AN IN-VIVO ASSESSMENT OF BRACKET FAILURE AND ADHESIVE REMNANT INDEX BETWEEN TWO DIFFERENT LIGHT CURE ADHESIVES WITH LIGHT EMITTING DIODE - *A SPLIT MOUTH STUDY*

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

BRANCH V

ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

MAY - 2018

THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY

CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"An In-Vivo Assessment of Bracket Failure and Adhesive Remnant Index Between Two Different Light Cure Adhesives with Light Emitting Diode - *A Split Mouth Study*"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. G. JAYAKUMAR, M.D.S.,** Professor, Department of Orthodontics and Dentofacial Orthopaedics, Ragas Dental College and Hospital, Chennai.

Date: 8.2.2018

Place: Chennai

Dr. M. Charles Finny
Post Graduate Student
Department of Orthodontics and
Dentofacial Orthopedics,
Ragas Dental College and Hospital,
Chennai

CERTIFICATE

This is to certify that this dissertation titled **"An In-Vivo Assessment of Bracket Failure and Adhesive Remnant Index Between Two Different Light Cure Adhesives with Light Emitting Diode - *A Split Mouth Study*"** is a bonafide record work done by **Dr. M. Charles Finny** under my guidance during his post graduate study period 2015-2018.

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the degree **of MASTER OF DENTAL SURGERY in BRANCH V** - Orthodontics and Dentofacial Orthopedics. It has not been submitted (partially or fully) for the award of any other degree or diploma.

RAGAS DENTAL COLLEGE Chennai

Guided by:

8/2/18

Dr. G. Jayakumar, M.D.S.,
Dip. Indian Board of Orthodontics
Professor, Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai.

Head of the Department:

N.R. 8/2/18

Prof. (Dr.) N.R. Krishnaswamy M.D.S.,
M. Ortho R.C.S. (Edin) Dip N.B. (Ortho)
Dip. Indian Board of Orthodontics
Professor and H.O.D
Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai.

Dr. N. R. KRISHNASWAMY.
PROFESSOR & HEAD
Dept. of Orthodontics
RAGAS DENTAL COLLEGE & HOSPITAL
2/102, East Coast Road
Uthandi, Chennai-600 119

Dr. N.S. Azhagarasan, M.D.S.,
Principal
Ragas Dental College and Hospital, Chennai.

PRINCIPAL
RAGAS DENTAL COLLEGE AND HOSPITAL
UTHANDI, CHENNAI-600 119.

THE TAMIL NADU Dr. MGR MEDICAL UNIVERSITY CHENNAI

PLAGIARISM CERTIFICATE

This is to certify the dissertation titled **"An In-Vivo Assessment of Bracket Failure and Adhesive Remnant Index Between Two Different Light Cure Adhesives with Light Emitting Diode - *A Split Mouth Study*"** of the candidate **Dr. M. CHARLES FINNY** for the award of **MASTER OF DENTAL SURGERY in BRANCH V - Orthodontics and Dentofacial Orthopedics.**

On verification with the urkund.com website for the purpose of plagiarism check, the uploaded thesis file from introduction to conclusion contains **2 percentage** of plagiarism, as per the report generated and enclosed in Annexure – II.

Date: 8.2.2018

Place: Chennai

M. Charles Finny

Dr. M. Charles Finny
Post Graduate Student,
Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai

G Jayakumar 8/2/18

Dr. Jayakumar M.D.S.,
Diplomate-Indian Board of Orthodontics
Guide,
Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai.

ACKNOWLEDGEMENT

I thank God Almighty, whose immense grace has been sufficient in all aspects in every circumstance encountered. He guided and helped me throughout my life in every endeavor and for that I am grateful.

I would like to acknowledge and thank my beloved Professor and Head, ***Dr. N. R. Krishnaswamy, M.D.S., M. Ortho (RCS, Edin), D.N.B. (Ortho), Diplomate of Indian board of Orthodontics,*** *Department of Orthodontics, Ragas Dental College and Hospital, Chennai. His everlasting inspiration, encouragement, constructive criticism and valuable suggestions conferred upon me have encouraged me in ways beyond explanation.*

I am privileged to express my extreme gratefulness to my respected guide, Professor ***Dr. G. Jayakumar, M.D.S., Diplomate of Indian board of Orthodontics,*** *for his guidance which helped me complete this study. I consider myself extremely fortunate to have had the opportunity to train under him. His enthusiasm, integral view on research, tireless pursuit for perfection has made a deep impression on me. His patience and technical expertise that he has shared throughout the duration of the study has encouraged me in many ways.*

My sincere thanks to ***Professor A. Kanakaraj,*** *Chairman and* ***Dr. N.S. Azhagarasan,*** *Principal, Ragas Dental College for providing me with an opportunity to utilize the facilities available in this institution in order to conduct this study.*

I would also like to acknowledge ***Dr. M. K. Anand*** *(Professor),* ***Dr. Sriram*** *(Professor),* ***Dr. Shakeel Ahmed*** *(Professor),* ***Dr. Rekha Bharadwaj*** *(Reader),* ***Dr. Shobbana Devi*** *(Reader),* ***Dr. Premalatha*** *(Reader),* ***Dr. Kavitha*** *(Reader),* ***Dr. Dhivya Lakshmi*** *(Senior Lecturer) and* ***Dr. Bharath Ramesh*** *(Senior Lecturer) for their support, enthusiasm & professional assistance throughout my post graduate course.*

I would also like to thank ***Dr. Reuben*** *(Professor, Oral Pathology) for his valuable suggestions during my statistical work and methodology.*

My heartfelt thanks to my wonderful batchmates, ***Dr. Aparnna, Dr. Mathew, Dr. Harish, Dr. Gopinaath, Dr. Sam Prasanth, Dr. Rishi,*** *and* ***Dr. Swathy*** *who were cheerfully available at all times to help me. Their support and friendship was constant during these last years, and I deeply appreciate it.*

I also extend my gratitude to my Seniors, Juniors and friends ***Dr. N. Revathi., Dr. R. Rajesh, Dr. B. N. Vineesha, Dr. R. Preeti, Dr. Evan. A. Clement, Dr. G. Preethi, Dr. S. Veerasankar, Dr. Dhanalakshmi, and Dr. S. Vidhu, Dr. Amrutha, Dr. Bajath, Dr. Vidhya, Dr. Kowtham, Dr. Lily, Dr. Grace, Dr. Sheril, Dr. Maryam and Dr. Bijivin*** *for their support.*

I would like to thank ***Mr. Ashok, Mr. Manikandan, Mr. Bhaskar, Sister Lakshmi, Sister Deivaanai, Sister Kanaka, Mrs. Uma, Mr. Thavamani*** *and the* ***Scribbles team*** *for their co-operation and help during my course of study. Finally, I would like to convey my gratitude and thanks to* ***my parents and my sister Dr. Celena Bency*** *to whom I am indebted forever.*

LIST OF TABLES

LIST OF GRAPHS

LIST OF CHARTS

LIST OF FIGURES

CONTENTS

Introduction

INTRODUCTION

As aesthetics is the highest priority in this 21st Century, Orthodontic bonding of brackets is considered the first step of utmost importance that paves a way for enhancement of aesthetics.

The introduction of acid etching technique by Bunocore in 1995 paved a path of possibility in direct bonding of orthodontic brackets in teeth, a technique that has now become an integral part of orthodontics.

Over the years this technique has been refined and variations described as new techniques or materials have become available.

The advent of dental bonding procedures has streamlined the placement of orthodontic appliances to a significant extent, and recent advancements in bonding materials and techniques have made bonding of brackets easier, effective, predictable and efficient. Bonding necessitates the use of orthodontic adhesives, which set by either chemical or light curing.[35]

The adhesive system plays a major role in the bracket – adhesive – tooth interface. Orthodontic bonding is one of the numerous variables that dictate the outcome and efficiency of orthodontic care.

An adhesive must be able to cope with numerous deleterious conditions in the oral cavity, such as constant moisture, relatively high ambient temperature, and adherent contamination that is difficult to remove completely. Further, it must be capable of withstanding considerable masticatory stress as well as applied orthodontic stress.[3]

Development in the field of orthodontic bonding materials is extensive and orthodontic adhesives have developed in line with emerging technologies in dentistry.[116]

Orthodontic adhesives developed for bracket bonding have come into widespread use in clinical orthodontic practice based on several advantages, including accurate bracket positioning, shorter working time, and easier removal of excess material, patient convenience and immediate insertion of the orthodontic arch wire.[82]

The adhesive material used to bond orthodontic brackets to teeth, neither should it fail during the treatment period as it may result in treatment delays, untoward expenses or patient inconvenience nor should it damage the enamel on debonding at the end of the treatment.[9]

However, there remains a potential for failure of orthodontic brackets through the course of orthodontic treatment.

Many commercially available orthodontic bonding materials have been experimentally evaluated in laboratories but not all were clinically tested to confirm their efficiency and effectiveness. Despite the lack of clinical evaluation, these materials are commonly used by orthodontists for bonding orthodontic appliances.[92]

The claim of the manufactures regarding their materials often fails to impress the expectations of an orthodontist. The quest to develop a "much more" efficient adhesive by the manufacturer and its search for satisfaction, by an orthodontist has been never ending.

Research has mainly concentrated on the reliability and effectiveness of the adhesive systems and on simplifying adhesive technique. Many clinical studies have been reported in publications evaluating many adhesive systems of different brands in the past. Nevertheless, no study has assessed these two different adhesive systems in the same patient by using quadrant variations.

This study was done to compare two distinguishably different light cure adhesive materials from two global manufactures, used in bonding of orthodontic brackets to teeth and evaluate the efficiency of the same.

The two light cure composite adhesives are Bracepaste (American orthodontics, Sheboygan, WI, USA) and Transbond XT (3M Unitek, Monrovia, CA, USA), used according to the manufacturer's recommendations.

The clinical study was designed as a double blinded prospective study with randomized selection of patients to compare the bond failure rates between the two light cure adhesives in vivo.

The purpose of the present study was to perform a 10-month clinical assessment of failure rate of brackets bonded with Bracepaste and Transbond XT adhesives. The number of bracket failures was also analyzed between dental arches, regions, sides, quadrants, age, gender and wire composition and dimensions.

Aim and Objectives

AIM AND OBJECTIVES

Aim:

To compare and evaluate clinical failure rates of metal brackets bonded with two different light cure composite resin materials activated using LED light cure unit. The two adhesives compared in this study are Transbond XT and Bracepaste.

Objectives of the Study:

- To assess the frequency and percentage of bracket failures which occur in relation to the two adhesive materials and within the different variables such as age, gender, arch, quadrants, segments, different tooth types and arch wires.
- To assess Adhesive Remnant Index and determine the interface at which the bracket failures occur.

Review of Literature

REVIEW OF LITERATURE

Sheen and Wang et al AO 1991[102] investigated the influence of acid etching using 37% phosphoric acid at two different durations of 15 seconds and 60 seconds between younger (9-16 years) and older permanent teeth (48-69 years). No statistical difference was seen between the bond strength of etching 15 seconds or 60 seconds, thus the shorter curing time was considered the better. However statistical difference was seen with the age group with older teeth showing better bond strength than younger teeth. ARI scores varied but enamel detachment occurred with teeth etched for 60 seconds.

Gardner and Hobson et al AJO 2001[38] conducted an ex vivo study to assess the optimal etching time and acid for acid etching. The etch patterns of 37% phosphoric acid and 25% nitric acid etched for 15,30 and 60 seconds were viewed under a scanning electron microscope and measured using a 5 point etch scale. Increase in duration increased the quality of etch of both acids. 37% Phosphoric acid was found better than 25% nitric acid at all durations. 60 seconds of etching time showed no significance than 30 seconds. 37% phosphoric acid with 30 seconds of duration was considered optimal.

Hobson et al AJO 2002[47] assessed the relationship of type of etching patterns and in vivo bond strength of brackets when etched with 37% phosphoric acid for 30 seconds. A statistical positive relation was seen between etch quality and bond survival. Type A etch pattern denoting good quality etch was seen in only 5% of cases (lower incisors). Type C (pitted enamel) was predominantly seen. Type D (no etch) was seen mostly in molars.

Hajrassie and Khier at al AJO 2007[43] compared the in vivo and invitro bond strength of brackets bonded with Transbond XT at various debond times 10 minutes, 24 hours, 1 week and 4 weeks. In his study he claimed that the in vivo mean bond strength values were approximately 40% lower than in vitro studies. The invitro and in vivo studies showed increasing bond strength over the tested time intervals but however insignificant statistically. The mean bond strength of Transbond XT was 7.39 X 10^{-3} and 7.11 X 10^{-3} MPa in invitro and in vivo studies respectively.

Owens and Miller et al AO 2000[81] conducted an invitro study and evaluated the shear bond strength of Transbond XT, Enlight (light cure composite resin) and Fuji Ortho LC (RMGIC). The light cure composite resins displayed higher bond strength than RMGIC with Transbond XT displaying the highest mean shear bond strength (7.9±2.1) in the study though not statistically significant with its light cure counterpart. ARI scores denoted higher amount of composite was found on enamel surface with composite resin and majority of adhesive attached to bracket base for RMGIC.

Andrew Summers and Peter Ngan et al in AJO 2004[109] assessed the survival rates in vivo split mouth study design and also invitro shear bond strength test, to compared the efficiency of light cure adhesive (Light Bond) and RMGIC (Fuji Ortho LC). Light Bond adhesive was used after etching the teeth with 37% phosphoric acid and brackets were bonded with RMGIC after etching with 10% polyacrylic acid. The invivo test results showed a no significant results. The invitro study showed increased bond strength at 24 hours compared with 30 minutes. Light cure adhesive displayed better bond strength than RMGIC. 37% phosphoric acid for 30 seconds showed rougher and porous surface than 10% polyacrylic acid.

Vicente et al AJO 2006[119] assessed the shear bond strength and ARI scores of 3 adhesive promoters (All Bond 2, Ortho Solo and Enhance LC) bonded with either Light Bond or Transbond XT adhesive in different combinations. Transbond XT alone showed significantly higher bond strength than Light Bond adhesive alone. None of the adhesive promoters significantly increased the bond strength, nevertheless, all showed adequate bond strength and the highest bond strength in the study was achieved with Enhance LC with Light Bond group. ARI scored displayed mixed results and enamel fractures occurred in all groups expect Transbond XT only group.

Douglas Rix et al AJO 2001[91] assessed the shear bond strength of three adhesives Transbond XT (light cure resin), FOLC (RMGIC) and Assure (polyacid modified composite resin). The teeth were stored in deionised water for 30 days and thermocycled for 24 hours before testing. Transbond XT displayed significantly higher mean shear bond strength (20.19 MPa) compared to the other two adhesives with Assure depicting the least bond strength. Higher number of enamel fractures occurred with adhesive with higher bond strength.

Catherine Sunitha et al AJO 2011[110] assessed the release of Bisphenol A from Transbond XT ashesive using a high performance liquid chromatography and correlate the release to the degree of conversion with three different light curing tip distances (0mm, 5mm and 10mm). An increase in release of BPA and decrease in the degree of conversion as the distance of light cure tip increased was noted. The author recommends the light cure tip placed as close as possible to ensure complete cure of the adhesive.

Christiana Gioka et al AJO 2005[40] assessed the degree of cure, leaching of monomers and biological properties of a chemical cure adhesive (Rely–a-bond) and a light cure composite (Reliance). Both materials showed no cytotoxic effects and no significant differences was found between the two adhesive types in terms of degree of cure and leaching of monomers.

Millett and Hallgren et al AO 1998[68] conducted an in vivo study to access the first time bond failure rates and the influence of patient's age, sex and malocclusion, thereby evaluating the efficiency of Transbond XT adhesive used for bonding brackets in the study. An overall failure rate of 6% was seen. The patient's age, sex or type of malocclusion did not seem to have an effect on first time failures. Transbond XT is considered a reliable resin for orthodontic bonding.

Ambesh Kumar Rai et al 2014 [87] assessed the rate of bracket failures which occurred with or without the application of primer before bonding of brackets with Transbond XT adhesive. The percentage of failures with or without primer application were 5.8% and 6.3% with an overall percentage of

6.1%. Though a higher number of failures occurred in group without primer application, no statistical significance was found between with or without primer groups in terms of bracket failure.

Romano et al 2012 [92] using a split mouth study design evaluated the bonding of metal brackets with different orthodontic adhesive systems (Concise, Transbond XT conventional, Transbond XT without primer, Transbond XT with Transbond Plus SEP) over a period of 6 months. Transbond XT conventional and Transbond XT with SEP showed least bracket failures while bracket bonded with Transbond XT without primer application and Concise adhesive system showed significantly higher bracket failures. No significant differences in bracket failures were seen between arches, sides or quadrant while anterior teeth displayed significantly lower failure rates than posterior teeth.

Hakan Tu¨rkkahraman et al AO 2005 [117] in an invitro study, compared the shear bond strength of orthodontic brackets cured with two different high-power light-emitting diode polymerization modes; one with fast-mode LED, the second with soft-start mode LED (Heliolux DLX) and a traditional halogen curing light MiniLEDY (Satelec). Brackets cured with soft-start mode LED produced the highest shear bond strengths (23.86 ± 6.20 MPa). No significant difference was found between fast-mode LED (17.14 ± 5.75 MPa) and the halogen group (17.38 ± 5.41 MPa). The LED is effective for bonding metal brackets to teeth, and the soft-start mode gives higher bond strengths than the fast mode.

Carine Maccarini Dall'Igna et al EJO 2011[29] assessed the influence of two light curing units, a light-emitting diode (LED) and a plasma arc light (PAC), on the shear bond strength (SBS) of brackets bonded to enamel of 90 bovine teeth specimens using Transbond XT. With 3 subdivisions each, LED group (Ortholux; 3M-Unitek) was light cured for 5, 10, and 15 seconds. And PAC (Apollo 95E; DenMed Technologies) group, the specimens were light cured for 3, 6, and 9 seconds. The brackets were submitted to SBS testing in a universal testing machine after 24 hours. The highest mean SBS was obtained with the LED at 15 seconds (16.68 MPa). The lowest mean SBS was obtained with the PAC 3 second group (8.29 MPa), which did not differ significantly from the PAC 6 second group. The LED at 5 seconds and the PAC at 3 seconds showed sufficient mean SBS. ARI index was also evaluated and a score of 3 was predominant. No significant influence found in relation to method of light curing.

Padhraig S. Fleming et al AJO 2013 [35] conducted a Systematic review and meta-analysis to review a total of 8 randomized controlled trials and controlled clinical trials to assess the risks of bracket failures and bonding time in brackets cured with halogen lights, LEDs, or plasma arc systems. No statistical difference in risk of bond failure to occur was observed in the meta-analysis comparing halogen lights, plasma arc and LEDs and concluded there was is no evidence to support the use of one specific light cure type over another on the basis of risk of bracket failures.

Serdar Arıkan et al AO 2006 [6] conducted an in vitro study using 40 freshly-extracted human premolars to test the null hypotheses that the type of light curing unit used (quartz-tungsten-halogen [QTH] or light-emitting diode [LED]) and the bracket type used (ceramic or metal) would not affect the amount of micro leakage observed beneath brackets. The brackets were randomly bonded with different light units and bracket types using Transbond XT adhesive. Micro leakage scores in concern to the bracket-adhesive-tooth interface at incisal and gingival margins showed ceramic brackets demonstrated significantly less micro leakage when cured with both LED and QTH curing units at both gingival and incisal margins.

Yagmur Sener et al AO 2006 [96] compared the polymerization shrinkage of three orthodontic Adhesives (Kurasper F, Light Bond, and Transbond XT) and determine the effectiveness of two light intensities (High-intensity quartz tungsten halogen (HQTH) for 10 seconds and quartz tungsten halogen (QTH) for 20 seconds) in curing orthodontic adhesives using a total of 120 glass ring moulds. The HQTH-curing unit (Optilux 501) resulted in a more polymerization shrinkage than did the QTH (Hilux 350) but with no statistically significant difference. The Highest shrinkage was observed for Light Bond cured with HQTH and least shrinkage with Transbond XT cured using QTH.

