



SATHYABAMA INSTITUTE OF SCIENCE & TECHNOLOGY

(Deemed to be University)

Jeppiar Nagar, Chennai



Efficacy of Two Different High Intensity Led Units on Shear Bond Strength of Orthodontic Brackets - An In Vitro Study

By

Dr. V.A. JANAGARATHINAM

Dissertation submitted to

**Sathyabama Institute of Science & Technology
(Deemed to be University) Chennai, Tamil Nadu.**

In partial fulfillment of the requirements for the degree of

Master of Dental Surgery

In the speciality of

Orthodontics and Dentofacial Orthopedics

Under the guidance of

Prof.Dr. Shahul Hameed Faizee

Head of the Department

Department of Orthodontics and Dentofacial Orthopedics

Sathyabama Dental College and Hospital

Jeppiaar Nagar, Chennai-600119, Tamil Nadu.

2018 – 2021

CERTIFICATE BY THE GUIDE

This is to certify that this dissertation titled "**Efficacy of Two Different High Intensity Led Units on Shear Bond Strength of Orthodontic Brackets - An In Vitro Study**" is the bonafide record of work done by **Dr. V.A.Janagarathinam**, under our guidance during his postgraduate study period between 2018-2021.

A Dissertation submitted to the **Sathyabama Institute of Science & Technology (Deemed to be University)** Chennai, Tamil Nadu, in partial fulfillment of the requirements for the degree of **Master of Dental Surgery in the Speciality of Orthodontics & Dentofacial Orthopedics**.

Co- guide

GUIDE


Dr.L.Xavier Dhayananth, M.D.S


Dr. Shahul Hameed Faizee, M.D.S

Reader

Professor and Head

Department of Orthodontics and
Dentofacial orthopedics
Sathyabama Dental College &
Hospital, Chennai.

Department of Orthodontics and
Dentofacial orthopedics
Sathyabama Dental College &
Hospital, Chennai.

Date: 11-03-2021

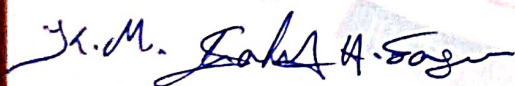
Place: Chennai

**ENDORSED BY THE HEAD OF THE INSTITUTION
AND HEAD OF THE DEPARTMENT**

This is to certify that the dissertation titled "**Efficacy of Two Different High Intensity Led Units on Shear Bond Strength of Orthodontic Brackets - An In Vitro Study**" is the bonafide record of work done by **Dr. V.A.Janagarathinam**, under the guidance of **Dr. Shahul Hameed Faizee, M.D.S**, Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Sathyabama Dental College & Hospital, Chennai, Tamil Nadu.

Head of the Department

DEAN



Dr. Shahul Hameed Faizee, M.D.S

Department of Orthodontics and
Dentofacial orthopedics
Sathyabama Dental College
& Hospital, Chennai.

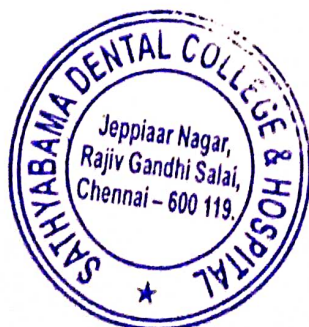


Dr. Thayumanavan, M.D.S

Sathyabama Dental College &
Hospital, Chennai.

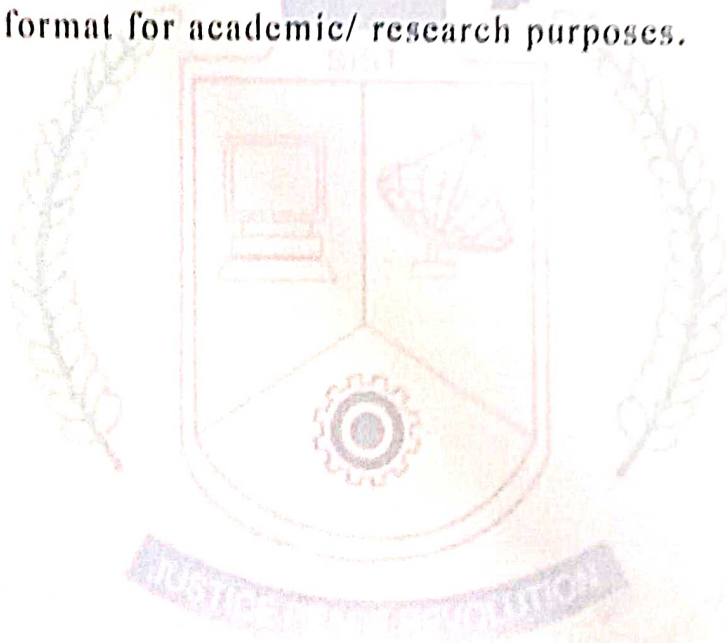
Date: 11-03-2021

Place: Chennai



DECLARATION BY THE CANDIDATE

I hereby declare that Sathyabama Institute of Science & Technology, Chennai, shall have the rights to preserve, use and disseminate this dissertation titled "Efficacy of Two Different High Intensity Led Units on Shear Bond Strength of Orthodontic Brackets - An In Vitro Study" as print or electronic format for academic/ research purposes.



V. A. Jella

Signature of the candidate

Date: 11-03-2021

Place: Chennai

DECLARATION OF PLAGIARISM CHECK

From,

V A Janagarathinam,

III year Post Graduate Student,

Department of Orthodontics and Dentofacial Orthopedics,

Sathyabama Dental College and Hospital,

Chennai.

To,

The Head of the Department,

Department of Orthodontics and Dentofacial Orthopedics,

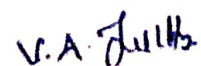
Sathyabama Dental College and Hospital,

Chennai.

SUB: Declaration of plagiarism check of my dissertation to be submitted to the "Sathyabama Institute of Science and Technology"- 2021.

I hereby declare that I have checked my dissertation for plagiarism using Smart Seo Tools - plagiarism checker software on 16-02-2021. The unique content was 98.71% and the plagiarism content was 1.29%. The plagiarism content corresponds to definitions and terminologies that have to be quoted.

Yours sincerely,



Dr. V.A. Janagarathinam



SATHYABAMA

DENTAL COLLEGE AND HOSPITAL

(DEEMED TO BE UNIVERSITY)



Accredited with "A" grade by NAAC

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119, Tamil Nadu, India.

Phone : 044 - 2450 3150 /51/52/54/55 Fax : 044 - 2450 2344

Website : www.sathyabama.ac.in

Ref No: Sathyabama University/ IHEC/study no064

08/11/2018

To,
Dr. Shahul Hameed Faizee,
Professor & HOD
Department of Orthodontics
Sathyabama Dental College & Hospital
Jeppiaar Nagar, Rajiv Gandhi Road, Chennai -119

Dr. Chandrasekar
Chairperson
Former Professor,
Oral and maxillofacial
pathology
Tamil Nadu Govt. Dental
College, Chennai

Dr. Thayumanvan
Deputy Chairperson
Dean, Head of Oral &
maxillofacial pathology
Sathyabama Dental
College & Hospital

Dr. C. Pravda
Member secretary
Professor & HOD,
Department of Oral
medicine and Radiology

I am pleased to inform you that the Institutional Human Ethics Committee (IHEC) has approved your project "**Efficacy of Two Different High Intensity LED Units on Shear Bond Strength of Orthodontic Brackets – An In Vitro Study**" based on the presentation of the proposal made and recommendations of the IHEC committee meeting held on 30/10/ 2018.

The validity of this ethical clearance is for only one year till 30/10/2019 and in case if the study is not completed within the stipulated time they have to apply to renew for ethical clearance. You are expected to submit six monthly progress and final report of the study to the IHEC.

Thanking you,

Dr. Thayumanvan

Deputy Chairperson
HUMAN ETHICAL COMMITTEE
SATHYABAMA
DENTAL COLLEGE & HOSPITAL
(DEEMED TO BE UNIVERSITY)
Jeppiaar Nagar, Rajiv Gandhi Salai,
Chennai - 600 119.

ACKNOWLEDGEMENT

Words seem less to express my deep sense of gratitude to my postgraduate teacher **Dr. K.M. Shahul Hameed Faizee, M.D.S, Professor and Head**, Department of Orthodontics and Dentofacial Orthopedics, Sathyabama Dental College and Hospital, Chennai, for his valuable guidance and suggestions, tireless pursuit for perfection, immense and constant support, encouragement and keen surveillance for the minute details throughout this dissertation and postgraduate course. I thank him for all the help that have been conferred upon me without which this dissertation would not have come true.

My sincere thanks to **Dr. B.Thayumanavan, M.D.S, Dean**, Sathyabama Dental College for providing me with an opportunity to utilize the facilities available in this institution and in successful completion of this study.

I am exceptionally gratified and sincerely express the sincere thanks to **Dr.L.Xavier Dhayananth, M.D.S**, Reader, **Dr.Navaneetha, M.D.S**, Reader, and **Dr.R.Piradhiba, M.D.S**, Reader, Department of Orthodontics and Dentofacial Orthopedics, Sathyabama Dental College and Hospital, Chennai, for their vehement personal interest, wise counsel and never ending willingness to render generous help to me in carrying out this work from its inception to its consummation.

I gladly utilize this opportunity to express my sense of gratitude and indebtedness to **Dr. S.Veerasankar, M.D.S**, Senior lecturer and **Dr. Evan A Clement, MDS**, Senior lecturer, for their everlasting inspiration, incessant encouragement, constructive criticism and valuable suggestions conferred upon me without which this dissertation would not have come true.

My heartfelt thanks to my wonderful batch mate **Dr. Anusha**, who was cheerfully available at all times to help me. I wish her a successful career ahead. I also extend my gratitude to my juniors **Dr. Hemamalini** and **Dr. A.Jyosthna**, for all their support.

My thanks to **Dr. P.Rajalingam** for helping me with the photographs and mental support for the study. I would like to thank **Mrs. Radha** sister and **Ms. Revathy** for their cooperation and help during my post-graduate course.

I also take this opportunity to pay my heartfelt gratitude to my father **Mr. V.V.Appachi** and mother **Mrs. V.A.Parameswari** for being a pillar of support during my postgraduate life. I am forever indebted for their sacrifice and prayers. Special thanks to my wife **Mrs. D.Keerthana** and son Master **J.Aniv** for their affection and understanding. Last but not the least let me pay my prayerful thanks to the almighty for his boundless blessings. Thank you all....

