A COMPARATIVE IN VIVO ASSESSMENT OF BRACKET BOND FAILURE RATE WITH TWO MOISTURE INSENSITIVE PRIMERS

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"A COMPARATIVE IN VIVO ASSESSMENT OF BRACKET BOND FAILURE RATE WITH TWO MOISTURE INSENSITIVE PRIMERS"** is a bonafide and genuine research work carried out by me under the guidance of **Dr.KAVITHA S IYER, M.D.S.,** Department of Orthodontics and Dentofacial Orthopaedics, Ragas Dental College and Hospital, Chennai.

Date: 10/02/2020

Place: **Chennai**

Dr.R.L.MUTHU PRADEEP
Post Graduate Student
Department of Orthodontics and
Dentofacial Orthopaedics,
Ragas Dental College and Hospital,
Chennai.

CERTIFICATE

This is to certify that this dissertation titled **"A COMPARATIVE IN VIVO ASSESSMENT OF BRACKET BOND FAILURE RATE WITH TWO MOISTURE INSENSITIVE PRIMERS"** is a bonafide record work done by **Dr.R.L.MUTHU PRADEEP** under my guidance during his post graduate study period 2017-2020.

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfilment 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.

Guided by:

10/2/2020

Dr. Kavitha S Iyer , M.D.S.,
Reader,
Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai.

Head of the Department

10/2/2020

Prof. (Dr.) N.R. Krishnaswamy M.D.S.,
M. Ortho R.C.S. (Edin) Dip N.B. (Ortho)
Diplomate-Indian Board of Orthodontics,
Professor &Head, 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, MDS,
Principal,
Ragas Dental College and Hospital,
Chennai

RAGAS DENTAL COLLEGE Chennai

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

PLAGIARISM CERTIFICATE

This is to certify the dissertation titled **"A COMPARATIVE IN VIVO ASSESSMENT OF BRACKET BOND FAILURE RATE WITH TWO MOISTURE INSENSITIVE PRIMERS "**of the candidate **Dr.R.L.MUTHU PRADEEP** for the award of **MASTER OF DENTAL SURGERY in BRANCH V - ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS.**

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Date: 10/02/2020

Place : Chennai

Dr.R.L.MUTHU PRADEEP
Post Graduate Student,
Department of Orthodontics and
Dentofacial Orthopaedics,
Ragas Dental College and Hospital,
Chennai.

Dr. KAVITHA S IYER , M.D.S.,
Reader and Guide,
Department of Orthodontics,
Ragas Dental College and Hospital,
Chennai.

10/2/2020

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I'm blessed with everything I need.
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Introduction

INTRODUCTION

There was a paradigm shift in the field of orthodontics when banding was replaced by bonding. Bonding of brackets as such is a crucial and technique sensitive procedure that determines the outcome of the orthodontic treatment.[75]The introduction of acid etching technique by **Bunocore** in 1995 paved a path of possibility in direct bonding of orthodontic brackets on teeth, a technique that has now become an integral part of orthodontics. [12]

This direct bonding technique is beneficial when compared to the earlier method of banding for both the patient as well as the practitioner. Patient's benefits include decreased enamel decalcification, less irritation of gingival tissue and better esthetics. Less chair side time and patient's improved oral hygiene are the benefits from practitioner's view.[106]

Reynolds stated that shear bond strength values for adequate bonding should be between 5.9 to 7.8 Megapascal (MPa).[75] There are various factors that can affect the bond strength during bonding procedure like prophylaxis, isolation, etchant (type, concentration, duration), primers, adhesives, bracket base (dimension and mesh design) and curing (type, duration,). Of these, moisture contamination is cited as the most common cause for bond failure.[104,13,107] The detrimental effect of moisture on orthodontic bonding may relate to water adsorption and exertion of a plasticizing effect in the polymer network. Moreover salivary contamination causes plugging of porosities

caused by acid etching and a reduction in surface energy thus increasing the bond failure rates. Since frequent bracket bond failure can delay the treatment time and affect the treatment outcome [2], bonding is directly related to the treatment duration and quality of the treatment. So this should be considered to a greater extent. For instance, bonding with the conventional hydrophobic system becomes challenging in cases of impacted tooth, second molar buccal tubes and partially erupted tooth which are more prone to contamination. [89, 13,107]

These requirements led to the advent of resin modified GIC which are hydrophilic which has combination of GIC and composite and holds fluoride releasing property. But the drawback of this cement is that, it has reduced bond strength when compared to the conventional light cure composite adhesive used. **Hegarty et al** compared the bracket retention between RMGIC and resin based adhesive which showed significantly higher bracket failure rate with RMGIC when compared with resin based adhesive system. The highest failure rate was observed for the RMGIC on brackets particularly with occlusal loads.[29]

To overcome these failures, in 1998 many hydrophilic primers were introduced by different manufacturers incorporating hydrophilic properties into the conventional primers that can aid in better adherence of bracket to the wet tooth surface which were termed as moisture insensitive primers.[23]

Moisture-insensitive primer (MIP) was developed based on dentin-bonding agents, which have hydrophilic components, such as hydroxyethyl methacrylate (HEMA) and maleic acid dissolved in acetone, that are efficient even in the presence of moisture. Self-etching primers were also proved to be effective in wet surface and they differ from MIP's in a way that they themselves etch the surface, and the calcium ions were not removed by rinsing instead they form a bond with the phosphate group when polymerized.

This clinical study was designed as a double blinded prospective split mouth study with randomized selection of patients.

The purpose of the present study was to perform a clinical assessment of failure rate of brackets bonded with Bracepaste adhesive over two different moisture insensitive primers, Transbond MIP and Bracepaste MTP. The number of brackets failed between dental arches, regions, teeth, and adhesive remnant index (ARI) were also analyzed.

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Review of Literature

REVIEW OF LITERATURE

George V Newman in AJO 1965[63] reported the usage of epoxy adhesive as an adjunct to the metal banding around teeth for orthodontic treatment purpose which is beneficial in better esthetics, decreased decalcification and decreased cost.

ETCHING

Abbas A. Hormati, et al JADA 1980[36] investigated the shear strength of the composite resin bonded to moisture contaminated and mechanically disturbed surfaces of etched enamel and the result of the study showed that etchant should be dabbed rather than rubbed and also if etched surface is contaminated with saliva then the tooth should be re etched rinsed and re dried and bonding has to be carried out.

Sheen and Wang et al AO 1991[101] investigated the influence of acid etching with 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 at two different duration. Thus the shorter curing time was considered the better. But 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[24] conducted an ex vivo study to assess the optimal etching time and acid for acid etching. The etch patterns of 37% phosphoric acid and 2.5% 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 2.5% nitric acid at all durations. 37% phosphoric acid with 30 seconds of duration was considered optimal.

Hobson et al AJO 2002[35] 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.

ADHESIVES

David J. Hegarty et al AJODO 2002[29] performed an in vivo study comparing the clinical performance of a resin modified glass ionomer adhesive with a no mix, resin based adhesive over a 12 month period. Compared with the resinbased adhesive, the RMGIC bracketed teeth showed improved clinical performance, no enamel surface loss, less enamel

demineralization, and faster adhesive removal. However, RMGIC had a 2.6 times greater bracket failure rate than the resin based product.

BRACEPASTE ADHESIVE

Krishnaswamy et al in orthodontic products 2019[42] compared Transbond xt and bracepaste and the results showed that both light cure composite resin adhesive materials displayed adequate and optimal bond strength suitable for application in orthodontic bonding procedures.

CURING SYSTEM

Krishnaswamy et al AJO 2007[41] evaluated the clinical performance of brackets cured with two light curing units: conventional halogen unit and LED. Thirty patients treated with fixed appliance were included. Results showed that there was no statistically significant differences were found in total bond failure rates in brackets cured with halogen lights and those cured with LED. Therefore, LED can be considered as an advantageous alternative to conventional light curing.

