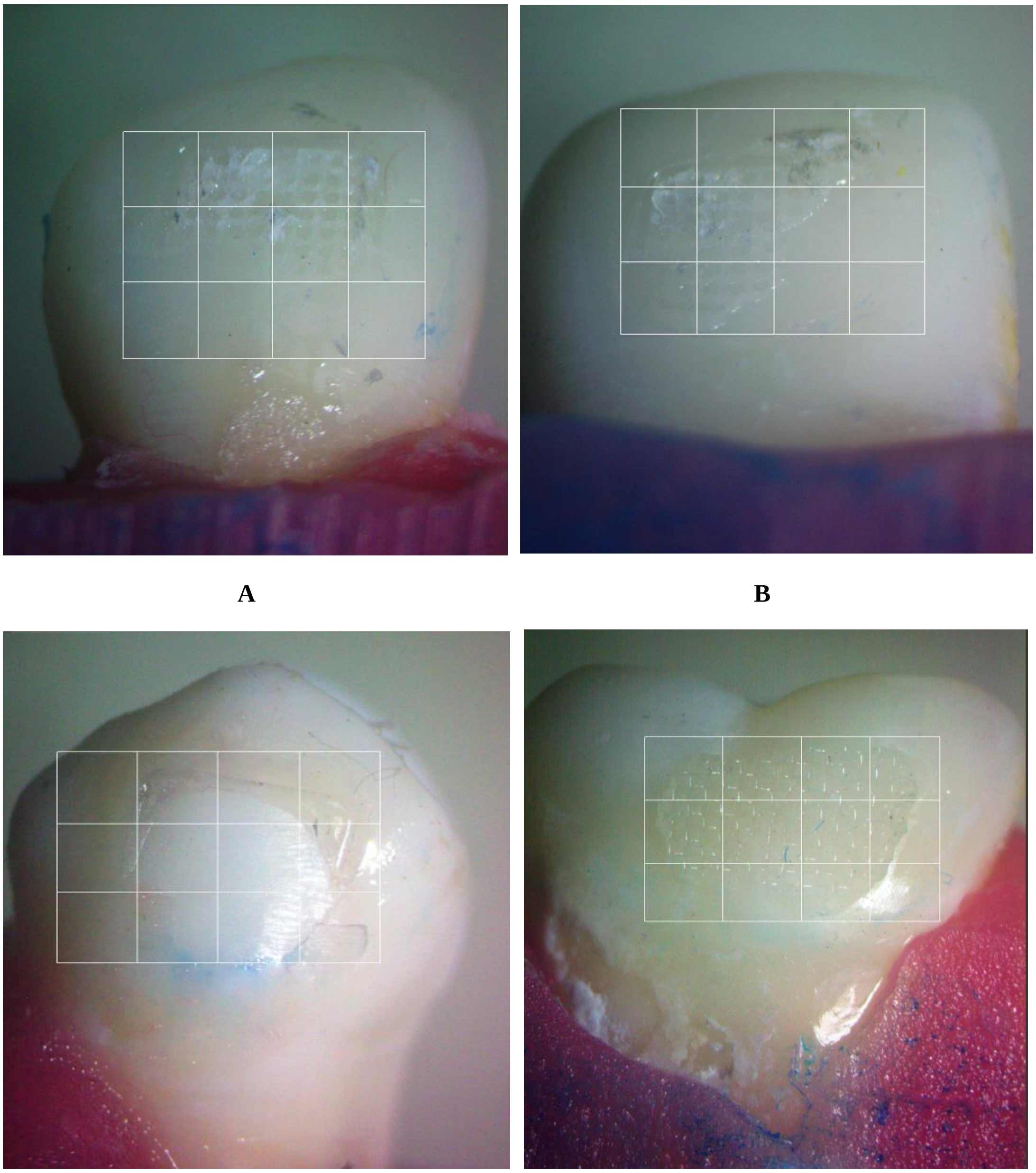


FIG 24:Visualizing the Adhesive Remanants using Optical stereomicroscope



A B

C D

FIG 25: Adhesive remnants on tooth surface visualised at 10x magnification using an optical stereomicroscope and grids for assessing the scores. Control group (a)incisors (b)canines (c)premolars (d)molars

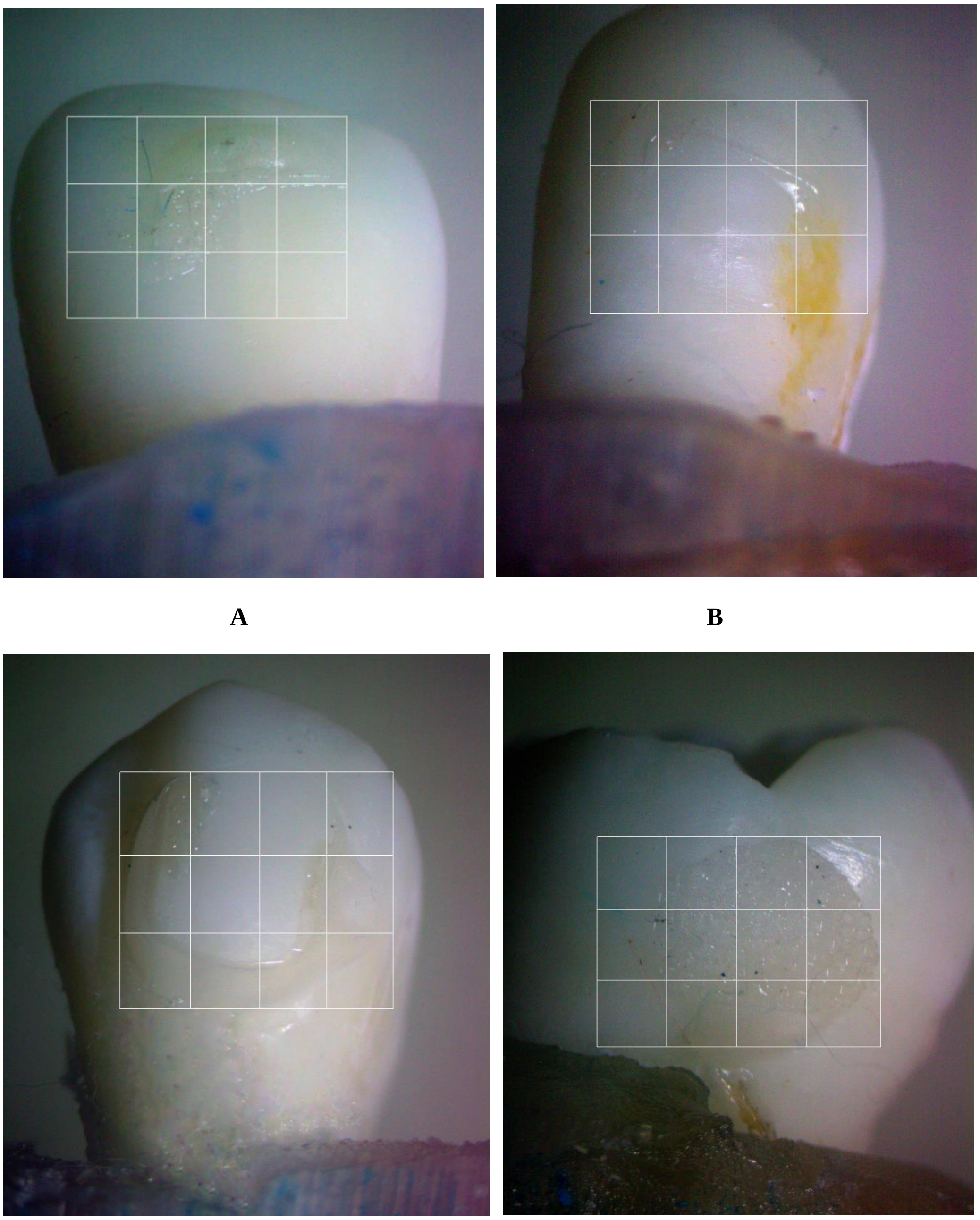
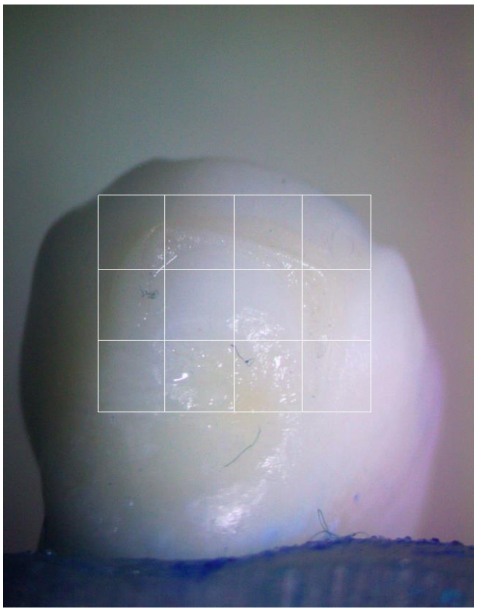
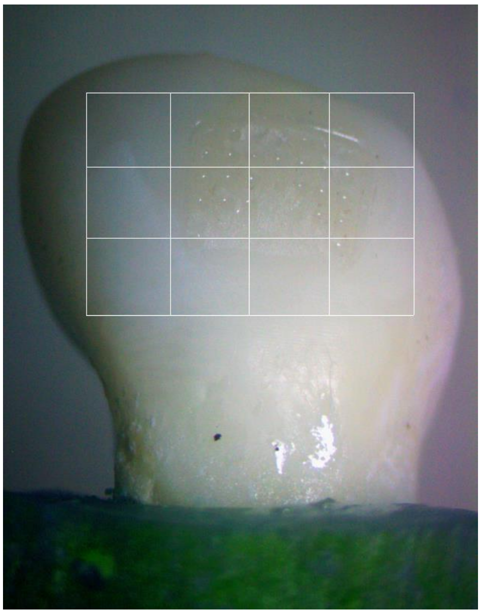


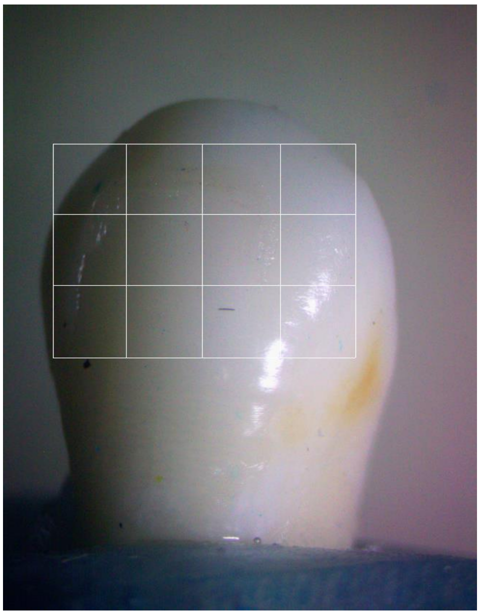
FIG 26: Adhesive remnants on tooth surface visualised at 10x magnification using an optical stereomicroscope and grids for assessing the scores. Experimental group1 (a)incisors (b)canines (c)premolars (d)molars



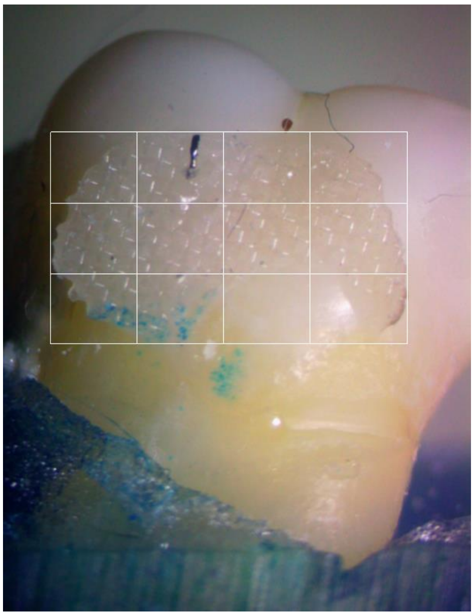
A



B



C



D

FIG 27: Adhesive remnants on tooth surface visualised at 10x magnification using an optical stereomicroscope and grids for assessing the scores. Experimental group2 (a)incisors (b)canines (c)premolars (d)molars

Results

RESULTS

This study involved comparison of shear bond strength of orthodontic brackets on maxillary teeth cured with single tip LED curing unit and cluster LED unit. It also compared the adhesive remnant index after the orthodontic brackets were debonded. The study basically had three main groups, the control group which included the samples cured with single tip LED unit for 15 seconds and two experimental groups in which the samples were cured with cluster LED light curing unit for 15 seconds and 30 seconds respectively. Each main group was divided in to 4 sub groups based on the tooth type as incisors, canines, premolars and molars group.