CONTENTS

S.NO	TITLE	PAGE NO.
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	5
3.	MATERIALS AND METHODS	22
4.	RESULTS	35
5.	DISCUSSION	43
6.	SUMMARY & CONCLUSION	52
7.	BIBLIOGRAPHY	54

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1.	SAMPLE OF TEETH AND COLOUR CODING OF GROUPS	29
2.	BONDING MATERIALS	29
3.	LIGHT CURE UNITS	30
4.	INTENSITY METER (BEHN-LED1)	31
5.	UNIVERSAL TESTING MACHINE	31
6.	STEREO MICROSCOPE (Leica M205 A)	32
7.	LIGHT INTENSITY TESTING USING BEHN-LED1	32
8.	A.BONDED SAMPLES, B.SHEAR BOND STRENGTH TESTING	33
9.	ARI SCORES	34

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1.	INTENSITY OF LIGHT CURE UNIT BEFORE EACH CURE	35
2.	SHEAR BOND STRENGTH (SBS) OF THREE GROUPS	36
3.	ARI SCORES FOR THREE GROUPS	37
4.	DESCRIPTIVE STATISTICS FOR SHEAR BOND STRENGTH (MPa)	38
5.	ONEWAY ANOVA TEST FOR SHEAR BOND STRENGTH BETWEEN GROUPS	39
6.	TUKEY HSD FOR SBS DIFFERENCE BETWEEN THREE GROUPS	39
7.	CROSS TABULATION FOR ARI SCORE	40
8.	Chi-Square Tests FOR ARI SCORE	41

LIST OF GRAPHS

GRAPH NO.	TITLE	PAGE NO.
1.	COMPARISION OF SBS BETWEEN THREE GROUPS	42
2.	ARI DIFFERENCE BETWEEN THREE GROUPS	42

INTRODUCTION

One among the prominent milestones in orthodontic field is the development of efficient attachment of brackets to teeth.¹ Good bond strength, measured as shear bond strength (SBS) is achieved by ensuring that electromagnetic energy contained in light photons reach all layers of composite to activate free radicals, via interaction with photo initiator molecules² and completely polymerize it.³ The minimum clinically adequate tensile bond strength according to Reynolds (1975) appears to be between 5.88-7.85 MPa.⁴

Shear bond strength depends on various factors such as the type of enamel conditioning, bonding materials, bracket type, base design, depth, and time of cure etc.⁵ The first and most popular bonding resins were chemical curing bonding systems. A major drawback of the auto cured adhesive systems is the inability of the practitioner to manipulate the setting time of the composite resin.⁶ Hence the use of light cured materials in vitro for orthodontic bonding was first described in 1980.⁷ A rapid polymerization occurs when visible light is applied, producing a “command set” that is of great advantage. Such setting “on demand” provides adequate working time and allowing more accurate bracket placement.⁸

Ultra-Violet light curing unit was the first to be used in light cure system to cure composite. The wavelength is narrow in the range of 364–367 nm. Drawback of Ultra-Violet curing could cause damage to the eye, limited depth of cure, carcinogenic, loss of

intensity over time. Hence halogen lamps were introduced to replace Ultra-Violet curing unit as the source of light for polymerization. The light is filtered to wavelength approximately 380–500 nm. Though it was a boon for the clinical achievements in the dental practice it had many demerits. Quick over heating of the filament of the halogen bulbs, gradual loss of high energy wavelengths in their light output, broad spectrum of light and prolonged curing time (20-40seconds) made its use restricted for lengthy procedures such as bonding brackets in orthodontics.⁹

In order to reduce the prolonged curing time plasma arc were introduced as a high-speed curing light with effective curing wavelength of 450–500 nm and energy level of 900 mW/cm² to 2000 mW/cm². However it had drawbacks such as ventilating fan is required, more bulky, and heavy to use. Argon laser curing became popular because of rapid curing having 488 nm wavelength and benefits of saving time but they were very expensive to purchase and the curing depth is limited to 1.5–2 mm.⁹

Mills et al in 1995 presented the solid-state Light Emitting Diode (LED), a new technology to overcome the shortcomings of standard quartz tungsten halogen visible Light Curing Units. LED light curing unit has a lifetime of over 10,000 h with relatively little degradation, require little power to operate, resistant to shock and vibration, lightweight, portable, require no filters to produce blue light and produces narrow spectrum of wavelength (450-490nm). All

these positive aspects make LED an excellent alternative to conventional halogen lamps.^{10,11}

First generation LED light cure units consist of 5mm “cans” arranged into a physical array typically from 8 to 64 in number to emit blue light with intensity 150–500 mW/cm². It requires much longer curing time up to 40 seconds to provide a similar level of curing performance as halogen light cure unit. To overcome low intensity output, second-generation LED light cure units utilize a single chip with multiple emission areas and higher surface area to produce light intensity up to 1000 mW/cm² and reduce curing time to 20 seconds which is better than their first-generation counterparts. However, it has drawbacks of, power loss on serial continuous discharge, excessive handpiece body light head heating and automatic unit shut off due to overheating, etc. Third-generation LED units use two or more diode frequencies to produce a broader spectral output with intensity exceeding 1000 mW/cm² and able to polymerize a broader range of resins than the second-generation curing lights.^{12,13}

Manufacturers of new generation high-intensity LED units with intensity up to 3200 mW/cm² claim that they combine all the advantages of their predecessors with a considerable reduction in the curing time as compared to conventional LED light cure with desired shear bond strength. However, the validity of the manufacture claim is questionable; moreover there is no significant literature evidence to support the advantage of high intensity light

cure systems. Furthermore there is a distinct disparity in the cost of the high intensity LED light cure units among various manufacturers. Hence the aim of this study is to compare shear bond strength of bracket bonding system between two commercially available high intensity LED light cure units where one brand is more expensive than the other one.

REVIEW OF LITERATURE

Buonocore M G et al¹⁴ (1955) described a method of bonding acrylic resin filling material to enamel surface by etching the enamel with 85% phosphoric acid and phosphomolybdate oxalic acid treatment to alter enamel surface chemically, originating the ideas from industries in which phosphoric acid was used to obtain better adhesion of paint and resin coatings to treated metal surfaces.

Bowen et al¹⁵ (1962) explored the possibility of using epoxy resins (diglycidyl ether of bisphenol A) mixed with silica particles. The in vitro results were promising, but the presence of moisture inhibited the polymerization process of epoxy resin. To overcome this problem, Bowen attached methyl methacrylate groups to the groups of the epoxy resin, thereby converting the epoxy resin to a dimethacrylate. The experiment outcome was successful and resulted in a new resin called Bisphenol A glycedyl methacrylate or BISGMA or Bowen's resin.

Bowen et al¹⁶ (1962) compared the tensile strength and modulus of elasticity of tooth structure and several restorative material. They concluded from the study that the tensile strength of enamel was lower than dentin but higher than silicate cements, the modulus of elasticity in tension of a silicate cement and human dentin were approximately the same and the tensile strength of a highly filled resin was dependent on the surface treatment of the filler.

Buonocore et al¹⁷ (1968) studied the penetration of dental materials in to enamel surfaces with reference to bonding. They showed enhanced bonding to acid conditioned surfaces due to presence of prism like tags. Poor bonding was associated with unconditioned surfaces.

George V Newman et al¹⁸ (1973) commented on the bonding of attachments. They mentioned the various systems that have been used. After various studies they concluded that the ideal adhesive system should readily wet the tooth surface, polymerize in situ forming a firm bond with tooth structure on one side and the attachment on the other, especially in shear and tensile strength and be able to be removed by the orthodontist without destroying the integrity of enamel surface. The adhesive and attachment together should be aesthetic, adhere to enamel surface for an adequate treatment period, withstand the forces of mastication, arch wire stress, resist changes in pH from foodstuff, resist temperature changes, and minimal leakage.

Silverstone et al¹⁹ (1974) showed that etching the enamel surface with phosphoric acid resulted in a superficial etched zone and underlying porous zones. Depth of etched zone depended on the acid concentration, duration of etching and chemical composition of surface enamel.

Reynolds⁴ (1975) reported that clinically, the bonded brackets should be able to withstand forces generated by treatment mechanics and occlusion, yet allow easy debonding without damage to enamel.

He has reported that maximum tensile bond strength of 5.9 to 7.9 MPa would be adequate to resist treatment forces but added that in vitro tensile strength levels of 4.9 MPa have proved clinically acceptable.

Thompson et al²⁰ (1981) conducted an in vitro study to determine the amount of enamel lost during prophylaxis and during multiple bonding/debonding procedures. Both bristle brush and rubber cup were used with four different prophylactic pastes. The enamel loss with the bristle brush (14.38 μ) was significantly greater than the loss with rubber cup (6.9 μ). No significant differences were associated with use of different pastes. Total enamel loss was 71.5 μ in the group bonded with a filled resin with prophylaxis and acid etching between bonds. This was significantly greater than the amount lost (22.3 μ) by the group bonded with the same resin without prophylaxis and acid etching between bonds.

Artun and Bergland et al²¹ (1984) in a comparative study of conventional acid etching with 37% orthophosphoric acid and crystal growth conditioning with polyacrylic acid which contain residual sulphate ion, found that the latter has less bond strength and debonding was easier since the bond failure occurred at tooth adhesive interface. He introduced more complex means of defining the site of bond failure by adhesive remnant index (ARI). The score ranged between 0-3 and criteria for scoring is as follows:

- Score 0 - No adhesive left on the tooth.
- Score 1 - Less than half of the adhesive left on the tooth.

- Score 2 - More than half of the adhesive left on the tooth.
- Score 3 - All adhesive left on the tooth, with distinct impression of the bracket mesh.

O'Brien et al²² (1988) tested the theory that there is a relationship between bond strength at the separate interfaces of the direct bonding system (direct and indirect) and the amount of residual debris remaining on the enamel surface following removal of a bonded appliance. They concluded that the site of bond failure and the amount of residual adhesive debris on the enamel surface when using bonding materials and bracket bases tested in the shear mode does not appear to be governed simply by the bond strengths at the separate interfaces, but also influenced by the design of the bracket base and the adhesive material used.

V P Joseph et al⁶ (1990) compared shear bond strengths of stainless steel and ceramic brackets used with chemically and light-activated composite resins. They concluded that all combinations produce shear bond strengths that were greater than those that are considered clinically acceptable and the ceramic groups exhibited significantly higher bond strength than that of the stainless steel group with more enamel fractures.