Erion Cerekja et al AO 2011[26] tested the hypothesis that short curing times using a high-intensity LED or high-power halogen did not compromise shear bond strength (SBS) of metal brackets before and after thermocycling in

240 extracted human premolar teeth bonded using a Transbond XT adhesive. The teeth were divided into six groups of 40 each with group 1 a conventional halogen light (Hilux) was used for 40 seconds to light cure the adhesive. In groups 2, 3, 4 a high power halogen light (Swiss Master) was used for 2, 3, and 6 seconds and in groups 5 and 6 a high-intensity LED (Bluephase) was used for 10 and 20 seconds, respectively. After bonding, half of the sample in each group were thermocycled, and all teeth were tested for SBS. After debonding, Adhesive Remnant Index was measured. The SBS with or without thermocycling was not statistically different in all groups expect group 2. The site of failure for groups 2 and 3 was at the bracket - adhesive interface and for groups 4, 5, 6 it was at the tooth - adhesive interface. He concluded that the 6 seconds of curing time with high-power halogen light and to 10 seconds with high-intensity LED was sufficient and did not compromise in vitro SBS of metal brackets.

Abdullah Alper Oz et al AJO 2016 [82] using a split mouth study design in forty patients compared the clinical failure rates of metal brackets bonded with two light-emitting diode devices Elipar S10 and VALO Ortho for 10 second and 3 seconds respectively. Bond failures during 12 months of orthodontic treatment were recorded. In-vitro performance of the brackets was also compared by bonding brackets to 20 extracted premolars each using the same light units and curing times Clinical bond failure rates were 2.90% for the Elipar and 3.16% for the VALO curing units depicting no statistically significance. Similarly no statistically significant difference was found between the in-vitro bond strengths of the groups. He concluded 10 seconds of light-curing with an Elipar LED and 3 seconds of light-curing with a VALO LED showed satisfactory results. Ari index was also evaluated.

Krishnaswamy et al AJ0 2007 [57] evaluated the clinical performance of brackets light cured with either a conventional halogen unit or an LED curing light using a split mouth study design on 30 patients bonded with Transbond XT adhesive over a period of 15 months. However no statistically significant differences between halogen light or LED were noted in relation to total bond failure rate or its clinical performance in relation to the arches and anterior-posterior segments. LED curing light is an appropriate substitute to conventional halogen light curing.

Evans et al AJO 2002 [32] evaluated the bond strength of brackets when bonded with Transbond XT adhesive using different light source-light guide-light curing time combinations. They brackets were subjected to shear forces at two intervals (5 minutes and 24 hours). The overall mean bond strength increased significantly from 5 minutes (23.2 MPa) to 24 hours (31 MPa). ARI displayed higher failures at the bracket-adhesive interface. Power slot and turbo tip light guides with reduced the curing times didn't affect the shear bond strength.

Dunn et al AJO 2002 [30] compared the bond strength of two halogen and two LED curing light bonded to teeth with Transbond XT adhesive (40 seconds each) by subjecting them to shear forces using a universal testing machine. He found no significant differences in bond strength between LED and halogen curing units. ARI displayed most of the remnant composite was present on the enamel surface.

Markus Niepraschk et al AJO 2007 [78] assessed the percentage of degree of cure of Eagle Spectrum (light cure composite resin from American Orthodontics) with different light cure units and duration of cure (Halogen unit- 10 seconds per edge incisal and cervical, Plasma Arc unit- 5 seconds per edge and LED 10 seconds and 5 seconds per edge). The author found Halogen unit and LED curing lights of overall 20 seconds irradiation time regimen showed the highest percentage of degree of cure.

David Lee Mitchell et al JADA 1967 [71] became the first person to recommend a retentive base for orthodontic attachments for better bonding. The '*M Bracket'* which had a hat shaped 24 karat gold retentive base soldered to orthodontic brackets provided better adhesion and also protected the cement from moisture.

Sunna and Rock BJO 1998 [111] recorded the incidences and site of first time failures in 40 patients over a period of 1 year to evaluate the performance of APC brackets and brackets with straight wire and dynalock base designs using Transbond XT and Right On adhesives light cured with LED curing light. An overall failure rate was 6.6%. Bond failures were found significantly higher in premolars and on left side in this study. No significant differences between bracket and adhesive combinations in terms of bond failure.

Wang et al AO 2004 [120] determined to study the bond strength and debonding interfaces of 6 bracket bases types each representing a unique combination of base design and size. He found that the size and design of the bracket base can affect the bond strength. The bracket bases with larger mesh spaces showed better bond strength. In this study circular concave bases showed higher bond strength than mesh bases when subjected to tensile forces.

Thanos et al AJO 1979 [114] investigated the bond strength of mesh bases and metal base brackets bonded with 5 different types of adhesives by means of shear, tensile and torsion forces. Mesh bases were found more retentive to tensile forces while metal bracket bases were retentive to shear forces. Bond-Eze, Adaptic and Solo-Tach showed good adhesive with 60 gauge mesh bases.

Sorel et al AJO 2002 [108] compared the bond strength of laser structured retentive base design and foil mesh design and evaluated the bond failure and debonding patterns to tensile forces. The adhesive system used was chemical cure No Mix adhesive. Laser structured retentive bases showed twice the bond strength of mesh bases. The mesh bases also showed adequate bond strength. ARI showed failure of laser structured bases was at enamel-adhesive interface while mesh bases had higher incidences of failure at bracket-adhesive interfaces.

Sharma Sayal et al AJO 2003 [101] performed a study to determine the effect of 6 metal bracket base designs on mean bond strength at 1hour and 24 hours, bonded using Transbond XT adhesive. The bond strength increased from 1 to 24 hours in all bracket adhesive combinations. The results suggest that the bracket base designs significantly influence SBS. 60 gauge foil mesh and integral undercut machined brackets showed higher bond strength. Sandblasted brackets can be reused if bracket base damage is minimal.

Smith and Reynolds et al BJO 1991 [107] evaluated the mean bond strength using tensile forces of three base types (fine mesh, coarse mesh and undercut base design).the adhesive used was Concise composite resin. Fine mesh design showed higher bond strength than coarse mesh which in turn showed higher bond strength than undercut base designs. The different types of coarse mesh bases (rough, smooth, defective) showed no significant differences.

Reynolds and Von Fraunhofer et al BJO 1976 [90] evaluated and compared the bond strength of mesh sizes of different gauges with three different filled diacrylate resins under tensile forces using a tensile testing jig. They concluded that diacrylate resins provided good adhesion and mesh gauge sizes 50-70 (British Standard Mesh Number) showed significant greater bond strength than 100-150 mesh gauge sizes. Coarse mesh gauge with wire diameter no less than 150 um displayed better mechanical retention.

Maijer and Smith et al AJO 1981[63] subjected premolar brackets of seven different manufactures to shear forces, to test the bond strength of the bracket bases when bonded with Dynabond composite resin. The brackets were viewed under SEM. The fine mesh base brackets of woven mesh type gave the best results. Welded bracket bases showed undesirable results as the weld spots at the margin of brackets predisposed to voids which were potential areas for bond failure and leakage.

MacColl and Rossouw et al AJO 1998 [62] tested the shear bond strength of four different bracket bases either untreated or sandblasted bonded to teeth with Phase II resin using different acid etching solutions (37% phosphoric acid gel and aqueous solution, 10% maleic acid gel and aqueous solution). He found that the bracket base area of minimum 6.82mm2 was necessary for adequate retention, below which significant reduction in shear bond strength was noted. Foil mesh bases were more retentive when pretreated by sandblasting or micro etching. 10% maleic acid showed higher bond strength while other 3 did not show any statistical difference.

Lopez et al AJO 1980 [61] evaluated the retentive properties of 16 bracket mesh types of the commercially available brackets by subjecting them to shear forces at two time intervals (24 hours and 30 days). No statistical differences in bond strength of any bracket base designs were seen between the two time intervals. Foil mesh bases displayed better retention than base designs such as indents with undercuts and solid bases with perforations. Smaller foil mesh bases did not seem to detriment the shear bond strength.

Jeremy Knox et al JO 2000 [54] studied the bracket-cement interface to determine the influence of bracket base designs (single mesh base design with 60, 80, 100 gauge sizes, a double mesh base, Dynalock and Mini twin base designs) bonded with different orthodontic adhesives (Transbond XT, Concise, Right On and Fuji Ortho LC) on the bond strength. The brackets were subjected to tensile forces. Certain bracket-adhesive combinations seemed to perform optimally. Transbond XT performed reasonably well with 80 gauge single mesh and double mesh designs. Single mesh designs displayed good bond strength with Consise and Right On while Dynalock and Mini twin performed well with all adhesives. Dynalock mesh design allowed better adhesive and curing light penetration.

Algera et al EJO 2006 [4] conducted an invitro study to determine any influence of different bracket base designs bonded with different adhesive systems (Transbond XT, Fuji Ortho LC and Fuji IX Fast). The brackets were also analyzed based on pretreatment types such as silica coating, tin plating and sandblasting. The teeth were subjected to shear and tensile forces after 24 hours. No significant improvement in bond strength was seen between the different types of pretreatment methods when compared with untreated control group. GIC adhesive showed lower bond strength than the other two adhesives. ARI showed more failures at bracket-adhesive interface. The bracket-adhesive interface was more prone to failure due to tensile forces than shear or compressive forces.

Bishara et al AO 2004 [16] compared the shear bond strength of two types of bracket base designs (single mesh and double mesh bracket base design) bonded using Transbond XT adhesive. The teeth were debonded half an hour after bonding using a universal testing machine. No statistical differences were seen between the bond strength and failure modes of single mesh and double mesh base designs. ARI of both bracket designs showed more adhesive on enamel rather on bracket base after debonding.

Cozza et al AO 2006 [28] tested the shear bond strength of 5 different commercially available orthodontic brackets types bonded to bovine incisors using Transbond XT adhesive. Victory series (foil mesh base) and equilibrium 2 brackets (laser structured base) showed highest shear bond strength while other designs showed optimal bond strength. Though larger base area increased the adhesion capacity, its adaptability to enamel surface decreased. He suggested base area below $7mm^2$ can exhibit good optimal retention. ARI in this studies showed varied outcomes.

Jeremy Knox et al AJO 2001 [55] evaluated the stresses generated to tensile load at bracket-cement-tooth interface when the physical and geometric properties of cement differed. He found foil meshes displayed higher tensile strength than integral bases.

Artun and Bergland AJO 1984 [8], used a classification for assessing the adhesive remnants on the enamel, in their study to determine whether different ion solutions containing sulfate induced solutions, can be a viable alternative for conventional acid etching technique. The 4 score classification ranged from score 0 which indicated no adhesive left on the tooth to score 3 which indicated that all adhesive was present on the tooth.

Bishara et al AJO 1990 [15]**,** in order to evaluate the residual adhesive and site of bond failure, introduced a 5 point scale classification in his study to determine the debonding characteristics of ceramic and metallic brackets. The

5 point scale ranged from 5 to 1, with point 5 indicating no adhesive on the enamel, point 4 indicating less than 10% of adhesive on the enamel and 90% on the bracket. Point 3 denoted more than 10% but less than 90% on the enamel. Point 2 indicated more than 10% of adhesive was present on the enamel surface and point 1 indicated 100% of adhesive present on the enamel surface.

Materials and Methods

MATERIALS AND METHODS

Materials

- ScotchBond etchant 37% Ortho Phosphoric acid (3M Unitek, Monrovia, CA, USA)
- Transbond XT bonding system and Transbond XT primer (3M Unitek, Monrovia, CA, USA)
- Bracepaste Adhesive and Primer (American Orthodontics, Sheboygan, WI USA)
- Fixed appliances Roth prescription 0.022 X 0.028 bracket system with upper triple buccal tube (main slot, auxiliary slot, head gear tube) (American Orthodontics, Sheboygan, WI USA)
- 3M S10 ELIPAR Light Curing Unit (3M Unitek, Monrovia, CA, USA)

Wire Sequence

Levelling and alignment was started with 0.014 and then 0.016 Nickel Titanium wire. In some cases with not much of crowding 0.014 inch Stainless Steel wire was used.

Inclusion Criteria:

- Patients eligible for orthodontic treatment
- Patients irrespective of the type of malocclusion or ethnic origin
- Both male and female patients
- Compliant patients

- Permanent dentition and patients above 12 years of age with fully erupted second molars

Exclusion Criteria:

- Patients with visible enamel defects or hypoplastic enamel such as fluorosis.
- Patients below the age of 12 or in mixed dentition stage without complete eruption of permanent dentition.
- Teeth which are endodontically treated or teeth with prosthesis such as acrylic or ceramic crown.
- Teeth which display severe attrition.
- Patients with severe deep bite, crossbite or scissor bite.

METHODOLOGY

- This prospective in vivo study was conducted at the department of orthodontics and dentofacial orthopaedics, Ragas Dental College, Chennai, India and approved by the Institutional Review board.
- The sample size of minimum 27 patients was calculated to ensure significant results. The study was designed as a split mouth study.
- A total of 30 patients were included in the study. These participants fulfilled the selection criteria and were also eligible for undergoing fixed orthodontic treatment.

- The participants were well informed in prior about the study and a written informed consent was obtained from the patient or the parent, however, the materials to be used were not disclosed.
- Patients were randomly selected without accounting the type of malocclusion or dental discrepancy.
- The co-investigator monitored the whole proceedings with distribution and randomization of patients and materials while the principal investigator carried out the procedure. The patients and the principal investigator were blinded such that, the distribution of material was kept unknown. Only the co-investigator who monitored the procedure knew the details about the material used in a particular quadrant. The etchant and primer were provided in a stipulated amount to the principal investigator on a small plate similar to a paint palette set. The adhesive syringes were also concealed with paper.
- A single operator performed the clinical procedure to avoid inter- operator variability.
- Bonding was done between second premolar to second premolar on both arches. The molars were banded with preformed bands.
- As a measure of prophylaxis, in all participants the surfaces of teeth to be bonded were cleansed using slurry of pumice using a rotary instrument with a rubber cup or bristle for 10 seconds, rinsed thoroughly with water for 20 seconds and air dried completely using an airway syringe.
- The teeth are isolated using cheek retractors, tongue guard and cotton rolls.

- The teeth to be bonded were acid etched using ScotchBond 37% phosphoric acid for 30 seconds. After thorough washing, the teeth were completely air dried. A frosty appearance of enamel is noticeably seen evenly on the tooth surface.
- All participants were randomly allocated an ID and each tooth a tooth ID. With a split mouth design being used, each of the participating patient's dentition was divided into four quadrants. In patients where only single arch was taken into account the dentition was divided onto two quadrants.
- The quadrants were randomly switched opposite each other with different combinations in all patients to avoid any operator bias.
- The two brands of adhesive materials used in the study are Transbond XT and Bracepaste.
- After adequate isolation, bonding agent of Transbond XT was applied using a micro brush and light cured using a 3M Elipar light cure unit for 10 seconds in one quadrant. In the opposing quadrant, the bonding agent of Bracepaste was applied and light cured with the same light cure unit for the same time interval.
- The adhesive was applied over the brackets (Roth prescription, 0.022 x 0.028 in slot, Mini Master Series, AMERICAN ORTHODONTICS) and fixed at appropriate positions on the teeth. While Transbond XT adhesive was applied over the brackets before fixation of brackets in a particular quadrant, Bracepaste adhesive was used similarly on the other quadrant.

- The excessive adhesive material are removed using a straight probe and the brackets are light cured using 3M S10 ELIPAR light cure unit for 10 seconds gingival and occlusal or incisal aspects of the bracket
- After bonding of brackets, a minimum of 10 minutes is provided before placement of the initial arch wire.
- The participants are reviewed every 3-4 week interval for failure of any brackets and the site, frequency and duration since bonding are tabulated over a period of 10 months.
- Only the first failure of brackets were taken into consideration. The teeth with recycled or newer brackets replaced were not further accounted in the study.
- A 20x Magnification loupe was used to check the Adhesive Remnant Index and the score was based on Bishara and Trulove classification.
- Adequate care was taken to take note of exact date of bracket failure. The patients were informed to give a call back in case of bracket failure within their appointment intervals and in case of missed appointments a recall from the clinician was made to ensure the date of failure of brackets were noted down and instructed to visit the department within the week.

Statistical analysis was performed to calculate the frequency of bracket failures between the variables and the two light cure adhesives, to understand the efficiency of the materials used and determine the better manufactured product for the purpose of orthodontic bonding of brackets.