SHEAR BOND STRENGTH MEAN AND SD- CONTROL GROUP

CONTROL GROUP	MEAN(Mpa)	SD
Group 1	13.23	2.863
Group 2	13.73	2.062
Group 3	13.99	3.109
Group 4	13.35	2.936

TABLE 6: The mean shear bond strength of 15 samples (incisors ,canine, premolar and molar teeth in the control group

SHEAR BOND STRENGTH MEAN AND SD- EXPERIMENTAL GROUP 1

EXPERIMENTAL GROUP 1	MEAN(Mpa)	SD
Group 5	9.385	1.699
Group 6	9.784	0.768
Group 7	9.993	1.826
Group 8	8.843	1.712

TABLE 7: The mean shear bond strength of 15 samples (incisors, canine, premolar and molar) in the Experimental group l

SHEAR BOND STRENGTH MEAN AND SD- EXPERIMENTAL GROUP 2

EXPERIMENTAL GROUP 2	MEAN(Mpa)	SD
Group 9	11.440	1.143
Group 10	12.028	2.221
Group 11	12.023	2.121
Group 12	11.549	1.249

TABLE 8: The mean shear bond strength of 15 samples (incisors ,canine, premolar and molar) in the Experimental group 2

FREQUENCY DISTRIBUTION OF THEADHESIVE REMNANT INDEX

GROUPS ARI SCORES	0 (no adhesive left on tooth)	1 (less than half on tooth)	2 (more than half on tooth)	3 (all left on tooth)	X2 VALUE	P VALUE
GROUP 1(control incisor)	0	5(33.3%)	8(53.3%)	2(13.3%)	**5.92**	0.74
GROUP 2(control canine)	0	5(33.3%)	9(60.1%)	1(6.6%)		
GROUP 3(control pre molar)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP 4(control molar)	0	6(40%)	8(53.3%)	1(6.6%)		

GROUP 5(E1 incisor)	2(13.3%)	7(46.6%)	6(40%)	0	**7.81**	
GROUP 6(E1 canine)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP 7(E1pre molar)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP 8(E 1 molar)	2(13.3%)	4(26.6%)	9(40%)	0		
GROUP 9(E2 incisor)	0	6(40%)	8(53.3%)	1(6.6%)	**182.06**	0.001*
GROUP 10(E2canine)	0	6(40%)	9(40%)	0		
GROUP 11(E2pre molar)	1(6.6%)	7(46.6%)	7(46.6%)	0		
GROUP 12(E2 molar)	**1(6.6%)**	**6(40%)**	**8(53.3%)**	**0**		

TABLE 9 : Frequency distribution of Adhesive remnant index
E1 EXPERIMENTAL GROUP 1
E2 EXPERIMENTAL GROUP 2

STATISTICAL ANALYSIS

Data was analysed using the statistical package SPSS 22.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Statistical analysis to find out the difference before-after the groups was done using One way ANOVA with Tukey's HSD post hoc test to assess the difference within the group.

Comparison of mean shear bond strength within the control group

CONTROL GROUP	MEAN	SD	F value	P value
Group 1	13.23	2.863	0.1885	0.903
Group 2	13.73	2.062		
Group 3	13.99	3.109		
Group 4	13.35	2.936		

Table 10 : Comparison of mean shear bond strength of incisors ,canine, premolar and molar in the control group

*p<0.05 is statistically significant

Post hoc test tukey's HSD – comparison within the control group

COMPARISON		P VALUE
Group 1	Group 2	0.95
Group 1	Group 3	0.99
Group 1	Group 4	0.99
Group 2	Group 3	0.88
Group 2	Group 4	0.98
Group 3	Group 4	0.92

Table 11: Post hoc test tukey's HSD – comparison of mean shear bond strength of incisors ,canine, premolar and molar in the control group

Comparison of mean shear bond strength within the experimental group1

EXPERIMENTAL GROUP 1	MEAN	SD	F value	P value
Group 5	9.385	1.699	1.577	0.204
Group 6	9.784	0.768		
Group 7	9.993	1.826		
Group 8	8.843	1.712		

Table 12: comparison of mean shear bond strength of incisors ,canine, premolar and molar in the experimental group 1

*p<0.05 is statistically significant

Post hoc test tukey's hsd – comparison within the experimental group 1

COMPARISON		P VALUE
Group 5	Group 6	0.89
Group 5	Group 7	0.71
Group 5	Group 8	0.77
Group 6	Group 7	0.98
Group 6	Group 8	0.35
Group 7	Group 8	0.19

Table 13: Post hoc test tukey's HSD – comparison of mean shear bond strength of incisors ,canine, premolar and molar in the experimental group 1

Comparison of mean shear bond strength within the experimental group 2

EXPERIMENTAL GROUP 2	MEAN	SD	F value	P value
Group 9	11.440	1.143	0.475	0.700
Group 10	12.028	2.221		
Group 11	12.023	2.121		
Group 12	11.549	1.249		

Table 14: comparison of mean shear bond strength of incisors ,canine, premolar and molar in the experimental group 2

*p<0.05 is statistically significant

Post hoc test tukey's hsd – comparison within the experimental group2

COMPARISON		P VALUE
Group 9	Group 10	0.79
Group 9	Group 11	0.79
Group 9	Group 12	0.99
Group 10	Group 11	0.98
Group 10	Group 12	0.87
Group 11	Group 12	0.87

Table 15: Post hoc test tukey's HSD – comparison of mean shear bond strength of incisors ,canine, premolar and molar in the experimental group 2

Comparison of mean shear bond strength between the sub groups in the three main groups did not show any statistical significance indicating that the bond strength achieved by incisors, canines , premolars and molars didn't vary depending up on the tooth structure and location in any of the main group. The mean shear bond strength within in the groups were comparable.

COMPARISON OF MEAN SHEAR BOND STRENGTH BETWEEN THE SUB GROUPS OF THE THREE MAIN GROUPS

GROUP/ TEETH		CONTROL GROUP	EXPERIMENT GROUP 1	EXPERIMENT GROUP 2	F VALUE	P VALUE
INCISORS	MEAN	13.23	9.385	11.440	13.504	0.0001*
	SD	2.863	1.699	1.143		

Table 16: Comparison between the incisor teeth of all the three groups

INCISORS		P VALUE
Group 1 (control)	Group 5 (EXP 1)	0.0001*
Group 1(Control)	Group 9(EXP 2)	0.05
Group 5(EXP 1)	Group 9(EXP2)	0.02*

Table 17: Post hoc test tukey's hsd –comparison between the incisor teeth of all the three groups

*P</=0.05 IS STATISTICALLY SIGNIFICANT

GROUP/ TEETH		CONTROL GROUP	EXPERIMENT GROUP 1	EXPERIMENT GROUP 2	F VALUE	P VALUE
CANINES	MEAN	13.734	9.784	12.028	14.389	0.0001*
	SD	2.062	1.768	2.221		

Table 18: Comparison between the canine teeth of all the three groups

CANINES		P VALUE
Group 2 (control)	Group 6 (EXP 1)	0.0001*
Group 2(Control)	Group 10(EXP 2)	0.06
Group 6(EXP 1)	Group 10(EXP2)	0.01*

Table 19: Post hoc test tukey's hsd – comparison between the canine teeth of all the groups

*P</=0.05 IS STATISTICALLY SIGNIFICANT

GROUP/ TEETH		CONTROL GROUP	EXPERIMENT GROUP 1	EXPERIMENT GROUP 2	F VALUE	P VALUE
PREMOLAR	MEAN	13.99	9.78	12.02	13.183	0.0001*
	SD	3.109	0.76	2.221		

Table 20: comparison between the premolar teeth of all the three groups

PREMOLARS		P VALUE
Group 3 (control)	Group 7 (EXP 1)	0.0001*
Group 3(Control)	Group 11(EXP 2)	0.05
Group 7(EXP 1)	Group 11(EXP2)	0.02*

Table 21 : Post hoc test tukey's hsd – comparison between the premolar teeth of all the three groups

*P</=0.05 IS STATISTICALLY SIGNIFICANT

GROUP/ TEETH		CONTROL GROUP	EXPERIMENT GROUP 1	EXPERIMENT GROUP 2	F VALUE	P VALUE
MOLARS	MEAN	13.35	8.843	11.549	17.52	0.0001*
	SD	2.936	1.712	1.249		

Table22 : Comparison between the molar teeth of all the three groups

MOLARS		P VALUE
Group 2 (control)	Group 6 (EXP 1)	0.0001*
Group 6(Control)	Group 10(EXP 2)	0.05
Group 2(EXP 1)	Group 10(EXP2)	0.01*

Table 23: post hoc test tukey's hsd – comparison between the molar teeth of all the three groups

*P<0.05 IS STATISTICALLY SIGNIFICANT

COMPARISON OF ARI SCORES BETWEEN CONTROL AND EXPERIMENTAL GROUP 1

GROUPS ARI SCORES	**0 (no adhesive left on tooth)**	**1 (less than half on tooth)**	**2 (more than half on tooth)**	**3 (all left on tooth)**	**X2 value**	**P value**
GROUP1 (con incisor)	0	5(33.3%)	8(53.3%)	2(13.3%)	136.25	**0.0001***
GROUP2 (con canine)	0	5(33.3%)	9(60.1%)	1(6.6%)		
GROUP3 (con pm)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP4 (con molar)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP 5 (E 15 incisor)	2(13.3%)	7(46.6%)	6(40%)	0		
GROUP6 (E15 canine)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP7 (E15 pm)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP8 (E 15 molar)	**2(13.3%)**	**4(26.6%)**	**9(40%)**	**0**		

Table 24: Comparison between control and experimental group 1

COMPARISON OF ARI SCORES BETWEEN CONTROL AND EXPERIMENTAL GROUP 2

GROUPS ARI SCORES	0 (no adhesive left on tooth)	1 (less than half on tooth)	2 (more than half on tooth)	3 (all left on tooth)	X2 value	P VALUE
GROUP1 (con incisor)	0	5(33.3%)	8(53.3%)	2(13.3%)	86.23	**0.0001***
GROUP2 (con canine)	0	5(33.3%)	9(60.1%)	1(6.6%)		
GROUP3 (con pm)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP4 (con molar)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP 9(E30 incisor)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP10 (E30canine)	0	6(40%)	9(40%)	0		
GROUP11 (E30 pm)	1(6.6%)	7(46.6%)	7(46.6%)	0		
GROUP12 (E30molar)	**1(6.6%)**	**6(40%)**	**8(53.3%)**	**0**		