G Oilo²³ (1992) studied the degradation processes, types of tests, measurements and analyses of substances leaching out from resin-based composite materials and glass-ionomer cements are reviewed. They concluded that in vitro tests tell us that certain substances or elements are constantly eluted. During a short initial period, the

elution rate is high and there after stabilizes at a low, but constant, value and the correlation between in vitro measurements and the in vivo situation is not established.

H E Goodis et al²⁴ (1993) conducted a study to determine the effects of duration of storage and selection of storage solution upon dentin permeability and bond strength over a period of 8 days to 6 months. Teeth were stored immediately after extraction in one of five commonly used solutions: 70% ethanol, 10% formalin, distilled water, distilled water with thymol, or phosphate-buffered saline with thymol. They concluded that bond strengths were unaffected by duration of storage or by solution type, except for saline.

Fox et al²⁵ (1994) suggested a possible standard technique for bond strength testing. He suggested the following protocol for bond strength testing in orthodontics.

- a) Surface of premolar enamel should be used on teeth extracted from adolescent patients for orthodontic reasons.
- b) Teeth should be used after 1 month and before 6 months of extractions. After bonding, the specimens should be immersed in water for 24 hrs at 37°C.
- c) Debonding should take place on an Instron or equivalent machine.
- d) The point of application and direction of force should be same for all specimens.
- e) At least 20 specimens should be used per test.

- f) Site of failure should be reported.
- g) Statistical analysis should include survival analysis to give a prediction of performance of the material.
- h) Bond strength should be quoted in either Newtons or Megapascals.

Eliades T and Brantley W A²⁶ (2000) conveyed in their study that bond strength studies were influenced by the testing environment (in vivo, in vitro, and ex vivo), loading mode (shear, tensile, and torsion), bonding substrate (enamel, restorative, and prosthetic materials), tooth selection, storage, bonding, testing, and data analysis with regard to the clinical applicability of the reported information, as well as the scientific integrity of the testing procedure.

Pickett et al²⁷ (2000) conducted a study to test a new in vivo debonding device and compare in vivo bond strengths recorded by this device with in vitro bond strengths recorded by a universal testing machine such as the Instron. They concluded that mean bond strengths recorded in vivo following comprehensive orthodontic treatment are significantly lower than bond strengths recorded in vitro.

Travis Q Talbot et al²⁸ (2000) evaluated the effect of argon laser irradiation on shear bond strength of orthodontic brackets and also investigated for their ability to confer demineralization resistance on enamel. Three different laser energies (200,230,300mW/cm²) were used in this study at 3 unique time points (before, during or

after bracket placement). The results showed that the mean bond strength was significantly different between all 3 bracket placement groups and also the mean bond strength of teeth lased after bonding was significantly higher than the control group.

L J Oesterle, W C Shellhart² (2001) conducted a study to determine the transmittance of the curing light through human enamel and the effect of transillumination on the bond strength of orthodontic brackets. They demonstrated that transillumination of maxillary incisors is an acceptable method of curing orthodontic adhesive, particularly if the exposure time is increased from 40 to 50 seconds with acceptable bond strength.

Larry James Evans et al²⁹ (2002) did a study to evaluate the effects of different curing times, light sources and light guides on shear bond strength of orthodontic brackets. The bond strength values were high in 24 hour groups compared with the 5 minute shearing groups but statistically there were no differences. They concluded that the power slot and turbo tip light guides with their collimation of visible light to increase its intensity can be advantageous for curing resins.

William J Dunn et al¹¹ (2002) compared the shear bond strength of orthodontic brackets bonded to teeth with two conventional halogen-based light-curing units (Optilux 501 and ProLite) and two commercially available LED curing units (LumaCure and VersaLux). They concluded that there is no difference in bond strength between the 4 groups.

Nazanin Emami et al³⁰ (2003) conducted a study to determine whether low light intensity and long but sufficient curing time can produce composites with volumetric shrinkage, degree of conversion (DC%) and Young's modulus (E-modulus) comparable to those of high light intensity cured composite was tested, when the contraction strain and heat generation were lower with low light intensity curing. The concluded that DC%, E-modulus, and the volumetric shrinkage values in cured composites were not affected by low light intensity, however, the contraction strain and polymerization's exotherm were decreased.

Samir E Bishara et al³¹ (2003) evaluated the efficacy of a light cure unit (UltraLume 2) on the shear bond strength of orthodontic brackets. They concluded that there is no differences in the shear bond strength between the Ortholux halogen light cure unit and the UltraLume 2 LED light cure unit.

Timothy Swanson et al³² (2004) in an in vitro study evaluated the relationship between the shear bond strength of orthodontic brackets bonded to enamel and the photopolymerization duration with three LED curing units (GC e-light,UltraLume LED-2,Ellipar FreeLight) and one halogen based light curing unit (Ortholux). The results showed higher bond strength for UltraLume LED-2 at 40 seconds and weaker bond strength with GC e-light at 10 and 40 seconds, but the bond strength for all groups were greater than 8 MPa even with a 10 second curing time.

Mavropoulos et al³³ (2005) did a in vitro study was to establish the minimum necessary curing time of 5 and 10 seconds to bond stainless steel brackets using new, intensive light-emitting diode curing units, Ortholux™ LED and Ultra-Lume™ LED. Results conclude that 10 seconds, the intensive LED curing units achieved sufficient SBS, comparable with the control. In contrast, 5 seconds resulted in significantly lower shear bond strength.

Hakan Turkkahraman, H Cenker Kucukesmen³⁴ (2005) compared the shear bond strength of orthodontic metal brackets by two high power light emitting diode modes and halogen light. Here forty five SS orthodontic bicuspid brackets were divided into three groups of fifteen each. In first group mini LED (Satelec, Merignac, France) fast mode LED for 20 seconds and second group helioux DLX (Vivadent ETS, Schoan, Leichtenstein) soft start mode LED for 40 seconds, third group halogen light for 40 seconds were used. The shear bond strength of fast mode LED is similar to halogen based illumination, where as soft start mode LED yielded higher shear bond strength than the other two groups.

Teresa Silta et al³⁵ (2005) did an in vitro study to evaluate the effect of shorter polymerization times when using the latest generation of light emitting diodes. The results of the study concluded that significant differences in bond strength when compared to different light types of light cure and curing time. The 6 seconds cured brackets showed lower bond strength than the 20 second cured brackets and bond strength of brackets cured for 20

seconds with Optilux 501 QTH LCU and the Ultralume LED 5 LCU were significantly high compared to 6 seconds cured brackets. Thus they recommend minimum 20 seconds of curing time with QTH or LED cutting lights.

Thind B S et al³⁶ (2006) investigated whether there were differences between the debond stress and adhesive remnant index (ARI) of an adhesive cured with three different orthodontic light sources (Ortholux XT, Ortho lite, Ortholux LED). They concluded that no difference was found in the debond stress of brackets bonded with Transbond TM, cured with any of the light sources tested. However, the distribution of ARI scores differed when the adhesive was cured using the plasma arc light.

Michael D Signorelli et al³⁷ (2006) did an in vitro shear bond strength test and also an in vivo survival rate of orthodontic brackets bonded with either a halogen with 20 seconds or a plasma arc light with 2,6 and 10 second curing time. The results of the study showed no statistically significant differences in bond strength and also the in vivo study also showed no significant difference in bracket failure.

Maria Francesca Sfondrini et al³⁸ (2006) did a study to assess the effect of light tip distance (0mm, 3mm, 6mm) on the shear bond strength of resin modified glass ionomer cured with three curing units (high intensity halogen, LED and plasma arc). They concluded that the plasma arc curing light produced higher bond strength than other two light curing systems.

Feng L et al³⁹ (2007) investigated exposure reciprocity law in photo polymerization of multi-functional acrylates and methacrylates. They concluded by demonstrating that when the oligomer/monomer mass ratio is equal to or greater than 6:4, the degree of double bond conversion of the resin, cured with a minimum radiant exposure, is a function of the product of irradiance and irradiation time. This justifies the applicability of the exposure reciprocity law to these binary resin systems.

Rengarajan Krishnaswamy N et al⁴⁰ (2007) done a randomized clinical trial to evaluate the clinical performance of brackets cured with 2 light-curing units, a conventional halogen unit and an LED. From the results they concluded that curing with an LED is an acceptable alternative to conventional halogen light curing.

Nikolaos S Koupis et al⁴¹ (2008) conducted randomized control study comprised 30 patients who were directly bonded and light cured for 10 seconds with the light-emitting diode (LED) lamp for 20 seconds with the conventional halogen lamp. They concluded LED curing units are an advantageous alternative to conventional halogen sources in orthodontics because they enable a reduced chair-time bonding procedure without significantly affecting bond failure rate.

Davide Mirabella et al⁴² (2008) tested the hypothesis that bonding with a blue light-emitting diode (LED) curing unit produces no more failures in adhesive-precoated (APC) orthodontic brackets than bonding carried out by a conventional halogen lamp. 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 recorded. Results showed no statistically significant difference in bond failure rate was found between APC brackets bonded with the halogen light-curing unit and those cured with LED light.

Anestis Mavropoulos et al⁴³ (2008) done a study to check the concept of "total energy," various combinations of power densities and exposure durations to obtain 3 levels of energy density (6000, 12000, and 24000 mJ/cm²). They concluded that the concept of "total energy" does not hold for orthodontic light-cure bracket bonding. An exposure time of less than 4 seconds, irrespective of the power density, cannot guarantee sufficient bracket bond strength. There seems to be an advantage of power density over exposure duration in the context of metallic bracket bonding. These results show that, for an efficient light-cure bracket bonding, there is an absolute lower limit of exposure duration (4 seconds) and an upper limit of useful power density (3000 mW/cm²).

Theorde Eliades⁴⁴ (2010) reviewed the fundamentals of photo curing with various type of lamps in orthodontics. The key properties such as polymerization efficiency (degree of cure), mechanical properties (bond strength), clinical performance (failure rate) and biological properties of blue light are reviewed to know their clinical usefulness in application to orthodontic bonding. The light intensity, their penetration into the adhesive, composition of the adhesives, their resin, fillers, initiators and inhibitors are

factors that can vary the polymerization efficiency. For any light cure lamp its light intensity, wavelength, and the curing time are the important factors to be considered before its selection for the orthodontic purpose. For evaluating the bond strength factors such as the bracket design, variation in load application, loading rate, teeth storage and preparation, testing conditions can significantly alter the results in addition to type of curing system used.