Carine Maccarini Dall'Igna et al EJO 2011[18] 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 in terms of curing time. 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

Abdullah Alper oz et al AJO 2016[66], compared the clinical failure rates and the in-vitro bond strengths of metal brackets bonded with different light emitting diode(LED) devices and curing times. Elipar and VALO LED units were usedwith curing times of 10 seconds and 3 seconds respectively. Clinical failure rates were 2.90% for the Elipar and 3.16% for the VALO units. Both the LED units had no statistically significant difference in bracket failure rates and in vitro bond strengths.

Fleming et ol AJO 2016[20], reviewed randomized controlled trials and controlled clinical to assess the risks of attachment failure and bonding time in orthodontic patients in whom brackets were cured with halogen lights, LEDs, or plasma arc system. Patients with full arc, fixed or bonded orthodontic appliances with the follow up of minimum six months were included. There was no statistically significant difference in bond failure risk between the halogen lights, LEDs or plasma arc system. Thus, no evidence to support the use of one light cure type over another.

CURING TIME

Wei Nan Wang in AJO 1992[102]evaluated the effectiveness of a visible lightsource in curing the resin under a solid metal bracket, compared the tensile bond strength atdifferent exposures, and analyzed the distribution between light-cured resin with various light exposure times and self-cured resin. The bond strength of Transbond with 60 and 40 seconds of light exposure was greater than both the bond strength of Transbond with 20 seconds of light exposure and the strength of the self-cured resin of Concise, with statistical significance.

Justin D. Ward in AO 2015[103] evaluated the clinical performance of brackets cured with a high-intensity, lightemitting diode (LED) with a shorter curing time in 34 patients using a split mouth design and showed that the high intensity LED light used with a shorter curing time may be considered an advantage due to the reduced chair time.

BRACKET DESIGN

Thanos et al AJO 1979[96] 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.

Smith and Reynolds et al BJO 1991 [90] 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.

Sorel et al AJO 2002[91] 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.

Wang et al AO 2004[100] 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.

BRACKET PRESCRIPTION

Bopelo Moesi et alin EJO 2013[59] investigated the subjective outcome of pre-adjusted edgewise treatment as judged by professionals in premolar extractions using either a Roth or a MBT prescription and found that bracket prescription had no effect on the subjective aesthetics.

Mohit Mittal et alin AO 2015[57] investigated whether there are any significant differences in the final inclination of the upper and lower anterior teeth of patients treated with a Roth or an MBT bracket prescription and the result of the study showed that the bracket prescriptions did not lead to any real clinically detectable differences in the final inclination of teeth.

BRACKET FAILURES

Nikolaos Pandisa and Theodore Eliadesb et al AJO 2005[68]is a comparative study to assess the bracket failure rate bonded with 2 self etching adhesives after 14 months of treatment in 22 patients and found that more failures were found in the mandibular arch and no difference in failure rates between anterior and posterior region.

Fábio lourenço Romano et al JAOS 2012[77]conducted an *in vivo* study with a split mouth design over a 6 months period that evaluated the bonding of metallic orthodontic brackets with different adhesive systems

Orthodontic Concise, conventional Transbond XT, Transbond XT without primer, and Transbond XT associated with Transbond Plus Self-

Etching Primer (TPSEP) . The largest number of bracket failures occurred with Orthodontic Concise and Transbond XT without primer systems and few bracket failures occurred with conventional Transbond XT and Transbond XT+TPSEP. More bracket failures were observed in the posterior region compared with the anterior region.

PRIMERS

Ambesh Kumar Rai et al 2014[72]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.

Farhan Bazargani et al in EJO 2015[6] conducted a randomized clinical trial to evaluate the incidence of failure of brackets bonded with and without primer in Fifty consecutive patients requiring bimaxillary orthodontic treatment with fixed appliances, results of the study showed Failure rate without primer was 5.5 per cent and with primer 3.1 per cent and Younger

ages (10– 13 years), boys, and mandible were significantly associated with higher failure rates

CONTAMINATION

Korkmaz Sayinsu et al AJO 2007[79], investigated whether the bond strength of a light cured system (Transbond XT, 3M UNITEK, Puchheim, Germany) used with a liquid polish (Biscover, Viso, Schaumburg, III) is affected by contamination with blood or saliva. One hundred twenty permanent premolars were divided into 6 groups of 20, and enamel surface conditions were studied: dry, blood contaminated and saliva contaminated. Transbond XT light cure bonding system was used. Shear forces were applied to the samples with a universal testing machine and bond strength were measured in megapascals. Results showed that the protective polish (Biscover) layer did not affect bond strength.

Lorenz Brauchli et al AJO 2010[11]**,** evaluated the influence of contamination on bond strength and to investigate possible decontamination procedures. Four bonding systems were evaluated. With the exception of Transbond SEP with saliva contamination, all other composite primers with contamination showed greatly reduced shear forces. Control and decontaminated group showed shear forces of 20MPa. Hence, decontamination with water and air, and also repriming is sufficient after contamination with blood and saliva.

ANTI SIALOGOGUES

Sirisha Ponduri et al in AJO 2007[69]investigatedthe effect of atropine sulphate premedication on orthodontic bond failures and also evaluated the attitudes of patients and parents toward its use in orthodontics and found out that although the use of a premedication to induce hypo-salivation before orthodontic bonding appears to be an acceptable procedure to most patients and their parents, they did not find a statistically significant effect on the observed bond failure rates.

Mette A.R. Kuijpers et al et al in the Journal of American Dental Association 2010[43] conducted a systematic review to assess whether there is a reduction of salivation when the antimuscarinic/anticholinergic agents known as antisialogogues are used, whether the use of antisialogogues reduces the chair time needed for dental procedures, and whether the use of antisialogogues reduces the failure rate of bonded orthodontic brackets , which included twenty-six studies which met the inclusion criteria and twenty-five of which were related to the effect of antisialogogues on salivation, and one study to bond failure and found that there is evidence that antisialogogues work, inconclusive evidence that they reduce bond failure, and no evidence that they reduce chair time for dental procedures and concluded that the use of antisialogogues for dental procedures in general is questionable.

Tom Roelofsa et al in AO 2017[76] investigated the causes of bonding failures of orthodontic brackets and tubes and the effect of premedicating for saliva reduction and concluded that the premedication did not lead to fewer bracket failures but the roles of the dental assistant and patient in preventing failures was relevant and also significantly higher failure rate for orthodontic appliances was found in the posterior regions.

MOISTURE INSENSITIVE PRIMERS

Littlewood et al AJO 2000[50] investigated the in vitro bond strength of brackets bonded using a new hydrophilic primer, designed to be insensitive to moisture, and compares it with a conventional primer.The median bond strength with the hydrophilic primer (6·43 MPa) was significantly lower than the conventional primer

Ross S. Hobson et al AJO 2001[32] evaluated the bond strength of Transbond MIP under dry, moist, and blood contaminated conditions. Three groups of teeth were bonded with Tranbond MIP after acid etching; the enamel surface were either dry, moist, or contaminated with human blood. Results showed that dry bonding had higher bond strength than moist or blood contaminated bonds.Transbond MIP is a suitable adhesive for bonding in conditions of poor moisture control or blood contamination.