Table 25: Comparison between control and experimental group 2

COMPARISON OF ARI SCORES BETWEENEXPERIMENTAL GROUP 1AND EXPERIMENTAL GROUP 2

GROUPS ARI SCORES	**0 (no adhesive left on tooth)**	**1 (less than half on tooth)**	**2 (more than half on tooth)**	**3 (all left on tooth)**	**X2 VALUE**	**P VALUE**
GROUP 5 (E 15 incisor)	2(13.3%)	7(46.6%)	6(40%)	0	65.35	**0.0001***
GROUP6 (E15 canine)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP7 (E15 pm)	3(20%)	7(46.6%)	5(33.3%)	0		
GROUP8 (E 15 molar)	2(13.3%)	4(26.6%)	9(40%)	0		
GROUP9 (E30 incisor)	0	6(40%)	8(53.3%)	1(6.6%)		
GROUP10 (E30canine)	0	6(40%)	9(40%)	0		
GROUP11 (E30 pm)	1(6.6%)	7(46.6%)	7(46.6%)	0		
GROUP12 (E30molar)	**1(6.6%)**	**6(40%)**	**8(53.3%)**	**0**		

Table 26 :Comparison Between Experimental Group 1and Experimental Group 2

INTERPRETATION OF STATISTICAL ANALYSIS

Statistical analysis with One way ANOVA and Post Hoc Tukey's HSD test to compare the mean shear bond strength between the incisors(group1), canines(group2), premolars(group3), and molars(group4) in the control group showed no significant difference. Similar was the results on comparison of mean shear bond strength within the experimental group1; the incisors(group5), canines(group6), premolars(group7), and molars(group8) showed no significant difference. Even experimental group 2 also did not show any statistically significant difference on comparison of mean shear bond strength between incisors(group9), canines(group10), premolars(group11), and molars(group12).

One way ANOVA and Post Hoc Tukey's HSD test was done to compare the mean shear bond strength between the corresponding tooth of control group and experimental group 1 and 2.

On comparison of incisor groups, the control group (group1) and experimental group 1(group5) showed significant difference. Expeimental group 1(group5) and experimental group 2(group9) also showed significant difference, where as no significant difference was noted between the control group (group 1) and experimental group 2(group9)

Canine groups showed significant difference between control group(group2) and experimental group1(group 6) as well as experimental group1(group6) and experimental group2(group10). But control group(group2) and experimental group2(group6) showed no significant difference.

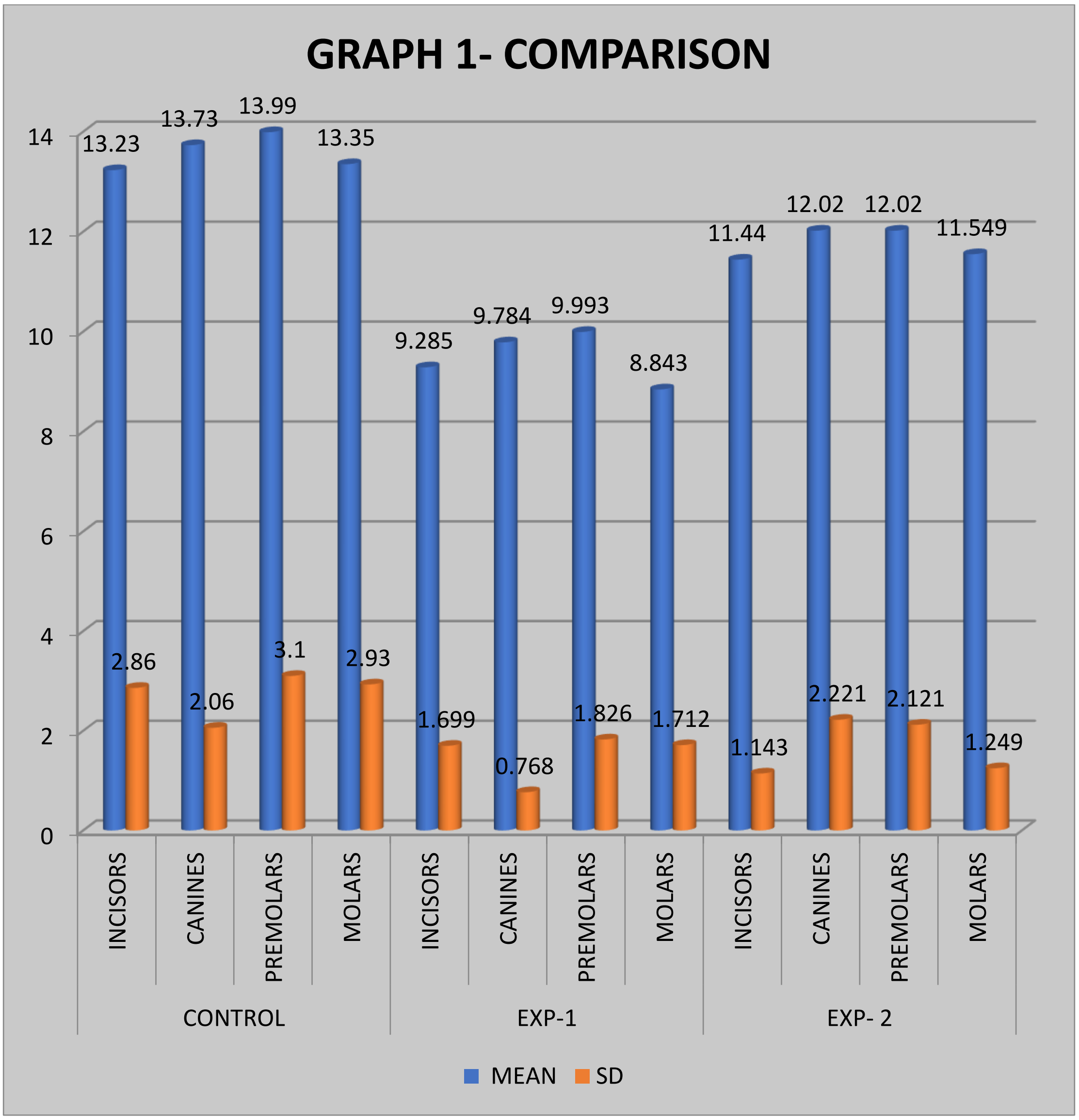
Comparison the shear bond strength of premolar groups, showed significant difference between the control group(group3) and experimental group 1(group7) and also experimental group 1(group7) and experimental group 2(group11). But there was no statistical difference between the control group(group3) and experimental group 2(group11).

Lastly the tests were also used to compare the molar groups and there was significant difference between the control group(group4) and experimental group1(group8). Simlilarly experimental group 1(group 8) and experimental group 2(group12) also showed significant difference. But there was no significant difference when control group(group4) and experimental group 2 (group12) were compared.

ARI scores showed significant difference on comparison between the three groups.