Finnema et al⁴⁵ (2010) performed a meta-analysis on 24 of 121 studies. The review found that storage conditions of the teeth prior to testing, photo polymerization time and crosshead speed significantly influenced bond strength values. From the 24 studies included in Finnema's study, the shear bond strengths ranged from 3.5 to 27.8 MPa (mean: 13.4; SD: 5.7). On average, tap water storage decreased bond strength by 10.7 MPa, each second of photo polymerization time increased bond strength by 0.077 MPa, and when crosshead speed increased by 1mm per minute, bond strength increased by 1.3 MPa. Most in vitro bond strength studies use distilled water as a storage solution, 40 seconds of light exposure for polymerizing the adhesive, and a crosshead speed of 0.5mm per minute.

Carine Maccarini Dall'Igna et al⁴⁶ (2011) conducted a study to assess the influence of two light units, a light-emitting diode (LED) and a plasma arc light (PAC), on the shear bond strength of brackets bonded to enamel. They concluded The LED at 5 seconds and the

PAC at 3 seconds provided sufficient mean shear bond strength to resist either orthodontic or masticatory forces

Adrian C Shortall et al⁴⁷ (2012) described the history of light curing in dentistry and about the generations of LED and about selection criteria for the clinician considering purchasing a new LED. The features of third generation LED such as reduced power consumption, their ergonomic design features, either battery powered or corded and broad spectral output with universal curing of photo activated dental resins irrespective of initiator formulation shorter irradiance time made them popular than the second generation blue LED. Now the LED is towards its fourth generation incorporating the features of third generation and also it has features of four different diode wavelength selection for curing adhesives with minimized over heating issues and the polymerization stresses are reduced due to its soft scan options.

Heravi F et al³ (2013) evaluated shear bond strength of orthodontic brackets using trans-illumination technique with different curing profiles of LED light-curing unit in posterior teeth. They concluded that in clinical limitations where light curing from the same side of the bracket is not possible, doubling the curing time, and increasing the light intensity during trans-illumination are recommended for achieving acceptable bond strengths.

Justin D Ward et al⁴⁸ (2015) evaluated the clinical performance of brackets cured with a high-intensity, light emitting diode (3200 mW/cm²) with a shorter curing time. They concluded that high-

intensity LED light used with a shorter curing time may be considered an advantage due to the reduced chair time.

Gange P⁷ (2015) reviewed the history of orthodontic bonding, especially the materials used in the bonding process. In the early 1970s, Miura developed a technique for bonding polycarbonate plastic brackets to phosphoric acid etched enamel using a restorative filling material developed by Masuhara et al. Retief et al partnered with 3M Unitek to develop a mesh grid welded onto flattened stainless steel band material with a metal bracket welded to it. In 1975, a no-mix, chemically cured direct bonding system was introduced. In the early 1980s, visible light-cured restorative materials were introduced in all areas of dentistry. In 2004, several single-paste light-cured, color changing adhesives entered the market from Reliance Orthodontic Products, 3M Unitek, andOrmco.

Waleed Bakhadher et al⁵ (2015) reviewed various factors affecting the shear bond strength of orthodontic brackets and concluded both material and teeth related factors influenced the shear bond strength of orthodontic brackets. Using conventional acid-etch technique, ceramic brackets and bonding to non-fluorotic teeth was reported to have a positive influence on the shear bond strength of orthodontic brackets, but higher shear bond strength found on using ceramic brackets can be dangerous for the enamel.

Abdullah Alper Oz et al⁴⁹ (2016) compared the clinical failure rates and the in vitro bond strengths of metal brackets bonded with different light-emitting diode (LED) devices (Elipar S10 and VALO

Ortho) and curing times (10 seconds and 3 seconds). They concluded that long-term clinical survival rates and in vitro bond strengths indicate 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.

Adrian C Shortall et al⁵⁰ (2016) discussed the development of LCUs in dentistry and also about the selection, use and maintenance of LED light-curing units. Early LED required longer exposure time because of their low energy output. In order to increase their output they started fitting multiple LED emitters in gun style or pen style models. The newly introduced third generation polywave LED simulated the broader emission spectrum of QTH and PAC units for activating materials containing alternative photo initiators which had 4 LED emitters each producing different wavelengths of light. Manufacturers of polywave LED curing light are Ivoclar Vivadent, GC, Heraeus Kalzer, Ultradent and their resins are benefited from polywave LED curing light as these composite manufacturers market materials that use alternative photo initiator other than camphoroquinone.

Mustafa M Al-Khatieeb et al⁵¹ (2017) evaluated the effect of different curing time (3 seconds and 1 seconds) of high intensity LED light cure on the shear bond strength. They concluded both of the LED unit's groups showed clinically acceptable shear bond strength in comparison to halogen, so the time of bonding reduced

without jeopardizing the shear bond strength or enamel surface after debonding.

Sanjay Prasad Gupta et al¹ (2018) compare the shear bond strength (SBS) of bracket-bonding system cured with light-emitting diode (LED) and halogen-based light-curing unit at various polymerization times (5 seconds and 10 seconds. They concluded that for bonding orthodontic brackets, photo activation with halogen for 20 seconds and LED for 5 seconds is suggested.

Guneet Guram et al⁵² (2018) Comparison of light-emitting diode-curing unit and halogen-based light-curing unit for the polymerization of orthodontic resins. They compared the shear bond strength of orthodontic brackets bonded to teeth with conventional halogen LCU (3M ESPE Elipar 2500) and LED LCU (3M ESPE Elipar Free Light 2) and concluded that LED LCUs containing even only a single LED can cure the composite and there is no statistically significant difference in the shear bond strengths of the two groups.

Hadole P G and Daokar S S⁹ (2019) reviewed four generations of light curing devices and concluded that both manufactures and researchers should include radiant power output throughout the exposure cycle, the spectral radiant power as a function of wavelength, analysis of the light beam profile, spectral emission across the light beam, measurement and reporting of the light the red blood cells specimen received as well as the output measured at the light tip.

MATERIALS AND METHODS

The various materials, apparatus and the methodology used in the study are enumerated and briefly described below.

MATERIALS

1. SAMPLES USED FOR THIS STUDY: (FIGURE 1)

Sixty sound human maxillary first premolars extracted for orthodontic purpose were collected and stored in distilled water at room temperature to eliminate dehydration. The distilled water was changed weekly to avoid bacterial growth.

Inclusion Criteria:

- Intact buccal enamel.
- No evidence of caries.
- No developmental defects.
- No cracks due to the pressure of the extraction forceps.
- Teeth without any restorations.
- Not immersed in chemical agents (such as hydrogen peroxide).

2. ARMAMENTARIUM:

A. BONDING MATERIALS: (FIGURE 2)

- 37% Orthophosphoric acid - Scotchbond (3M Unitek, Monrovia, California).

- Transbond XT light cure adhesive primer and paste (3M Unitek, Monrovia, California).
- Hand piece with polishing cup.
- Slurry of pumice and mixing well.
- Bracket placement instrument and Explorer.
- Primer applicator tip.
- Compressed air and water facility with a three way syringe.
- Dental micromotor unit with hand piece.

B. Universal maxillary premolar brackets of 0.022 slot MBT prescription (3M Unitek-Victory series, Monrovia, California).

C. LIGHT CURE UNITS: (FIGURE 3)

Three light cure units are used:

- a. Conventional 3M-ESPE Elipar 2500 halogen with intensity up to $1300\text{mW}/\text{cm}^2$.
- b. Woodpecker iLED plus (turbo mode) with intensity up to $2500\text{mW}/\text{cm}^2$.
- c. Ivoclar Blue phase power cure (3s mode) LED with intensity up to $3050\text{ mW}/\text{cm}^2$.

D. INTENSITY METER: (FIGURE 4)

BEHN-LED1 (Guangdong, China) for measuring light intensity from $50\text{-}3600\text{ mW}/\text{cm}^2$.

E. UNIVERSAL TESTING MACHINE: (FIGURE 5)

Universal testing machine (Associated Scientific Engg. Works, New Delhi) with Digital Encoder (Auto Instruments, Kholapur) and FIE make Software (India) was used for measuring mean shear bond strength. Custom made fixture was used for holding blocks.

F. STEREO MICROSCOPE: (FIGURE 6)

Stereo microscope Leica M205 A (Wetzlar, Germany) with 10× magnification is used to record ARI score.

METHODOLOGY

STUDY DESIGN:

In vitro study

NULL HYPOTHESIS:

No difference in shear bond strength of orthodontic brackets cured with Group 1, Group 2, Group 3 light cure units selected for this study.

SAMPLE PREPARATION: (FIGURE 1)

1. Sixty human maxillary first premolars extracted for orthodontic purpose were collected over 4 week period. The teeth were debrided and examined for caries, pre-existing fractures, and restorations. The criteria included intact buccal enamel surface with no cracks caused by pressure of the extraction forceps. The teeth were stored in distilled water for a period of 2 months to prevent dehydration.
2. Sixty premolar teeth were randomly assigned to 3 groups with 20 teeth per group.
3. Each group was given different colour coding
 - A. Group 1-Red
 - B. Group 2-White
 - C. Group 3-Blue

4. Each tooth from the in vitro sample was mounted on color coded acrylic stubs with roots embedded in a fast set self cure polymethyl methacrylate resin.
5. The teeth were oriented in such a way labial surface of the tooth was kept perpendicular to the bottom surface of the mold.

BONDING PROCEDURE:

1. Teeth were polished with non-fluoridated pumice and prophylactic rubber cup and then rinsed thoroughly with water spray.
2. Enamel surface of the teeth were etched with 37% ortho phosphoric acid (3M Unitek, Monrovia, California) for 30 seconds, and then rinsed with water spray for 30 seconds, then gently dried with oil free air till the etched tooth appeared chalky white.
3. A thin coat of light cure adhesive Transbond XT primer (3M Unitek, Monrovia, California) was applied to acid-etched enamel surface and Transbond XT composite resin (3M Unitek, Monrovia, California) was applied on the bracket base, which was then placed on to the teeth with a bracket placement instrument near the centre of the buccal surfaces with sufficient manual pressure that leads the excess material to flow at the margins of the bracket which was then removed with a exploratory probe before polymerization.