Webster et al in AJO 2001[104] compared the shear bond strength of Transbond XT with MIP and the result of the study showed that If the

contamination occurs after the primer had been placed and cured then a simple drying and reapplication of primer may be all that is necessary to obtain adequate bond strengths and the hydrophilic primers also showed improved bond strengths with reapplication of primer after saliva contamination

Shane Schaneveldt et al AJO 2002[81]an in vitro study to evaluate the effectiveness of two MIP's (reliance and 3m unitek) by comparing it with a control (Transbond XT) The groups with when saliva contamination was before application of the primer then the failures were at the enamel/adhesive interface, suggesting that complete penetration of primer was prevented, and when the saliva contamination after the first application of primer showed more frequent failures at the adhesive/bracket interface.

T.Eliades et al EJO 2002[19] investigated the reactivity with water of a Transbond MIP in conjunction with unite no mix orthodontic adhesive and smartbond moisture insensitive adhesive and these brackets were debonded with a shear force and are subjected to fractographic analysis which showed that unite + Transbond MIP showed more adhesive fractures whereas smartbond showed high frequency of cohesive failures.

Zeppieri et al AJO 2003[107]investigated the effect of saliva contamination on the shear bond strength of an orthodontic adhesive used with Transbond Moisture-Insensitive Primer and Transbond Plus Self-Etching Primer and with Hydrophobic Transbond XT primer as a control. Result of

which showed that the control group had the highest mean shear bond strength followed by the MIP group in a dry field, saliva contamination decreases the bond strength of Transbond MIP but does not affect Transbond SEP . So it can be clinically acceptable to use Transbond XT adhesive with Transbond MIP and Transbond SEP primer in wet and dry field

Vittorio Cacciafesta et al AJO 2003[13] assessed the effect of water and saliva contamination on the shear bond strength and bond failure site of 3 different orthodontic primers (Transbond XT, Transbond Moisture Insensitive Primer, and Transbond Plus Self Etching Primer) used with a light-cured composite resin (Transbond XT). Each primer–adhesive combination was tested under 7 different enamel surface conditions and the study showed that noncontaminated enamel surfaces had the highest bond strengths for conventional, hydrophilic, and self-etching primers and the self-etching primer was the least influenced by water and saliva contamination,

Vittorio Cacciafesta et al AJODO 2004[82], assessed the effect of blood contamination on the shear bond strength and failure site of 2 orthodontic primers (Transbond XT and 3M), when used with adhesive-precoated brackets (APC II brackets; 3M). Each primer adhesive combination was tested under different enamel surface condition: dry, blood contaminated before priming, and after priming. Results showed that non contaminated enamel surface had highest bond strength for both conventional

and hydrophilic primer. Whereas, blood contaminated enamel had lower bond strength values.

Rangaswamy Rajagopal, **et al AO 2004** [73]compared shear bond strength , debonding charecteristics of conventional , moisture insensitive and self etching primer and the result showed that Both MIP and self-etch primer showed adequate bond strength superior to that of conventional primer in case of moisture contamination. All primers showed typical debonding characteristics of separation at the bracket-adhesive interface or within the adhesive itself, with the exception of the conventional primer used with moisture-contaminated enamel where the failure was at tooth enamel interface.

Ram Kumar Grandhi et al AJO 2009[26]evaluated the shear bond strength of stainless steel bracket bonded with moisture insensitive primer (TRANSBOND XT) on a wet and dry etched surface of a 32 extracted bovine teeth and effectiveness of these primers with chemically activated and light activated resins. The result of the study showed that MIP and TRANSBOND XT combination produced comparable bond strength and also MIP be used only with light activated composite resin

Chandresh Shukla et al in JIOS 2012[85] compared the mean shear bond strength of four orthodontic bonding materials. Self-cure composite adhesive , light cure composite adhesive , light cure with self-etching primer and light cure with moisture-insensitive primer and the result of the study

showed that Light cure composite adhesive had the highest shear bond strength followed by light cure SEP followed by light cure MIP and the lowest was self-cure composite adhesive.

A. Mavropoulos et al jo 2013[54] compared the clinical performance of two moisture-resistantorthodontic adhesive systems: a chemically-cured composite resin Unite in conjunction with Transbond MIP and a fluoride-releasing light-cured compomer ,Assure. The result of the study showed Assure exhibited a significantly higher bond failure rate than Unite and Transbond MIP

Chandresh Shuklaet al JOS 2014[84] compared the mean shear bond strength (SBS) of moisture insensitive primer (MIP) used for orthodontic bonding in the presence and absence of saliva. He evaluated 60 human noncarious maxillary premolars using light cure Transbond XT and Transbond MIP in the presence and absence of saliva and concluded that Moisture insensitive primer is effective in the presence/absence of moisture and has SBS value of more than 7.8 Mpa as stated by Reynolds and this material is suitable for clinical use.

Anand et al in AJDR 2014[3] investigated the effectiveness of two hydrophilic primers(Transbond MIP,opal prismo) with respect to conventional hydrophobic primer(Transbond XT) with a common adhesive Transbond XT ,samples were divided into multiple groups and Shear forces were applied to

the samples with a universal testing machine and found that The mean SBS produced by Transbond MIP was higher than Opal Primo but the overall bond strength of these hydrophilic primer was lower when compared to Transbond XT, it as shown that Transbond XT adhesive with Transbond MIP or Opal Primo have clinically acceptable bond strength in wet fields.

Arunima Goswami et al JOS 2014[25] compared in vitro shear bond strength (SBS) and debonding characteristic of moisture-insensitive primer (MIP) (Transbond MIP) and self-etching primer (SEP) in combination with a color changing adhesive system (Transbond Plus Color Change) under both dry and contaminated condition. Extracted sample teeth were randomly divided into multiple groups in different enamel condition and the result showed that Moisture contamination did not affect the SBS and adhesive remaining on tooth for both MIP and SEP.

Kavitha Odathurai Marusamy in JSOM 2015[52] compared the shear bond strength of two commercially available light cured orthodontic bonding materials, RMGIC and composite resin with moisture-insensitive primer (MIP) and self-etching primer (SEP) and the result showed that composite with SEP provides the highest mean shear strength of up to 16.66 MPa followed by the composite with MIP with a bond strength of 14.30 MPa.

Jacob John et al APOS Trends in orthodontics 2016 [38]an invitro study to evaluate the shear bond strength of brackets bonded with self-etching

primer and moisture insensitive primer (MIP) and compare it with the conventional adhesive system on a wet and dry field on a 90 extracted human teeth showed that under dry condition conventional primer is the material of choice and under wet condition MIP showed high bond strength and it can be the material of choice

Girish Kumar et al in IJOR 2018[45] compared the shear bond strength of orthodontic brackets bonded with a MIP against a conventional primer contaminated with saliva with a sample of 60 extracted maxillary premolars which showed that Under dry condition, the shear bond strength of conventional primer (TRANSBOND XT) was significantly increased when compared to MIP. Under wet conditions MIP (TRANSBOND MIP) showed the highest shear bond strength and hence can be considered as a material of choice in wet conditions.

AmnaTahir et al PODJ 2018[95], compared the mean shear bond strength of orthodontic brackets cured with or without the prior application of primer resins. Thirty groups were cured with the application of moisture insensitive primer resin (group MP); and another thirty groups with conventional primer resins (group P). Results showed there was a higher bond strength values in MP group, but no statistically significant difference between the shear bond strength in both the groups.

BRACKET FAILURES

Naif Almosa et al in Pak J Med Sci 2018[2] conducted a systematic review on the incidence of orthodontic brackets detachment during orthodontic treatment. The numbers of brackets examined in the studies ranged between 361 and 3336 and the incidence of brackets detachment ranged from 0.6 to 28.3%.

ADHESIVE REMNANT INDEX

Artun and Bergland AJO 1984[4], 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[10]**,** 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.