Figures

FIGURE 1. MATERIALS USED

FIGURE 2. ADHESIVES USED FOR COMPARISON IN THIS STUDY

TRANSBOND XT

BRACEPASTE

FIGURE 3. PICTURES OF THE BRACKET-ADHESIVE INTERFACE OF THE FAILED BRACKETS

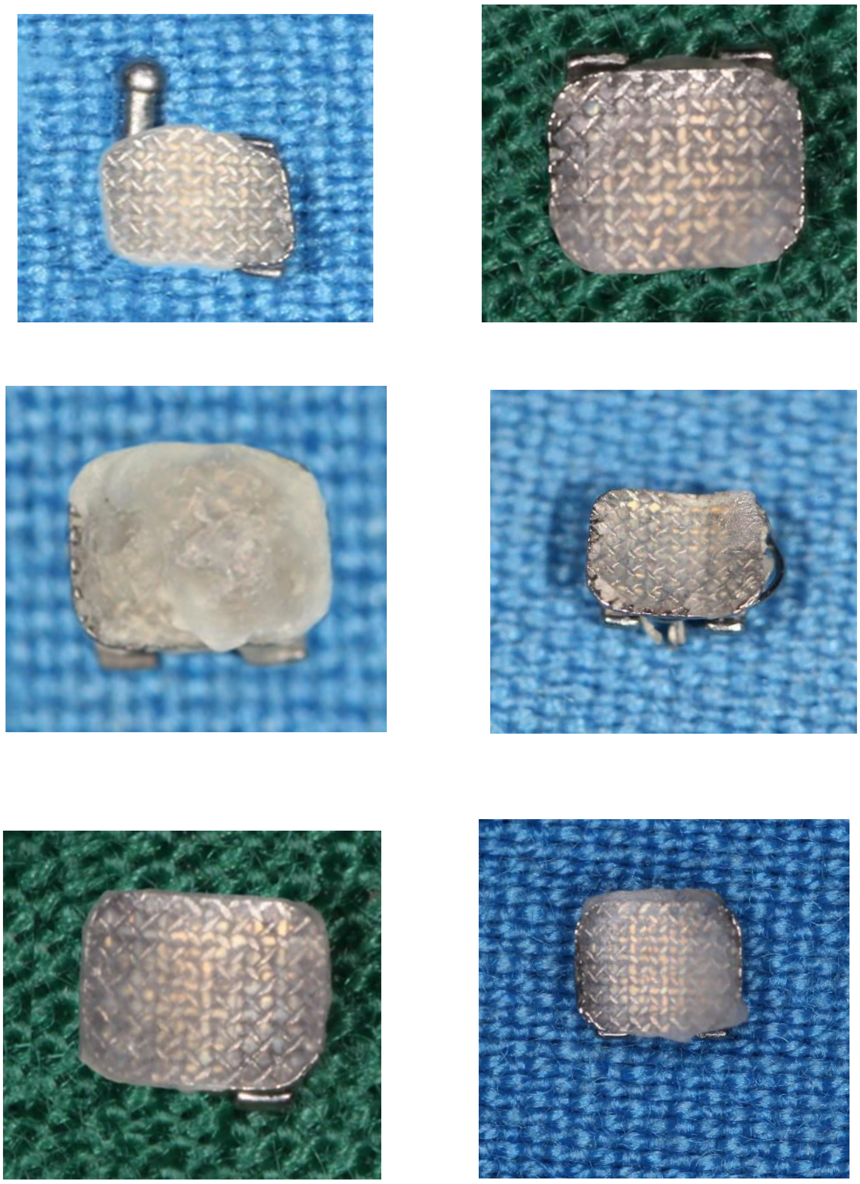
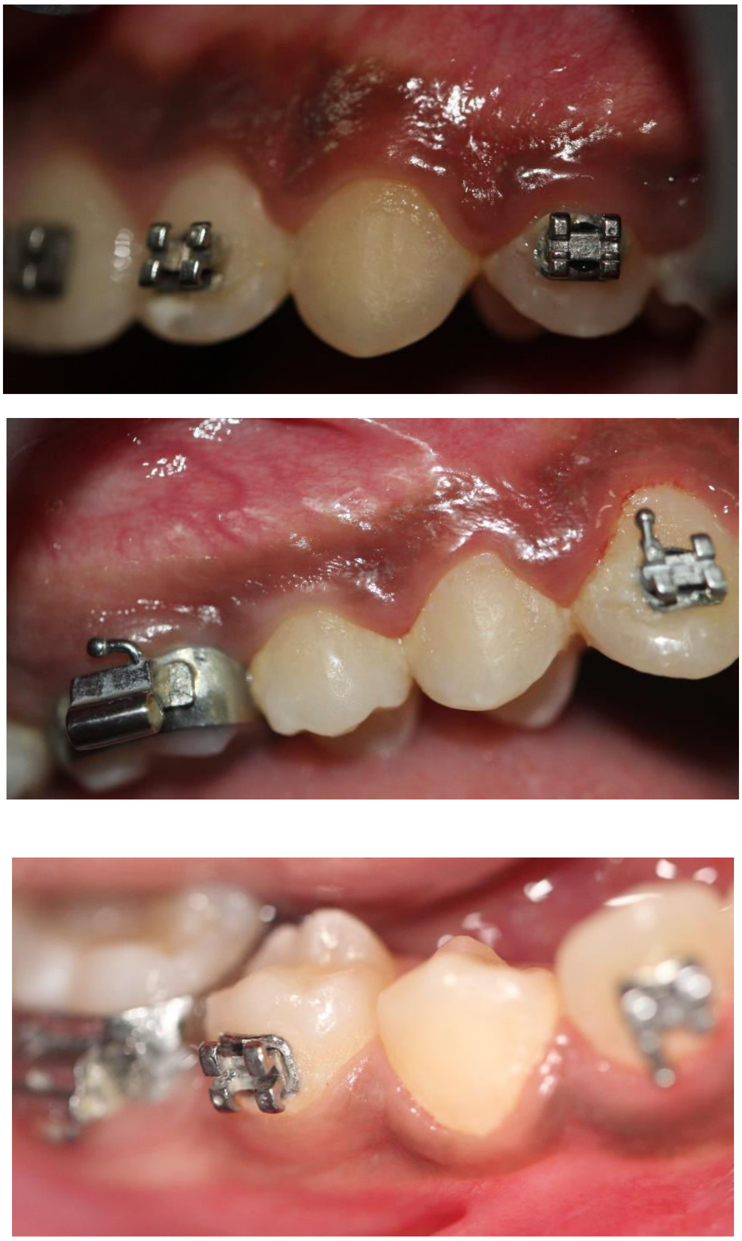


FIGURE 4. PICTURES OF THE ENAMEL-ADHESIVE INTERFACE OF THE FAILED TEETH



Results

STATISTICAL ANALYSIS

Despite All statistical analysis was performed using IBM SPSS (Statistical Software for Social Science) software v 23.0 New York, USA.

Descriptive statistical analysis was done to calculate the frequency and percentage of the distribution of material between the samples and within the dentition. Also, the frequency and percentage of failure and success rates of the brackets within the different variables included in the study, such as age, gender, arch, quadrant, segments, wire composition and dimension were calculated.

A Chi-Square Test was performed to find the frequency and percentage of failure and determine if the failure of brackets within each variable in accordance with the two adhesive materials included in the study displayed a statistical significance.

A Kaplan Meier Plot was done to plot the failed brackets and understand the survival index of the adhesive materials used in the study, within the study duration of 10 months (305 days).

RESULTS

The sample size of minimum 27 patients was calculated to ensure significant results. To begin with 30 patients were included in the study with anticipation of dropouts.

2 patients failed to keep appointments for extended period of time therefore were excluded from the study. An additional problem encountered during the study was the positioning of brackets. Multiple teeth in 5 patients had to be positioned offset due to severe crowding and tipping and was further repositioned during the course of treatment or the experiment. Such teeth were omitted and in order to maintain symmetry in the number of teeth, the particular arch was excluded. In three patients, due to crossbite tendency, the mandibular arch bonding was postponed and excluded from the study.

In order to achieve uniform distribution of material within the arch, 10 patients were further included in the study with only a single jaw taken into consideration. With a split mouth design the adhesive materials were randomly interchanged within the specific jaw of the patients.

Finally, the study comprised of 38 patients inclusive of 58 arches and 560 teeth in total.

Adhesive Material

The two light cure adhesives used in the study were Transbond XT and Bracepaste. A split mouth study design aided in even distribution of the two adhesive materials within the dentition in all patients.

Total Dentition

A total of 560 teeth were bonded among 38 patients included in the study. Transbond XT was used as an adhesive for bonding the brackets in 280 teeth (50%) and Bracepaste was used as the adhesive for bracket fixation in 280 teeth (50%). (TABLE 1.1)

A total of 44 bracket failures (7.9%) inclusive of both adhesive material occurred, out of which, adhesive material Transbond XT exhibited bracket failure in 25 brackets with a failure percentage of 4.5% and success percentage of 45.5%, with no bracket failure in 255 teeth. Similarly, adhesive material Bracepaste presented with bracket failure in 19 brackets with a failure percentage of 3.4% and success percentage of 46.6%, with no bracket failure in 261 teeth. No statistically significant difference between bracket failures with Transbond and Bracepaste adhesives was noted (p value = 0.346) (TABLE 1.2 and GRAPH 7)

A total of 112 brackets were bonded evenly in Central and Lateral Incisors, Canines, First and Second Premolars. The second premolars exhibited the highest number of failures (22 brackets). The order of tooth type in accordance with the frequency of bracket failures are second premolars (22 brackets; 19.6%), first premolars (14 brackets; 12.5%), canines (4 brackets; 3.6%) and incisors (central incisor displaying 2 bracket failures and lateral incisor displaying 2 bracket failures, both with a failure percentage of 1.8% respectively) (TABLE 1.3)

The central and lateral incisors did not display failure in 110 brackets thus exhibiting a success percentage of 98.2%. Similarly, canines exhibited a success percentage of 96.4% (108 brackets). The first and second premolars showed a success rate of 87.5% and 80.4% displaying no failures in 98 and 90 teeth respectively. (TABLE 1.3)

Transbond XT exhibited higher number of failures than Bracepaste in relation to second premolars, first premolar and canine. Transbond XT and Bracepaste exhibited equal number of failures in relation to incisors. The central and lateral incisors displayed a failure rate of 1 bracket each (1.8%) in both adhesive groups. The canines displayed failure in only the Transbond group (4 brackets; 7.1%). None of the canines in Bracepaste adhesive group displayed any failure (0%). The first and second premolars exhibited failures in 6 brackets (10.7%) and 13 brackets (22.3%) respectively in the Transbond group. The first and second premolars exhibited failures in 8 brackets (14.3%) and 9 brackets (16.1%) respectively in the Bracepaste group. A significant difference between bracket failures in different tooth types was noted in Transbond XT group (p value=0.000) and Bracepaste group (p value = 0.000) (TABLE 1.4)

AGE

Among the 38 patients included in this study, 16 patients were below 18 years of age and 22 patients were above 18 years. Among the 560 teeth (100%) included in the study, a sum of 230 brackets (41.1%) were bonded in patients below 18 years and remaining 330 brackets (58.9%) were bonded in patients above 18 years.

A total of 44 bracket failures (7.9%) ensued in brackets bonded inclusive of both patients below and above 18 years. Patients below 18 years exhibited bracket failure in 20 brackets with a failure percentage of 3.6% and success percentage of 37.5% with no bracket failure in 210 teeth. Patients above 18 years presented with bracket failure in 24 brackets with a failure percentage of 4.3% and success percentage of 54.6% with no bracket failure in 306 brackets. No statistically significant difference between bracket failures in patients below or above 18 years was noted (p value = 0.322). (TABLE 2.1 and GRAPH 2)

Transbond XT was used in bonding a total of 115 brackets in patients below 18 years and 165 brackets in patients above 18 years. Similarly, Bracepaste was used in bonding a total of 115 teeth with brackets in patients below 18 years and 165 brackets in patients above 18 years.

Transbond XT showed a failure percentage of 5.0% and 3.9% when compared in patients below and above the age of 18 years respectively, with bracket failure in 14 brackets in patients below 18 years and 11 brackets in patients above the age of 18 years.

Bracepaste showed a failure percentage of 2.1% and 4.6% in patients below and above 18 years respectively, with bracket failure of 6 brackets in patients below the age of 18 years and 13 brackets in patients above the age of 18 years. No significant difference between bracket failures in patients below and above 18 years was noted in Transbond group (p value=0.112) and Bracepaste group (p value= 0.384) (Table 8.1 and GRAPH 2)

Below 18 years

Taking into consideration patients below 18 years alone, of the 230 brackets (100%), 20 brackets failed and 210 brackets displayed no bracket failure with a failure percentage of 8.7% and success percentage of 91.2% respectively.

Transbond XT was used in bonding a total of 115 teeth (50%), of which, 14 brackets (6.1%) showed bracket failure and the success percentage was calculated to be 43.9% with no failure in 101 teeth. Bracepaste was used in bonding a total of 150 brackets (50%), of which, 6 brackets (2.6%) showed bracket failure and the success percentage was calculated to be 47.3% with no failure in 109 brackets. (TABLE 2.2)

Above 18 Years

Taking into consideration patients above the age of 18 years, of the 330 brackets (100%), 24 brackets failed and 306 brackets displayed no bracket failure with a failure percentage of 7.2% and success percentage of 92.8% respectively.

Transbond XT was used in bonding a total of 165 brackets (50%) of which, 11 teeth (3.3%) showed bracket failure and the success percentage was calculated to be 46.7% with no failure in 154 brackets. Bracepaste was used in bonding a total of 165 teeth (50%) of which, 13 teeth (3.9%) showed bracket failure and the success percentage was calculated to be 46.1% with no failure in 152 brackets. (Table 2.3)

Gender

A total of 38 patients included in this study comprised of 21 males and 17 females. Of the total 560 teeth (100%), a sum of 300 teeth (53.6%) comprised of males and remaining 260 teeth (46.4%) females.

A total of 44 bracket failures (7.9%) ensued in brackets bonded inclusive of both males and females. Males exhibited bracket failure in 30 brackets with a failure percentage of 5.4% and success percentage of 48.2% with no bracket failure in 270 teeth. Females presented with bracket failure in 14 brackets with a failure percentage of 2.5% and success percentage of 43.9% with no bracket failure in 246 brackets. A statistically significant difference between bracket failures in males and females was noted (p value = 0.043) (TABLE 3.1 and GRAPH 1)

Transbond XT was used in bonding a total of 150 brackets in males and 130 brackets in females. Similarly Bracepaste was used in bonding a total of 150 brackets with brackets in males and 130 brackets in females.

Transbond XT showed a failure percentage of 6.0% and 2.9% when compared with both males and females respectively, with bracket failure of 17 brackets in males and 13 brackets in females. Bracepaste showed a failure percentage of 4.6% and 2.2% when compared with both males and females respectively, with bracket failure of 8 teeth in males and 6 teeth in females. No significant difference between bracket failures in males and females was noted in Transbond group (p value=0.130) and in Bracepaste group (p value= 0.179) (Table 8.2 and GRAPH 1)

Males

Taking male patients alone into consideration, of the 300 brackets bonded (100%), 30 brackets failed and 270 brackets displayed no bracket failure with a failure percentage of 10% and success percentage of 90% respectively.

Transbond XT was in bonding a total of 150 brackets (50%) in males, of which, 17 brackets (6.0%) showed bracket failure and the success percentage was calculated to be 44% with no failure in 133 brackets. Bracepaste was in bonding a total of 150 brackets (50%) in males, of which, 13 brackets (4.0%) showed bracket failure and the success percentage was calculated to be 46% with no failure in 137 brackets. (TABLE 3.2)

Females

Taking female patients alone into consideration, of the 260 brackets bonded (100%), 14 brackets failed and 246 brackets displayed no bracket failure with a failure percentage of 5.4% and success percentage of 94.6% respectively.

Transbond XT was used in bonding a total of 130 brackets (50%) in females, of which, 8 brackets (3.0%) showed bracket failure and the success percentage was calculated to be 47.0% with no failure in 122 brackets. Bracepaste was used in bonding a total of 130 brackets (50%) in females, of which, 6 brackets (2.4%) showed bracket failure and the success percentage was calculated to be 47.6% with no failure in 124 brackets. (Table 3.3)

Arch

When the entire dentition was taken into consideration (both maxilla and mandible), in a total of 560 teeth (100%) the maxillary arch comprised of 280 teeth (50%) and mandible arch 280 teeth (50%) respectively.

A total of 44 bracket failures (7.9%) inclusive of both arches occurred, out of which, maxillary arch exhibited bracket failure in 19 brackets with a failure percentage of 3.4% and success percentage of 46.6% with no bracket failure in 261 teeth. In the mandibular arch, 25 brackets failed with a failure percentage of 4.5% and success percentage of 45.5% with no bracket failure in 255 teeth. No statistically significant difference between bracket failures in maxilla and mandible was noted (p value =0.346) (TABLE 4.1 and GRAPH 3)

Transbond XT was used in bonding a total of 140 brackets in the maxillary arch and 140 brackets in the mandibular arch. Similarly Bracepaste was used in bonding a total of 140 brackets in the maxillary arch and 140 brackets in the mandibular arch. (TABLE 4.2 and 4.3)

Transbond XT showed a failure percentage of 2.9% and 6.1% in maxilla and mandible respectively with 8 bracket failures in maxilla and 17 bracket failures in mandible. Bracepaste showed a failure percentage of 3.9% and 2.9% in maxilla and mandible respectively with 11 bracket failures in maxilla and 8 bracket failures in mandible. A significant difference between bracket failures in maxilla and mandible was noted in Transbond group (p value=0.05) but not in Bracepaste group (p value= 0.476) (TABLE 8.3 and GRAPH 3).

Maxilla

Taking into consideration the maxillary arch alone, of the 280 brackets bonded (100%), 19 brackets failed and 261 brackets displayed no bracket failure with a failure percentage of 6.8% and success percentage of 93.2% respectively.

Transbond XT was used in bonding a total of 140 brackets (50%) in maxillary arch, of which, 8 teeth (2.9%) showed bracket failure and the success percentage was calculated to be 47.1% with no failure in 132 teeth. Bracepaste was used in bonding a total of 140 brackets (50%) in maxillary arch, of which, 11 teeth (3.9%) showed bracket failure and the success percentage was calculated to be 46.1% with no failure in 129 teeth. (TABLE 4.2)

Mandible

Taking into consideration the mandibular arch alone, of the 280 brackets bonded (100%), 25 brackets failed and 255 brackets displayed no bracket failure with a failure percentage of 8.9% and success percentage of 91.1% respectively.

Transbond XT was used in bonding a total of 140 brackets (50%) in mandibular arch, of which, 17 teeth (6.1%) showed bracket failure and the success percentage was calculated to be 43.9% with no failure in 123 teeth. Bracepaste was used in bonding a total of 140 brackets (50%) in mandibular arch, of which, 8 teeth (2.9%) showed bracket failure and the success percentage was calculated to be 47.1% with no failure in 132 teeth. (TABLE 4.3)

Quadrant

When the entire dentition was taken into consideration (both right and left), of a total of 560 teeth (100%) right quadrant comprised of 280 teeth (50%) and left quadrant 280 teeth (50%) respectively.

A total of 44 bracket failures (7.9%) inclusive of both quadrants occurred out of which, right side exhibited failure in 24 brackets with a failure percentage of 4.3% and success percentage of 45.7% with no bracket failure in 256 teeth. Left quadrant presented with bracket failure in 20 brackets with a failure percentage of 3.6% and success percentage of 46.4% with no bracket failure in 260 teeth. There was no significant difference between bracket failures in right and left quadrants ($p = 0.530$) (TABLE 5.1 and GRAPH 4)

Transbond XT was used in bonding a total of 145 brackets in the right quadrant (51.8%) and 135 brackets (48.2%) in the left quadrant. Similarly Bracepaste was used in bonding a total of 135 teeth (48.2%) in the right quadrant and 145 teeth in the left quadrant. (51.8%)

Transbond XT showed failure in 25 teeth (8.9%) and no failure in 255 teeth (91.1%) inclusive of both right and left quadrants and similarly Bracepaste showed failure in 19 teeth with a failure rate of (6.8%) and success rate of (93.2%) with no bracket failure in 261 teeth.

Transbond XT showed a failure percentage of 5.7% and 3.2% in right and left quadrants respectively with 16 bracket failures in right quadrant and 9 bracket failures in left quadrant. Bracepaste showed a failure percentage of 2.9% and 3.9% in right and left quadrants with 8 bracket failures in right quadrant and 11 bracket failures in left quadrant. There was no significant difference between bracket failures in right and left quadrant in Transbond group (p=0.200) and Bracepaste group (p=0.581) (TABLE 8.4 and GRAPH 4)

Right Quadrant

Taking into consideration the right quadrant alone, of the 280 brackets bonded (100%), 24 brackets failed and 256 brackets displayed no bracket failure with a failure percentage of 8.6% and success percentage of 91.4% respectively.

Transbond XT was used in bonding a total of 145 brackets (51.8%) in right quadrant, of which, 16 teeth (5.7%) showed bracket failure and the success percentage was calculated to be 46.1% with no failure in 132 teeth. Bracepaste was used in bonding a total of 135 teeth (48.2%) in right quadrant, of which, 8 teeth (2.9%) showed bracket failure and the success percentage was calculated to be 45.4% with no failure in 127 teeth. (TABLE 5.2)

Left Quadrant

Taking into consideration the left quadrant alone, of the 280 brackets bonded (100%), 20 brackets failed and 260 brackets displayed no bracket failure with a failure percentage of 7.1% and success percentage of 92.9% respectively.

Transbond XT was used in bonding a total of 135 teeth (48.2%) in left quadrant, of which, 9 teeth (3.2%) showed bracket failure and the success percentage was calculated to be 45.0% with no failure in 126 teeth. Bracepaste was used in bonding a total of 145 teeth (51.8%) in left quadrant, of which, 11 teeth (3.9%) showed bracket failure and the success percentage was calculated to be 47.9% with no failure in 134 teeth. (TABLE 5.3)

Anterior- Posterior Segments

The total 560 teeth (100%) comprised of a total of 336 anterior teeth (60%) and 224 teeth posterior teeth (40%) respectively.