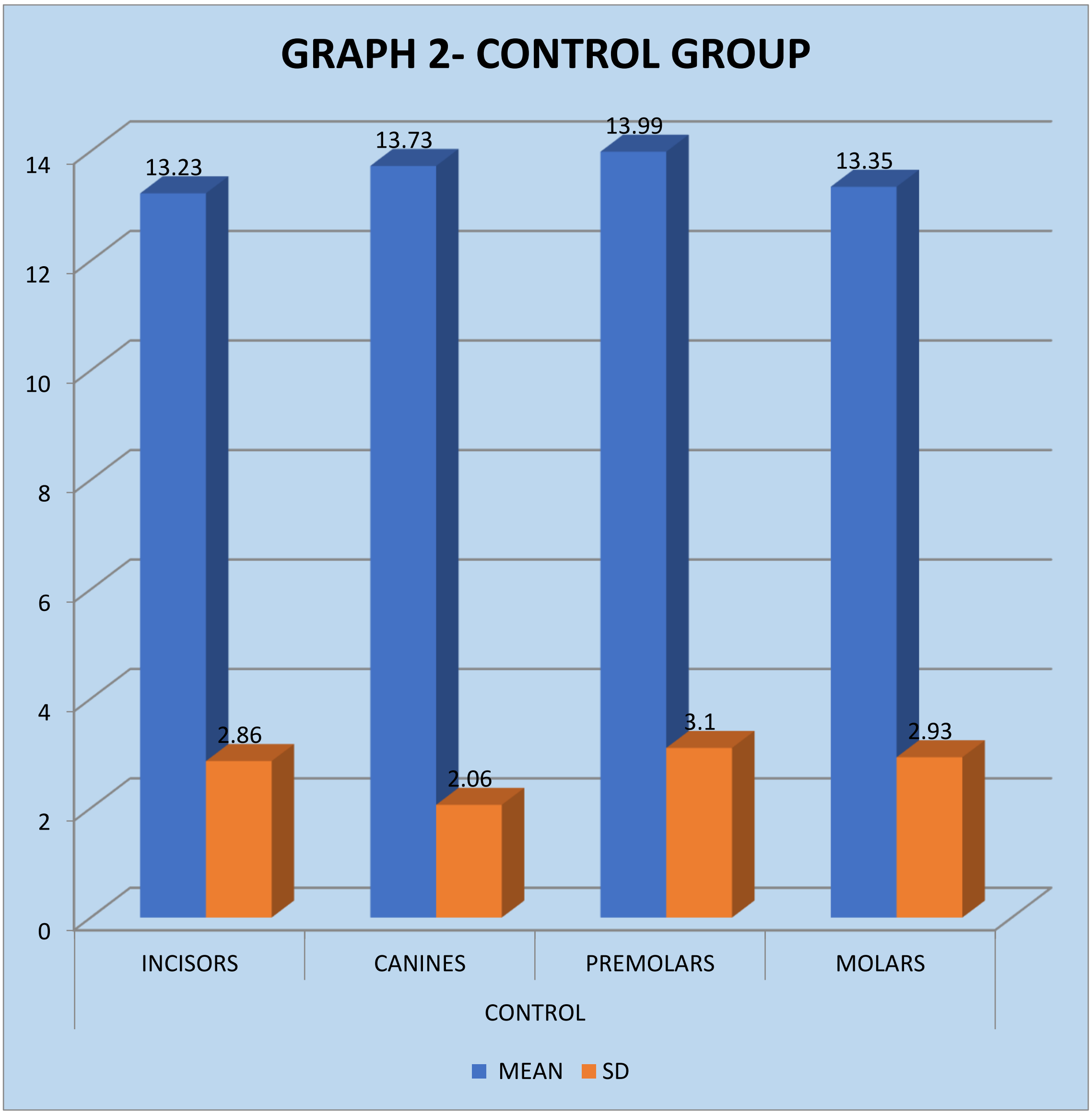
GRAPHS

COMPARISON OF SHEAR BOND STRENGTH BETWEEN THE GROUPS



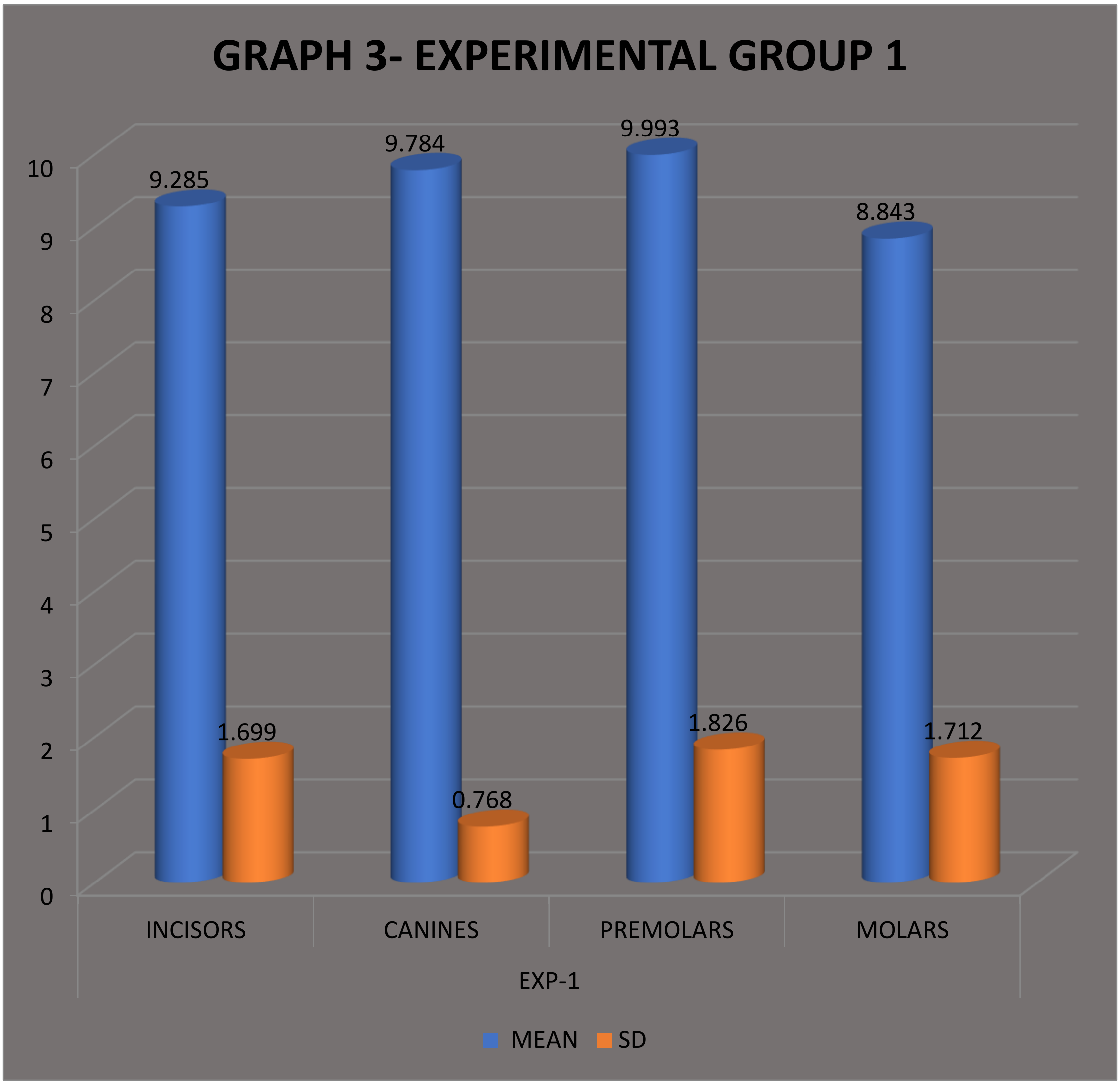
Graph 1: Comparison of shear bond strengthbetween the control group, experimental group 1 and experimental group 2

COMPARISON OF SHEAR BOND STRENGTH WITHIN THE CONTROL GROUP



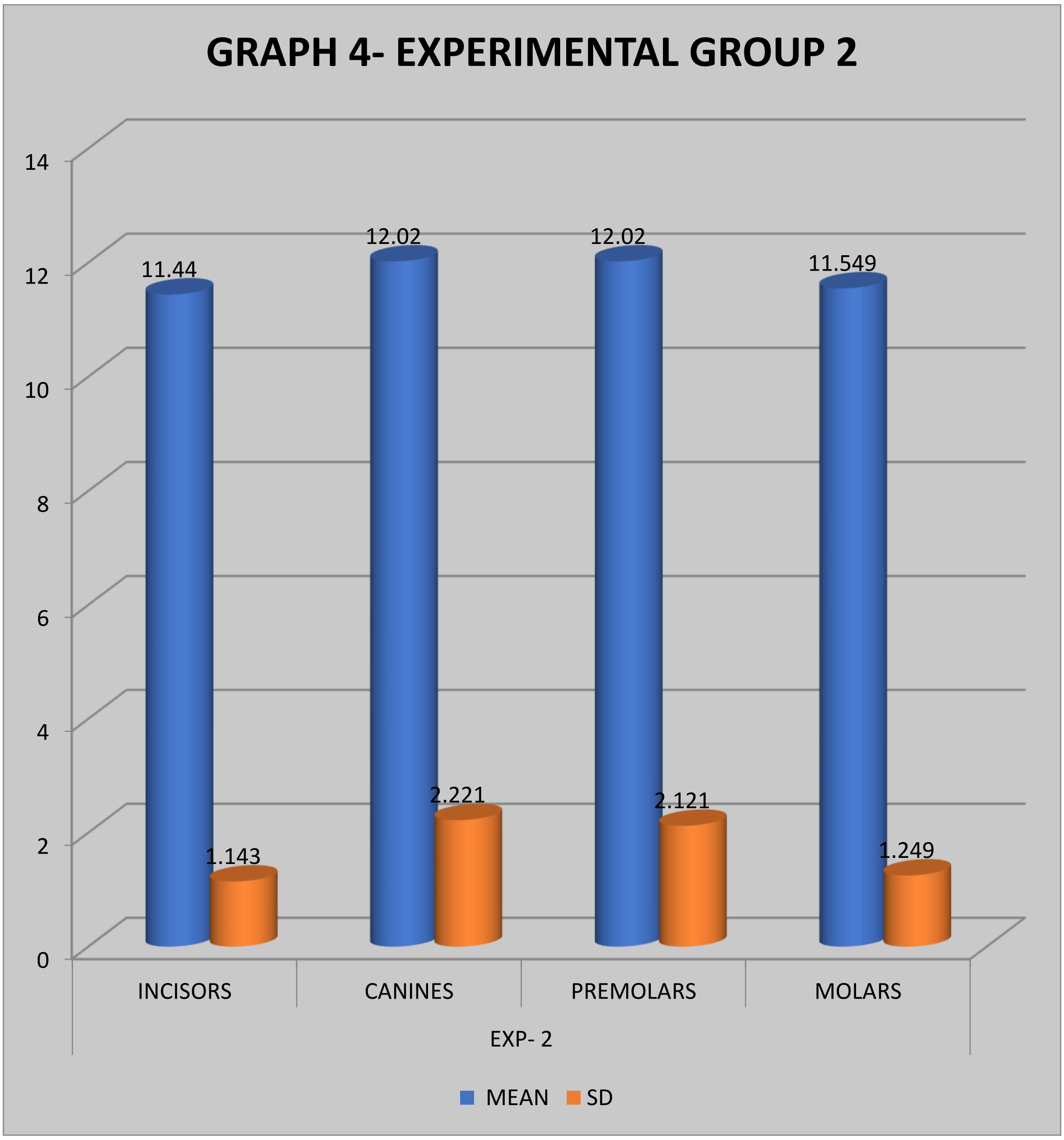
Graph 2: Comparisonof shear bond strength between the sub groups of control group

COMPARISON OF SHEAR BOND STRENGTH WITHIN THE EXPERIMENTAL GROUP



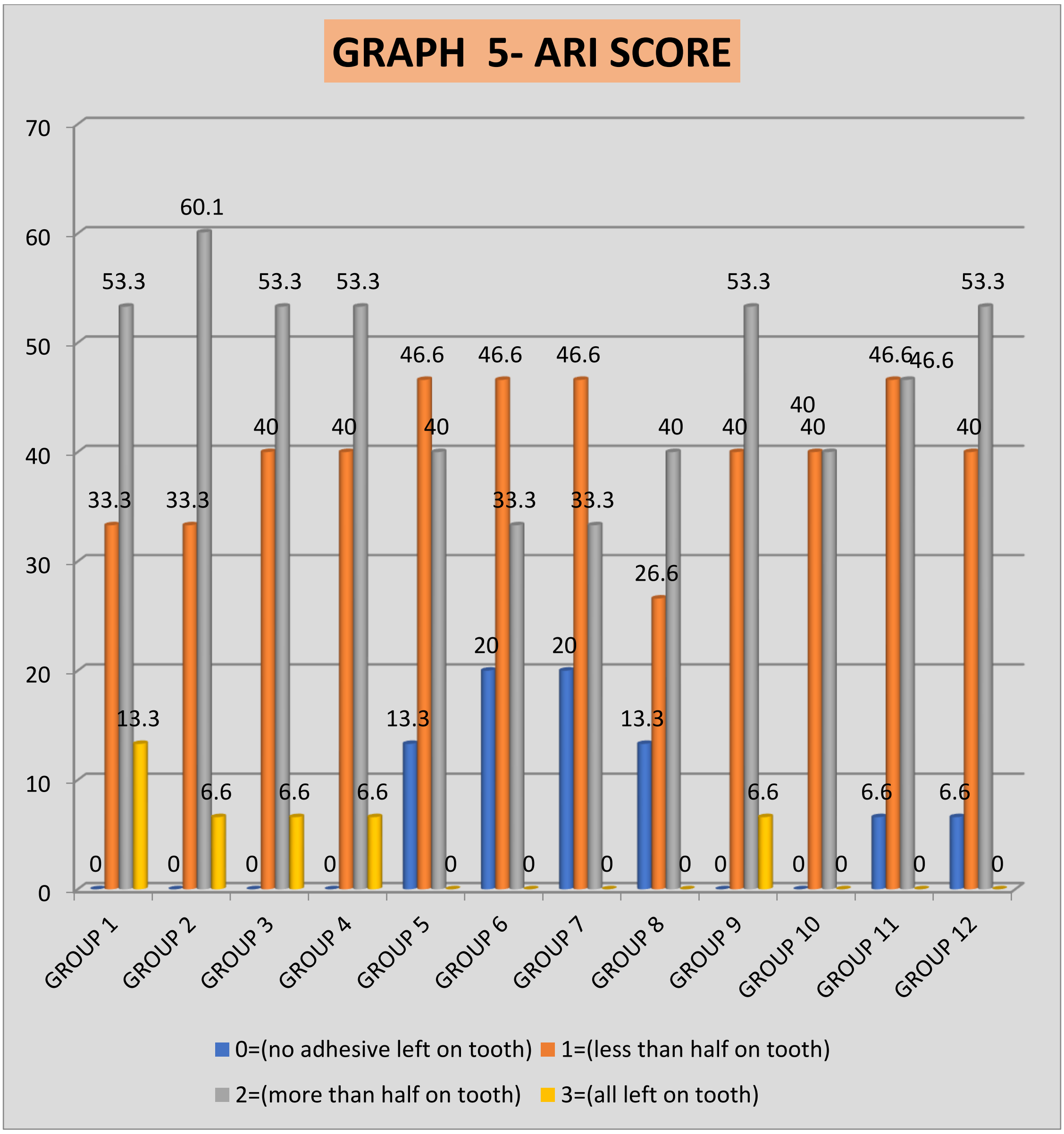
Graph 3: Comparison of shear bond strength between the sub groups of Experimental group 1

COMPARISON OF SHEAR BOND STRENGTH WITHIN THE EXPERIMENTAL GROUP 2



Graph 4: Comparison of shear bond strength between the sub groups of Experimental group 2

COMPARISON OF ARI SCORES



Graph 5 :comparison of ARI scores

Discussion

DISCUSSION

Bracket bonding is one of the most time-consuming procedure in orthodontic practice. Reducing the time required for light curing of orthodontic brackets would increase the treatment efficiency and improve patient comfort.[84]With the advent of photosensitive (light-cured) restorative materials in dentistry, various methods were suggested to enhance their polymerization and thereby to shorten the curing time, including the use of high intensity light-curing devices.[30]Several studies reported the use of high intensity light curing unit to shorten the curing time of orthodontic brackets[62, 84,85].Curing time can also be reduced ,by using light cure units that can cure multiple teeth simultaneously ,but only limited number of studies [14,21,80] were spotted in the scientific literature in this field. The purpose of this study was to cure multiple teeth at a shot using a cluster LED unit and to compare the shear bond strength of the metallic brackets so cured with the shear bond strength of brackets cured using a standard single tip LED unit of same wave length and of comparable intensity of light.