REGION AND TEETH

Aneel Bherwani et al AO 2008[8] determined the bond failure pattern and time to first bond failure at an orthodontic clinic. Overall bracket survival rates were estimated using Kaplan-Meier test. Results showed that total percentage of bond failure was 17.87%. Mean survival time for the sample was 235 days. Significantly higher failure rates were observed in posterior teeth, class II division 2 malocclusion. No difference were observed between dental arches or gender.

H R Sukhia et al PODJ 2011[92] investigated the prevalence of orthodontic bracket breakage and de-bonding amongst the orthodontic patients. Patients were bonded with 3M Transbond XT light cure orthodontic syringe adhesive system. Results of the study showed more mandibular dentition bracket debonding, also lower buccal segment had a higher incidence of bracket breakage. Teenagers had more bracket breakage than adults.

Ahmad Hasan et al JBUMDC 2017[27] analysed the frequency of bracket failure in orthodontic patients with normal overbite and deepbite. Sample consisted of 100 patients, of which 76% patients with deepbite and 10% with normal overbite showed bracket bond failure. Females showed higher incidence and most common location was buccal segment in maxillary arch. Most frequent tooth that had bracket failure was second premolar.

Omer hatipoglu et al JOS 2019[28] made a systematic review and meta-analysis of studies to investigate the effects of positional factors on the bonding failure of brackets. Result of the study showed that Clinicians should be more careful when operating in the mandibular region and posterior segment. However, they showed no difference between the left and right arches.

Material and Methods

MATERIALS AND METHODS

MATERIALS

- 37% Ortho Phosphoric Acid (D-tech) was used for etching
- Bracepaste MTP (American Orthodontics, Sheboygan, WI USA) **(figure 2)**
- Transbond MIP (3M Unitek, Monrovia, CA, USA) **(figure 1)**
- Bracepaste adhesive **(figure 3)**
- Fixed appliances Roth prescription 0.022 X 0.028 bracket system
- (American Orthodontics, Sheboygan, WI USA)
- Light Curing Unit (3M S10 ELIPAR) (3M Unitek, Monrovia, CA, USA)

WIRE SEQUENCE

Leveling and alignment was started with 0.014 and progressed with 0.016, 6×22 and 18×25 nickel titanium wires.

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

EXCLUSION CRITERIA:

- Patients with visible enamel defects or hypoplastic enamel such as fluorosis.
- Patients 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, hypodontia and supernumerary teeth.
- Teeth which display severe attrition.
- Patients with severe deep bite, cross bite or scissor bite.

METHODOLOGY

This prospective in vivo study was conducted at the department of orthodontics and dentofacial orthopedics, Ragas Dental College, Chennai, India and approved by the Institutional Review board.

The study was designed as a split mouth study. A total of 22 patients were randomly selected before the end of June 2019 and 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, 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 materials were 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. The adhesive syringes were also concealed with paper.

A single operator performed the clinical procedure to avoid inter-operator variability. Bonding was done from right second premolar to left second premolar in both arches. The molars were banded.

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 were isolated using cheek retractors, tongue guard and cotton rolls. The teeth to be bonded were acid etched using 37% phosphoric acid (D-tech) for 30 seconds. After thorough washing, the teeth were completely air dried. A frosty appearance of enamel was noticeably seen evenly on the tooth surface.

Participating patient's dentition was divided into four quadrants to carryout split mouth design.The quadrants were randomly switched opposite to each other with different combinations in all patients.

The two brands of primers used in the study were Transbond MIP and Bracepaste MTP **(Figure 1,2).**

After adequate isolation, primers for particular quadrants were segregated. Transbond MIP was applied using a micro brush in one quadrant and light cured using a 3M Elipar light cure unit for 10 seconds. In the opposing quadrant, the primer Bracepaste MTP was applied and light cured with the same light cure unit for the same time interval.

The Bracepaste adhesive was kept constant, which were applied over the brackets (Roth prescription, 0.022 x 0.028 inch slot, Mini Master Series, AMERICAN ORTHODONTICS) and fixed at appropriate positions on the teeth.

The excessive adhesive materials were removed using a straight probe and the brackets were light cured using 3M S10 Elipar light cure unit for 10 seconds gingival and occlusal or incisal aspects of the bracket. Initial arch wire was placed 10 mins after bonding the bracket.

The participants were reviewed every 3-4 week time interval to check for failure of any brackets, the site, frequency and duration since bonding were tabulated.

Only the first failure of brackets was 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 [10].

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.

Statistical analysis was performed to calculate the frequency of bracket and chi square test was done to assess failures between the arches and specific dentition to understand the efficiency of the two materials used.

Results

RESULTS

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 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 arch, teeth and region 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 primer materials included in the study displayed a statistical significance.

Estimated sample size of our study was 20 but we ended up having 32 patients from which we have taken only 22 patients into consideration, since only those patients underwent full mouth bonding which is considered ideal for a split mouth design. Reasons for excluding 10 patients were that 2 patients failed to get back after upper arch bonding and in the remaining 8 patients, we were managed to bond only the lower arch. Only 22 patients were considered, since comparison was done between the arches. As individual tooth count of 440 teeth samples were included in the study.

In short this study has 22 patients, 440 teeth which were evaluated to assess the bond failure rate between two moisture insensitive primers in

various parameters like arches, individual teeth, region and adhesive remnant index (ARI)

1. COMPARISON BETWEEN ADHESIVE MATERIALS

In this study, Bracepaste adhesive resin was kept constant in both the groups. Two moisture insensitive primers compared were Bracepaste MTP and Transbond MIP. These primers were distributed uniformly between arches in a split mouth design.

A total number of 440 teeth were bonded in 22 patients; quadrants were allocated for primers in a sequential pattern. 220 teeth were bonded with Bracepaste MTP and 220 teeth were bonded with Transbond MIP. During the study period, 16 brackets were failed in Bracepaste MTP group and 9 brackets were failed in Transbond MIP group **(TABLE 1,GRAPH 1),** which showed Bracepaste MTP exhibited higher failure rates compared with Transbond MIP which were statistically insignificant (p - 0.160).

Materials were also compared between multiple variables which include arches, teeth, region and based on adhesive remnant index.

2. COMPARISON BETWEEN ARCHES

A. Comparison irrespective of primers

Out of 440 teeth sample, 220 were maxillary teeth and 220 were mandibular teeth. On comparing the bracket bond failure rates between maxilla and mandible irrespective of the material used, 6 brackets were failed

in the maxillary arch and 19 brackets were failed in the mandibular arch. The percentage of failures in the maxillary arch was 2.72% and for the mandible it was 8.63%. These values concludes that the mandibular arch showed higher failure rates which was statistically significant (p-0.007*). Success percentage of maxilla was relatively higher (88.18%) when compared to the mandibular arch (82.27%) **(TABLE 2.1, GRAPH 2.1).**

B. <u>Comparison between primers</u>

When assigning primer materials between arches, numbers were equally distributed in every individual patient between contra lateral quadrants.

Bracepaste MTP was distributed among 220 teeth, of which 110 teeth were from maxillary arch and 110 teeth were from mandibular arch. On evaluation, Bracepaste MTP showed 5 failures in maxillary arch (1.8%) and 11 failures in mandibular arch (10%). Difference for failure rates of Bracepaste MTP among arches were statistically insignificant (p-0.063). This showed that failure occurrence in Bracepaste MTP group did not differ much between arches. **(Table 2.2, Graph 2.2)**.

Transbond MIP was also distributed among 220 teeth, of which 110 teeth were from maxillary arch and 110 teeth were from mandibular arch. On evaluation, Transbond MIP showed 1 failure in maxillary arch (0.9%) and 8 failures in mandibular arch (7.2%). Difference for failure rates of Transbond

MIP among arches were statistically significant (p-0.016*). This shows that high failure rates for Transbond MIP were observed only in mandibular arch **(Table 2.2, Graph 2.2).**

So Bracepaste MTP showed relatively higher failure in both the arches whereas Transbond MIP showed high failure rate only in the mandibular arch.