A total of 44 bracket failures (7.9%) inclusive of both segments occurred. Anterior segment exhibited bracket failure in 8 brackets with a failure percentage of 1.4% and success percentage of 58.6% with no bracket failure in 328 teeth. In Posterior segment, 36 brackets failed, with a failure percentage of 6.4% and success percentage of 43.6% with no bracket failure in 188 teeth. A statistically significant difference between bracket failures in anterior and posterior quadrants was noted (p value = 0.000). (TABLE 6.1 and GRAPH 5)

Transbond XT was used in bonding a total of 168 brackets in the anterior segment and 112 brackets in the posterior segment. Similarly, Bracepaste was used in bonding a total of 168 brackets in the anterior segment and 112 brackets in the posterior segment. (TABLE 6.2 and 6.3)

Transbond XT showed a failure percentage of 2.1% and 6.8% in anterior and posterior segments respectively with 6 teeth displaying bracket failure in anterior segment and 19 teeth with bracket failure in posterior segment. Bracepaste showed a failure percentage of 0.7% and 6.1% in anterior and posterior segments respectively with 2 bracket failures in anterior segment and 17 bracket failures in posterior segment. A significant difference between bracket failures in anterior and posterior segments was noted in Transbond group (p value = 0.000) and Bracepaste group (p value = 0.000). (TABLE 8.5 and GRAPH 5)

Anterior Segment

Taking into consideration the anterior segment alone, of the 336 brackets bonded (100%), 8 brackets failed and 328 brackets displayed no bracket failure with a failure percentage of 2.4% and success percentage of 97.6% respectively.

Transbond XT was used in bonding a total of 168 brackets (50%) in anterior segment, of which, 6 teeth (1.8%) showed bracket failure and the success percentage was calculated to be 48.2% with no failure in 162 teeth. Bracepaste was used in bonding a total of 168 brackets (50%) in anterior segment, of which, 2 teeth (0.6%) showed bracket failure and the success percentage was calculated to be 49.4% with no failure in 166 teeth. (TABLE 6.2)

Posterior Segment

Taking into consideration the posterior segment alone, of the 224 brackets bonded (100%), 36 brackets failed and 188 brackets displayed no bracket failure with a failure percentage of 16.1% and success percentage of 83.9% respectively.

Transbond XT was used in bonding a total of 112 brackets (50%) in posterior segment, of which, 19 teeth (8.5%) showed bracket failure and the success percentage was calculated to be 41.5% with no failure in 93 teeth. Bracepaste was used in bonding a total of 112 bracket (50%) in posterior segment, of which, 17 teeth (7.6%) showed bracket failure and the success percentage was calculated to be 42.4% with no failure in 95 teeth. (TABLE 6.3)

Wire Diameter

A total of 44 bracket failures (7.9%) ensued out of 560 brackets fixed, with no failure in 516 brackets displaying a success percentage of 92.1 %. 41 bracket failures (7.5%) occurred on using round arch wires and 3 brackets (0.4%) failed on using rectangular arch wires. A statistically significant difference between bracket failures was noted on using both round and rectangular arch wires (p value = 0.000). (TABLE 7.2 and GRAPH 6)

Transbond XT showed failure percentages of 8.2% and 0.7% on comparing bracket failures which occurred on using round and rectangular arch wires respectively, with 23 teeth displaying bracket failure with round wires and 2 teeth with bracket failure on using rectangular wires. Bracepaste showed a failure percentage of 6.4% and 0.4% on using round and rectangular arch wires respectively, with 18 teeth displaying bracket failure with round wires and 1 teeth with bracket failure on using rectangular wires. A significant difference between bracket failures in round and rectangular wires was noted in Transbond group (p value = 0.000) and Bracepaste group (p value = 0.000). (TABLE 8.7 and GRAPH 6)

Wire Composition

A total of 44 bracket failures (7.9%) ensued, out of 560 brackets fixed with no failure in 516 brackets displaying a success percentage of 92.1 %. on using of NiTi arch wires and 0 brackets (0.0%) failed on using Stainless Steel arch wires. (Table 7.1) (GRAPH 6)

Adhesive material Transbond XT was used in bonding a total of 280 teeth, similarly Bracepaste was in bonding a total of 280 teeth in the dentition.

Transbond XT showed failure in 25 teeth (8.9%) and no failure in 255 teeth (91.1%), inclusive of bracket failures on using of both NiTi and Stainless Steel wires. Similarly, Bracepaste showed failure in 19 teeth with a failure rate of 6.8% and success rate of 93.2% with no bracket failure in 261 teeth. A statistically significant difference between bracket failures was noted on using both NiTi and Stainless Steel arch wires (p value = 0.000).

Transbond XT showed failure percentage of 8.9% and 0% when compared with NiTi and Stainless Steel wires respectively, with 25 brackets displaying bracket failure on using NiTi wires and no bracket failure with Stainless Steel arch wires. Bracepaste showed failure percentage of 6.8% and 0% when compared with Stainless steel wires respectively, with 19 brackets displaying failure with NiTi wires and no bracket denoting bracket failure on using Stainless Steel arch wires. (TABLE 8.6 and GRAPH 6)

A significant difference between bracket failures on using NiTi and Stainless Steel wires was noted in Transbond group (p value = 0.000) and Bracepaste group (p value = 0.000).

Adhesive Remnant Index displayed a predominant score of 5 (37 teeth) based on Bishara and Trulove classification depicting 100% of adhesive at the bracket base. 7 brackets displaying score 4 which denotes more than 90% of the adhesive on the bracket base was noted. Transbond XT displayed score 4 in 3 instances of bracket failure and score 5 in 22 instances of bracket failure. Similarly, Bracepaste displayed score 4 in 4 occasions of bracket failure and score 5 in 15 occurrences of bracket failure. (TABLE 8 and GRAPH 8)

Kaplan Meier survival analysis index was done to chart the survival rate of the brackets bonded with Transbond XT and Bracepaste adhesive system. (CHART 1, 2 and 3)

Tables and Graphs

TABLE 1.1 Distribution of Light cure adhesives Transbond XT and Bracepaste within the dentition

Material	No. of teeth		Total
Transbond XT	280	50%	560 (100%)
Bracepaste	280	50%	

TABLE 1.2 Frequency and percentage of success and failure of brackets in relation to Adhesive Material

Material	Failure Rate		Success Rate		p Value
	Frequency	%	Frequency	%	
Transbond XT	25	4.5%	255	45.5%	0.346
BRACEPASTE	19	3.4%	261	46.6%	
TOTAL	44	7.9%	516	92.1%	

TABLE 1.3 Frequency and percentage of failure and success rate of brackets in relation to different tooth types

Tooth Type	Total No.	Failure		Success		P Value
		Frequency	%	Frequency	%	
Central Incisor	112	2	1.8%	110	98.2%	**0.000**
Lateral Incisor	112	2	1.8%	110	98.2%	
Canine	112	4	3.6%	108	96.4%	
First Premolar	112	14	12.5%	98	87.5%	
Second Premolar	112	22	19.6%	90	80.4%	

TABLE 1.4 Frequency and percentage of failure rate of brackets corresponding to different tooth types between the two adhesives

Tooth Type	Transbond XT		Bracepaste		p value*	p value**
	Frequency	%	Frequency	%		
Central Incisor	1	1.8%	1	1.8%	**0.000**	**0.000**
Lateral Incisor	1	1.8%	1	1.8%		
Canine	4	7.1%	0	0%		
First Premolar	6	10.7%	8	14.3%		
Second Premolar	13	22.3%	9	16.1%		
* p value for Transbond XT ; ** p value for Bracepaste						

TABLE 2.1 Frequency and percentage of success and failure rate of brackets in relation to Age Criteria

Age	No .Of Teeth	Failure Rate		Success Rate		p value
		Frequency	%	Frequency	%	
< 18 years	230 (41.1%)	20	3.6%	210	37.5%	0.322
> 18 years	330 (58.9%)	24	4.3%	306	54.6%	
TOTAL	560 (100%)	44	7.9%	516	92.1%	

TABLE 2.2 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in age group below 18 years

Age	Material					
	Transbond XT		Bracepaste		Total	
< 18 years	14	6.1%	6	2.6%	20	8.7%
	101	43.9%	109	47.3%	210	91.2%
TOTAL	115	50%	115	50%	230	100%

TABLE 2.3 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in age group above 18 years

Age	Material					
	Transbond XT		Bracepaste		Total	
> 18 years	11	3.3%	13	3.9%	24	7.2%
	154	46.7%	152	46.1%	306	92.8%
TOTAL	165	50%	165	50%	330	100%

TABLE 3.1 Frequency and percentage of success and failure rate of brackets in relation to Gender Criteria

Gender	No. of Teeth	Failure Rate		Success Rate		p value
		Frequency	%	Frequency	%	
Males	300 (53.6%)	30	5.4%	270	48.2%	**0.043**
Females	260 (46.4%)	14	2.5%	246	43.9%	
TOTAL	560 (100%)	44	7.9%	516	92.1%	

TABLE 3.2 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Males

Gender	Material					
	Transbond XT		Bracepaste		Total	
Males	17	6.0%	13	4.0%	30	10%
	133	44%	137	46%	270	90%
TOTAL	150	50%	150	50%	300	100%

TABLE 3.3 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Females

Gender	Material					
	Transbond XT		Bracepaste		Total	
Females	8	3.0%	6	2.4%	14	5.4%
	122	47.0%	124	47.6%	246	94.6%
TOTAL	130	50%	130	50%	260	100%

TABLE 4.1 Frequency and percentage of success and failure rate of brackets in relation to Arch

Arch	No .Of Teeth	Failure Rate		Success Rate		p value
		Frequency	%	Frequency	%	
Maxilla	280 (50%)	19	3.4%	261	46.6%	0.346
Mandible	280 (50%)	25	4.5%	255	45.5%	
TOTAL	560 (100%)	44	7.9%	516	92.1%	

TABLE 4.2 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Maxilla

Arch	Material					
	Transbond XT		Bracepaste		Total	
Maxilla	8	2.9%	11	3.9%	19	6.8%
	132	47.1%	129	46.1%	261	93.2%
TOTAL	140	50%	140	50%	280	100%

TABLE 4.3 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Mandible

Arch	Material					
	Transbond XT		Bracepaste		Total	
Mandible	17	6.1%	8	2.9%	25	8.9%
	123	43.9%	132	47.1%	255	91.1%
TOTAL	140	50%	140	50%	280	100%

TABLE 5.1 Frequency and percentage of success and failure rate of brackets in relation to Right and Left quadrants

Quadrants	No .Of Teeth	Failure Rate		Success Rate		p value
		Frequency	%	Frequency	%	
Right	280 (50%)	24	4.3%	256	45.7%	0.530
Left	280 (50%)	20	3.6%	260	46.4%	
TOTAL	560 (100%)	44	7.9%	516	92.1%	

TABLE 5.2 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Right quadrant

Quadrants	Material					
	Transbond XT		Bracepaste		Total	
Right	16	5.7%	8	2.9%	24	8.6%
	132	46.1%	127	45.4%	256	91.4%
TOTAL	145	51.8%	135	48.2%	280	100%

TABLE 5.3 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Left quadrant

Quadrants	Material					
	Transbond XT		Bracepaste		Total	
Left	9	3.2%	11	3.9%	20	7.1%
	126	45.0%	134	47.9%	255	92.9%
TOTAL	135	48.2%	145	51.8%	280	100%

TABLE 6.1 Frequency and percentage of success and failure rate of brackets in relation to Anterior and posterior segments

Segment	No .Of Teeth	Failure Rate		Success Rate		p value
		Frequency	%	Frequency	%	
Anterior	336 (60%)	8	1.4%	328	58.6%	**0.000**
Posterior	224 (40%)	36	6.4%	188	43.6%	
TOTAL	560 (100%)	44	7.9%	516	92.1%	

TABLE 6.2 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Anterior Segment

Segment	Material					
	Transbond XT		Bracepaste		Total	
Anterior segment	6	1.8%	2	0.6%	8	2.4%
	162	48.2%	166	49.4%	328	97.6%
TOTAL	168	50%	168	50%	336	100%

TABLE 6.3 Frequency and percentage of bracket failures between Transbond XT and Bracepaste Adhesives in Posterior Segment

Segment	Material					
	Transbond XT		Bracepaste		Total	
Posterior segment	19	8.5%	17	7.6%	36	16.1%
	93	41.5%	95	42.4%	188	83.9%
TOTAL	112	50%	112	50%	224	100%

TABLE 7.1 Frequency and percentage of success and failure rates of brackets in relation to Arch Wire compositions

Wire Composition	Failure Rate		Success Rate		p value
	Frequency	%	Frequency	%	
Stainless steel	0	0.0%	560	100%	**0.000**
NiTi	44	7.9%	516	92.1%	
TOTAL	44	7.9%	516	92.1%	

TABLE 7.2 Frequency and percentage of success and failure rates of brackets in relation to Arch Wire Dimensions

Wire Dimension	Failure Rate		Success Rate		p value
	Frequency	%	Frequency	%	
Round	41	7.5%	518	92.5%	**0.000**
Rectangular	3	0.4%	558	99.6%	
TOTAL	44	7.9%	516	92.1%	

TABLE 8 Adhesive Remnant Index Scores of the two light cure adhesives (Transbond XT and Bracepaste)

	No. of teeth failed	ARI INDEX SCORE *	Inference	Type of failure
Transbond XT	22 teeth	5	100% of adhesive at the bracket base and 0% at enamel surface	Adhesive failure
	3 teeth	4	More than half of the 90% of adhesive at bracket base	Cohesive failure
Bracepaste	15 teeth	5	100% of adhesive at the bracket base and 0% at enamel surface	Adhesive failure
	4 teeth	4	More than half of the 90% of adhesive at bracket base	Cohesive failure
Total	7	4	More than half of the 90% of adhesive at bracket base	Cohesive failure
	37	5	100% of adhesive at the bracket base and 0% at enamel surface	Adhesive failure

TABLE 8.1 Frequency and percentage of success and failure rate of brackets within the age groups in comparison between the two adhesives

MATERIAL	AGE	FAILURE		SUCCESS		p Value
Transbond XT	< 18 years	14	5.0%	101	36.1%	0.112
	> 18 years	11	3.9%	154	55%	
Bracepaste	< 18 years	6	2.1%	109	39%	0.384
	> 18 years	13	4.6%	152	54.3%	

TABLE 8.2 Frequency and percentage of success and failure rate of brackets within gender in comparison between the two adhesives

MATERIAL	Gender	Failure		Success		p Value
Transbond XT	Males	17	6.0%	133	47.5%	0.130
	Females	8	2.9%	122	43.96%	
Bracepaste	Males	13	4.6%	137	52.5%	0.179
	Females	6	2.2%	124	47.5%	

TABLE 8.3 Frequency and percentage of success and failure rate of brackets within the arch in comparison between the two adhesives

Material	Arch	Failure		Success		p Value
Transbond XT	Maxilla	8	2.9%	132	47.1%	**0.05**
	Mandible	17	6.1%	123	43.9%	
Bracepaste	Maxilla	11	3.9%	129	46.1%	0.476
	Mandible	8	2.9%	132	47.1%	

TABLE 8.4 Frequency and percentage of success and failure rate of brackets within the quadrants in comparison between the two adhesives

Material	Quadrant	Failure		Success		p Value
Transbond XT	Right	16	5.7%	129	46.1%	0.200
	Left	9	3.2%	126	45.0%	
Bracepaste	Right	8	2.9%	127	45.4%	0.581
	Left	11	3.9%	134	47.9%	

TABLE 8.5 Frequency and percentage of success and failure rate of brackets within anterior-posterior segments in comparison between the two adhesives

Material	Segment	Failure		Success		p Value
Transbond XT	Anterior	6	2.1%	162	57.9%	**0.000**
	Posterior	19	6.8%	93	33.2%	
Bracepaste	Anterior	2	0.7%	166	59.3%	**0.000**
	Posterior	17	6.1%	95	33.9%	

TABLE 8.6 Frequency and percentage of success and failure rate of brackets between different wire composition (Stainless steel and NiTi) in comparison with the two adhesives materials.

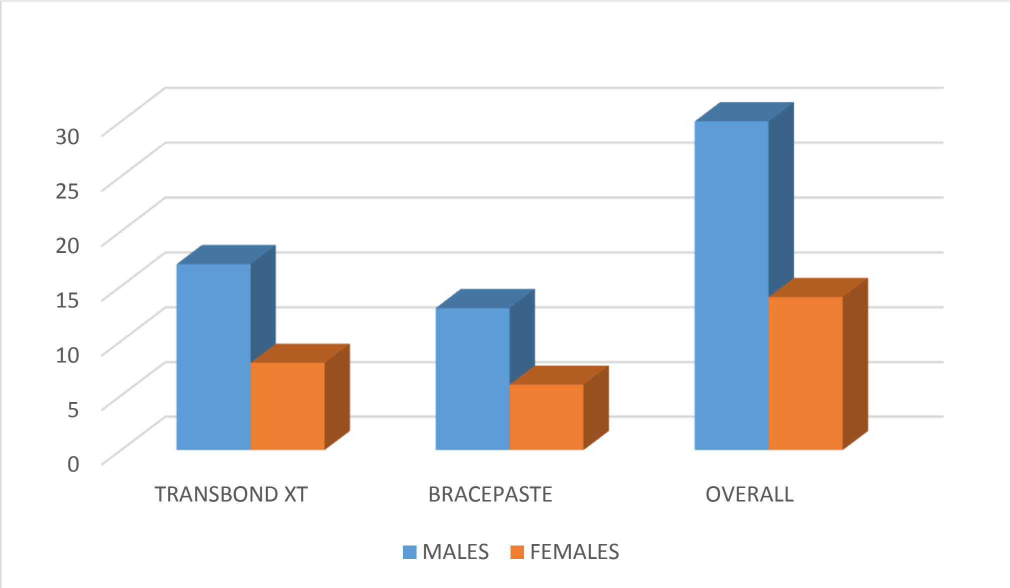
Material	Wire Composition	Failure		Success		p Value
Transbond XT	Stainless Steel	0	0.0%	560	100%	**0.000**
	NiTi	25	8.9%	535	91.1%	
Bracepaste	Stainless Steel	0	0.0%	560	100%	**0.000**
	NiTi	19	6.8%	541	93.2%	

TABLE 8.7 Frequency and percentage of success and failure rate of brackets between different wire dimensions (Round and Rectangular) in comparison with the two adhesives materials.