CURING PROCEDURE:

1. The light intensity of the curing unit was recorded with BEHN-LED1 intensity meter before each cure (FIGURE 7), (TABLE I).
2. Group 1 is cured with conventional 3M-ESPE Elipar 2500 halogen light cure unit for 20 seconds from each of mesial and distal sides of bracket.
3. Group 2 is cured with conventional Woodpecker iLED plus light cure unit for 3 seconds from each of mesial and distal sides of bracket.
4. Group 3 is cured with conventional Ivoclar Blue phase power cure light cure unit for 3 seconds from each of mesial and distal sides of bracket.
5. The light cure head is placed as close to the bracket base while curing.

SHEAR BOND STRENGTH DETERMINATION: (FIGURE 8A, 8B)

All the samples are stored in distilled water for 24 hours shear load test in a universal testing machine for shear bond strength. The specimens were placed in a custom made mounting jig in the universal testing machine in such a way that the bracket base was parallel to the shear-peel load. A shear debonding force was applied to the bracket base in an occlusogingival direction at a crosshead speed of 1mm/min. The maximum force necessary to debond or

initiate bracket fracture was recorded in Newtons and then converted into Megapascals (MPa) using the formula,

$$\text{SBS (MPa)} = \frac{\text{Peak load at bond failure (N)}}{\text{Bracket surface area (mm}^2\text{)}}$$

(The surface area of the bracket base was 9.08 mm² as described by the manufacturer)

TEST FOR DEBONDING CHARACTERISTICS: (FIGURE 9)

The tooth surface of debonded specimens were studied under 10x magnification in stereo microscope (Leica M205 A, Wetzlar, Germany), and the debonding characters was assessed using the adhesive remnant index (ARI) which describes the amount of adhesive remaining on the tooth surface.

Adhesive remnant index developed by Artun and Bergland were used in this study to assess each specimen.

The score ranges for ARI are:

- Score 0 - No adhesive left on the tooth.
- Score 1 - Less than half of the adhesive left on the tooth.
- Score 2 - More than half of the adhesive left on the tooth.
- Score 3 - All adhesive left on the tooth, with distinct
impression of the bracket mesh.

FIGURE 1: SAMPLE OF TEETH AND COLOUR CODING OF GROUPS



FIGURE 2: BONDING MATERIALS



FIGURE 3: LIGHT CURE UNITS



3M-ESPE Elipar 2500 halogen light cure unit



Woodpecker iLED plus light cure unit



Ivoclar Blue phase power cure light cure unit

FIGURE 4: INTENSITY METER (BEHN-LED1)



FIGURE 5: UNIVERSAL TESTING MACHINE



FIGURE 6: STEREO MICROSCOPE (Leica M205 A)

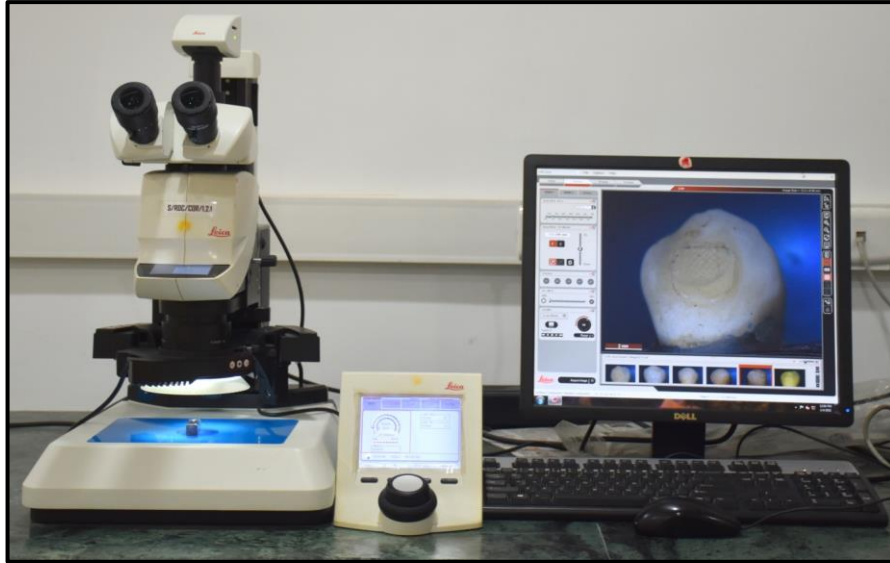


FIGURE 7: LIGHT INTENSITY TESTING USING BEHN-LED1



FIGURE 8A: BONDED SAMPLES



FIGURE 8B: SHEAR BOND STRENGTH TESTING

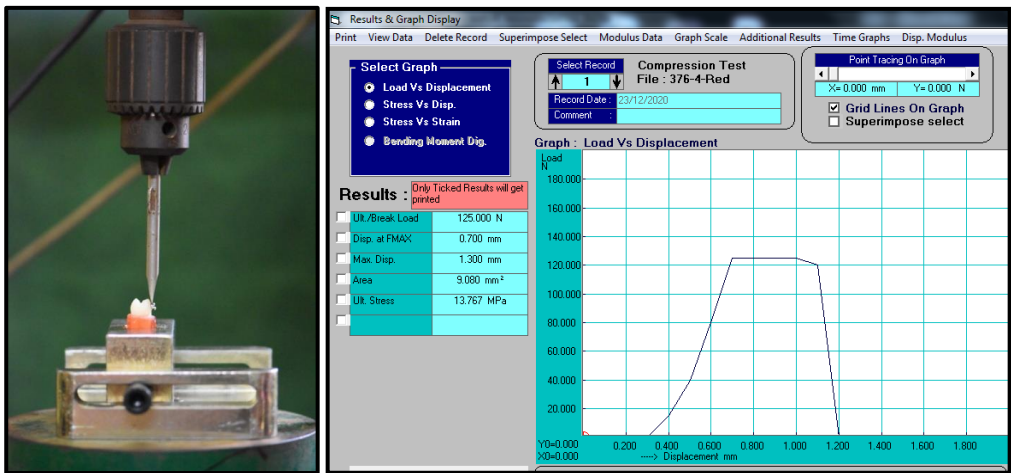
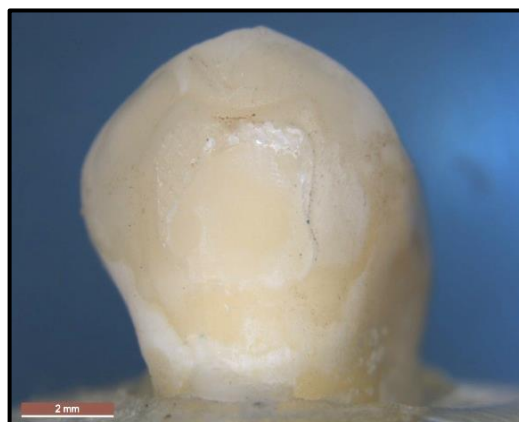


FIGURE 9: ARI SCORES



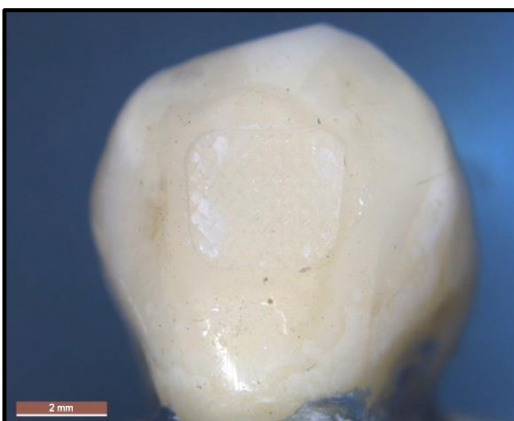
SCORE 0



SCORE 1



SCORE 2



SCORE 3

RECORDED DATA

TABLE I: INTENSITY OF LIGHT CURE UNIT BEFORE EACH CURE

Sample	Group 1 (mW/cm ²)	Group 2 (mW/cm ²)	Group 3 (mW/cm ²)
1	1228	2228	3024
2	1225	2494	2960
3	1201	2430	2980
4	1212	2402	3115
5	1230	2440	2996
6	1226	2428	3016
7	1203	2410	3007
8	1216	2401	2986
9	1208	2492	3046
10	1220	2407	3014
11	1230	2470	2996
12	1206	2450	3092
13	1261	2415	3017
14	1232	2490	2991
15	1226	2406	2971
16	1220	2420	3030
17	1236	2460	3011
18	1205	2446	3032
19	1210	2416	2986
20	1223	2420	3017
Mean	1220.9	2426.25	3009.35

TABLE II: SHEAR BOND STRENGTH (SBS) OF THREE GROUPS

Sample	Group 1 (MPa)	Group 2 (MPa)	Group 3 (MPa)
1	11.564	14.868	12.665
2	13.216	9.361	7.709
3	11.013	7.819	15.969
4	13.767	9.361	11.564
5	12.665	10.022	9.912
6	8.881	9.802	13.326
7	10.679	11.563	11.674
8	11.013	8.26	11.013
9	10.479	7.269	8.881
10	9.802	12.225	10.463
11	12.445	9.581	11.564
12	14.317	9.031	11.894
13	9.251	11.784	12.775
14	11.564	9.361	10.679
15	12.115	9.802	11.344
16	9.692	8.811	12.225
17	11.894	9.912	9.251
18	13.216	10.22	11.894
19	14.978	13.106	14.868
20	11.013	7.819	12.665

Table III: ARI SCORES FOR THREE GROUPS

Sample	Group 1 (ARI score)	Group 2 (ARI score)	Group 3 (ARI score)
1	1	2	2
2	2	1	0
3	1	2	1
4	0	0	1
5	2	1	2
6	2	2	3
7	1	1	2
8	2	2	1
9	2	1	0
10	3	3	2
11	1	2	1
12	2	2	2
13	3	2	1
14	1	2	2
15	2	1	2
16	1	1	3
17	2	0	1
18	2	0	2
19	0	2	2
20	2	2	1

STATISTICAL ANALYSIS

Statistical analysis was performed with SPSS 24.0 software. Descriptive statistics of SBS (mean, standard deviation and significance) were calculated for all groups. One-way analysis of variance (ANOVA) was carried out for SBS to determine significant differences among the groups. The intergroup comparison of SBS was done with Tukey HSD test. Chi-square test was performed to determine the differences in ARI scores of all three groups. The statistical significance level was established at $p < 0.05$.