3. COMPARISON BETWEEN TEETH

From 440 teeth samples, each type of teeth (central incisor, lateral incisor, canine, 1stpremolar, 2ndpremolar) hold 88 numbers which were equally distributed.

A. Comparison irrespective of primers

Individual teeth were compared and analyzed for bond failures. When compared irrespective of materials and arches, it showed highest bond failure rate in 2nd premolars (11 teeth) followed by central incisors (5 teeth), lateral incisors (4 teeth), 1st premolars (3 teeth) and canines (2 teeth). So the failure percentage was highest for 2nd premolars (12.5%) followed by central incisors (5.6%). In general comparison, canines showed the least bond failure rate and 2nd premolars showed the highest bond failure rates. Success rate was highest for the canines (97.7%) and least for the 2nd premolars(87.5%) **(TABLE 3.1, GRAPH 3.1).**

B. Comparison between primers

Individual teeth bond failure rates were compared with respect to the primers used. In central incisors, Bracepaste MTP showed 4 failures and Transbond MIP showed 1 failure, among lateral incisors, failures were equally distributed by 2 in each group, whereas in canine, Bracepaste MTP showed 2 failures and Transbond MIP did not show any failures. Whereas in 1st premolars Bracepaste MTP showed 2 failures and Transbond MIP showed 1 failure and in 2nd premolars Bracepaste MTP showed 6 failures, Transbond MIP showed 5 failures. So the failure percentage was higher in 2nd premolar in both the primer groups. On overall comparison between teeth it did not show much significant difference between the groups (p-0.764%) **(TABLE 3.2,GRAPH 3.2).**

C. 2nd Premolar comparison

Since 2nd premolars showed highest number of failures, they were separately evaluated with respect to the primers used between the arches. Bracepaste MTP group showed equal number of bond failures in both the arches (13.6%) which were statistically insignificant **(p-1.00).** Whereas, Transbond MIP showed 2nd premolar failure only in the mandibular arch (22.2%) and no failure was observed in the maxillary arch which was statistically significant (p-0.02*) **(TABLE 3.3, GRAPH 3.3).**

4. COMPARISON BETWEEN REGION

Out of 440 teeth, 264 were anterior teeth and 176 were posterior teeth. Among these, Bracepaste MTP was used for bonding in 132 anterior teeth and 88 posterior teeth. Transbond MIP was used for bonding in 132 anterior teeth and 88 posterior teeth.

A. Comparison irrespective of primers

Overall comparison between anterior and posterior region irrespective of primer materials showed that higher bond failure was seen in mandibular posteriors (12.5%) followed by mandibular anteriors (5.3%). Then maxillary posteriors (4.5%) and maxillary anteriors which showed least amount of bond failures (2.3%) **(TABLE 4.1, 4.2).**

On taking primers into consideration, two comparisons were made. Firstly, both the primers were compared with anterior and posterior region irrespective of arches **(Table 4.3) (Graph 4.1)**; secondly, comparison were made between primers, region and arches **(Table 4.4&4.5) (Graph4&2,4.3).**

B. Comparison of primers with the region irrespective of the arches

Total of 220 teeth were bonded using Transbond MIP, of which 132 teeth were from anterior region and 88 teeth were from posterior region. Out of these, 3 brackets were failed from anterior region (2%) and 6 brackets were

failed from posterior region (6.8%). On comparing the failure rates, they showed no statistical significant difference (p-0.161) **(Table-4.3) (Graph 4.1).**

Similarly, 220 teeth were bonded with Bracepaste MTP, of which 132 teeth were from anterior region and 88 teeth were from posterior region. Out of these, 7 brackets were failed from anterior region (5.3%) and 9 brackets were failed from posterior region (10.2%). On comparing these, they showed no statistically significant difference (p-0.168) **(Table-4.3) (Graph 4.1).**

C. Comparison of primers with the region and arches

First, both the primers were compared between the anterior region of maxillary and mandibular arches, and then they were compared with posterior region of both the arches.

Anterior region:

Total of 132 anterior teeth were bonded with Transbond MIP of which maxillary anterior region holds 66 teeth and mandibular anterior region holds 66 teeth. Transbond MIP showed 1 failure in maxillary anterior region (1.5%) and 1 failure in mandibular anterior region (1.5%) which is statistically insignificant (p-1.00) **(Table 4.4) (Graph 4.2).**

Similarly other 132 anterior teeth were bonded with Bracepaste MTP. Of which maxillary anterior region holds 66 teeth and mandibular anterior region holds 66 teeth. Bracepaste MTP showed 2 failures in maxillary anterior

region (3%) and 5 failures in mandibular anterior region (7%) which is statistically insignificant (p-1.00) **(Table 4.4) (Graph 4.2).**

Out hence primers when compared between anterior region of both the arches, showed no significant difference in bracket failure rates.

Posterior region:

Total of 88 posterior teeth were bonded with Transbond MIP of which maxillary posterior region holds 44 teeth and mandibular posterior region holds 44 teeth. Transbond MIP showed 0 failure in maxillary posterior region and 6 failures in mandibular posterior region (13.6%) which is statistically significant (p-0.026) **(Table 4.5) (Graph 4.3).**

Similarly other 88 posterior teeth were bonded with Bracepaste MTP of which maxillary posterior region holds 44 teeth and mandibular posterior region holds 44 teeth. Bracepaste MTP showed 4 failures in maxillary posterior region (9%) and 5 failures in mandibular posterior region (11%) which were statistically insignificant (p-1.00) **(Table 4.5) (Graph 4.3).**

So primers when compared clinically between posterior region of both arches, it showed that Bracepaste MTP had a higher failure rate in posterior region of both the arches, whereas Transbond MIP showed significantly higher failure rate only in the mandibular posterior region.

5. ADHESIVE REMNANT INDEX

All 25 failed brackets fell in two categories of adhesive remnant index which were ARI 4 and ARI 5. Out of these 25 failed brackets, 21 brackets showed adhesive failures ARI 5 (84%) and 4 brackets showed cohesive failure ARI 4 (16%). On comparing with primers, Bracepaste MTP showed 13 adhesive failed brackets (5%) and 3 cohesive failed brackets (1.36%) from a total of 16 failed brackets and Transbond MIP showed 8 adhesive failed brackets (3.3%) and 1 cohesive failed bracket (0.45%) from a total of 9 brackets. This showed that both the primers exhibited a high adhesive failure than a cohesive failure. There was no statistically significant difference in type of failure between the primers (p-0.88) **(Table 5, Graph 5).**

Tables and Graphs

TABLE 1 :- OVERALL COMPARISON OF BOND FAILURE RATES

BETWEEN PRIMERS

MATERIALS	N	FAILURE AND SUCCESS RATES		P-VALUE
		FAILURE	SUCCESS	
BRACEPASTE MTP	220	16	204	0.160
TRANSBOND MIP	220	9	211	
OVERALL	440	25	415	