The samples of the control group cured with the single tip LED unit for 15 seconds had greater shear bond strength than that of the samples of experimental group, in which cluster LED unit was used to cure the samples for 15 seconds. The mean shear bond strength of different types of teeth in the control group were (table 6); incisors(13.23+/-2.863Mpa), canine(13.73+/-2.062Mpa), premolars (13.99+/-3.109Mpa), and molars (13.35+/-2.936Mpa). The teeth cured with the cluster LED unit for 15 seconds had shear bond strength of (table7) 9.385 +/-1.699 Mpa for incisor group, 9.784+/-0.768Mpa for canines, 9.993+/-1.826Mpa for Premolars and 8.843+/-1.712Mpa for molars. This is in accordance with the results of the study by Mariana Marquezan where in the shear bond strength of the brackets cured with standard LED unit for 20 seconds was greater than the samples cured with cluster LED unit for 20 seconds.[14]

The shear bond strength of those samples cured with cluster LED unit for 30 seconds had a comparable bond strength as that of control group. The incisors had a bond strength of(11.440+/-1.143Mpa), canines (12.028+/-2.221Mpa), premolars (12.023+/-2.121Mpa) and molars (11.549+/-1.249Mpa) (table 8) respectively and the difference was not statistically significant in any of the sub groups, that is, incisor (p value =0.05) (table 17), canine (p value =0.06) (table 19), premolar (p value =0.05) (table 21) and molar groups (p value =0.05) (table 23) when compared to the corresponding sub groups of control group.

The average values of shear bond strength in the experimental group in which orthodontic brackets were cured for a longer time (30 sec) was higher than the experimental group where in the samples were cured for 15 sec. These results were in agreement with that of the results of the study by Peutzfeldt and Asmussen in which they found an increase in shear bond strength with an increase in light-curing time[86]. Carine Maccarini also reported that with increasing exposure of time (5, 10 or 15 seconds) with the same LED unit there was a gradual increase in shear bond strength.[63]This relationship between time and bond strength may be due to the higher rates of monomer/polymer conversion that occur with the increase in light-curing time. Other authors have also reported similar findings[20,37]

This in vitro study also found that the shear bond strength of brackets bonded to teeth samples using the LED cluster light satisfied the optimal bond strength range of 5.8-7.8 Mpa as reported by Reynolds[15] and 8 to 9 Mpa as suggested by Di Nicoló R[87].

In a clinically innovative study by Akshatha Vasudevamurthy[80], a prototype light-curing unit was developed with multiple LED units which allows multiple teeth to be cured at a shot, reducing the curing time by an additional one-third. Similarly, in this study, the cluster LED unit reduced the time required for curing and at the same time satisfied the mean shear bond strength. The equipment cured four teeth in an arch simultaneously for 15 sec and attained a mean bond strength in the range of 9 Mpa (table 7) and for 30 sec curing a mean shear bond strength in the range of 11 Mpa(table 8) respectively compared to the mean bond strength of 13 Mpa in the control group(table 6) , which took 15 sec to cure single tooth, and a total of 60 sec to cure four teeth. Hence experimental group 1 took only one-fourth of the time and experiment group 2 took half of the time for curing compared to the curing time for control group.

The results of this study hence suggests that the cluster LED curing light may be a useful adjunct to reduce the time necessary to bond an orthodontic appliance to a dental arch with light-polymerized composites.

Nkenke E reported that bond strengths over 10 MPa have been associated with enlarged risk of enamel fracture during debonding[88]. And another study reported that bond strength higher than 14 MPa can cause enamel cracks on the tooth surface[15].In this study none of the samples showed enamel fracture. Both the control group and experimental groups showed values less than 14Mpa and only experimental group 1 had bond strength less than the range suggested by Nkenke.

Hobson in a previous study has reported, that in the upper arch, bond strength was greater on the anterior teeth than the posterior teeth[24]. Another study by Linklater and Gordon found that, upper incisors demonstrated a significantly lower mean shear bond strength than all the other teeth. [89]

But in the present study no significant difference in the mean shear bond strength was noted within the control group, experiment group1 and experiment group 2 respectively.

In control group, group 1(incisors) had a mean shear bond strength of 13.23+/-2.863Mpa, which was comparable to that of canine(13.73+/-2.062Mpa), premolars (13.99+/-3.109Mpa), and molars (13.35+/-2.936Mpa) (table 6).

Similarly, experiment group 1 also did not show much variation in mean shear bond strength within the group. Mean shear bond strength of incisor group was 9.385 +/-1.699 Mpa, canines 9.784+/-0.768Mpa, Premolars 9.993+/-1.826Mpa and molars 8.843+/-1.712Mpa (table 7).

The difference in mean shear bond strength of samples with in the experimental group 2 were also not statistically significant, with incisors having 11.440+/-1.143Mpa, canines 12.028+/-2.221Mpa, premolars 12.023+/-2.121Mpa and molars 11.549+/-1.249Mpa (table 8).

In this study, Adhesive Remnant Index (ARI) system by Artun and Bergland was used to evaluate the amount of adhesive left on the tooth after debonding.

The criteria used for scoring was:

score 0 = no adhesive remaining on the tooth;

score 1 = less than half of the adhesive remaining on the tooth;

score 2 = more than half of the adhesive remaining on the tooth; and

score 3 = all adhesive remaining on the tooth with a distinct impression of the bracket mesh.[90]

The ARI scores of this study differed between the groups that used different LED sources and different polymerization timings. This did not match the findings of studies by Usumez et al.[20] and Swanson [34]in which they reported no difference in the ARI scores when varying time-polymerization and LED sources. Thind et al[44]tested an LED source with a 10 s polymerization time and found that the ARI scores of mainly 2 and 3. In the present study ARI score evaluation showed that scores of 1 and 2 were more in all the 3 groups. Compared to the experimental groups, control group samples had more of ARI score 3 which indicated higher bond strength compared to other two groups which is in accordance with results of Faria-Júnior ÉM which reports that high ARI scores have been associated with higher bond strengths.[91] Experimental Group 1 had more of lower ARI scores of 0 compared to the other two groups. These low ARI scores (0 and 1) have been considered favourable by some authors.[26,92] Since there is less adhesive to remove from the tooth surface and, thus less risk of iatrogenic damage during enamel polishing. Studies have been conducted over this matter, since the literature contains conflicting reports of whether low ARI scores are desirable or not. [92]

Bond failures at the enamel-adhesive interface has been considered desirable by some authors,[26,92] as this would result in less amount of adhesive to remove from the surface of enamel after debonding. In addition to longer chair side time, adhesive remnant removal from surface of the tooth may also cause surface scratches, cracking and loss of sound enamel[92]. Experiment group 1 and experiment group 2 had less ARI scores of 3 in this study, indicating that less amount of time is required in these two groups to remove the remnants compared to the control group which had more samples with ARI score 3. Hence experimental group 2, apart from having comparable bond strength to control group, makes the adhesive remanent removal easier and contributes in saving the chair side time for adhesive removal.

In a study by Kimberly Gronberg on the distance and time effect on Shear Bond Strength of Brackets, no statistically significant difference was noted between mean shear bond strength at 1 or 10 mm of source to specimen distance[42]. In another study, Meyer GR , analysed the decrease in power output of a new light emitting diode curing devices with increasing distance to filling surface and concluded that LED lights showed significant decrease in power output at 10mm from light tip compared with Quartz tungsten halogen units.[31]In the current study, intensity of cluster LED unit was checked using a photometer placed at the maximum closest distance (within the range of 10 mm) from the LED units, same as where the teeth samples were placed for curing and a reduction in intensity was noted to 800mW/cm^2 compared to manufacturer value of 2000mW/cm^2. This decrease in intensity is not so less to cure the brackets, as Rueggeberg has recommended an intensity of at least 400 mW/cm^2 to achieve an optimal bond strength.[4] Distance between composite and light sources could affect composite polymerization because the irradiance of a point light source decreases as an inverse square function of distance.[42] So much of reduction in intensity has not happened with the cluster LED unit. This could be because the source of light was not a point source.

A study conducted by Yoav Shapinko on the bond Strength of Orthodontic Bracket cement cured using bleaching light, concluded that simultaneous full-arch curing of orthodontic bracket cement using a bleaching light is clinically acceptable in all, except the most posterior locations along the dental arch[21]. In their study the curing of orthodontic brackets was done from the front region, so the amount of light reaching the posterior region was less compared to that reached on the anterior teeth.

The present study had the advantage of comparable shear bond strength with in the control and experimental groups as in this study half-arch curing was done by blocking the light penetration in the contralateral side, ensuring equal amount of light reaching in the anterior and the posterior regions. Therefore the resultant bond strength was comparable within the control and experimental groups samples.

Many studies used bovine teeth as a substitute for human teeth for testing the shear bond strength. Stefan Rüttermann concludes that solely conducted shear bond strength studies on bovine substrate are not sufficient to judge the performance of adhesives, thus bovine teeth are questionable as a substrate for shear bond testing.[67] Another study by L J Oesterle found that the bond strength to bovine enamel was 21% to 44% weaker than to human enamel.[23]Taking this in to consideration, this study included only natural human teeth.

In this study, bonded brackets were stored in distilled water for 24 hours before testing as it has been reported in the literature that a latency period of 24 hours after bonding increases the setting time of the light-cured adhesives [93,94]. Allowing setting for 24 hours [95] to 7 days [96]increases the shear bond strength.

This study was also an invitro study. To obtain clinically relevant results from *in vitro* studies, it is essential to stimulate precise clinical condition. However, this is a difficult and an unrealistic goal considering the numerous variables involved on *in vivo* environment[97,98,99,100]. Hence the majority of studies over dental adhesives remain *in vitro*[98.]

K L Pickett conducted a study to compare in-vivo and in-vitro orthodontic bond strengths. The results indicated that mean bond strengths recorded in vivo following comprehensive orthodontic treatment were significantly lower than bond strengths recorded in vitro.[101] Another study conducted by Stephen to compare in vivo and in vitro shear bond strength also indicated differences between bond strength testing in vitro and in vivo[67].

Eliades T reported that most bond strength studies fit into the invitro study category because performing in-vitro tests are much easier and there is also reasonably good control on the study design[100]

The present study was conducted in an in-vitro set up similar to what has been recommended for *in vitro* bond strength studies in Orthodontics.[102] Distilled water at 37 °C for 24 hours was used to store all the samples after bracket bonding. The shear bond strength test was then performed with crosshead speed of 0.5 mm/min and the results were expressed in MPa and ARI as proposed by Artun and Bergland was used.