Table IV: DESCRIPTIVE STATISTICS FOR SHEAR BOND STRENGTH (MPa)

Group	No	Mean	Std. Deviation	Std. Error	95% CI for mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group1	20	11.6782	1.68139	.37597	10.8913	12.4651	8.88	14.98
Group2	20	9.9989	1.88915	.42243	9.1147	10.8830	7.27	14.87
Group3	20	11.6168	1.92509	.43046	10.7158	12.5177	7.71	15.97

Inference: Table IV shows Group 1(QTH-3M Elipar 2500) has the highest mean shear bond strength of 11.6782 ± 1.68139 MPa, followed by Group 3 (Ivoclar blue phase power cure LED) with mean shear bond strength of 11.6168 ± 1.92509 MPa. Group 2 (Wood pecker iLED plus) have the lowest mean shear bond strength of 9.9989 ± 1.88915 MPa among the three groups.

TABLE V: ONEWAY ANOVA TEST FOR SHEAR BOND STRENGTH BETWEEN GROUPS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	36.277	2	18.139	5.387	.007

Inference: Table V shows one-way analysis of variance ($F = 5.387$) indicated statistically significant differences ($p < 0.05$) exists between the groups in shear bond strength.

TABLE VI: TUKEY HSD FOR SBS DIFFERENCE BETWEEN THREE GROUPS

Mean Difference Between Groups			Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	1.67935	.58028	.015	.2829	3.0758
	Group 3	.06145	.58028	.994	-1.3350	1.4579
Group 2	Group 1	-1.67935	.58028	.015	-3.0758	-.2829
	Group 3	-1.61790	.58028	.019	-3.0143	-.2215
Group 3	Group 1	-.06145	.58028	.994	-1.4579	1.3350
	Group 2	1.61790	.58028	.019	.2215	3.0143

Inference: Table VI shows that Group 2 have statistically significant difference in mean shear bond strength compared to Group 1 ($p < 0.05$) and Group 3 ($p < 0.05$). It also shows no statistically significant difference ($p > 0.05$) in shear bond strength between the Group 1 and Group 3.

TABLE VII: CROSS TABULATION FOR ARI SCORE

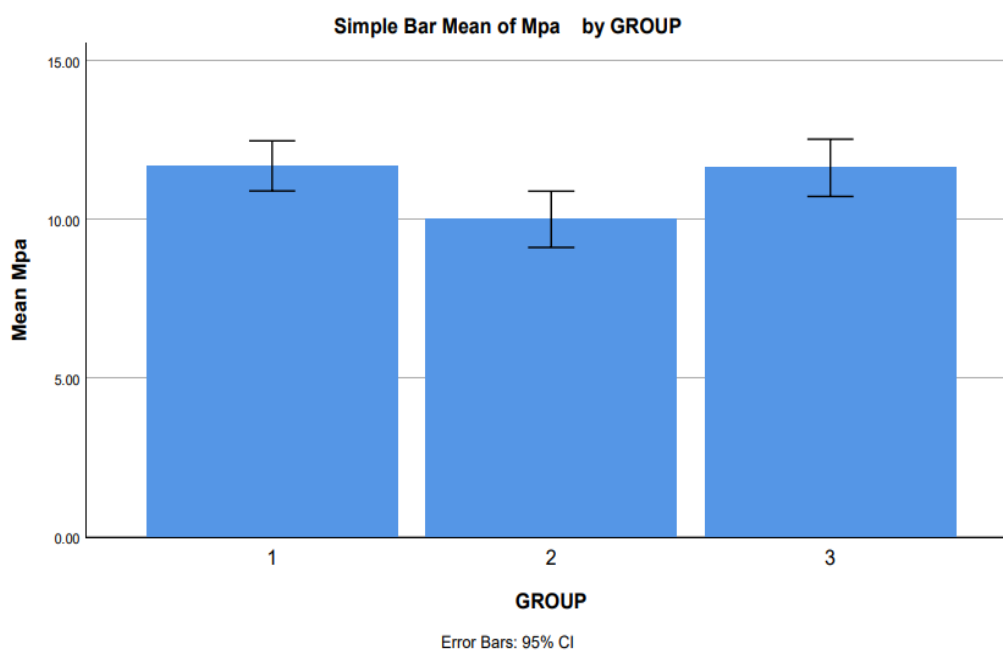
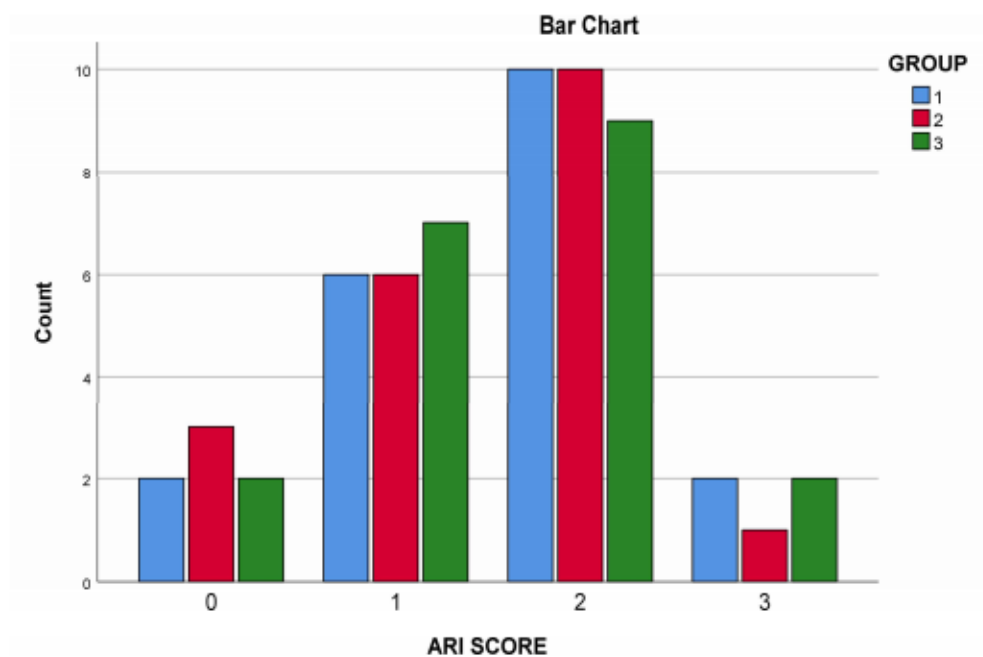
ARI SCORE		GROUP		
		1	2	3
0	Count	2	3	2
	% within ARI SCORE	28.6%	42.9%	28.6%
	% within GROUP	10.0%	15.0%	10.0%
1	Count	6	6	7
	% within ARI SCORE	31.6%	31.6%	36.8%
	% within GROUP	30.0%	30.0%	35.0%
2	Count	10	10	9
	% within ARI SCORE	34.5%	34.5%	31.0%
	% within GROUP	50.0%	50.0%	45.0%
3	Count	2	1	2
	% within ARI SCORE	40.0%	20.0%	40.0%
	% within GROUP	10.0%	5.0%	10.0%

Inference: Table VII shows, ARI score 2 being predominant in all the three groups. Group 1 has 10.0% of ARI score 0, 30.0% of ARI score 1, 50% of ARI score 2, 10.0% of ARI score 3; Group 2 has 15.0% of ARI score 0, 30.0% of ARI score 1, 50% of ARI score 2, 5.0% of ARI score 3; Group 3 has 10.0% of ARI score 0, 35.0% of ARI score 2, 45.0% of ARI score 2, 10.0% of ARI score 3.

TABLE VIII: Chi-Square Tests FOR ARI SCORE

	Value	Df	Asymptotic Significance (2- sided)
Pearson Chi-Square	0.860 ^a	6	.990
Likelihood Ratio	.885	6	.990
Linear-by-Linear Association	.038	1	.846
N of Valid Cases	60		

Inference: Table VIII shows revealed no statistically significant difference ($p > 0.05$) between three groups in ARI scores with chi square value of 0.860.

GRAPH 1: COMPARISON OF SBS BETWEEN THREE GROUPS**GRAPH 2: ARI DIFFERENCE BETWEEN THREE GROUPS**

DISCUSSION

All orthodontists and patients prefer good quality of treatment in shorter duration of time, however orthodontic treatment time can be greatly influenced by various factors and frequent debonding of brackets during treatment is one among them, which can lead to lack of progress in the treatment. Therefore bond strength between the bracket and enamel has become an important factor in orthodontics. Many studies have shown that factors such as enamel conditioning, design of the brackets base, type of adhesive system, and the mode of cure can influence the bond strength.^{3,5,10,18} The most important of these factors is that the adhesive composite should reach utmost polymerization which will adequately retain the bracket to the tooth when orthodontic forces are applied. As new light curing systems with high intensity and short curing time to enhance bonding are constantly being introduced, the orthodontic practitioners should be aware of various types of light sources, polymerization efficiency, performance, their lamp properties, and their application to orthodontic bonding.

The literature contains abundance of studies, comparing advantages and disadvantages of different light cure units such as quartz tungsten halogen lamps, argon lasers, xenon plasma arc lights, light emitting diode curing lights etc.

First light cure unit had ultraviolet light source introduced in 1970. Because of the safety concerns of Ultra Violet light and longer duration to cure composite, visible light curing was then

introduced around 1980. The visible light cure resin systems use a diketone absorber as activator to create free radicals that initiate the polymerization process. Most resin photo initiator systems use camphoroquinone as the diketone absorber, which had maximum curing in the blue region of the visible light spectrum at a wavelength of 470nm.

The most popular method of delivering blue light has been with quartz tungsten halogen (QTH) light curing units. Halogen bulbs produce light by utilizing electric energy to heat a small tungsten filament to high temperature. Selective screen filters the wavelength so that only blue light is emitted with a bandwidth between 400 to 520 nm. Most of the energy put into the halogen system is changed into heat but a small portion is given off as light producing an energy density of approximately 400 W/cm². Despite their popularity, halogen bulbs have several shortcomings such as effective lifetime of the bulb is approximately 100 hours only, since high heat is generated it degrades the components of the halogen bulb over time, and also long curing time is needed.⁹

The argon laser introduced in the late 1980's and early 1990's are capable of curing in 10 seconds for filled resins and 5 seconds for unfilled resins at a wavelength of 488 nm. In a study by Travis Q Talbot et al²⁸ showed the use of argon laser to bond orthodontic brackets can yield excellent bond strengths in significantly less time. Further more in mid 1990s xenon plasma arc light units have

been introduced for rapid light curing in dentistry. The curing time range from 2 to 9 seconds for plasma arc curing lights.⁵³

In 1995, Mills et al proposed solid state light emitting diode (LED) technology for the polymerization of light activated dental materials. LED's produce visible light by quantum mechanics effects.⁵⁴ First- generation LED light cure units emit blue light with intensity 150–500 mW/cm². Recently attention towards manufacture of high power LED units with intensity >2000mW/cm² is gaining popularity since more photons are available for absorption by the photosensitizers which react with the amine and form free radicals for polymerization.