Chi-square test- significant p value ≤ 0.05

GRAPH 1

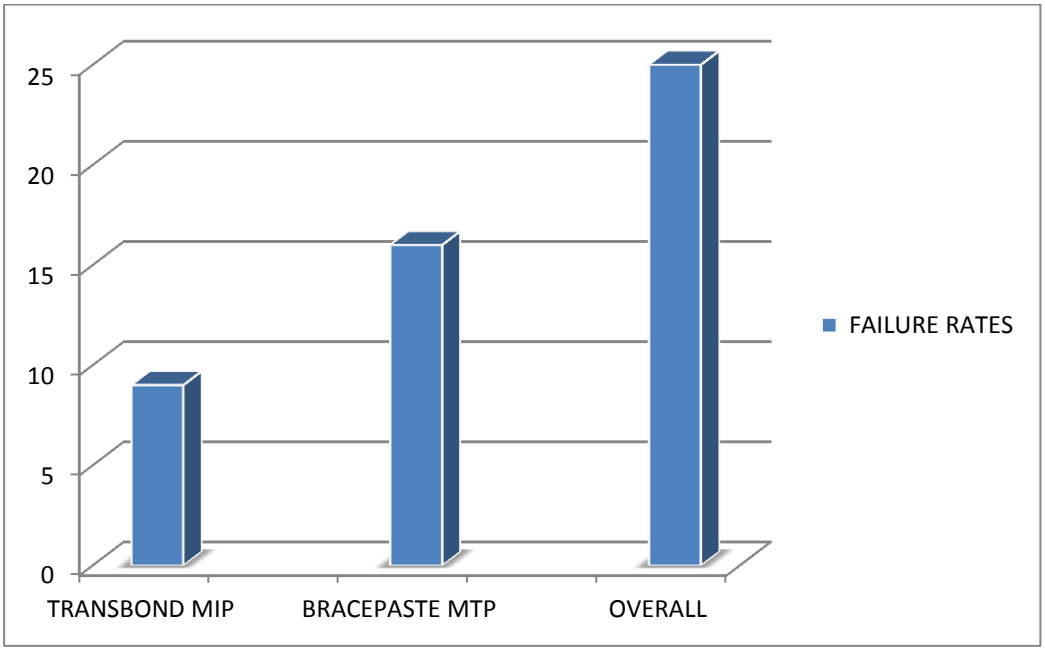


TABLE 2.1 :- COMPARISON OF BOND FAILURE RATES BETWEEN ARCHES

ARCHES	N	FAILURE AND SUCCESS %				p-VALUE
		FAILURE	PERCENTAGE	SUCCESS	PERCENTAGE	
Maxilla	220	6	2.72%	194	88.18%	**0.007***
Mandible	220	19	8.63%	181	82.27%	

Chi -square test- significant p value ≤ 0.05

GRAPH 2.1

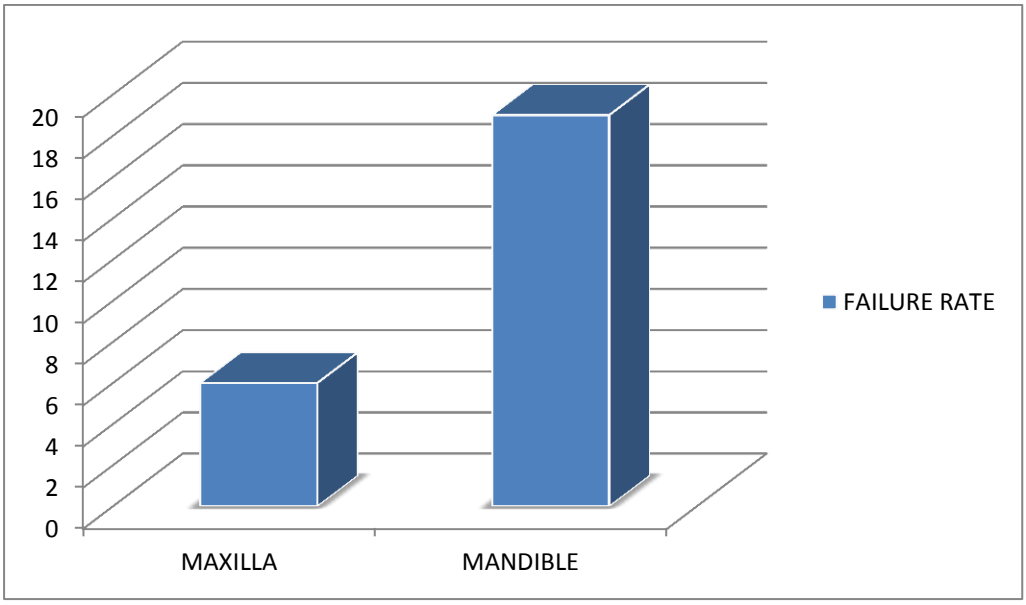


TABLE 2.2 :- COMPARISON OF BOND FAILURE RATES OF PRIMERS BETWEEN ARCHES

MATERIALS	ARCHES	FAILURES		SUCCESS		P VALUE
BRACEPASTE MTP (N=220)	MAXILLA (N=110)	5	4.5%	105	95.4%	0.063
	MANDIBLE (N=110)	11	10%	99	90%	
TRANSBOND MIP (N=220)	MAXILLA (N=110)	1	0.9%	109	99%	**0.016***
	MANDIBLE (N=110)	8	7.2%	102	92.7%	

Chi -square test- significant p value ≤ 0.05

GRAPH 2.2

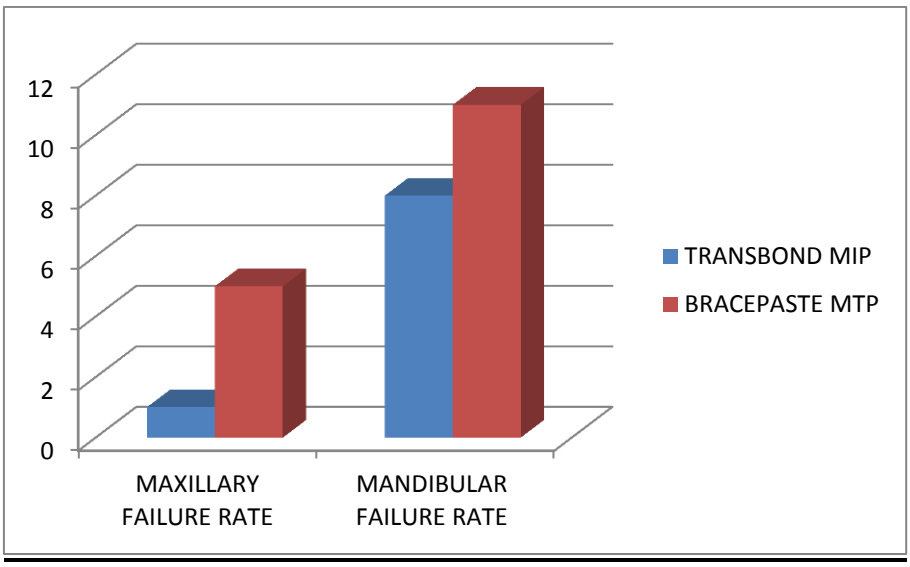


TABLE 3.1 :- COMPARISON OF BOND FAILURE RATES BETWEEN TEETH IRRESPECTIVE OF PRIMERS

TEETH	N	SUCCESS AND FAILURE PERCENTAGE				p-value
		FAILURE	PERCENTAGE	SUCCESS	PERCENTAGE	
CENTRAL INCISORS	88	5	5.6%	83	94.3%	0.764
LATERAL INCISORS	88	4	4.54%	84	95.4%	
CANINES	88	2	2.27%	86	97.7%	
1^{st} PREMOLARS	88	3	3.40%	85	96.5%	
2^{ND} PREMOLARS	88	11	12.5%	77	87.5%	