In vitro results of some authors suggested that the use of light curing units with higher irradiance values than 1,200 mW/cm^2 may harm the pulp tissue.[103]

In a recently conducted study by Alexandra Vinagre on Pulp temperature rise induced by Light-Emitting Diode light-curing units using an ex vivo Model in different curing modes reported that, pulp temperature rise was higher than 5.0 °C for the high-energy curing modes. The low-intensity modes induced approximately a 2.5 °C rise. A strong positive correlation was found between the energy density and pulp temperature increase .[104]

In this study the light intensity of the single tip LED unit and cluster LED unit were checked using a photometer and a reading of 850mW/cm^2 and 800mW/cm^2 were obtained. Both these values were lesser compared to the intensity of light mentioned in the literature that can cause pulpal damage, but the study did not include any direct method to check the pulpal damage if any.

LIMITATIONS OF THE STUDY

1. As this study was done in an in-vitro set up , the results cannot be conclusive as the oral environment is entirely different and the orthodontic force loading is done immediately after the bracket bonding.

2. The cluster LED unit used in the study was not a point source of light .So accurate measurement of light reaching on individual tooth was difficult to measure.

3. As light is emitted from a curved surface, the accurate measurement of distance from the tooth was difficult to assess.

4. Due to the difficulty in collecting natural human teeth only 4 type of teeth were included in the half arch for curing instead of a full complement of normal teeth. So a detailed analysis on a complete dental arch was not achieved.

5. Pulpal changes induced by the curing equipment was not tested.

6. A cluster LED unit of this design cannot be used for direct curing of lingual brackets.

FUTURE SCOPE OF THE STUDY

This study gives a ray of hope for inventing a standardized light cure unit of suitable design with cluster of LED units having an intensity of light that does not endanger the pulpal tissue and which can cure multiple teeth simultaneously. In addition the design should permit the placement of the device at the maximum closest distance from the teeth to be cured to ensure adequate bond strength.

For better and accurate measurements of shear bond strength, the study has to be conducted in an in-vivo environment. This can evaluate the other factors influencing the shear bond strength of the orthodontic brackets. Effect of immediate loading can also be studied more accurately.

Conclusion

CONCLUSION

The shear bond strength of the orthodontic brackets cured using cluster LED light curing unit satisfied the optimal bond strength range as reported in the literature. Brackets cured with cluster LED unit for longer curing time of 30 seconds had shear bond strength comparable to that of the standard single tip LED unit. No difference in shear bond strength was noted with variation in tooth type. The study used a cluster LED unit for curing in a half arch pattern. It was noted that the shear bond strength didn’t vary depending up on the location of tooth.

With 30 seconds of curing time using the cluster LED unit there was a reduction in the time taken to cure the same number of teeth up to 50 % compared to a single tip LED unit. There was also a reduction of one fourth of the time using a cluster LED with 15seconds of curing time.

Therefore the cluster LED unit can be considered as a useful adjunct for curing the orthodontic brackets during bonding procedures.

References

REFERENCES

1. P Gange.The evolution of bonding in orthodontics.Am J Orhod Dentofacial Orthop.2015;147:S56-63.

2. Strassler HE.Cure depths using different light units. Dental Town Magazine 2002, August:22-24.

3. Rueggeberg FA.State-of-the-art:dental photocuring-a review.Dent Mater. 2011 Jan;27(1):39-52.

4. Daokar S, Hadole P. Light-curing unit (devices). International Journal of Orthodontic Rehabilitation. 2019;10(3):121.

5. Chaukse A, Dubey R, Agrawal N, Jain A.A review of orthodontic curing lights. Indian J Stomatol 2013;4:40-4.

6. Malhotra N, Mala K.Light curing considerations for resin based composite materials: A review. Part I.Compend Contin Educ Dent.2010;31:498-505.

7. Radzi Z,Yahya NA,Zamzam N,Wood DJ.Light curing units:Tips for orthodontists.Annal Dent Univ Malaya.2004;11:13-23.

8. International Organization for Standardization. ISO 4049:2000. Dentistry-Polymer Based Filling, Restorative and Luting Materials. 3rd ed. Geneva, Switzerland: International Organization for Standardization; 2000.

9. de Gee AJ, ten Harkel-Hagenaar E, Davidson CL. Color dye for identification of incompletely cured composite resins. J Prosthet Dent 1984;52:626-31.

10. Lange C, Bausch J, Davidson C. The Curing Pattern Of Photo-Initiated Dental Composites. Journal Of Oral Rehabilitation. 1980;7(5):369-377.

11. Yearn JA. Factors affecting cure of visible light activated composites.Int Dent J.1985;35:218-25.

12. Mills RW, Jandt KD, Ashworth SH.Dental composite depth of cure with halogen and blue light emitting diode technology.Br Dent J 1999;186:388 91.

13. CacciafestaV, SfondriniMF, ScribanteA, BoehmeA, Jost BrinkmannPG.Effect of light tip distance on the shear bond strengths of composite resin.Angle Orthod 2005;75:386 91.

14. Marquezan M, Lau T, Rodrigues C, Sant'Anna E, Ruellas A, Marquezan M, Elias C.Shear bond strengths of orthodontic brackets with a new LED cluster curing light.J Orthod. 2010 Mar;37(1):37-42.

15. Reynolds I.A review of direct orthodontic bonding.Br J Orthod. 1975;2:171–178.

16. Rueggeberg FA, Caughman WF, Curtis JW, Jr.Effect of light intensity and exposure duration on cure of resin composite. Oper Dent 1994; 19: 2.

17. Dunn WJ, Taloumis LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. Am J Orthod Dentofacial Orthop 2002; 122: 236–41. 4.

18. Silta YT, Dunn WJ, Peters CB. Effect of shorter polymerization times when using the latest generation of light-emitting diodes.Am J Orthod Dentofacial Orthop 2005; 128: 744–48.

19. Turkkahraman H, Kucukesmen HC. Orthodontic bracket shear bond strengths produced by two high-power light-emitting diode modes and halogen light. Angle Orthod 2005; 75: 854–57. 7.

20. Usumez S, Buyukyilmaz T, Karaman AI. Effect of lightemitting diode on bond strength of orthodontic brackets.Angle Orthod 2004; 74: 259–63.

21. Shapinko Y, Eleftheriadi I, Shpack N, Davidovitch M, Bitsanis E, Matalon S, Brosh T.Bond Strength of Orthodontic Bracket Cement Using a Bleaching Light for Curing.Open Journal of Stomatology,2018, 8, 81-89.

22. Fox NA, McCabe JF, Buckley JG. A critique of bond strength testing in orthodontics.Br J Orthod 1994; 21: 33–43. 18.

23. Oesterle LJ, Shellhart WC, Belanger GK. The use of bovine enamel in bonding studies. Am J Orthod Dentofacial Orthop 1998; 114: 514–19.

24. R.S Hobson , J.F.Mc Cabe , S.D.Hogg. Bond strength to surface enamel for different tooth types.Dental materials.2001;171:84-189.

25. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 1955 Dec;34(6):849-53.

26. R W Mills.Blue light emitting diodes--another method of light curing?.Br Dent J 1995 Mar 11;178(5):169.

27. Bishara S E, Gordan V V, VonWald L, Jakobsen J R. Shear bond strength of composite, glass ionomer, and acidic primer adhesive systems.Am J Orthod Dentofacial Orthop 1999 Jan;115(1):24-8.

28. Sfondrini M F, Cacciafesta V, Pistorio A, Sfondrini G. Effects of conventional and high-intensity light-curing on enamel shear bond strength of composite resin and resin-modified glass-ionomer.Am J Orthod Dentofacial Orthop 2001 Jan;119(1):30-5.

29. Oesterle LJ, Newman SM, Shellhart WC.Comparative bond strength of brackets cured using a pulsed xenon curing light with 2 different light-guide sizes.Am J Orthod Dentofacial Orthop. 2002 Sep;122(3):242-50.

30. Bishara S E. Evaluation of a new curing light on the shear bond strength of orthodontic brackets.Clinical Trial.Angle Orthod 2003 Aug;73(4):431-5.

31. Meyer GR, Ernst CP, Willershausen B.Decrease in power output of new light-emitting diode (LED) curing devices with increasing distance to filling surface. J Adhes Dent. 2002;4(3):197-204.

32. Caldas DB, de Almeida JB, Correr-Sobrinho L, Sinhoreti MA, Consani S. Influence of curing tip distance on resin composite Knoop hardness number, using three different light curing units. Oper Dent. 2003 May-Jun;28(3):315-20.

33. Seema K Sharma-Sayal , P Emile Rossouw, Gajanan V Kulkarni, Keith C Titley. The influence of orthodontic bracket base design on shear bond strength.Am J Orthod Dentofacial Orthop 2003 Jul;124(1):74-82.

34. Swanson T, Dunn W, Childers D, Taloumis L. Shear bond strength of orthodontic brackets bonded with light-emitting diode curing units at various polymerization times. Am J Orthop and Dentofacial Orthop.2004;125(3):337-341.

35. Oyama N, K Akira, N Rizako.Evaluation of light curing units used for polymerization of orthodontic bonding agents.Angle Orthod 2004 Dec;74(6):810-5.

36. Kleverlaan CJ, de Gee Anton J.Curing efficiency and heat generation of various resin composites cured with high-intensity halogen lights. European journal of oral sciences. 2004. Feb;112;84-88.

37. Staudt CB, Mavropoulos A, Bouillaguet S, Kiliaridis S, Krejci.Light-curing time reduction with a new high-power halogen lamp.Am J Orthod Dentofacial Orthop.2005 Dec;128(6):749-54.

38. Silta T.Effect of shorter polymerization times when using the latest generation of light-emitting diodes comparative study.Am J Orthod Dentofacial Orthop. 2005 Dec;128(6):744-8.

39. Adrian U J Yap 1, M S Soh.Curing efficacy of a new generation high-power LED lamp.Oper Dent. Nov-Dec 2005;30(6):758-63.

40. Watts DC, Silikas N.In situ phototopolymerisation and polymerization shrinkage phenomena. Dental Hard Tissues and Bonding.2005;123-154.

41. Yazici R, Müftü A, Kugel G, Perry R D.Comparison of temperature changes in the pulp chamber induced by various light curing units, in vitro A Comparative Study.Oper Dent 2006Mar-Apr;31(2):261-5.

42. Gronberg K, Rossouw P E, Miller H, Buschang P. Distance and time effect on shear bond strength of brackets cured with a second-generation light-emitting diode unit. Angle Orthod2006 Jul;76(4):682-8.

43. Sfondrini M F.Effect of light-tip distance on the shear bond strengths of resin-modified glass ionomer cured with high-intensity halogen, light-emitting diode, and plasma arc lights.American journal of orthodontics and dentofacial orthopedics 2006 May 129(4):541-6.

44. Thind BS, Stirrups DR, Lloyd CH. A comparison of tungsten-quartz-halogen, plasma arc and light-emitting diode light sources for the polymerization of an orthodontic adhesive. Eur J Orthod. 2006 Feb;28(1):78-82.

45. Eliades T. Polymerization Lamps and Photocuring in Orthodontics. Seminrs in ortho. 2010;16(1):83-90.

46. Cacciafesta V, Sfondrini MF, Stifanelli P, Scribante A, Klersy C.The effect of bleaching on shear bond strength of brackets bonded with a resin-modified glass ionomer.Am J Orthod Dentofacial Orthop .2006 Apr;129(4):541-6.