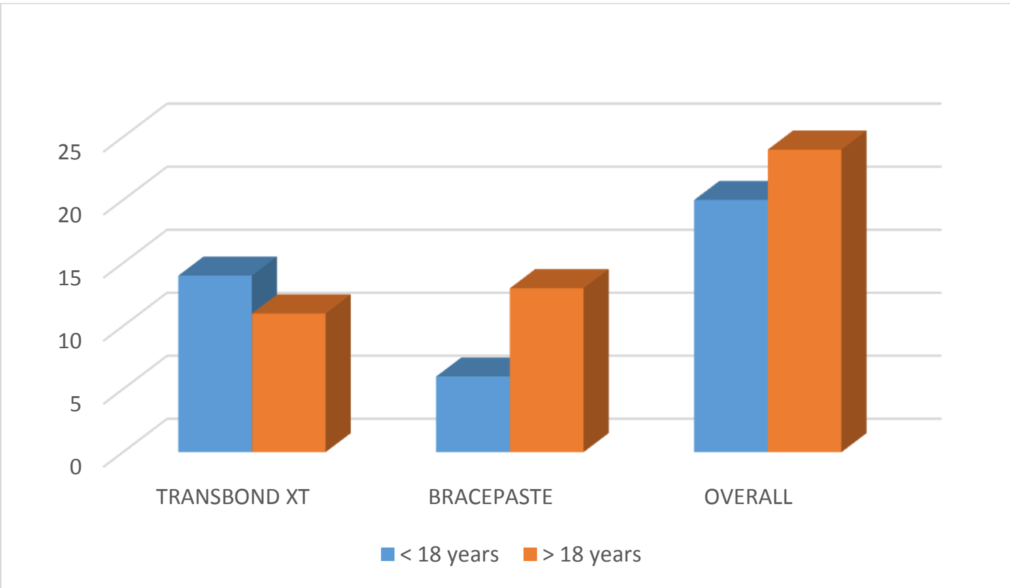
Material	Wire Dimension	Failure		Success		p Value
Transbond XT	Round	23	8.2%	257	91.8%	**0.000**
	Rectangular	2	0.7%	278	99.3%	
Bracepaste	Round	18	6.4%	262	93.6%	**0.000**
	Rectangular	1	0.4	279	99.6%	

Tables and Graphs

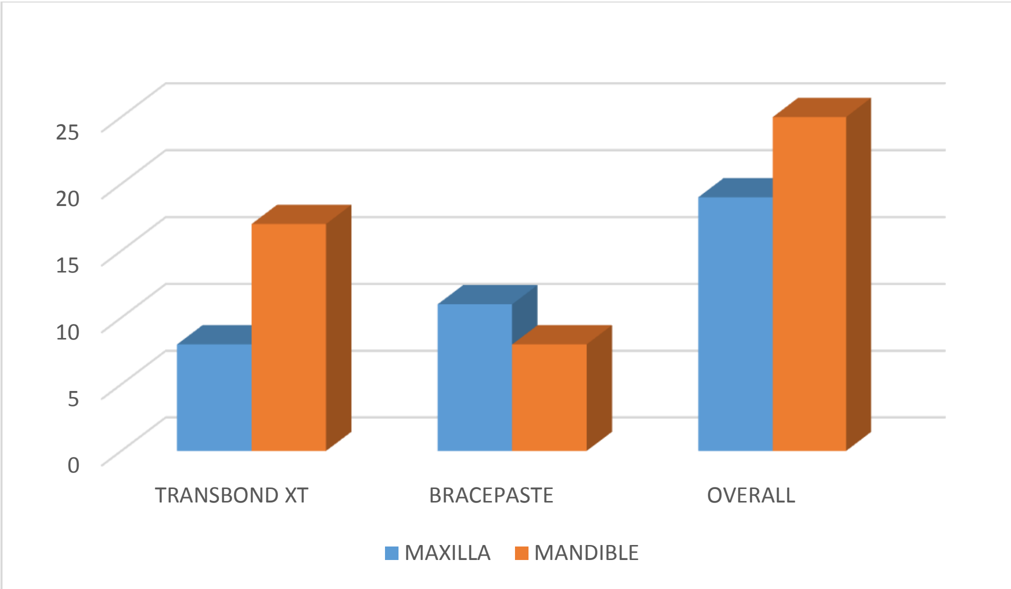
GRAPH 1 Comparison of bracket failure rates between the two adhesives among both genders



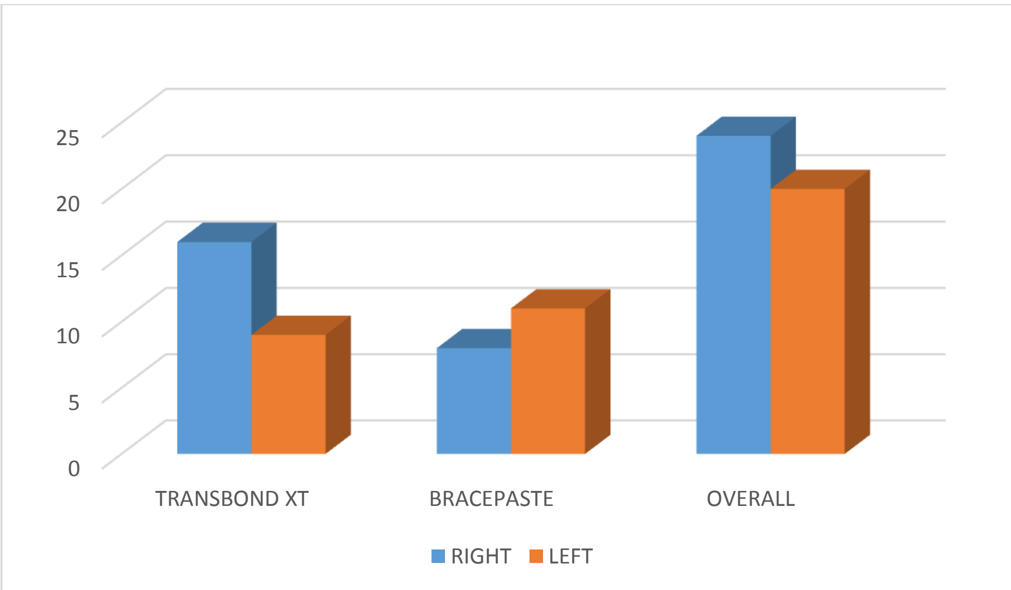
GRAPH 2 Comparison of bracket failure rates between the two adhesives among the age groups



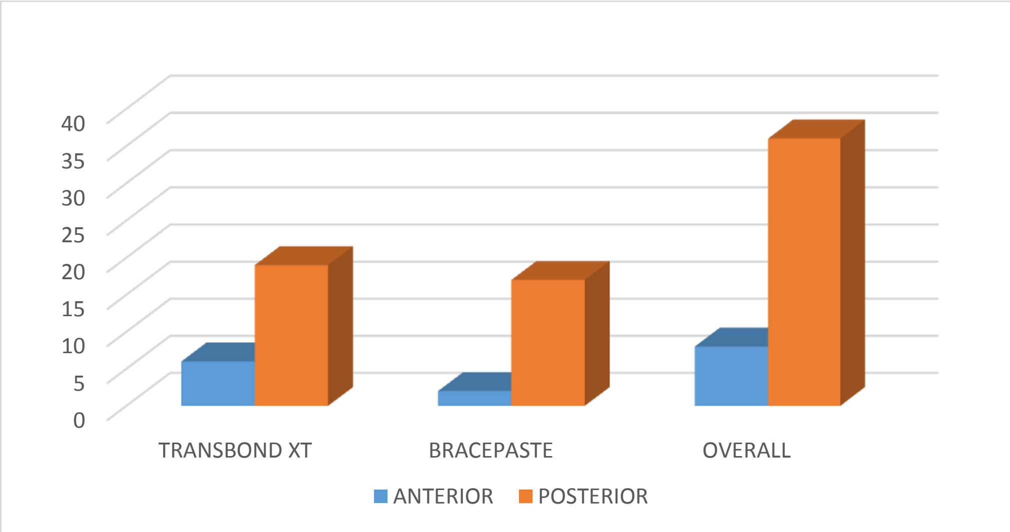
GRAPH 3 Comparison of bracket failure rates between the two adhesives within Maxilla and Mandible



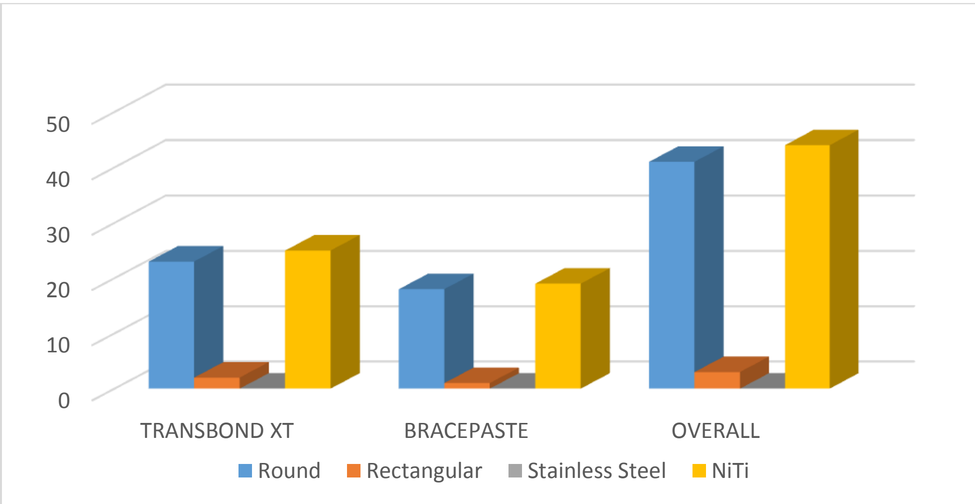
GRAPH 4 Comparison of bracket failure rates between the two adhesives within right and left quadrants



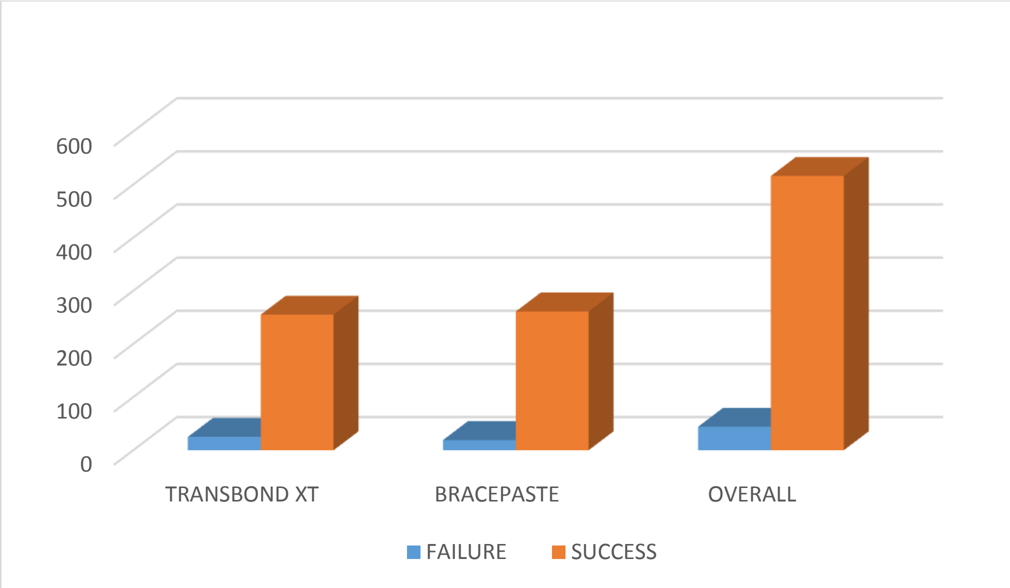
GRAPH 5 Comparison of bracket failure rates between the two adhesives within anterior and posterior segments



GRAPH 6 Comparison of bracket failure rates between the two adhesives with different arch wire dimensions and compositions



GRAPH 7 Comparison of success and failure rates of brackets between the two adhesives



GRAPH 8 Description of overall Adhesive Remnant Index scores and in comparison between the two adhesives

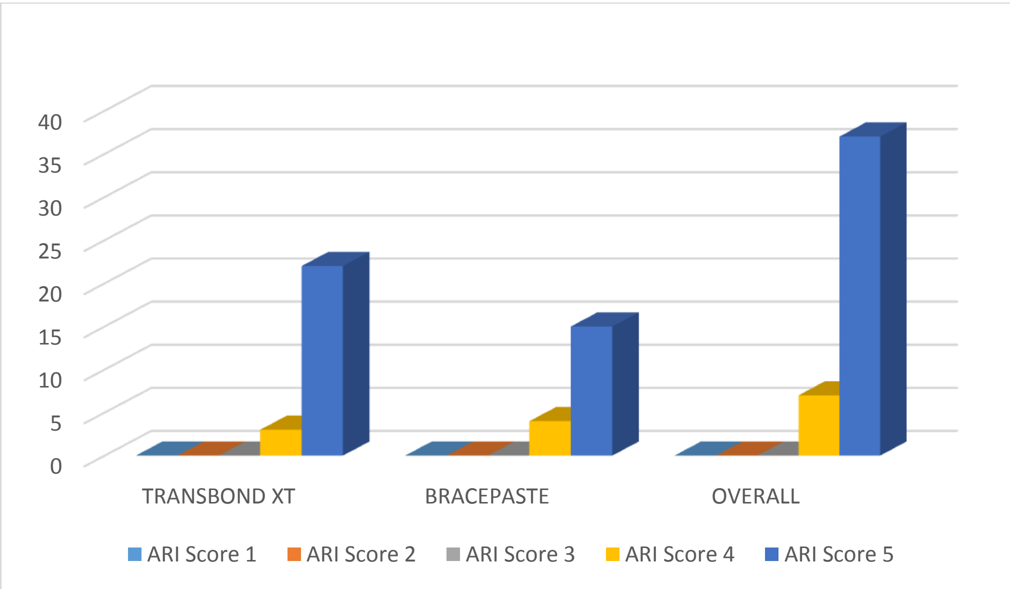


CHART 1. Kaplan Meier Plot for Adhesive Material Transbond XT within the study duration of 10 months (305 days)

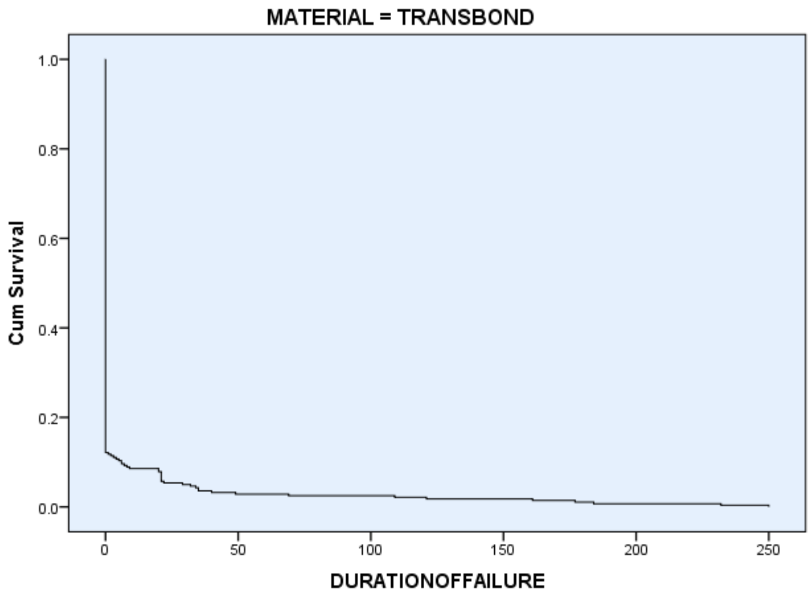


CHART 2. Kaplan Meier Plot for Adhesive Material Bracepaste within the study duration of 10 months (305 days)

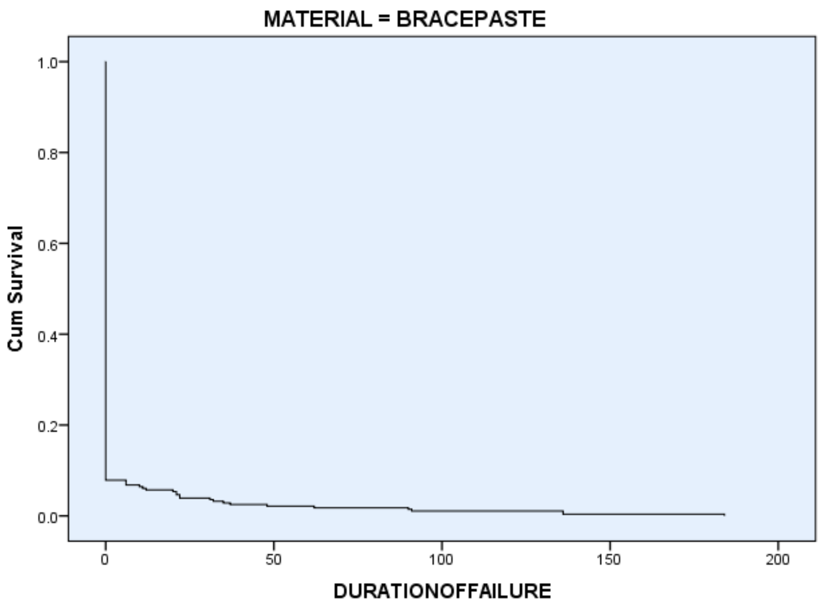
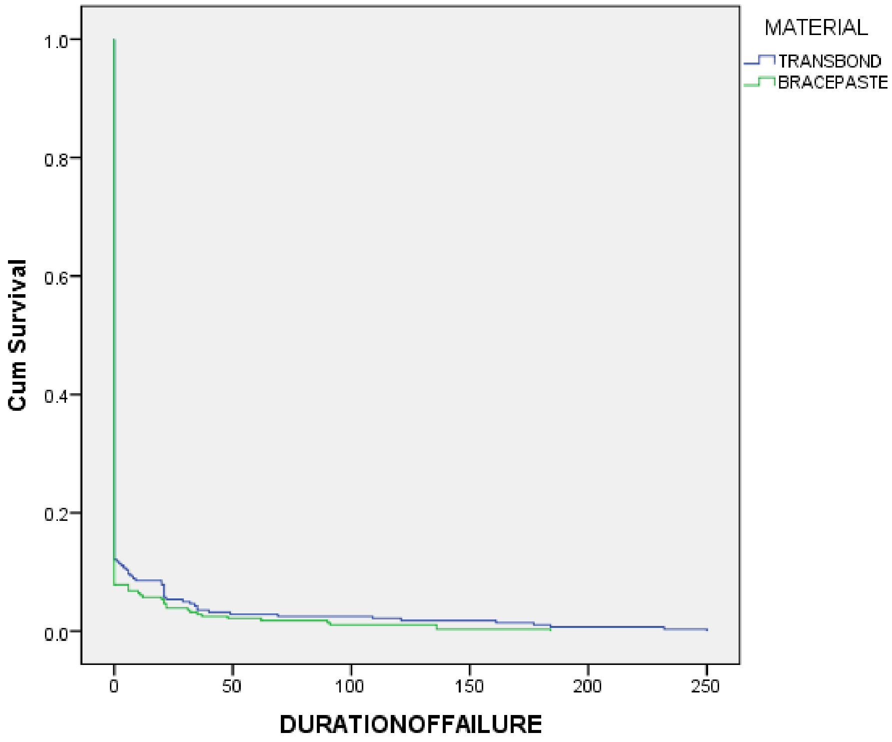


CHART 3. Kaplan Meier Plot comparing the two adhesives (Transbond XT and Bracepaste) within the study duration of 10 months (305 days)



Discussion

DISCUSSION

Orthodontic bonding has become a routine procedure in contemporary orthodontics. It is the foremost and important step that paves a way for functional stability and enhancement of aesthetics in a patient.

Until the 1960s this procedure was tedious for a clinician because circumferential bands with brackets welded was luted using cements such as Zinc Oxide Eugenol, Zinc Phosphate and Zinc Polycarboxylate.[93,94,85] It led to however inadequate aesthetic result and several needs to be considered such as increased chair time, patients inconvenience to gingival irritation, pain, plaque accumulation, dental caries etc.[88]

Three noteworthy milestones which changed the way a clinician and patient comprehended orthodontics were the introduction of acid etching technique by Buonocore[20] into the orthodontic field by Newman[76] in 1965 which aided the possibility of direct bonding of brackets in orthodontics, which resulted in good aesthetic results, improved patient's compliance, decreased chair time and increased the efficiency of treatment. The development of a resin material by Bowen[18,19] showed less shrinkage, water absorption and greater bond strength that the previously used cements, and the invention of light activated resin[77] and light curing units[70,113] which provided sufficient working time with control over the polymerization setting reaction.

A bracket which is fixed to the enamel is expected to last long, throughout the overall duration of treatment. Orthodontic bracket failure is a very common incidence which tends to occur during the course of orthodontic treatment. Bracket failure leads to unwanted delay in treatment duration and unnecessary appointments. It is economically compromising and may decrease the treatment efficiency.[9]

The enamel - adhesive - bracket interface has been a well scrutinized area of interest in literature. Many modifications in technique and different innovative materials have been introduced. But in spite of all these modifications bracket failure still exists as an imminent frustrating issue to manage.[85]

Reynolds et al[89] took great interest in studying the bracket- adhesive system. According to him a bond strength of 5.9-7.9 MPa was necessary for successful adhesion of brackets to the teeth.