Light intensity is the important factor that contributes to the degree of polymerization. Mavropoulos et al⁴³ stated that shear bond strength depends on energy density, but the relationship is nonlinear and is influenced by both intensity and curing time of the light cure units. Rueggeberg⁵⁵ stated that higher the light intensity, greater the number of photons reaching the resin resulting in higher number of free radicals available for polymerization. There was a direct relation between increasing the time of curing with shear bond strength. This was attributed to higher rate of monomer/polymer conversion occurred with increasing curing time never the less it has been claimed higher the intensity of light, shorter the curing time needed. This postulate was derived from the “exposure reciprocity law”, which states that there is reciprocity between irradiance levels and exposure time to achieve equivalent

polymerization of resin based composites.³⁹ It has been demonstrated that many resins appear to follow exposure reciprocity with regard to the degree of conversion, hardness, elastic modulus and cure depth.³²

Several studies have shown that LED-curing units are as effective as halogen-curing units and stated that there was no significant difference in shear bond strength (SBS).^{35,36,40,41}

Mustafa M Al-Khatieeb et al⁵¹ compared the effect on SBS with different curing time (3 seconds and 1 seconds) of high intensity LED light cure unit with a QTH light cure unit. They concluded both of the LED unit's groups showed clinically acceptable SBS of 8.231 ± 2.120 MPa and 6.426 ± 1.839 MPa respectively in comparison to QTH with SBS of 4.56 ± 1.649 MPa, so the time of bonding reduced without affecting the shear bond strength or enamel surface after debonding.

Chanamallappa Ramappa Ganiger et al⁵⁶ compared the SBS of brackets bonded with conventional LED light cure unit for 10 seconds and high intensity LED light cure unit for 3 seconds and debonded at different times. The results showed no statistically significant difference in SBS for the conventional LED (8.84 ± 3.141 MPa) and high intensity LED (9.87 ± 5.591 MPa). Moreover, the SBS was improving with time from 12 hours to 7 days in both the units.

Due to number of high intensity light cure units available in the market at different curing efficacy and cost; the clinicians are in uncertainty to select among various high intensity light cure units available that could provide clinically acceptable bond strength.

Even though literatures have evidence of comparison of high intensity light cure unit with conventional halogen or conventional LED light cure unit, to our knowledge there is no study to compare the efficacy of both economical and costlier high intensity light cure units for 3 seconds used in orthodontics for bonding of brackets.

The aim of the present study is to compare shear bond strength of bracket bonding system between two commercially available high intensity LED light cure units, where one brand is the more expensive than the other one.

Sixty human maxillary first premolars with intact buccal enamel without tooth caries, pre-existing fractures and restorations were used. The teeth were stored in distilled water for two month to prevent dehydration. Fox et al²⁵ recommended distilled water as a pre-bonding storage media and it has been found that distilled water storage did not adversely affect the bond strength of the teeth stored for up to 6 months.²⁴

Sixty premolar teeth were randomly assigned to 3 groups with 20 teeth per group. Each group was given different colour coding as Group 1 - Red, Group 2 - White, Group 3 - Blue. The teeth were

oriented in such a way the labial surface of the tooth was kept perpendicular to the bottom surface of the mold.

Teeth were etched with 37% orthophosphoric acid for 30 seconds and premolar brackets were bonded to the buccal tooth surface using light cure units.

The light intensity of the curing unit was verified with radiometer before each cure using BEHN-LED1 (Table I). Group 1 was cured with conventional QTH (3M-ESPE Elipar 2500) with intensity up to 1300 mW/cm^2 for 40 seconds (20 seconds mesial and 20 seconds distal). Group 2 was cured with Woodpecker iLED plus light cure unit with intensity upto 2500 mW/cm^2 for 6 seconds (3 seconds mesial and 3 seconds distal). Group 3 was cured with Ivoclar blue phase power cure light cure unit with intensity up to 3050 mW/cm^2 for 6 seconds (3 seconds mesial and 3 seconds distal). In this study the light cure head is placed as close to the bracket base while curing.

All the samples were stored in distilled water for 24 hours at 37°C before testing shear bond strength in a universal testing machine. It has been observed that SBS of the brackets at 5 minutes from curing is only about 60-70% of that of 24 hours value.⁵⁷ So the SBS value reaches maximum only after 24 hours of bonding.

The samples were tested using universal testing machine for shear bond strength. The maximum force necessary to debond or initiate bracket fracture was recorded in Newtons and then converted into Megapascals (MPa).

The results obtained from this study were subjected to statistical analysis. All the three groups in the study were able to achieve clinically acceptable SBS (Table III). Among the 3 Groups, Group 1 (QTH-3M ESPE Elipar 2500) had the highest SBS of 11.6782 ± 1.68139 MPa, followed by Group 3 (Ivoclar blue phase power cure) with SBS of 11.6168 ± 1.92509 MPa respectively. However the difference is not statistically significant. Group 2 (Woodpecker iLED plus) have the lowest shear bond strength of 9.9989 ± 1.88915 MPa among three groups and statistically significant compared to Group 1 and Group 3, however the SBS values are more than the ideal bond strength required for Orthodontics.

The results of our study shows mean SBS of Group 1(QTH-3M ESPE Elipar 2500) is 11.6782 ± 1.68139 MPa which is relatively higher to the result obtained in the study conducted by Guram et al,⁵² who stated that mean SBS for QTH group is 8.89 ± 2.46 Mpa. This difference may be attributed to the fact, enamel conditioning and distance between the light cure tip and bracket base may be varied.

Similarly the mean SBS of Group 2 (woodpecker iLED plus) is 9.9989 ± 1.88915 MPa which is relatively higher to the results of the study done by Mustafa M Al-Khatieeb et al⁵¹ who states that mean SBS is 8.231 ± 2.120 MPa. This difference may be because; in

that study curing was done from occlusal direction, and only once for 3 seconds.

The mean SBS of Group 3 (Ivoclar blue phase power cure) is 11.6168 ± 1.92509 MPa. The results of our study was in accordance with the similar type of study by Abdullah Alper Oz et al⁴⁹ revealed that mean SBS is 11.43 ± 3.56 MPa using similar high intensity LED light cure units.

Since all three light cure units used in the study was able to achieve clinically acceptable SBS above 8MPa and below 14.5MPa, the high intensity LED light cure units is a better alternative to conventional light cure units as it reduces the chair side time and increases patient comfort. The mean adequate SBS for majority of the clinical situations is 5.9–7.8MPa as proposed by Reynolds.⁴ Bowen and Rodriguez¹⁶ states that clinical bond strength at or above 14.5 MPa can have enamel fractures upon debonding.

The tooth surface of de-bonded specimens was studied for ARI score under 10x magnification in stereo microscope. O'Brien et al²² claimed that the ARI score depended on many factors, including the bracket base design, the adhesive type and not simply on the bond strengths at the interfaces.

In the present study all the three groups predominantly have ARI score of 2 and there is no statistically significant difference in ARI scores between the groups. ARI score 2 implies that bond failures occurred mostly at the bracket–adhesive interface after debonding, with more than 50% of the adhesive material adhered to

the tooth surface that allows removal of composite resin and preservation of the enamel from possible trauma.³¹

The results of our study suggest that, both high intensity LED units Woodpecker iLED plus and Ivoclar Blue phase power cure can be used in bracket bonding with reduced curing time compared to conventional light cure units without affecting the clinically acceptable bond strength. This reduction in curing time can lead to various advantages like shorter chair time and lower the risk of contamination of saliva during Orthodontic bonding.

Limitation of this study may be that being an in vitro study, it cannot completely reproduce the complex interaction processes that occur in the oral cavity. In vivo complex interaction includes intra oral aging of resin composites, pH variations, temperature fluctuation, complex cyclic loading, microbial attack, and enzymatic degradation.^{23,26,27.}

Thus further SBS study is warranted to stimulate in vivo condition, and also determine the depth of cure, degree of conversion, effects of increase temperature on pulpal tissue. Moreover the intensity degradation of high intensity light cure unit over a period of time should also be monitored.

SUMMARY AND CONCLUSION

This study evaluated the shear bond strength of orthodontic metal brackets polymerized with two different high intensity LED light cure units available in the market - woodpecker iLED plus and Ivoclar blue phase power cure, which was projected to reduce the curing time effectively to 3 seconds with acceptable clinical bond strength, when compared to conventional light cure units. The results showed all the three groups in the study were able to achieve clinically acceptable shear bond strength. Among the 3 Groups, Group 1 (Halogen-3M ESPE Elipar 2500) had the highest SBS of 11.6782 ± 1.68139 MPa, followed by Group 3 (Ivoclar blue phase power cure) with shear bond strength of 11.6168 ± 1.92509 MPa respectively. However the difference is not statistically significant. Group 2 (woodpecker iLED plus) have the lowest shear bond strength of 9.9989 ± 1.88915 MPa among three groups and statistically significant compared to Group 1 and Group 3, however they are more than the ideal bond strength required for orthodontics. Therefore the null hypothesis is rejected since there was significant difference in shear bond strength in Group 2 when compared with Group 1 and Group 3 light cure units.

We conclude the study by stating that, high intensity LED units Woodpecker iLED plus and Ivoclar blue phase power cure can be used in orthodontic bonding with 3 seconds curing time as an alternate to conventional light cure units without affecting the clinically acceptable bond strength. The reduction in curing time leads to various advantages like shorter chair time and lower risk of contamination of saliva.

Furthermore, less expensive light cure unit (Woodpecker iLED plus) was also able to achieve clinically acceptable shear bond strength as claimed by the manufactures and can be preferred for orthodontic bonding.