47. Signorelli MD , Kao E , Ngan PW , Gladwin MA.Comparison of bond strength between orthodontic brackets bonded with halogen and plasma arc curing lights: An in-vitro and in-vivo study.Am J Orthod Dentofacial Orthop.2006 Feb;129(2):277-82.

48. Yamamoto A, Yoshida Ta, Keishi T, Takamizawa T, Kurokawa H, Miyazaki M.Orthodontic bracket bonding: enamel bond strength vs time.Am J Orthod Dentofacial Orthop.2006 Oct;130(4):435.e1-6.

49. Uzel A, Buyukyilmaz T, Kayalioglu M, Uzel I.Temperature Rise During Orthodontic Bonding With Various Light-curing Units—An In Vitro Study Angle Orthod (2006) 76 (2): 330–334.

50. Pandis N, Strigou S, Eliades T..Long-term failure rate of brackets bonded with plasma and high-intensity light-emitting diode curing lights :a clinical assessment Angle Orthod.2007 Jul;77(4):707-10.

51. Hajrassie MK, Khier SE. In-vivo and in-vitro comparison of bond strengths of orthodontic brackets bonded to enamel and debonded at various times. Am J Orthod Dentofacial Orthop..2007 Mar;131(3):384-390.

52. Baysal A, Uysal T, Ulker M, Usumez S .Effects of high-intensity curing lights on microleakage under bonded lingual retainers.Angle Orthod.2008 Nov;78(6):1084-8.

53. Durey K, Santini A, Miletic V. Pulp chamber temperature rise during curing of resin-based composites with different light-curing units. Prim Dent Care. 2008 Jan;15(1):33-8.

54. Carrasco TG, Carrasco-Guerisoli LD, Fröner IC. In vitro study of the pulp chamber temperature rise during light-activated bleaching.J Appl Oral Sci. 2008 Sep-Oct;16(5):355-9.

55. Krämer N, Lohbauer U, García-Godoy F, Frankenberger R.Light curing of resin-based composites in the LED era. Am J Dent. 2008.21:135-142.

56. Antonson SA, Antonson DE, Hardigan PC .Should my new curing light be an LED? Oper Dent Jul-Aug 2008;33(4):400-7.

57. Corciolani G, Vichi A, Davidson CL,Ferrari M.The influence of tip geometry and distance on light-curing efficacy.Oper Dent (2008) 33 (3): 325–331.

58. Mirabella D, Spena R, Scognamiglio G, Luca L, Gracco A, Siciliani G. LED vs halogen light-curing of adhesive-precoated brackets.Angle Orthod 2008 Sep;78(5):935-40.

59. Zhu S, Platt J A.Curing efficiency of three different curing lights at different distances for a hybrid composite. Am J Dent. 2009 Dec;22(6):381-6.

60. Rahiotis C, Patsouri K, Silikas N, Kakaboura A.Curing efficiency of high-intensity light-emitting diode (LED) devices. A.J Oral Sci. 2010 Jun;52(2):187-95

61. Rachala MR, Yelampalli MR.Comparison of shear bond strength of orthodontic brackets bonded with light emitting diode (LED).International journal of orthodontics (Milwaukee, Wis.) 2010December.21(4):31-5.

62. Cerekja E , Cakirer B.Effect of short curing times with a high-intensity light-emitting diode or high-power halogen on shear bond strength of metal brackets before and after thermocycling .Angle Orthod. 2011 May;81(3):510-6.

63. Dall'Igna C M, Marchioro E M, Spohr A M, Mota E G.Effect of curing time on the bond strength of a bracket-bonding system cured with a light-emitting diode or plasma arc light.Eur J Orthod 2011 Feb;33(1):55-9.

64. Wahbi M A, Aalam F A, Fatiny F I, Radwan S A, Eshan I Y, Al-Samadani K H. Characterization of heat emission of light-curing units.Saudi Dent J.2012 Apr;24(2):91-8.

65. Mota Júnior SL, da Silva Campos MJ, Gravina MA, Fraga MR, Vitral RWF.Prototype of a new tip developed to be coupled to dental light-curing units for optimizing bonding of orthodontic brackets and accessories.Dental Press J Orthod Nov-Dec 2013;18(6):112-6.

66. Neves MG, Brandão GAM, de Almeida HA, Brandão AMM, de Azevedo DR.In vitro analysis of shear bond strength and adhesive remnant index comparing light curing and self-curing composites. Dental Press J Orthod May-Jun 2013;18(3):124-9.

67. Rüttermann S, Braun A, Janda R. Shear bond strength and fracture analysis of human vs. bovine teeth. PLoS One. 2013;8(3):e59181.

68. Cantekin K, Buyuk SK.J .Shear bond strength of a new low-shrinkage flowable composite for orthodontic bracket bonding.Dent Child (Chic).2014 May-Aug;81(2):63-6.

69. Aksakalli S, Demir A, Selek M, Tasdemir S, Temperature increase during orthodontic bonding with different curing units using an infrared camera.Acta Odontol Scand. 2014 Jan;72(1):36-41.

70. Gomes P, Portugal J, Jardim, L. Effect of high-powered LED-curing exposure time on orthodontic bracket shear bond strength. Estomatol.Cir. Maxilofac. 2014.55:78-82.

71. Ward JD, Wolf BJ, Leite LP, Zhou J. Clinical effect of reducing curing times with high-intensity LED lights. Angle Orthod. 2015 Nov;85(6):1064-9.

72. Ramoglu SI, Karamehmetoglu H, Sari T, Usumez S. Temperature rise caused in the pulp chamber under simulated intrapulpal microcirculation with different light-curing modes. Angle Orthod (2015) 85 (3): 381–385A.

73. Armellin E, Bovesecchi G, Coppa P, Pasquantonio G, Cerroni L. LED Curing Lights and Temperature Changes in Different Tooth Sites. Biomed Res Int. 2016;2016:1894672.

74. Jang Y, Ferracane JL, Pfeifer CS, Park JW, Shin Y, Roh BD. Effect of Insufficient Light Exposure on Polymerization Kinetics of Conventional and Self-adhesive Dual-cure Resin Cements. Oper Dent. 2017 Jan/Feb;42(1):E1-E9.

75. Mondelli RF, Soares AF, Pangrazio EG, Wang L, Ishikiriama SK, Bombonatti JF.Evaluation of temperature increase during in-office bleaching. J Appl Oral Sci. 2016 Apr;24(2):136-41.

76. Chalipa J, Jalali YF, Gorjizadeh F, Baghaeian P, Hoseini MH, Mortezai O. Comparison of Bond Strength of Metal and Ceramic Brackets Bonded with Conventional and High-Power LED Light Curing Units. J Dent (Tehran). 2016 Nov;13(6):423-430.

77. Oz AA, Oz AZ, Arici S. In-vitro bond strengths and clinical failure rates of metal brackets bonded with different light-emitting diode units and curing times. Am J Orthod Dentofacial Orthop.2016 Feb;149(2):212-6.

78. Tiwari A, Shyagali T, Kohli S, Joshi R, Gupta A, Tiwari R. Effect of Dental Chair Light on Enamel Bonding of Orthodontic Brackets Using Light Cure Based Adhesive System: An In-Vitro Study.Acta Inform Med.2016 Oct;24(5):317-321.

79. Al-Khatieeb MM., Nahidh M, Al-Khawaja NFK.Effect of Reducing Curing Time on the Shear Bond Strength of Metal Orthodontic Brackets: An In Vitro Comparative Study.International Journal of Science and Research.2017June 6(6):201-206.

80. Akshatha MV, Shashikumar GM, Fakkirsab W, Singhvi A.An Innovative Light-Curing Unit for More Efficient Bonding. J Clin Orthod. 2019;53(12):732-736.

81. Dallel I, Lahwar S, Jerbi MA, Tobji S, Ben Amor A, Kassab A. Impact of adhesive system generation and light curing units on orthodontic bonding: In vitro study. Int Orthod. 2019 Dec;17(4):799-805.

82. Kabil SH, Haridy MF, Farid MR.Effect of High Light Intensity Bleaching Protocol versus Descending Light Intensities Bleaching Protocol on Post Bleaching Teeth Sensitivity: A Randomized Clinical Trial. Open Access Maced J Med Sci. 2019;7(13):2173-2181.

83. Groddeck AL, Schwestka-Polly R, Hecker H, Sostmann M. Temperatures in the pulpal cavity during orthodontic bonding using an LED light curing unit : An in vitro pilot study. J Orofac Orthop. 2020 Nov;81(6):396-406.

84. Almeida LF, Martins LP, Martins RP. Effects of reducing light-curing time of a high-power LED device on shear bond strength of brackets. J Orofac Orthop. 2018 Sep;79(5):352-358.

85. Palomares NB, Cal-Neto JP, Sampaio-Filho H, Almeida MA, Miguel JA. Effect of high-intensity LED units at reduced curing time on in vitro bond strength of orthodontic brackets.World J Orthod. 2008 Fall;9(3):203-8.

86. Peutzfeldt A, Asmussen E. Resin composite properties and energy density of light cure.J Dent Res. 2005 Jul;84(7):659-62.

87. Di Nicoló R, Araujo MA, Alves LA, Assunção e Souza RO, Rocha DM. Shear bond strength of orthodontic brackets bonded using halogen light and light-emitting diode at different debond times.Braz Oral Res.2010 Jan-Mar;24(1):64-9.

88. Nkenke E, Hirschfelder U, Martus P, Eberhard H.Evaluation of the bond strength of different bracket-bonding systems to bovine enamel.Eur J Orthod. 1997 Jun;19(3):259-70.

89. Linklater RA, Gordon PH. An ex vivo study to investigate bond strengths of different tooth types.J Orthod. 2001 Mar;28(1):59-65.

90. Artun, J. and S. Bergland.Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment.Am J Orthod 1984. 85:333–340.

91. Faria-Júnior ÉM, Guiraldo RD, Berger SB, Correr AB, Correr-Sobrinho L, Contreras EF, Lopes MB.In-vivo evaluation of the surface roughness and morphology of enamel after bracket removal and polishing by different techniques. Am J Orthod Dentofacial Orthop. 2015 Mar;147(3):324-9.

92. Chang WG, Lim BS, Yoon TH, Lee YK, Kim CW. Effects of salicylic-lactic acid conditioner on the shear bond strength of brackets and enamel surfaces. J Oral Rehabil. 2005;32(4):287–295.

93. Evans LJ, Peters C, Flickinger C, Taloumis L, Dunn W. A comparison of shear bond strengths of orthodontic brackets using various light sources, light guides, and cure times. Am J Orthod Dentofacial Orthop.2002 May;121(5):510-5.

94. Oesterle LJ, Messersmith ML, Devine SM, Ness CF. Light and setting times of visible-light-cured orthodontic adhesives. J Clin Orthod. 1995 Jan;29(1):31-6.

95. Brunhano, I.H.V, Fernander D,de Miranda S M, Artese F.Influence of Surface treatment on shear bond strength of orthodontic brackets. Dental Press Journal of Orthodontics.2013.18, 54-62.

96. Bishara S.E, Laffoon JF, VonWald L, Warren JJ. Evaluation of Non-Rinse Conditioning Solution and a Compomer as an Alternative Method of Bonding Orthodontic Bracket.The Angle Orthodontist.2001, 71, 461-465.

97. Finnema KJ, Ozcan M, Post WJ, Ren Y, Dijkstra PU. In-vitro orthodontic bond strength testing: a systematic review and meta-analysis.Am J Orthod Dentofacial Orthop. 2010;137(5):615–622.e3.