Several factors are responsible for a bond failure to occur. Deficiency in isolation leading to moisture contamination such as saliva and /or blood, inefficient prophylaxis and inadequate etching of enamel which may be due to differences in technique, enamel microstructure or mineral content and finally adhesive related factors like kind of adhesive, source and time of light curing and other factors like bracket base designs, loading of wire etc.

A preliminary step in the orthodontic bonding is adequate isolation and prophylaxis. Studies have found etched enamel damp from saliva or blood which weakens the bond by 50% on forming an organic layer which resists removal and fills the etched surface.[23,80,95,98] A pumice prophylaxis aids removal of smear layer or any organic pellicle which are assumed to weaken the bond strength. However most studies have mentioned pumice prophylaxis does not seem to have a positive impact on conventional etching and bonding procedure in enhancing the mean bond strength.[12,49,50,59]

Undoubtedly, the technique of acid etching is the most important aspect to consider for a good bond strength at the enamel adhesive interface.

Enamel with differences in mineral content is well known to affect the bond strength and various modifications in techniques have been discussed in literature. But since differences in protocol may affect the study, only healthy enamel were included in this study and thus limiting the discussion on the effects of mineral content in bond strength.

Different concentration of different acids and their durations have been described in literature claiming to produce a significant bond strength. Maleic acid, Citric acid, Polyacrylic acid, Nitric acid, Hydrochloric acid, Hydrofluoric acid and Phosphoric acid have been used as etchants but Phosphoric acid has proved to be the ideal acid for etching.[38,46,126]

Similarly, studies have analyzed the bond strength of various concentrations of Phosphoric acid from 2% to above 60%[24,58,103] and it has been denoted that 35-37% is ideal. Duration also seems to play a vital role. Variations in acid etch patterns and bond strength based on duration have been analyzed and found that 15-60 seconds can be the duration of application of Phosphoric acid.[52,85]

In this study 37% Phosphoric acid have been used for 30 seconds and rinsed thoroughly for 60 seconds. This is in accordance with studies by Gardner[38] and Sharma Sayal[101], who claimed this concentration and duration optimal for an efficient etch pattern, depth of resin tags and the resulting bond strength.

Similarly, the type of etch pattern[36,106] varies from tooth to tooth due to its morphological differences in enamel microstructure such as presence and orientation of enamel prisms (enamel rods), in turn affects the bond strength at the Orthodontic Bond Area (OBA).[47,65]

Though Hobson and McCabe[47] quoted that a Type A pattern (well etched) is seldom seen, a majority of Type B (good etch) was been in anterior teeth and Type C (poor etch) was seen in premolars specifically. Hobson[48] and Whittaker[122] in their studies quoted that the absence of prismatic layer in posterior teeth such as premolars and molars show a resistant layer for acid attack or etching thereby leading to poor etch pattern. Similarly, Hobson[47] quoted that lesser the bond area more good the type of etch pattern (Type A pattern) and it was more commonly seen in lower incisors.

But it should be taken into consideration that the etch pattern though predominant, may not necessarily weaken the bond strength.

Numerous commercial adhesives have been introduced each claiming to have better or ideal bond strength as quoted by Reynolds. The adhesive systems can be broadly classified as Light cure resins, Chemical cure resins, Resin Modified Glass Ionomer Cements, Cyanoacrylates and Flowable Composite. Light cure resins offer effortless application, lesser degree of polymerization shrinkage and increased bond strength.

In appreciation of increased chair time, one bottle systems, no mix adhesives have been introduced. However, conventional acid etching technique (Multistep or 3-step etch and rinse method) has been considered a gold standard protocol to follow.

The light cure resins used in this study are Transbond XT and Bracepaste. **Transbond XT** is a well-documented orthodontic bonding system reviewed in literature and is considered an efficient traditional or conventional light cure bonding system. Many invitro studies[27,43] and clinical trials[68] have analyzed the bond strength of Transbond XT and also compared it with other chemical cure resins, resin modified glass ionomer cements and other light cure resin adhesive systems. It has been suggested that Transbond XT does exhibit a sufficient shear bond strength more than that recommended by Reynolds for an efficacious bond.

Transbond XT has also been proven safe with a low release of Bisphenol A or other cytotoxic substances than the recommended dosage levels. It has been well acknowledged and used by many clinicians.[13,73,110]

Bracepaste is a newer adhesive material from American orthodontics into the orthodontic market claimed to have similar properties and composition of substances as in Transbond XT with the major ingredients being BIS GMA and Quartz Silica. The laboratory testing also have shown results claiming it to have properties as effective as Transbond XT. Its increased viscosity has been quoted to aid to positioning of brackets by preventing drifting away of the brackets. However no clinical trials have been conducted to analyze its efficiency.

The bracket base and mesh design are vital in providing additional bond strength to the bracket adhesive interface.

Literature has documented Mitchell[71] as the first person to comment on the use of metal bracket with a retentive base. A minimum of 6.82 mm^2 bracket base dimension is considered necessary for providing sufficient bond strength[62]. Ever since many modifications have been introduced with variation in mesh designs such as integrated or welded foil mesh bases with single or multiple layer having different thickness and spacing between them.[28] Single foil mesh bases have known to generate more stress on the enamel rather than brackets with double layer foil mesh designs[93]. Double foil mesh designs allow better penetration of the adhesives and light penetration during curing process than single mesh design.[105] Foil mesh bases have been known to withstand tensile forces better than other type mesh designs[114]. Studies by Wang[120] and Knox[54] show foil mesh designs to have better bond strength than integral meshes and a 60- 80 gauge mesh provides sufficient bond strength.

The mean bracket base of the bracket used in the study was $9.42mm^2$ with a double layered 80µm gauge mesh over a micro etched foil base by photochemical process. 0.022 x 0.028 slot, Roth prescription, Mini Master Series, American orthodontics brackets were used in this study. This mini master series brackets have been analyzed in literature and have been proven to show sufficient bond strength.[45,101]

In this study, since the brackets used were from American orthodontics, a newer adhesive from the same brand was selected in an assumption to find out if it can be a viable alternative for Transbond XT. Transbond XT was used in the other group to compare with the newer material as literature has evidence to show that it had reasonable success.

Similarly it is worthwhile to mention the impact of LED curing lights in orthodontics. The ergonomics and efficiency of LED unit have been documented in literature[29,117]. QTH or the halogen curing unit and the plasma arc curing units despite their known efficiency to polymerize the adhesive have their own adverse effects such as thermal damage to pulp.[41] Krishnaswamy and Sunitha et al[57] and other authors in several studies have compared the efficiency of LED with halogen and plasma arc curing units and found no difference in their efficiency.[35] Studies also have investigated and found that the distance between the light cure tip and adhesive surface should be as close as possible for sufficient and even depth of curing of the material to occur.[110,97]

In this study a 3M Elipar S10 light curing unit capable of emitting visible light at a wavelength of 430 to 480nm with an intensity of

1200mW/cm^2 was used to cure the adhesive by placing it as close as possible to the bracket and light cured for 20 seconds.

Various studies have been previously done to test the effectiveness of adhesive materials in vitro.[3,14,116,] This is because in vitro conditions have been known as the best method to find the true effectiveness and efficiency of an adhesive system allowing more standardized procedures. But studies have also concluded that many in vitro orthodontic bond strength assessments failed to report test conditions that could significantly alter their outcome. Invitro studies have not been successful in predicting in vivo effectiveness and very few studies have been conducted in vivo. [34,118]

Similarly in order to reduce the probability of bias in terms of inter-patient variability to control the bias to within – patient influences, the study was conducted as a split mouth study.

Failure rate is often used to indicate the clinical performance of bonding adhesives, and it allows comparisons to be made between studies.[28] Therefore the study was designed as an in vivo split mouth design study and the number of bracket failures was calculated to analyze and find out the better adhesive system

In this study, a total of 44 brackets, 7.9%, exhibited bond failures among 560 bonded teeth. The percentage of failures in this study can be considered within the range of failure percentages as mentioned in previous in vivo studies which ranged from 0.5% to 16% with an average of 6%. [47,111,123]

AGE

The influence of age has not been extensively discussed in literature. Studies have evaluated and shown varying outcomes on significance between the age groups based on their age group selection.[67] Many authors[5,57,121] have omitted the criteria for age to be taken into consideration bearing in mind the evaluations of previous studies that it does not to influence bond failure. However, these literature does give us instances and rationalizations about the influences of age in failure rates of brackets.

Most studies compared the age group mostly between 12-35 years. This is because by 12 years the permanent dentition would have been established.

A clinical study by Millett et al[67] found patients below the age of 12 years showed 3 times the failure rate of patients above 16 years.

Below 12 years the premolars especially would have been erupting and interfere in the placement of brackets and make it more prone to gingival fluid seepage.[52,123]

Bearing in mind these factors, in this study we included patients 12 years and above. The mean age was 19.4 years with the highest quartile being 33 years.

This study demonstrated higher number of failures in patients above 18 years compared to patients within the age group below 18 years. (TABLE 2.1)

But contradictory results were noticed when correlating the two adhesives with age as a criteria. Transbond XT displayed a higher rate of bracket failures in patients below 18 years while Bracepaste displayed a higher rate of failures in patients above 18 years. No statistical significance was seen in relation to bracket failures in patients below or above 18 years and in relation between the adhesives. (TABLE 2.1 and 8.1)

Studies mostly denoted the failure in brackets in perspective of age is mainly due to patient's compliance and inattention to maintain a proper diet protocol by avoiding hard foodstuff.

Another reason assumed to cause failure is the eruption levels of teeth, especially premolars and canines the position of attachments close to the gingival exposes it to higher risk of moisture contamination due to gingival fluid seepage which may in turn lead to bracket failure.[123]

Increase in overbite is considered an indicator for bracket failure. The establishment of Curve of Spee takes place after complete eruption of second molars by the age of 14 years,[64,112] until which a transient physiological deep bite may cause cuspal interferences with either direct or indirect increased load on the brackets or attachments placed.

In late adolescents and adults the occlusal forces mainly the bite force or chewing force have been an important factor in bond failure. Studies by various authors[10,41] show that the bite force increases proportionately as age progresses due to the developing muscle forces between 6-18 years of age and decreases after 25 years in females and 45 years in males. Higher number of failures in individuals above 16-18 years is caused by increased masticatory or bite forces.

This study failed to show a statistical significance between the age group of below 18 years when compared with participants above 18 years of age. (TABLE 2.1)

This study showed similar results with previous studies with the age difference not playing a significant role in failure rates of brackets between young adolescents to young adults.[52]

Clinically it was contradictory to a general assumption that the number of failures was higher in patients in the lower age group[51]. This can be justified by the increased number of patients above 18 years included in the study.

The other rational justifications for the bracket failures in this study could be the patient's negligence to follow the instructions of the clinician such as to avoid hard food or not to handle the attachments.

The gender variations on failure rates display males to have a greater percentage than females.[56,67] Few studies displayed females to have insignificant but higher bracket failures, which were substantiated by the number of increased sample size.[22,60,115]

In this study a higher number of failures were seen in males than females. A statistical significance of p value < 0.5 was seen denoting a predominance of males than females. (Table 3.1)

When correlated with adhesive materials, both adhesives displayed higher failures in males than females. Transbond XT displayed higher bracket failures than Bracepaste in males and females. (TABLE 8.2)

Very few studies have considered the differences in failure related to gender.[67,68] Some studies[5,57] failed to evaluate bracket failures related to gender and the results of previous studies claims no significant differences between the gender. A general assumption based on clinical observation is that males tend to display significantly higher bite forces than females.[83] Nikolaos Koupis[56] and Imad Shamma[100] claimed that Females are more attentive and take better care of fixed appliances than males.

Though differences in observations of predominance of males and females in bond failure rates and various clinical trials have been observed, several reasons have been obvious.

Various reasons such as the increased arch size and tooth size in males compared to females, the difference in body build, which all can be attributes to increased bite force has been provided to justify the predominance of failures in males.[11,104]

An average bite force of 17.5 kg in males and females 13.9 kg in age groups between 10 to 25 years was observed in previous literature. There was no significant variation in bite force between genders within 11-16 year age interval which was attributed to early occurrence of pubertal peak in females.[39]

In this study a statistical significance was noted between males and females with males displaying higher percentage of failure than females. The most common reason in this study could be inattentiveness of male patients to take better care in avoiding circumstances that may lead to bond failure.

ARCH

In this study, the mandibular arch displayed a higher number of clinical bracket failures than maxillary arch but failed to show a statistical significance. (Table 4.1)

Transbond XT displayed a statistical significance in displaying higher failures in mandibular arch compared to the maxilla arch and Bracepaste showed a clinically higher number of failures in maxilla than mandible but no statistical significance in failures between the arches was noted. Correlating the two adhesives, Transbond XT displayed higher failures in mandible while Bracepaste exhibited higher failures in maxilla. (Table 8.3)

Literature studies have also shown a significant trend in the past years with mandible showing higher number of failures than maxilla despite the various techniques, type of material or light curing unit used.[56,57,60]

The previous studies have substantiated high occlusal forces as the common factor for this trend in predominant mandibular arch failures.[1]

Another reason could be also the type of malocclusion. With the mandible overlying the maxillary arch, in cases of deep bite as commonly seen in class II div 2 cases, the occlusal trauma may lead to failure of the brackets in the mandibular arch. In order to prevent this, authors have suggested a bite plane or pads to create a leeway and thus preventing the brackets from direct contact of upper tooth cusps or incisal edges.[68,69]

Similar circumstances were experienced in this study. Though mild bite pads were placed to alleviate the occlusal load from causing trauma, failures did occur in certain instances due to patient's chewing pattern.[51,56]

Orthodontic bonding in patients with increased overbite or closed bite were postponed until a significant clearance was achieved. Similarly patients with a mild cross bite were given a bite plane in order to prevent failure of brackets. Such steps were taken to prevent the component of malocclusion in creating a bias in the study.

Nevertheless, mandibular arch showed higher instances of failure of brackets than maxillary arch. Thus it can be substantiated that masticatory forces or heavy occlusal forces and to a lesser extent increase in the bite of the patient were the cause of higher failure of brackets in mandibular arch. Likewise, moisture contamination despite precautionary steps undertaken, patient's unconcerned attitude and irregular force delivery during brushing may be probable reasons for failures in maxillary arch or especially maxillary anterior teeth.[56]

Quadrants.

The study did not signify any statistical significance in the failure of brackets between the right and left segments though higher failures was seen in the right side than left side of the patients. (TABLE 5.1) Though the results of this study may correlate with the study by Mohammed et al[72], it contradicts majority of previous literature studies where the same side of the clinicians working hand has been known to provide better results.[1,31,111]

Transbond XT depicted a higher number of failures on right side, while higher number of failures were noticed on left side in teeth bonded with Bracepaste. But no statistical significance between the sides was seen between the two adhesives. (TABLE 8.4)

Literature has documented two broad notions in elucidating the failure between different segments.

Firstly the clinician's right-handedness or left-handedness has shown to play a vital role in his or her efficiency in bonding of brackets with the segments. A right handed clinician has been known to show ease in bonding technique on the right segment of the patient especially visibility, moisture control and positioning of brackets.[1,111] However Kinch et al[52] claimed a right handed clinician found better access in bracket placement on the left side.

Secondly, the patient's habitual manner to chew food on a particular side, and inequality in the forces applied during brushing tending to apply a heavier force on one side may cause arch wire distortion leading to bracket failure.[52]

Different operators may prevent intra- operator bias but lead to inter-operator variability. The reason for using a single operator in this study was to remove inter – operator variability. A split mouth study design helped in randomized allotment of material within the study and the operator was also blinded to remove as much bias as possible from the study.

Greater care was taken during the bonding of brackets in this study to consider the factors such as moisture control and delivery of consistent pressure between the brackets on either side. Thus in this study it can be safely presumed that the patients behavioral characteristics had a major role in bracket failures between the segments.

Anterior or posterior

Differences in the ratio of bracket failures within anterior and posterior segment has shown a predominance in posterior segment.[53,57,92]

This study was no different and showed a higher number of failed brackets in posterior teeth. A statistical significant value was noted with posterior segment showing higher failure rates. Transbond XT and Bracepaste both showed significant results. Transbond XT displayed higher failures than Bracepaste in both anterior and posterior segments (Table 6.1 and 8.5)

Several reasons have been substantiated for the increased number of failure in posterior teeth than anterior teeth. Moisture control either saliva, gingival fluid seepage or blood have been a concern to terms of bond strength. Various authors have mentioned that a dry field during bonding is best for efficient bond strength.[21,95,125] The proximity of salivary duct opening make it difficult in controlling the salivary flow in posterior segment especially the buccal aspect.

The heavy occlusal forces or masticatory forces and most importantly the maximum voluntary bite force or the chewing force is higher in posterior region of dentition.[52,82] The anterior segment, though failure of brackets are highly predisposed by the aspect of overbite the occurrence is less seen due to the decreased amount of incisal bite force.[52]

Incisal bite force ranged between 13-15 kg while the posterior bite force exceeded 30 kg at instances when hard food was masticated.[51] Similarly according to Arnold[7], a ratio of 4:2:1 is observed when the bite force of the molars, premolars and incisors is accepted. According to Knoll[53], fatigue at the enamel adhesive interface occurs as these forces are transmitted past the crown to the interface.

The anatomy and characteristics of teeth in the anterior segment compared to the posterior segment are different which in turn affect the seating of brackets and the etching pattern.

In this study visibility can be considered major factor. In posterior segment, the visibility and accessibility were greatly reduced[22,57] especially the second premolars (molars were banded) because of the oral musculature causing difficulty in positioning of brackets and removal of excess adhesive. Irrespective of the type of adhesive material, certain failed brackets showed excess flash present despite the caution undertaken to remove the excess flash present around the bracket especially the distal and gingival aspect of second premolars.

Another issue was uneven thickness of resin distribution found in failed brackets of posterior teeth. Knoll[53] describes it as a significant reason for bond failure. A thicker adhesive at a particular area may increase polymerization shrinkage and differences in coefficient of thermal expansion/ contraction thus build stresses within the resin resulting in bond failure.[37,53]

Occlusal forces or masticatory forces and most importantly patient’s negligence to follow the instructions to avoid hard food which can dislodge the brackets and showed higher potential in leading to bracket failure in this study.

Teeth anatomy and position.

The premolars displayed a higher number of failures than the other tooth types such as canines and incisors. (Table 1.3)

The second premolar displayed a failure percentage of 50% of the overall failed brackets. The remaining tooth types displayed failure in the decreasing order of first premolar, canines, incisor respectively.

Both Transbond XT and Bracepaste displayed higher failures in 2nd premolars and consecutively the 1st premolars. No failures were seen in canines in the Bracepaste group while 4 teeth failed in Transbond XT group. Similar number of failures were seen in both adhesives in relation to teeth failed in incisor tooth type (Table 1.4)

The influence of teeth, with its varied anatomy and location in the arch on the nature of the bond have been deeply studied. The canines and premolars have known to show variations in the anatomy of their clinical crown.

Similarly though the brackets placed on premolars and canines are more curved than the incisors to adapt the contour of the clinical crown, the problem of adaptation was encountered during placement of brackets in application of uniform force and even distribution of material within the bracket base was difficult. This led to improper penetration of adhesive at certain sites in the bracket mesh which reduced the effectiveness of the mechanical bond between the adhesive and bracket base.

Short clinical crown heights affect the positioning of bracket bringing it closer to the gingiva causing more chances of failure due to gingival flow.[52,123]

A predisposing factor for bond failure explained by Whittaker[122] using a SEM study is the enamel structure and found that the premolars and molars have aprismatic enamel while the anterior teeth; the incisors and canines have prismatic enamel. The acid etching pattern was found poor in teeth with aprismatic enamel due to lack of porous prismatic outer surface which did not allow formation of deep resign tags. Less penetration of adhesive and weak bond strength are noted. Similarly it is considered that lesser the Orthodontic Bonding Area better the quality of etch pattern and subsequently the bond strength. Thus, lower incisors more predominantly display higher bond strength and molars display poor etch patterns leading to weaker bond and higher failures.[47,65]

A study by Hobson and McCabe[47] analyzed the acid etch pattern types and found differences in the etch pattern of anterior teeth and posterior teeth especially the premolars and molars.