Chi -square test- significant p value ≤ 0.05

GRAPH 3.1

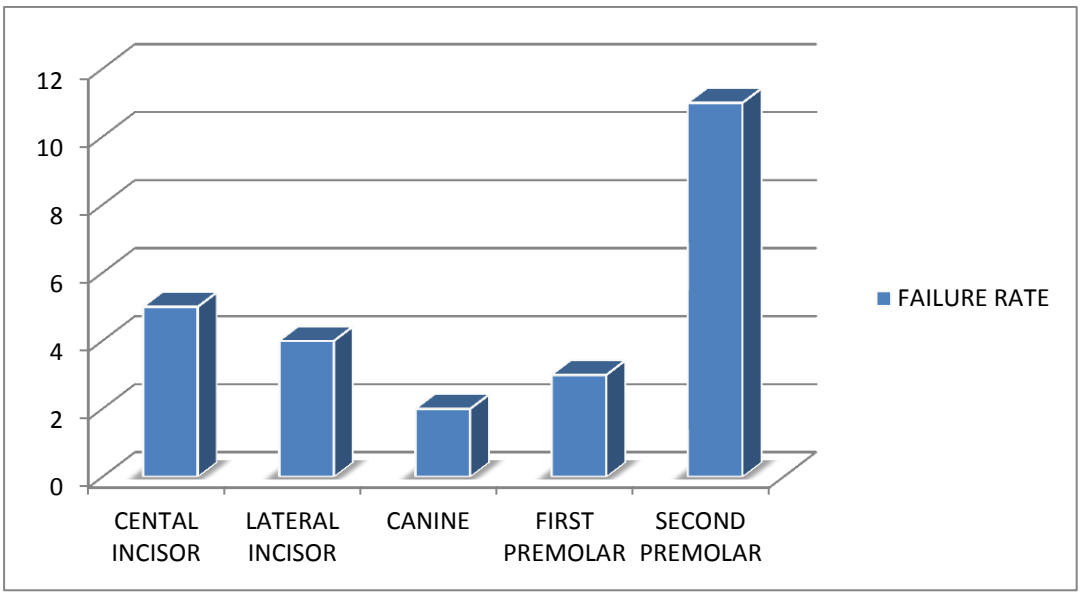


TABLE 3.2 :- COMPARISON OF BOND FAILURE RATES OF TEETH BETWEEN PRIMERS

TEETH	FAILURE AND SUCCESS PERCENTAGE						P-VALUE
	BRACE PASTE MTP FAILURES	PERCENTAGE	TRANSBOND MIP FAILURES	PERCENTAGE	OVERALL FAILURES	PERCENTAGE	
CENTRAL INCISORS	4	9.0%	1	2.27%	5	5.68%	0.964
LATERAL INCISORS	2	4.54%	2	4.54%	4	4.54%	
CANINES	2	4.54%	0	0	2	2.27%	
1^{ST} PREMOLARS	2	4.54%	1	2.27%	3	3.40%	
2^{ND} PREMOLARS	6	13.6%	5	11.36.%	11	12.5%	

Chi -square test- significant p value ≤ 0.05

GRAPH 3.2

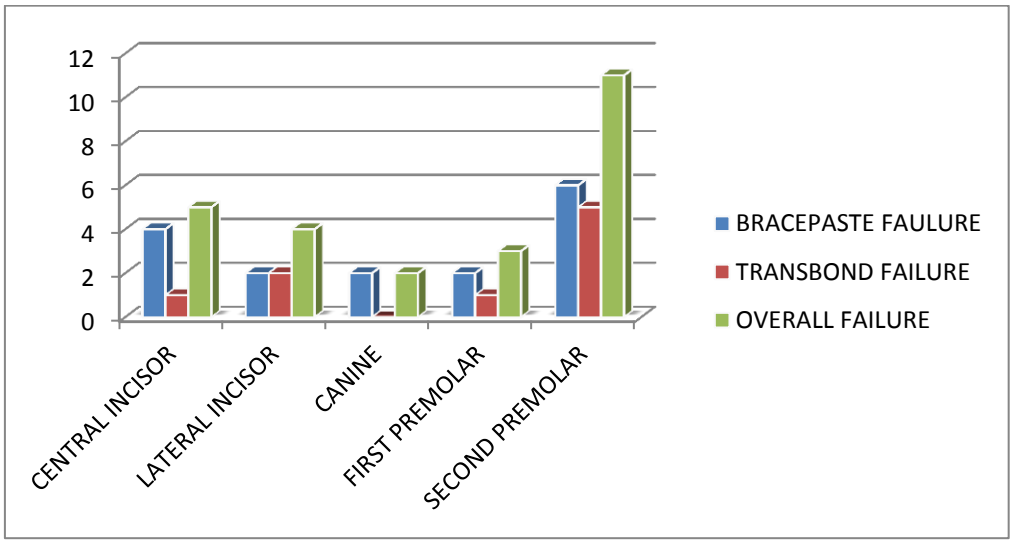


TABLE 3.3 : COMPARISON OF BOND FAILURE RATES OF 2ND PREMOLARS BETWEEN PRIMERS AND ARCHES

MATERIAL	ARCHES	FAILURES		SUCCESS		P VALUE
BRACEPASTE MTP (N=44)	MAXILLA N=22	3	13.6%	19	86.3%	1.00
	MANDIBLE N=22	3	13.6%	19	86.3%	
TRANSBOND MIP (N=44)	MAXILLA N=22	0	0%	22	100%	**0.02***
	MANDIBLE N=22	5	22.2%	17	77.2%	

Chi -square test- significant p value ≤ 0.05

GRAPH 3.3

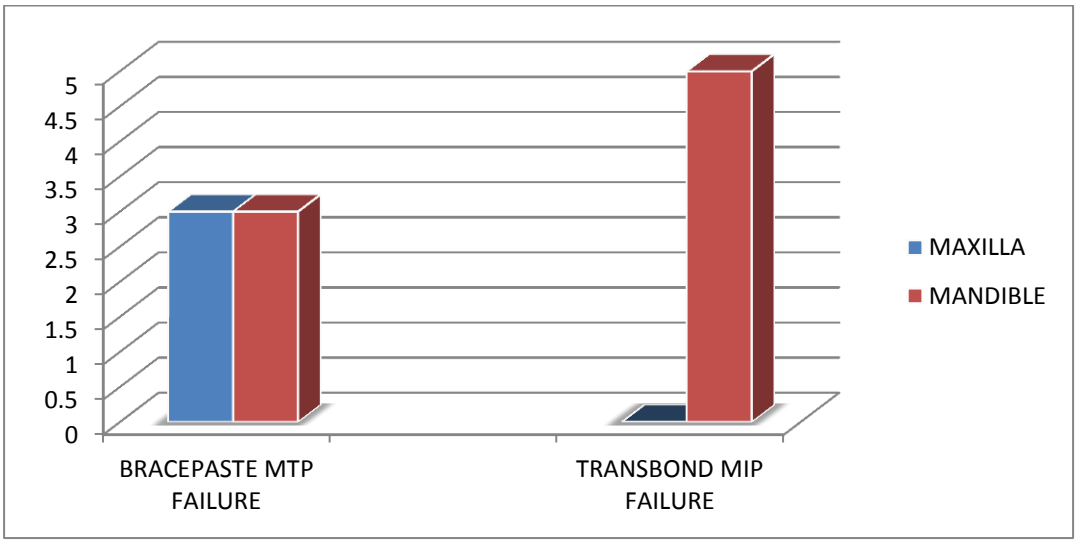


TABLE 4.1 : COMPARISON OF BOND FAILURE RATES BETWEEN MAXILLARY AND MANDIBULAR ANTERIOR REGION

ARCHES & REGION	FAILURE & SUCCESS	FREQUENCY	PERCENTAGE
MAXILLARY ANTERIORS N=132	FAILURE	3	2.3%
	SUCCESS	129	97.7%
MANDIBULAR ANTERIORS N=132	FAILURE	7	5.3%
	SUCCESS	125	95.4%