98. Murray SD, Hobson RS. Comparison of in vivo and in vitro shear bond strength. Am J Orthod Dentofacial Orthop. 2003;123(1):2–9.

99. Kokich VG. In-vitro vs in-vivo materials research. Am J Orthod Dentofacial Orthop. 2013 Apr;143(4 Suppl):S11.

100. Eliades T, Brantley WA. The inappropriateness of conventional orthodontic bond strength assessment protocols.Eur J Orthod. 2000 Feb;22(1):13-23. 1.

101. Pickett KL, Sadowsky PL, Jacobson A, Lacefield W.Orthodontic in vivo bond strength: comparison with in vitro results. Angle Orthod.2001 Apr;71(2):141-8.

102. Cal Neto JO,Miguel JA.An analysis of in vitro bond strength testing in Orthodontics. Rev Dental Press Ortod Ortop Facial. 2004;9(4):44–51.

103. Mouhat M, Mercer J, Stangvaltaite L, Ortengren U.Light-curing units used in dentistry: factors associated with heat development-potential risk for patients. Clin Oral Investig.2017;21(5):1687-96.

104. Vinagre A, Ramos JC, Rebelo C, Basto JF, Messias A, Alberto N, Nogueira R. Pulp Temperature Rise Induced by Light-Emitting Diode Light-Curing Units Using an Ex Vivo Model.Materials (Basel). 2019 Jan 29;12(3):411.

Annexures

ANNEXURES

Annexure 1. Shear bond strength of samples of control group

INCISOR GROUP (GROUP1) SAMPLES	SHEAR BOND STRENGTH (Mpa)	CANINE GROUP (GROUP 2) SAMPLES	SHEAR BOND STRENGTH (Mpa)	PREMOLAR GROUP (GROUP 3)	SHEAR BOND STRENGTH (Mpa)	MOLAR GROUP (GROUP4)	SHEAR BOND STRENGTH (Mpa)
1	14.646	1	13.783	1	13.834	1	13.563
2	14.747	2	15.765	2	14.674	2	15.833
3	15.022	3	13.803	3	13.839	3	13.453
4	14.893	4	13.945	4	15.834	4	14.023
5	14.075	5	14.639	5	13.403	5	14.374
6	15.098	6	14.649	`	13.735	6	13.673
7	14.743	7	15.784	7	14.823	7	14.865
8	13.343	8	13.303	8	15.001	8	13.901
9	15.009	9	13.007	9	13.984	9	14.678
10	13.465	10	13.342	10	15.449	10	13.869
11	13.509	11	14.709	11	13.409	11	14.638
12	14.836	12	13.934	12	15.037	12	13.749
13	13.745	13	15.135	13	14.473	13	15.011
15	14.954	15	14.734	15	13.901	15	14.089

Annexure 2.Shear bond strength of samples of control group

INCISOR GROUP (GROUP5) SAMPLES	SHEAR BOND STRENGTH (Mpa)	CANINE GROUP (GROUP 6) SAMPLES	SHEAR BOND STRENGTH (Mpa)	PREMOLAR GROUP (GROUP 7)	SHEAR BOND STRENGTH (Mpa)	MOLAR GROUP (GROUP8)	SHEAR BOND STRENGTH (Mpa)
1	9.009	1	7.4509	1	8.647	1	9.045
2	8.023	2	9.834	2	9.056	2	9.087
3	8.0023	3	9.659	3	9.657	3	7.994
4	9.784	4	8.984	4	8.943	4	7.823
5	9.834	5	7.0084	5	8.735	5	7.912
6	8.012	6	8.659	6	8.894	6	8.478
7	7.999	7	9.705	7	7.993	7	9.002
8	8.034	8	8.759	8	7.893	8	9.124
9	10.834	9	9.003	9	8.893	9	9.674
10	8.934	10	9.132	10	8.492	10	8.938
11	8.432	11	8.658	11	7.499	11	8.023
12	9.486	12	7.399	12	6.403	12	8.959
13	9.645	13	8.495	13	9.547	13	7.945
15	8.934	15	9.003	15	9.001	15	6.843

Annexure 3.Shear bond strength of samples of control group

INCISOR GROUP (GROUP1) SAMPLES	SHEAR BOND STRENGTH (Mpa)	CANINE GROUP (GROUP 2) SAMPLES	SHEAR BOND STRENGTH (Mpa)	PREMOLAR GROUP (GROUP 3)	SHEAR BOND STRENGTH (Mpa)	MOLAR GROUP (GROUP 4)	SHEAR BOND STRENGTH (Mpa)
1	12.895	1	11.213	1	11.856	1	12.309
2	12.509	2	11.564	2	11.044	2	11.938
3	11.984	3	12.089	3	12.093	3	11.783
4	10.437	4	12.313	4	12.786	4	11.222
5	11.675	5	12.004	5	11.708	5	12.396
6	11.753	6	11.946	`	12.869	6	12.307
7	12.894	7	11.067	7	11.087	7	11.993
8	11.786	8	11.856	8	11.985	8	11.846
9	12.476	9	11.987	9	11.786	9	11.674
10	12.695	10	12.756	10	12.336	10	12.009
11	13.759	11	11.901	11	11.076	11	11.901
12	11.659	12	11.002	12	12.078	12	10.999
13	12.438	13	10.849	13	11.998	13	11.938
14	12.658	14	11.001	14	12.002	14	12.002
15	11.743	15	11.944	15	11.067	15	11.453

Annexure 4 Adhesive Remnant Index scores

GROUPS / ARI SCORES	0 (no adhesive left on tooth)	1 (less than half on tooth)	2 (more than half on tooth)	3 (all left on tooth)
GROUP 1(con incisor)	0	5	8	2
GROUP 2(con canine)	0	5	9	1
GROUP 3(con pm)	0	6	8	1
GROUP 4(con molar)	0	6	8	1
GROUP 5(E 15 incisor)	2	7	6	0
GROUP 6(E15 canine)	3	7	5	0
GROUP 7(E15 pm)	3	7	5	0
GROUP 8(E 15 molar)	2	4	9	0
GROUP 9(E30 incisor)	0	6	8	1
GROUP 10(E30canine)	0	6	9	0
GROUP 11(E30 pm)	1	7	7	0
GROUP 12(E30molar)	1	6	8	0

ST. GREGORIOS DENTAL COLLEGE

UNDER THE MANAGEMENT OF MJSCE TRUST, PUTHENCRUZ

CHELAD , KOTHAMANGALAM, ERNAKULAM DIST, KERALA - 686681

ETHICAL CLEARANCE CERTIFICATE

SGDC/152/2018/3382/5 **Date:- 20-12-2018**

To,

Dr.AparnaAnand

St. Gregorios Dental College

Chelad, Kothamangalam

Dear Dr.AparnaAnand

Subject: Ethics Committee Clearance Reg.

protocol- Comparison of shear bond strength of orthodontic brackets on maxillary teeth using single tipped led curing unit and cluster led unit - An *in vitro* study

After the Institutional Ethics Committee (TEC) held on 19th of December 2018, this study was examined and discussed. After the consideration, the committee had 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. CKK Nair – Former BARC science**
2. **Dr.OmmenAju Jacob – Dean, St. Gregorios Dental College, Chelad**
3. **Dr.Cinu Thomas A – Scientist, Senior Lecturer, Department of Pharmaceutical Sciences Center for Professional and Advanced Studies**
4. **Rv. Fr. Shanu K. Paulose**
5. **Lissy Jose – Former Member Women's Welfare Association**
6. **Adv. Jose Aranjani – Advocate**
7. **Dr.Sauganth Paul – Senior Lecturer, Department of Biochemistry, St. Gregorios Dental College**
8. **Dr.EapenCherian – Secretary**
9. **Dr. Jain Mathew – Principal and Head of the Department, Department of Conservative Dentistry and Endodontics**
10. **Dr. George Francis – Head of the Department, Department of Prosthodontics Crown & Bridge**
11. **Dr.BinaoyKurian – Head of the Depaertment, Department of Orthodontics &Dentofacial Orthopeadics**

Dr. CKK Nair

Chairman Institutional Ethics Committee

St. Gregorios Dental College, Chelad

Dr. EapenCherian

Secretary

Phone : 0485-2572529, 530, 531, 2571429, Fax : 0485-2572530,
Email : sgdc@rediffmail.com, Web : sgdc.ac.in

Acknowledgement

ACKNOWLEDGEMENT

I owe my first expression of deepest gratitude to the **God Almighty** in whose name I started the journey and who has always been on my side in all my work showering His favours up on me.

I would like to express my infinite gratitude and indebtedness to my esteemed HOD, Professor, **Dr. Binnoy Kurian** for his valuable guidance, constant encouragement, sound advice, and wholehearted support throughout the course of my training as a post graduate student.

I sincerely thank **Dr. Tony Michael,** Professor, Department of Orthodontics and Dentofacial Orthopaedics for his noble support and guidance throughout this study.

I would like to express my sincere gratitude to my beloved teachers, **Dr. Renji K Paul and Dr. Abraham George**, for providing me every help and consistently propelling me to arrive at the completion.

Words would not suffice to express my indebtedness to **Dr. Aravind S Raju** ,the former faculty for the support and timely advices.

I would like to take this opportunity to thank **Dr. Mathew Jain and Dr. Deaby Miriam** for being very supportive.

My Heartfelt thanks to our esteemed principal **Dr. Jain Mathew** for his encouragement and support.

I am extremely thankful to Professor **Dr.A.Mujeeb** and Asst Professor **Dr.Ratheesh R**, Department of Photonics , Cochin University of Science and Technology, without them this study would not have been possible.

I am also thankful to **Dr Honey John**, Professor, Department of polymer science and Rubber Technology ,Cochin University of Science and Technology, for availing me every help and allowing me to conduct my study at their department.

I would like to thank **Dr. Abdul Saheer** for the statistical works.

Thanks to my batch mates **Dr. Jayasree J Prakash** and **Dr. Sheetal Sara Varghese** and to my seniors **Dr. Anjitha Devaraj ,Dr.Besty Levi, and Dr.Vincy mol J** for their support.

I also thank my juniors **Dr.Jose Nelson**, **Dr. Jishnu S** and **Dr. Kareena Kafeel** and my sub juniors **Dr.Lissie**, **Dr. Sreenath** and **Dr. Serjin** for their cooperation.

I am also thankful to **Priyamvadha C and Annu Thomas**, House surgeons , St Gregorios Dental college, for their timely assistance during the conduct of my study.

Words may fail to express the gratitude I have for the sacrifices of my parents, **Mr. Ananda Krishnan** and **Mrs. Jyothi Bai** in unison with the prayers of my loving sister **Krishna Anand.**

I thank my husband, **Rohith** for being so understanding. I greatly value his contributions and deeply appreciate his belief in me. I thank my little one, **Advik** who always try to do everything to make his presence felt.

Dr. Aparna Anand

LIST OF ABBREVIATIONS USED

ANN	Artificial Neural Network
ARI	Adhesive Remnant Index
APC	Adhesive Precoated
E&R	Etch and Rinse
FIG	Figure
FWS	Flexible Spiral Wire Retainer
GAS	Generation Adhesive System
HQTH	High Intensity Quartz Tungsten Halogen
IR	Infra Red
KHN	Knoop Hardness Number
LED	Light Emitting Diode
LCU	Light Curing Unit
PAC	Plasma Arc Curing Unit
SBS	Shear Bond Strength
SD	Standard deviation
S/ SEC	Seconds
SE	Self etching
SGU	Shade Guide Units
RBC	Resin Bond Composite
QTH	Quartz Tungsten Halogen