BIBLIOGRAPHY

1. Gupta SP, Shrestha BK. Shear bond strength of a bracket-bonding system cured with a light-emitting diode or halogen-based light-curing unit at various polymerization times. *Clinical, cosmetic and investigational dentistry*. 2018;10:61.
2. Oesterle LJ, Shellhart WC. Bracket bond strength with transillumination of a light-activated orthodontic adhesive. *The Angle orthodontist*. 2001 Aug;71(4):307-11.
3. Heravi F, Moazzami SM, Ghaffari N, Jalayer J, Bozorgnia Y. Evaluation of shear bond strength of orthodontic brackets using trans-illumination technique with different curing profiles of LED light-curing unit in posterior teeth. *Progress in orthodontics*. 2013 Dec;14(1):1-5.
4. Reynolds IR. A review of direct orthodontic bonding. *British journal of orthodontics*. 1975 Jul 1;2(3):171-8.
5. Bakhadher W, Halawany H, Talic N, Abraham N, Jacob V. Factors affecting the shear bond strength of orthodontic brackets—A review of in vitro studies. *Acta medica*. 2015 Aug 31;58(2):43-8.
6. Joseph VP, Rossouw E. The shear bond strengths of stainless steel and ceramic brackets used with chemically and light-activated composite resins. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1990 Feb 1;97(2):121-5.

7. Gange P. The evolution of bonding in orthodontics. American Journal of Orthodontics and Dentofacial Orthopedics. 2015 Apr 1;147(4):S56-63.
8. Trimpeneers LM, Verbeeck RH, Dermaut LR, Moors MG. Comparative shear bond strength of some orthodontic bonding resins to enamel. The European Journal of Orthodontics. 1996 Jan 1;18(1):89-95.
9. Hadole PG, Daokar SS. Light-curing unit (devices). International Journal of Orthodontic Rehabilitation. 2019 Jul 1;10(3):121.
10. Mills RW. Blue light emitting diodes--another method of light curing?. British dental journal. 1995 Mar 11;178(5):169.
11. Dunn WJ, Taloumis LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. American Journal of Orthodontics and Dentofacial Orthopedics. 2002 Sep 1;122(3):236-41.
12. Rueggeberg FA, Giannini M, Arrais CA, Price RB. Light curing in dentistry and clinical implications: a literature review. Brazilian oral research. 2017 Aug;31.
13. Pelissier B, Jacquot B, Palin WM, Shortall AC. Three generations of LED lights and clinical implications for optimizing their use. 1: from past to present. Dental update. 2011 Dec 2;38(10):660-70.

14. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res 1955;34: 849-53.
15. Bowen RL. Adhesive bonding of various materials to enamel surfaces. J Dent Res. 1962;110:690-95.
16. Bowen RL, Rodriguez MS. Tensile strength and modulus of elasticity of tooth structure and several restorative materials. The Journal of the American Dental Association. 1962 Mar 1;64(3):378-87.
17. Buonocore MG, Matsui A, Gwinnett AJ. Penetration of resin dental materials into enamel surfaces with reference to bonding. Archives of oral biology. 1968 Jan 1;13(1):61-IN20.
18. Newman GV. Current status of bonding attachments. Journal of clinical orthodontics: JCO. 1973 Jul 1;7(7):425-34.
19. Silverstone LM, Saxton CA, Dogon IL, Fejerskov O. Variation in the pattern of acid etching of human dental enamel examined by scanning electron microscopy. Caries research. 1975;9(5):373-87.
20. Thompson RE, Way DC. Enamel loss due to prophylaxis and multiple bonding/debonding of orthodontic attachments. American journal of orthodontics. 1981 Mar 1;79(3):282-95.
21. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. American journal of orthodontics. 1984 Apr 1;85(4):333-40.

22. O'brien KD, Watts DC, Read MJ. Residual debris and bond strength—is there a relationship?. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1988 Sep 1;94(3):222-30.
23. Øilo G. Biodegradation of dental composites/glass-ionomer cements. *Advances in Dental Research*. 1992 Sep;6(1):50-4.
24. Goodis HE, Marshall Jr GW, White JM, Gee L, Hornberger B, Marshall SJ. Storage effects on dentin permeability and shear bond strengths. *Dental Materials*. 1993 Mar 1;9(2):79-84.
25. Fox NA, McCabe JF, Buckley JG. A critique of bond strength testing in orthodontics. *British journal of orthodontics*. 1994 Feb 1;21(1):33-43.
26. Eliades T, Brantley WA. The inappropriateness of conventional orthodontic bond strength assessment protocols. *The European Journal of Orthodontics*. 2000 Feb 1;22(1):13-23.
27. Pickett KL, Lionel Sadowsky P, Jacobson A, Lacefield W. Orthodontic in vivo bond strength: comparison with in vitro results. *The Angle Orthodontist*. 2001 Apr;71(2):141-8.
28. Talbot TQ, Blankenau RJ, Zobitz ME, Weaver AL, Lohse CM, Rebellato J. Effect of argon laser irradiation on shear bond strength of orthodontic brackets: an in vitro study. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2000 Sep 1;118(3):274-9.

29. 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. *American journal of orthodontics and dentofacial orthopedics*. 2002 May 1;121(5):510-5.
30. Emami N, Söderholm KJ, Berglund LA. Effect of light power density variations on bulk curing properties of dental composites. *Journal of Dentistry*. 2003 Mar 1;31(3):189-96.
31. Bishara SE, Ajlouni R, Oonsombat C. Evaluation of a new curing light on the shear bond strength of orthodontic brackets. *The Angle Orthodontist*. 2003 Aug;73(4):431-5.
32. Swanson T, Dunn WJ, Childers DE, Taloumis LJ. Shear bond strength of orthodontic brackets bonded with light-emitting diode curing units at various polymerization times. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2004 Mar 1;125(3):337-41.
33. Mavropoulos A, Staudt CB, Kiliaridis S, Krejci I. Light curing time reduction: in vitro evaluation of new intensive light-emitting diode curing units. *The European Journal of Orthodontics*. 2005 Aug 1;27(4):408-12.
34. Türkkahraman H, Küçükeşmen HC. Orthodontic bracket shear bond strengths produced by two high-power light-emitting diode modes and halogen light. *The Angle Orthodontist*. 2005 Sep;75(5):854-7.

35. Silta YT, Dunn WJ, Peters CB. Effect of shorter polymerization times when using the latest generation of light-emitting diodes. *American journal of orthodontics and dentofacial orthopedics*. 2005 Dec 1;128(6):744-8.
36. 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. *The European Journal of Orthodontics*. 2006 Feb 1;28(1):78-82.
37. 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. *American journal of orthodontics and dentofacial orthopedics*. 2006 Feb 1;129(2):277-82.
38. Sfondrini MF, Cacciafesta V, Scribante A, Boehme A, Jost-Brinkmann PG. 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 Apr 1;129(4):541-6.
39. Feng L, Suh BI. Exposure Reciprocity Law in Photopolymerization of Multi-Functional Acrylates and Methacrylates. *Macromolecular Chemistry and Physics*. 2007 Feb 5;208(3):295-306.

40. Krishnaswamy NR, Sunitha C. Light-emitting diode vs halogen light curing of orthodontic brackets: a 15-month clinical study of bond failures. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2007 Oct 1;132(4):518-23.
41. Koupis NS, Eliades T, Athanasiou AE. Clinical evaluation of bracket bonding using two different polymerization sources. *The Angle Orthodontist*. 2008 Sep;78(5):922-5.
42. Mirabella D, Spina R, Scognamiglio G, Luca L, Gracco A, Siciliani G. LED vs halogen light-curing of adhesive-precoated brackets. *The Angle Orthodontist*. 2008 Sep;78(5):935-40.
43. Mavropoulos A, Cattani-Lorente M, Krejci I, Staudt CB. Kinetics of light-cure bracket bonding: power density vs exposure duration. *American journal of orthodontics and dentofacial orthopedics*. 2008 Oct 1;134(4):543-7.
44. Eliades T. Polymerization lamps and photocuring in orthodontics. In *Seminars in orthodontics* 2010 Mar 1 (Vol. 16, No. 1, pp. 83-90). WB Saunders.
45. Finnema KJ, Özcan M, Post WJ, Ren Y, Dijkstra PU. In-vitro orthodontic bond strength testing: a systematic review and meta-analysis. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2010 May 1;137(5):615-22.
46. Dall'Igna CM, Marchioro EM, Spohr AM, Mota EG. Effect of curing time on the bond strength of a bracket-bonding system

- cured with a light-emitting diode or plasma arc light. The European Journal of Orthodontics. 2011 Feb 1;33(1):55-9.
47. Shortall AC, Palin WM, Jacquot B, Pelissier B. Advances in light-curing units: four generations of LED lights and clinical implications for optimizing their use: Part 2. From present to future. Dental update. 2012 Jan 2;39(1):13-22.
48. Ward JD, Wolf BJ, Leite LP, Zhou J. Clinical effect of reducing curing times with high-intensity LED lights. The Angle Orthodontist. 2015 Nov 1;85(6):1064-9.
49. 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. American Journal of Orthodontics and Dentofacial Orthopedics. 2016 Feb 1;149(2):212-6.
50. Shortall AC, Price RB, MacKenzie L, Burke FJ. Guidelines for the selection, use, and maintenance of LED light-curing units-Part 1. British dental journal. 2016 Oct;221(8):453-60.
51. Al-Khatieeb MM, Nahidh M, Al-Khawaja NF. 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 (IJSR) ISSN (Online). 2017.
52. Guram G, Shaik JA. Comparison of light-emitting diode-curing unit and halogen-based light-curing unit for the polymerization of orthodontic resins: An in vitro study.

- Journal of International Society of Preventive & Community Dentistry. 2018 Sep;8(5):409.
53. 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. American journal of orthodontics and dentofacial orthopedics. 2006 Feb 1;129(2):277-82.
54. Cacciafesta V, Sfondrini MF, Jost-Brinkmann PG, Boehme A. Light-emitting diode technology for orthodontic bonding. Journal of clinical orthodontics: JCO. 2002 Aug 1;36(8):461-5.
55. Rueggeberg F. Contemporary issues in photocuring. Compendium of continuing education in dentistry.(Jamesburg, NJ: 1995). Supplement. 1999 Jan 1(25):S4-15.
56. Ganiger CR, Ahammed AR, Shetty V. Shear bond strength of brackets bonded with different LED units & curing times and at different debond times in an in-vitro study. Dentistry. 2017;7(456):2161-1122.
57. Tavas MA, Watts DC. A visible light-activated direct bonding material: an in vitro comparative study. British Journal of Orthodontics. 1984 Jan 1;11(1):33-7.