The higher occlusal or masticatory forces undergone by the second premolars which are located posterior and closer to the molars may have caused higher instances of failure.

Incorrect brushing technique and more importantly the impingement of hard food substances on the premolars and molars which are most commonly used for crushing and tearing have been denoted as major reasons for failure of brackets in previous studies and also in this study.[51,60,123]

The lower canines during their excursive movements are subjected to occlusal load and trauma which cause bracket failure. The increase in overbite is the major reason of failure in lower incisors.[52]

Wire Dimension and Composition

The wire sequence to be used in levelling and aligning stages and further proceeding steps can vary depending on technique, type of brackets, practitioner preference and treatment goals.

Usually the selection of arch wire sequence progression from less rigid round wires in the early stages to enable dental alignment, and then more rigid rectangular wires in the final stages to three-dimensionally control dental movements.[74]

NiTi wires are flexible and have shape memory and elastic properties while Stainless steel wires are known for their rigidity and stiffness.[74] In some cases where initial torque requirements are necessary, rectangular NiTi wires are used as they are less stiffer than Stainless Steel wires and are capable of delivering light and continuous forces with less deformation.

In this study, round NiTi wires were used during the initial stages. Rectangular wires and Stainless steel wires proceeded as the teeth aligned.

As the study duration was limited to 10 months, the assessment bracket failures was mainly recorded during the initial alignment and levelling stages.

Very limited studies are present in relation to wire dimension and composition on bracket failure.

According to Al Huwaizi,[2] especially in rectangular wires, as the wire-bracket slot interface or wire play increased, the brackets displayed lower bond strength in both Stainless Steel and NiTi wires. However, the bond strength of adjacent brackets was found higher as the wire play increased in Stainless Steel and much lower in NiTi.

This may be due to less force being transferred to the adjacent brackets because of increased play between the arch wire and bracket slot and the higher flexibility of the lower size arch wire in Stainless Steel. NiTi wires due to their super elasticity transmit higher forces to adjacent brackets as the wire play increases, leading to failure of the adjacent brackets.

Similarly NiTi rectangular wires displayed lower bond strength than Stainless steel wires. However, as the wire play increased, the adjacent brackets displayed higher or better bond strength with NiTi wires. Similarly as the wire play decreased, Stainless steel brackets displayed higher or better bond strength a wire play decreased in adjacent brackets.

This may be the reason for higher failures while using round and NiTi wires. This study recorded higher failures in round wires than rectangular wires. Higher number of failures were noted in NiTi wires than Stainless Steel wires within the study duration. (Tables 7.1 and 7.2)

Transbond XT displayed higher number of bracket failures in both NiTi wires, round wires and rectangular wires than Bracepaste adhesive. (Table 8.6; 8.7) No failures occurred with Stainless steel arch wires in the study. (Table 7.1)

Between Adhesive Materials

Transbond XT showed a higher number of bracket failures than Bracepaste within the study duration of 10 months. However, the difference was not statistically different. (TABLE 1.2)

Differences in bracket failure rates were comprehended in most of the verified variables but a demarcating difference was seen in terms of age, arch and quadrants.

Transbond XT showed a statistically significant increase in the number of failures in mandible. The adhesive material Bracepaste, though insignificant, showed a higher rate of failure in maxilla. (TABLE 8.3)

Similarly, despite a statistical insignificance, Transbond XT showed higher failure rates on right side while Bracepaste displayed higher failures in left side. (TABLE 8.4)

Transbond XT showed higher failure rates in patients below 18 years while Bracepaste displayed higher failures in patients above 18 years. (TABLE 8.1)

The study was conducted as a split mouth design. Due to randomization the number of teeth bonded with Transbond XT and Bracepaste slightly differed in terms of quadrants. But the adhesive materials was distributed within the dentition such that the randomization and allotment of material to a particular arch or quadrant would not affect the outcome of the study. The operator was also blinded so that the operator bias may not influence the outcome of results between the two different materials.

The incidence of bracket drifting distally and/or gingivally due to gravity by the time teeth are bonded from premolar on one side of the arch to the other side, and the movement of bracket during removal of excess flash was less in Bracepaste than Transbond XT.

The slight opaqueness of the material Bracepaste aided in visibility in removal of excess flash to a certain extent more than Transbond XT.

Two brackets bonded with Bracepaste adhesive material debonded immediately during loading of initial levelling wire (0.016 NiTi, Preformed), 10 minutes after bracket bonding. Four brackets bonded with Bracepaste adhesive material failed within 1 week of orthodontic bonding. These incidents should be deeply analyzed. The effect of time over the bond strength of adhesive material both in vivo and invitro has been analyzed in few studies.[27,43,60,75] The results between studies when compared, are different and inconsistent. Chamda et al[27] in an invitro study using Transbond XT adhesive, measured at various times the bond strength after bonding (0, 2, 5, 10, 60 minutes and 24 hours) found the bond strength continued to increase up to 10 minutes. The bond strength at 24 hours and at 1 day was no different statistically. An in vivo study (using Transbond XT adhesive) showed however the bond strength was below the recommended level by Reynolds at 10 minutes and 1 week.[43]

Several aspects should be kept in mind. These estimates can only be checked in vitro with a standardized environment for addressing the efficiency of bond strength. The incidence of failure did not occur on their own but the brackets were debonded at various intervals and the bond strength was calculated based on the force applied. However, in this study, the brackets failed and was not debonded by the clinician. The brackets were subjected to an oral environment condition, patient compliance and patient conduct which are out of hand of the clinician.

The four brackets which failed at 6 days did not occur at the notice of the clinician. Therefore, the reason provided by the patient (exposed to hard food) had to be acknowledged a reason for failure.

The brackets which failed immediately however may have occurred due to decreased bond strength to withstand loading. Other factors could be heavy occlusal load, inadequate moisture control which may compromise the bond strength. The brackets were bonded and loaded immediately. It should be noted that these brackets did not fail again during the course of the study.

Therefore it can be assumed that the cause was improper moisture control that weakened the bond and not the bond strength of the material.

The survival rates of the brackets plotted showed most of the bracket failures occurred within the first three months of failure. 50% of bracket failures occurred within the first 35 days with Transbond XT and 32 days for Bracepaste material. These results are similar to the previous studies that the initial 3 months portrayed higher failure rates.[31,44,92]

However in a study by Murray and Hobson[75], Transbond XT in in vivo and invitro investigations showed increased shear bond strength in the first 4 months and decreasing bond strength noted between 4-8 months. This may be contradictory to the result of this study. But it should be observed that the forces that influence the bracket failure are not the shear forces alone and lot of factors which influence the bracket from debonding as explained above, may lead to failure of brackets during the first 3 months.

One of the failed brackets in the study occurred during arch wire ligation when attempted using steel ligature. Though it may be of no greater significance with regards to this study, a clinician should keep in mind that heavy pull forces are not much withstood by any adhesive. Zachrisson[123] recommends a firm pressure should be used to hold the wire within the bracket slot during ligation rather pulling it tight with the ligature wire.

Identification of Adhesive Remnants is considered as one of the best methods by which the efficiency of the adhesive can be assessed.[25] Studies have found a direct correlation between ARI and Shear bond Strength. Though many studies have measured using Artun and Bergland's classification[8], in this study the modified 5 scale classification of Bishara and Truelove[15,25] seemed more illustrative and fitting to describe the remnant on the failed brackets in this study.

Two types of failures have been discussed; adhesive failure which denotes failure between two interfaces and cohesive failure which denotes failure within the adhesive.[79,124] Most failure in this study occurred at the bracket adhesive interface and the remaining with more than 90 % on the bracket mesh and only 10 % on the enamel. Literature has shown contradictory results on the interface of bond failure. Several authors have denoted that the failure mostly occurs at the bracket-adhesive interface.[8,84] However, this study was found in correlation with studies by Sfondrini et al[97,98] and Henkin et al[45] who claimed that the bond failure occurred more predominantly at the enamel-adhesive interface.

A breakage at the enamel interface signifies poor efficiency of adhesive as the chemical bond and partial mechanical bond created by penetration of adhesive on the etched enamel surface is vital.[8] But, the bond at the enamel surface is technique sensitive. Any short coming associated with depth of etch may lead to a weak bond.[86] Similarly improper depth and degree of cure may also result in polymerization shrinkage and bracket failure at enamel interface.[12,17] Similarly the oral environment, the changes in pH may all lead to failure of brackets.[42] Thus, the adhesive failure at enamel surface cannot be substantiated to the efficiency of adhesive alone.

A failure at enamel surface may also be considered beneficial at instances as it may not result in unnecessary enamel damage associated with removal of the adhesive. It may also demonstrate that the bracket mesh, which also plays an important role in orthodontic bonding, has a satisfactory bond strength and the bracket adhesive interface bond strength is higher than that of the enamel adhesive interface.[73]

A negligible number of brackets (7 brackets) showed cohesive failure and majority showed adhesive failure. Thus it can be safely assumed in this study, that the efficiency of the two adhesive materials is optimal to be used in practice. Necessary care should be taken into consideration to follow ideal protocols in allied procedures and techniques such as isolation, etching, curing etc. to minimize bracket failure.

Summary and Conclusion

SUMMARY AND CONCLUSION

Despite several decades with numerous advancements and innovations, ever since its inception, the multi-step or 3 step etching technique still remains the gold standard of orthodontic bonding. Likewise, a major drawback in the orthodontic bonding frequently encountered over the past decades is the failure of brackets within the duration of orthodontic treatment.

Various modifications in the techniques, adhesive systems, bracket base designs have been introduced and various products marketed by different manufactures have been analyzed in perspective of identifying an adhesive system and technique which displays adequate bond strength preventing bond failure. So far, though many adhesive systems have displayed adequate bond strength, the bracket failures could not be prevented from occurring.

This may also be due to numerous other environmental and patient compliance related factors such as age, gender, food habits of the patient, chewing pattern, brushing techniques etc. or inability to maintain a strict protocol by the clinician at all instances such as maintaining a dry field during bonding, proper duration and concentration of etching, adaptation of bracket bases to the contour of the enamel surface, adequate application of pressure during placement, adequate time of curing for complete polymerization etc. It has been assumed that bracket failures occurring within a range of 0.5-16% with an average of 6% is normal.

Assessment of bracket failures clinically has been considered one of the best ways to determine the efficiency of the adhesive material. Similarly, the Adhesive Remnant Index also defines the quality and efficiency of the adhesive material.

This study was conducted as an in vivo study to assess the failure rates of metallic brackets bonded to enamel using two different light cure adhesives marketed by different manufactures (Transbond XT, 3M USA and Bracepaste, American Orthodontics). Adhesive remnant Index scored based on Bishara and Trulove Classification was tabulated and survival indexes of brackets bonded using the two adhesives within the duration of treatment were also charted.

The study was conducted as a split mouth design study over a duration of 10 months. The bracket failures were assessed and correlated with variables such as age, gender, dentition (within the arch, within the quadrants and within the segments) and between the different wire dimension and compositions used during the study duration.

Transbond XT adhesive exhibited higher failures than Bracepaste adhesive material, however, the number of failures were statistically insignificant (p value > 0.05). The posterior region displayed statistically significant higher number of failures than anterior region. Similarly, males and NiTi wires displayed statistically significant higher failure of brackets (p value

< 0.05) than their corresponding counterparts. In this study, in the mandibular arch, patients above 18 years and the left quadrant, though displaying higher rate of failures than their counterparts did not show a statistical significance.

Transbond XT displayed a statistically significant, higher number of failures in mandible while Bracepaste, though insignificant, displayed higher failure rates in maxilla. Transbond XT displayed higher failure rates in patients above 18 years and on the right quadrant, while Bracepaste displayed higher failure rates in patients below 18 years and on the left quadrant. The ARI scores depicted a predominance of 5 according to Bishara and Truelove classification denoting higher failures at the enamel adhesive interface.

The following conclusions were drawn from the present study:

- It can be safely assumed in this study that both the light cure composite resin adhesive materials (Transbond XT, 3M USA and Bracepaste, American Orthodontics) display adequate and optimal bond strength and are suitable for application in orthodontic bonding procedures in day to day clinical practice.
- Necessary care should be taken into consideration to follow ideal protocols in allied procedures and techniques such as isolation, etching, curing etc.

Bibliography

BIBLIOGRAPHY

1. **Adolfsson U, Larsson E, Ögaard B.** Bond failure of a no-mix adhesive during orthodontic treatment. *American journal of orthodontics and dentofacial orthopedics. 2002;122(3):277–281.*
2. **Al Huwaizi AF, Mohammed HA.** Effect of arch wire ligation on shear bond strength of metal brackets. *Journal of Baghdad College of Dentistry. 2007;19(1):81–87.*
3. **Alexandre P, Young J, Sandrik JL, Bowman D.** Bond strength of three orthodontic adhesives. *American Journal of Orthodontics and Dentofacial Orthopedics. 1981;79(6):653–660.*
4. **Algera TJ, Kleverlaan CJ, Prahl-Andersen B, Feilzer AJ.** The influence of different bracket base surfaces on tensile and shear bond strength. *The European Journal of Orthodontics. 2008 Aug 27;30(5):490–4.*
5. **Arash V, Bijani A, Shokri Z.** Light-emitting diode versus halogen light Curing of orthodontic brackets: A clinical study of bond failure. *Rev Clín Pesq Odontol. 2009;5(3):267–272.*
6. **Arıkan S, Arhun N, Arman A, Cehreli SB.** Microleakage beneath ceramic and metal brackets photopolymerized with LED or conventional light curing units. *The Angle Orthodontist. 2006;76(6):1035–1040.*

7. **Arnold M.** Bruxism and the occlusion. *Dent Clin North Am 1981;25:395-407*

8. **Artun J, Bergland S.** Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod Dentofacial Orthop. 1984;85(4):333–340.*

9. **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 (Hradec Kralove, Czech Republic). 2015;58(2):43–8.*

10. **Bakke M, Holm B, Jensen BL, Michler L, Moller E.** Unilateral, isometric bite force in 8–68 year old women and men related to occlusal factors. *Scand J Dent Res. 1990;98:149–158.*

11. **Bakke M.** Bite Force and Occlusion. *Sem Orthod. 2006 Jun;12(2):120–6.*

12. **Barry GRP.** A Clinical Investigation of the Effects of Omission of Pumice Prophylaxis on Band and Bond Failure. *Br J Orthod. 1995 Aug;22(3):245–8.*

13. **Bationo R, Jordana F, Boileau M-J, Colat-Parros J.** Release of monomers from orthodontic adhesives. *Am J Orthod Dentofacial Orthop. 2016 Sep;150(3):491–8.*

14. **Bishara SE, Olsen ME, Jakobsen JR.** Evaluation of a new light-cured orthodontic bonding adhesive. *Am J Orthod Dentofacial Orthop. 1998;114(1):80–87.*

15. **Bishara SE, Ortho D, Truiove TS.** Comparisons of different debonding techniques for ceramic brackets: an in vitro study: Part I. Background and methods. *Am J Orthod Dentofacial Orthop. 1990;98(2):145–153.*

16. Bishara SE, Soliman MM, Oonsombat C, Laffoon JF, Ajlouni R. The effect of variation in mesh-base design on the shear bond strength of orthodontic brackets. *Angle Orthod. 2004;74(3):400–404.*

17. **Borgen, Kari K.** The effect of curing light source on polymerization contraction stress and degree of conversion over time in an orthodontic adhesive. *Scholar Archive (2006) 2932. https://digitalcommons.ohsu.edu/etd/2932*

18. **Bowen RL.** Adhesive bonding of various materials to hard tooth tissues. II. Bonding to dentin promoted by a surface-active comonomer. *J dent res. 1965;44(5):895–902.*

19. **Bowen RL**. Dental filling material comprising vinyl silane treated fused silica and a binder consisting of the reaction product of bisphenol and glycidyl acrylate. *US Patent 3066 112.*

20. **Buonocore MG.** A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J denta res. 1955;34(6):849–853.*

21. Cacciafesta V, Sfondrini MF, De Angelis M, Scribante A, Klersy C.

Effect of water and saliva contamination on shear bond strength of brackets bonded with conventional, hydrophilic, and self-etching primers. *Am J Orthod Dentofacial Orthop. 2003 Jun;123(6):633–40.*

22. **Cal-Neto JP e, Quintão CA, de Oliveira Almeida MA, Miguel JAM.**
Bond failure rates with a self-etching primer: A randomized controlled trial. *Am J Orthod Dentofacial Orthop. 2009 Jun;135(6):782–6.*

23. **Campoy MD, Plasencia E, Vicente A, Bravo LA, Cibrián R.** Effect of saliva contamination on bracket failure with a self-etching primer: A prospective controlled clinical trial. *Am J Orthod Dentofacial Orthop. 2010 May;137(5):679–83.*

24. **Carstensen W.** Effect of reduction of phosphoric acid concentration on the shear bond strength of brackets. *Am J Orthod Dentofac Orthop 1995;108:274-7.*

25. **Cehreli SB, Polat-Ozsoy O, Sar C, Cubukcu HE, Cehreli ZC.** A comparative study of qualitative and quantitative methods for the assessment of adhesive remnant after bracket debonding. *Eur J Orthod. 2012 Apr 1;34(2):188–92.*

26. **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.*

27. **Chamda RA, Stein E.** Time-related bond strengths of light-cured and chemically cured bonding systems: an in vitro study. *Am J Orthod Dentofacial Orthop. 1996;110(4):378–382.*

28. **Cozza P, Martucci L, De Toffol L, Penco SI.** Shear bond strength of metal brackets on enamel. *Angle Orthod. 2006;76(5):851–856.*

29. **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. *Eur J of Orthod. 2011 Feb 1;33(1):55–9.*

30. **Dunn WJ, Taloumis LJ.** Polymerization of orthodontic resin cement with light-emitting diode curing units. *Am J Orthod Dentofacial Orthop. 2002 Sep;122(3):236–41.*

31. **Elekdag-Turk S, Isci D, Turk T, Cakmak F.** Six-month bracket failure rate evaluation of a self-etching primer. *Eur J Orthod. 2008 Jan 21;30(2):211–6.*

32. **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.*

33. **Faria-Júnior ÉM, Guiraldo RD, Berger SB, Correr AB, Correr-Sobrinho L, Contreras EF.** 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.*

34. **Finnema KJ, Özcan 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 May;137(5):615–622.e3.*

35. **Fleming PS, Eliades T, Katsaros C, Pandis N.** Curing lights for orthodontic bonding: A systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop. 2013 Apr;143(4):S92–103.*

36. **Galil KA, Wright GZ.** Acid etching patterns on buccal surfaces of permanent teeth. *Pediatr Dent. 1979;1(4):230–4.*

37. Galindo HRA, Sadowsky PL, Vlachos C, Jacobson A, Wallace D. An in vivo comparison between a visible light-cured bonding system and a chemically cured bonding system. *Am J Orthod Dentofacial Orthop. 1998;113(3):271–275.*

38. **Gardner A, Hobson R.** Variations in acid-etch patterns with different acids and etch times. *Am J Orthod Dentofacial Orthop.2001 Jul;120(1):64–7*

39. **Garner LD, Kotwal NS.** Correlation study of incisive biting forces with age, sex and anterior occlusion. *J Dent Res 1973; 52:698- 702*

40. **Gioka C, Bourauel C, Hiskia A, Kletsas D, Eliades T, Eliades G.** Light-cured or chemically cured orthodontic adhesive resins? A selection based on the degree of cure, monomer leaching, and cytotoxicity. *Am J Orthod Dentofacial Orthop. 2005 Apr;127(4):413–9.*

41. **Goyal A, Hurkadle J, Magegowda S, Bhatia P.** Use of light-curing units in orthodontics. *J Inv Clin Dent. 2013 Aug;4(3):137–41.*
42. **Guzman UA, Jerrold L, Vig PS, Abdelkarim A.** Comparison of shear bond strength and adhesive remnant index between precoated and conventionally bonded orthodontic brackets. *Progress in orthodontics. 2013;14(1):39.*
43. **Hajrassie MKA, 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):384–90.*
44. **Hegarty DJ, Macfarlane TV.** In vivo bracket retention comparison of a resin-modified glass ionomer cement and a resin-based bracket adhesive system after a year. *Am J Orthod Dentofacial Orthop. 2002;121:496–501.*
45. **Henkin F de S, Macêdo É de OD de, Santos K da S, Schwarzbach M, Samuel SMW, Mundstock KS.** In vitro analysis of shear bond strength and adhesive remnant index of different metal brackets. *Dent Press J Orthod. 2016 Dec;21(6):67–73.*
46. **Hermsen RJ, Vrijhoef MMA.** Loss of enamel due to etching with phosphoric or maleic acid. *Dent Materials 1993;9:332-6.*

47. **Hobson RS, McCabe JF, Rugg-Gunn AJ.** The relationship between acid-etch patterns and bond survival in vivo. *Am J Orthod Dentofacial Orthop. 2002 May;121(5):502–9.*

48. **Hobson RS, Rugg-Gunn AJ, Booth TA.** Acid-etch patterns on the buccal surface of human permanent teeth. *Arc oral bio. 2002;47(5):407–412.*

49. **Ireland AJ, Knight H, CartSherriff M.** An in vivo investigation into bond failure rates with a new self-etching primer system. *Am J Orthod Dentofacial Orthop. 2003 Sep;124(3):323–6.*

50. **Ireland AJ, Sherriff M.** The effect of pumicing on the in vivo use of a resin modified glass poly (alkenoate) cement and a conventional no-mix composite for bonding orthodontic brackets. *J Orthod. 2002;29(3):217–220.*

51. **Jung M-H.** Survival analysis of brackets and tubes: *A twelve-month assessment*. *Angle Orthod. 2014 Nov;84(6):1034–40.*

52. **Kinch AP, Taylor H, Warltler R, Oliver RG, Newcombe RG.** A clinical trial comparing the failure rates of directly bonded brackets using etch times of 15 or 60 seconds. *Am J Orthod Dentofacial Orthop. 1988;94(6):476–483.*

53. **Knoll M, Gwinnett AJ, Wolff MS.** Shear strength of brackets bonded to anterior and posterior teeth. *Am J Orthod Dentofacial Orthop 1986; 89:476-479*

54. **Knox J, Husbh P, Jones ML, Middleton J.** The influence of bracket base design on the strength of bracket-cement interface. *J Orthod 2000; 27:249-254.*

55. **Knox J, Kralj B, Hubsch P, Middleton J, Jones ML.** An Evaluation of the Quality of Orthodontic Attachment Offered by Single- and Double-Mesh Bracket Bases Using the Finite Element Method of Stress Analysis. *Angle Orthod 2001;71:149–15.*

56. **Koupis NS, Eliades T, Athanasiou AE.** Clinical Evaluation of Bracket Bonding Using Two Different Polymerization Sources. *Angle Orthod. 2008 Sep;78(5):922–5.*

57. **Krishnaswamy NR, Sunitha C.** Light-emitting diode vs halogen light curing of orthodontic brackets: A 15-month clinical study of bond failures. *Am J Orthod Dentofacial Orthop. 2007 Oct;132(4):518–23.*

58. **Legler LR, Retief DH, Bradley EL, Denys FR, Sadowsky PL.** Effects of phosphoric acid concentration and etch duration on the shear bond strength of an orthodontic bonding resin to enamel: an in vitro study. *Am J Orthod Dentofacial Orthop. 1989;96(6):485–492.*

59. **Lill DJ, Lindauer SJ, Tüfekçi E, Shroff B.** Importance of pumice prophylaxis for bonding with self-etch primer. *Am J Orthod Dentofacial Orthop. 2008 Mar;133(3):423–6.*

60. **Linklater RA, Gordon PH.** Bond failure patterns in vivo. *Am J Orthod Dentofacial Orthop. 2003;123(5):534–539.*

61. **Lopez JI.** Retentive shear strengths of various bonding attachment bases. *Am J Orthod Dentofacial Orthop. 1980;77(6):669–678.*

62. **MacColl GA, Rossouw PE, Titley KC, Yamin C.** The relationship between bond strength and orthodontic bracket base. *Am J Orthod Dentofacial Orthop.* 1998;113:276–281.

63. **Maijer R, Smith DC.** Variables influencing the bond strength of metal orthodontic bracket bases. *Am J Orthod Dentofacial Orthop. 1981;79(1):20–34.*

64. **Marshall SD, Caspersen M, Hardinger RR, Franciscus RG, Aquilino SA, Southard TE.** Development of the curve of Spee. *Am J Orthod Dentofacial Orthop. 2008 Sep;134(3):344–52.*

65. **Mattick CR, Hobson RS.** A comparison of in-vivo acid etched buccal surfaces of different tooth types. *J Dent Res 1999;75:1158.*

66. **McCourt JW, Cooley RL, Barnwell S.** Bond strength of light cure fluoride-releasing base-liners as orthodontic bracket adhesives. *Am J Orthod Dentofacial Orthop 1991; 100:47-52.*

67. **Millett DT, Gordon PH.** A 5-year clinical review of bond failure with a no-mix adhesive (Right on®). *Eur J Orthod. 1994;16(3):203–211.*

68. **Millett DT, Hallagren A, Cattanach D, McFadzean R, Pattison, Robertson M, Love J.** A 5 year clinical review of bond failure with a light-cured resin adhesive. *Angle Orthod 1998;68(4): 351-356.*

69. **Millett DT, McCluskey L-A, McAuley F, Creanor SL, Newell J, Love J.** A comparative clinical trial of a compomer and a resin adhesive for orthodontic bonding. *Angle orthod. 2000;70(3):233–240.*

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

71. **Mitchell DL.** Bandless orthodontic bracket. *J Am Dent Assoc 1967; 74: 103-110.*

72. **Mohammed RE, Abass S, Abubakr NH, Mohammed ZMS.** Comparing orthodontic bond failures of light-cured composite resin with chemical-cured composite resin: A 12-month clinical trial. *Am J Orthod Dentofacial Orthop. 2016 Aug;150(2):290–4.*

73. **Moreira MR, Matos LG, de Souza ID, Brigante TAV, Queiroz MEC, Romano FL.** Bisphenol A release from orthodontic adhesives measured in vitro and in vivo with gas chromatography. *Am J Orthod Dentofacial Orthop. 2017 Mar;151(3):477–83.*

74. **Moresca R, Moro A, Dominguez GC, Vigorito JW.** Effects of nickel-titanium and stainless steel leveling wires on the position of mandibular incisors. *Dental Press J Orthod 2011 Sept-Oct;16(5):74-81*

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

76. **Newman GV.** Epoxy adhesives for orthodontic attachments: progress report. *Am J Orthod Dentofacial Orthop. 1965;51(12):901–912.*

77. **Newman SM, Murray GA, Yates JL.** Visible lights and visible light-activated composite resins. *J pros dent. 1983;50(1):31–35.*

78. **Niepraschk M, Rahiotis C, Bradley TG, Eliades T, Eliades G.** Effect of various curing lights on the degree of cure of orthodontic adhesives. *Am J Orthod Dentofacial Orthop. 2007 Sep;132(3):382–4.*

79. **O'brien KD, Watts DC, Read MJF.** Residual debris and bond strength—is there a relationship? *Am J Orthod Dentofacial Orthop. 1988;94(3):222–230.*

80. **Oonsombat C, Bishara SE, Ajlouni R.** The effect of blood contamination on the shear bond strength of orthodontic brackets with the use of a new self-etch primer. *Am J Orthod Dentofacial Orthop. 2003 May;123(5): 547–50.*

81. **Owens Jr SE, Miller BH.** A comparison of shear bond strengths of three visible light-cured orthodontic adhesives. *Angle Orthod. 2000;70(5):352–356.*

82. **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.*

83. **Pandis N, Eliades T.** A comparative in vivo assessment of the long-term failure rate of 2 self-etching primers. *Am J Orthod Dentofacial Orthop. 2005 Jul;128(1):96–8.*

84. **Pinto CM de S, Ferreira JTL, Matsumoto MAN, Borsatto MC, Silva RAB da, Romano FL.** Evaluation of different LED light-curing devices for bonding metallic orthodontic brackets. *Braz dent J. 2011;22(3):249–253.*

85. **Powers JM, Kim HB, Turner DS.** Orthodontic adhesives and bond strength testing. *Sem Orthod. Elsevier; 1997. p. 147–156.*

86. **Preoteasa CT, Ionescu E, Proteasa E.** Risks and complications associated with orthodontic treatment. In: Bourzgui F, editor. Orthodontics-Basic Aspects and Clinical Considerations. *Rijeka, Crotia: InTech; 2012. pp. 403–28.*

87. **Rai AK.** Evaluation of bracket failure rate in orthodontic patients bonded with and without primer. *The Saudi J Dent Res. 2015 Jan;6(1):48–53.*

88. **Retief DH, Dreyer CJ, Gavron G.** The direct bonding of orthodontic attachments to teeth by means of an epoxy resin adhesive. *Am J Orthod Dentofacial Orthop. 1970;58(1):21–40.*

89. **Reynolds IR.** A Review of Direct Orthodontic Bonding. *Br J Orthod. 1975 Jul;2(3):171–8.*

90. **Reynolds IR, von Fraunhofer JA**. Direct Bonding of Orthodontic Attachments to Teeth: The Relation of Adhesive Bond Strength to Gauze Mesh Size. *Br J Orthod. 1976Apr;3(2):91–5.*

91. **Rix D, Foley TF, Banting D, Mamandras A.** A comparison of fluoride release by resin-modified GIC and polyacid-modified composite resin.
Am J Orthod Dentofacial Orthop. 2001 Oct;120(4):398–405.

92. **Romano FL, Correr AB, Correr-Sobrinho L, Magnani MBB de A, Ruellas AC de O.** Clinical evaluation of the failure rates of metallic brackets. *J App Oral Sci. 2012;20(2):228–234.*

93. **Rossouw PE.** A historical overview of the development of the acid-etch bonding system in orthodontics. *Sem Orthod. 2010;16(1): 2–23.*

94. **Sadowsky PL, Retief DH.** A comparative study of some dental cements used in orthodontics.

95. **Sayinsu K, Isik F, Sezen S, Aydemir B.** Effect of blood and saliva contamination on bond strength of brackets bonded with a protective liquid polish and a light-cured adhesive. *Am J Orthod Dentofacial Orthop. 2007 Mar;131(3):391–4.*

96. **Sener Y, Uysal T, Basciftci FA, Demir A, Botsali MS**. Conventional and high-intensity halogen light effects on polymerization shrinkage of orthodontic adhesives. *Angle Orthod. 2006;76(4):677–681.*

97. **Sfondrini MF, Cacciafesta V, Scribante A, Boehme A, Jost-Brinkmann P-G.** 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. *Am J Orthod Dentofacial Orthop. 2006 Apr;129(4):541–6.*

98. **Sfondrini MF, Cacciafesta V, Scribante A, De Angelis M, Klersy C.** Effect of blood contamination on shear bond strength of brackets bonded with conventional and self-etching primers. *Am J Orthod Dentofacial Orthop. 2004 Mar;125(3):357–60.*

99. **Sfondrini MF, Cacciafesta V, Scribante A, Klersy C.** Plasma arc versus halogen light curing of orthodontic brackets: a 12-month clinical study of bond failures. *Am J Orthod Dentofacial Orthop. 2004 Mar;125(3):342–7.*

100. **Shammaa I, Ngan P, Kim H, Kao E, Glawdin M, Gunel E, BrownC.** Comparison of bracket debonding force between two conventional resin adhesives and a resin-reinforced glass ionomer cement: An invitro an in vivo study. *Angle Orthod 1999;69:463-469.*

101. **Sharma-Sayal SK, Rossouw PE, Kulkarni GV, Titley KC.** The influence of orthodontic bracket base design on shear bond strength. *Am J Orthod Dentofacial Orthop. 2003 Jul;124(1):74–82.*

102. **Sheen DH, Wang WN, Tarng TT.** Bond strength of younger and older permanent teeth with various etching times. Angle Orthod 1993;63:225-9.

103. **Shinchi MJ, Soma K, Nakabayashi N.** The effect of phosphoric acid concentration on resin tag length and bond strength of a photo-cured resin to acid-etched enamel. *Dent Materials. 2000;16(5):324–329.*

104. **Shinogaya T, Bakke M, Thomsen CE, Vilmann A, Sodeyama A, Matsumoto M.** Effects of ethnicity, gender and age on clenching force and load distribution. *Clin Oral Investigations. 2001;5(1):63-68.*

105. **Shyagali TR, Bhayya DP, Urs CB, Subramaniam S.** Finite element study on modification of bracket base and its effects on bond strength. *Dent Press J Orthod. 2015 Apr;20(2):76–82.*

106. **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 Res 1975; 9:373-387*

107. **Smith NR, Reynolds IR.** A Comparison of Three Bracket Bases: An In Vitro Study. *Br J Orthod. 1991 Feb;18(1):29–35.*

108. **Sorel O, El Alam R, Chagneau F, Cathelineau G.** Comparison of bond strength between simple foil mesh and laser-structured base retention brackets. *Am J Orthod Dentofacial Orthop. 2002 Sep;122(3):260–6.*

109. **Summers A, Kao E, Gilmore J, Gunel E, Ngan P.** Comparison of bond strength between a conventional resin adhesive and a resin-modified glass ionomer adhesive: An in vitro and in vivo study. *Am J Orthod Dentofacial Orthop. 2004 Aug;126(2):200–6.*

110. **Sunitha C, Kailasam V, Padmanabhan S, Chitharanjan AB.** Bisphenol A release from an orthodontic adhesive and its correlation with the degree of conversion on varying light-curing tip distances. *Am J Orthod Dentofacial Orthop*. 2011 Aug;140(2):239–44.

111. **Sunna S, Rock WP.** Clinical performance of orthodontic brackets and adhesive systems: a randomized clinical trial. *Br J Orthod 1998;25:283-7*

112. **Tamizharasi S, Senthil Kumar K.** Significance of curve of Spee: An orthodontic review. *J Pharm Bioallied Sci. 2012;4(6):323.*

113. **Tavas MA, Watts DC.** A Visible Light-activated Direct Bonding Material: An In Vitro Comparative Study. *Br J Orthod. 1984 Jan;11(1):33–7.*

114. **Thanos CE, Munholland T, Caputo AA.** Adhesion of mesh-base direct-bonding brackets. *Am J Orthod Dentofacial Orthop. 1979;75(4):421–430.*

115. **Thind BS, Stirrups DR, Hewage S.** Bond failure of gingivally offset mandibular premolar brackets: A randomized controlled clinical trial. *Am J Orthod Dentofacial Orthop. 2009 Jan;135(1):49–53.*

116. **Trimpeneers LM, Dermaut LR.** A clinical trial comparing the failure rates of two orthodontic bonding systems. *Am J Dentofac Orthop. 1996; 110:547-50*

117. **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;75(5):854–857.*

118. **Verma SK, Maheshwari S, Tariq M, Khan S.** The inadequacy of in-vitro orthodontic bond strength testing in clinical application. *Intl J Dent Sci Res. 2013 May;1(2):54–7.*

119. **Vicente A, Bravo LA, Romero M, Ortíz AJ, Canteras M.** Effects of 3 adhesion promoters on the shear bond strength of orthodontic brackets: An in-vitro study. *Am J Orthod Dentofacial Orthop. 2006 Mar;129(3):390–5.*

120. **Wang WN, Li CH, Chou TH, Wang DDH, Lin LH, Lin CT.** Bond strength of various bracket base designs. *Am J Orthod Dentofacial Orthop. 2004 Jan;125(1):65–70.*

121. **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.*

122. **Whittaker DK.** Structural variations in the surface zone of human tooth enamel observed by scanning electron microscopy. *Archives of oral biology. 1982;27(5):383–392.*

123. **Zachrisson BU.** A posttreatment evaluation of direct bonding in orthodontics. *Am J Orthod Dentofacial Orthop. 1977;71(2):173–189.*

124. **Zanarini M, Gracco A, Lattuca M, Marchionni S, Gatto MR, Bonetti GA.** Bracket base remnants after orthodontic debonding.

Angle Orthod. 2013 Sep;83(5):885–91.

125. **Zeppieri IL, Chung C-H, Mante FK.** Effect of saliva on shear bond strength of an orthodontic adhesive used with moisture-insensitive and self-etching primers. *Am J Orthod Dentofacial Orthop. 2003 Oct;124(4):414–9.*

126. **Zhu JJ, Tang AT, Matinlinna JP, Hägg U.** Acid etching of human enamel in clinical applications: A systematic review. *J Prost Dent. 2014;112(2):122–135.*

Annexure

ANNEXURE I

RAGAS DENTAL COLLEGE & HOSPITAL
(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai
2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA
Tele : (044) 24530002, 24530003 - 06. Principal (Dir) 24530001 Fax : (044) 24530009

TO WHOMSOEVER IT MAY CONCERN

Date: 18.12.2017
Place: Chennai

From
The Institutional Review Board,
Ragas Dental College and Hospital,
Uthandi,
Chennai – 600 119.

The dissertation topic titled **"AN IN- VIVO ASSESSMENT OF BRACKET FAILURE AND ADHESIVE REMNANT INDEX BETWEEN TWO DIFFERENT LIGHT CURE ADHESIVES WITH LIGHT EMITTING DIODE: A SPLIT MOUTH STUDY."** submitted by **Dr. CHARLES FINNY. M.,** has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

Dr. N.S. Azhagarasan M.D.S,
Member secretary,
Institution Ethics Board,
Ragas Dental College & Hospital
Uthandi, Chennai – 600 119.

RAGAS DENTAL COLLEGE Chennai

ANNEXURE II

URKUND

Urkund Analysis Result

Analysed Document:	Charles plag check 1.doc (D35008903)
Submitted:	1/25/2018 10:10:00 AM
Submitted By:	Charliefinn92@gmail.com
Significance:	2 %

Sources included in the report:

Nithin Final thesis.pdf (D34340389)
https://www.sciencedirect.com/science/article/pii/S0889540615011804
https://pocketdentistry.com/in-vitro-bond-strengths-and-clinical-failure-rates-of-metal-brackets-bonded-with-different-light-emitting-diode-units-and-curing-times/

Instances where selected sources appear:

8

ANNEXURE- III

CONSENT FORM

I ………………………………………………………... aged ………. years, residing at ………………………………………………… …………… ………… …………………………… ……………………………………… ……………..,
do hereby solemnly and state as follows.

I……….…………………………………… am the parent/guardian of the deponent herein. I am aware of the facts stated below do hereby solemnly and state as follows. (FOR PATIENTS BELOW 18 YEARS OF AGE ONLY)

Dr ……………………………….. informed and explained about the pros and cons of the treatment and his study protocol in the ……………………………. language known to me.

- The importance of the present treatment in relation to the overall health and development has been explained
- Assurance was provided that the same standard of therapeutic quality will be administered should I/he/she fail to accept participation in the study protocol.
- I assure that I/he/she shall come for each and every sitting without fail.
- I authorize the doctor to proceed with further treatment according to his study protocol.
- I have given voluntary consent to undergo treatment without any individual pressure or duress.
- I am also aware that I am free to withdraw the consent given at any time during the study in writing

----

Signature of the parent/guardian/patient