TABLE 4.2 : COMPARISON OF BOND FAILURE RATES BETWEEN MAXILLARY AND MANDIBULAR POSTERIOR REGION

ARCHES & REGION	FAILURE & SUCCESS	FREQUENCY	PERCENTAGE
MAXILLARY POSTERIORS N=88	FAILURE	4	4.5%
	SUCCESS	84	95.5%
MANDIBULAR POSTERIORS N=88	FAILURE	11	12.5%
	SUCCESS	77	87.5%

TABLE 4.3: COMPARISON OF BOND FAILURE RATES BETWEEN PRIMERS AND REGION IRRESPECTIVE OF ARCHES

MATERIALS	REGION	FAILURE AND SUCCESS PERCENTAGE				P-VALUE
		FAILURE	PERCENT	SUCCESS	PERCENT	
TRANSBOND MIP (N=220)	ANTERIOR (N=132)	3	2%	129	98%	0.161
	POSTERIOR (N=88)	6	6.8%	82	93%	
BRACEPASTE MTP (N=220)	ANTERIOR (N=132)	7	5.3%	125	95%	0.168
	POSTERIOR (N=88)	9	10.2%	79	90%	

GRAPH 4.1

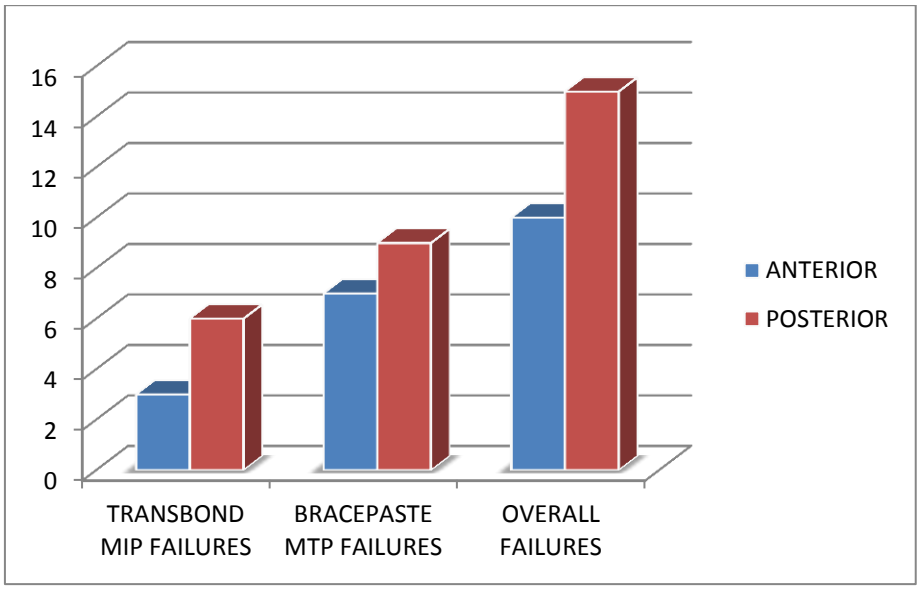


TABLE 4.4: COMPARISON OF BOND FAILURE RATES IN ANTERIOR REGION BETWEEN MAXILLA AND MANDIBLE WITH RESPECT TO PRIMERS

MATERIALS	REGION & ARCH	FAILURE AND SUCCESS PERCENTAGE				p-VALUE
		FAILURE	PERCENT	SUCCESS	PERCENT	
TRANSBOND MIP (N=132)	MAXILLARY ANTERIORS (N=66)	1	1.5%	65	99%	1.00
	MANDIBULAR ANTERIORS (N=66)	1	1.5%	65	99%	
BRACEPASTE MTP (N=132)	MAXILLARY ANTERIORS (N=66)	2	3%	64	97%	1.00
	MANDIBULAR ANTERIORS (N=66)	5	7.6%	61	92%	

Chi -square test- significant p value ≤ 0.05

GRAPH 4.2

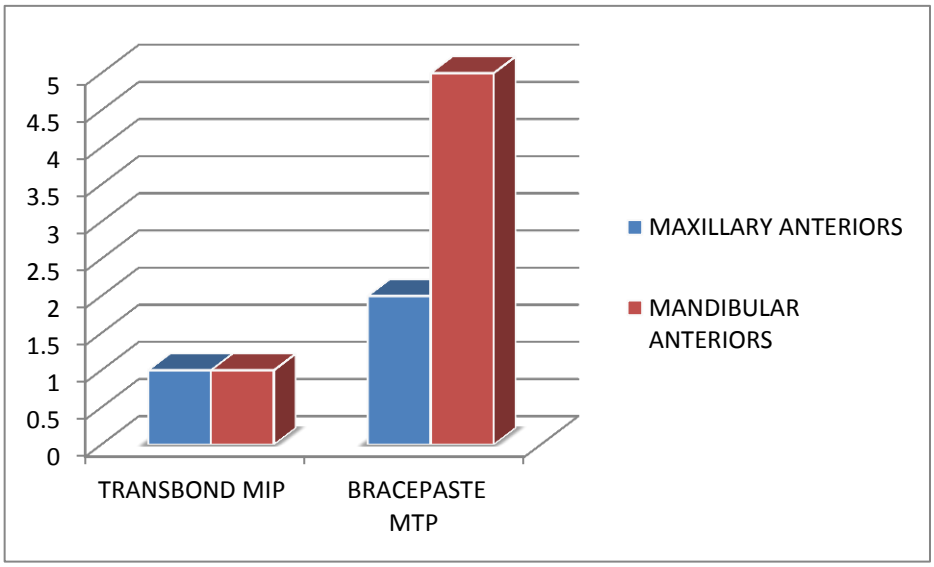


TABLE 4.5: COMPARISON OF BOND FAILURE RATES IN POSTERIOR REGION BETWEEN MAXILLA AND MANDIBLE WITH RESPECT TO PRIMERS

MATERIALS	REGION & ARCH	FAILURE AND SUCCESS PERCENTAGE				p-VALUE
		FAILURE	PERCENT	SUCCESS	PERCENT	
TRANSBOND MIP (N= 88)	MAXILLARY POSTERIORS (N=44)	0	0%	44	100%	**0.026***
	MANDIBULAR POSTERIORS (N=44)	6	13.6%	38	86%	
BRACEPASTE MTP (N= 88)	MAXILLARY POSTERIORS (N=44)	4	9%	40	90%	1.00
	MANDIBULAR POSTERIORS (N=44)	5	11%	39	88%	

Chi -square test- significant p value ≤ 0.05

GRAPH 4.3:

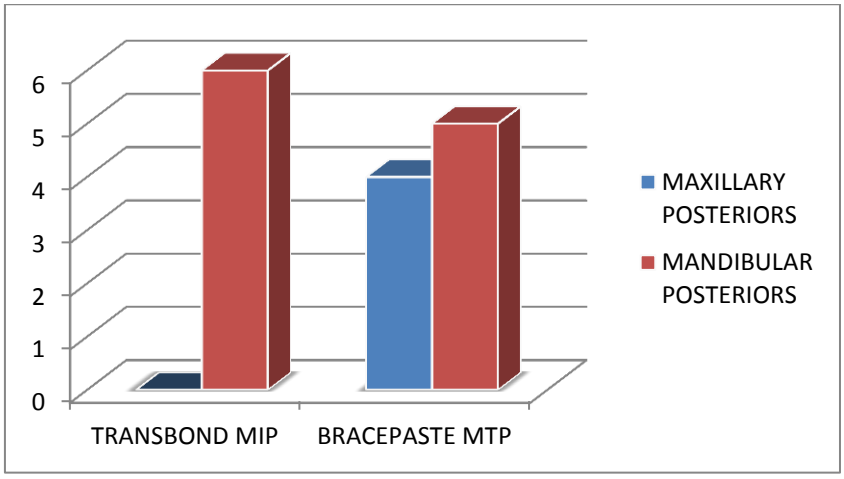


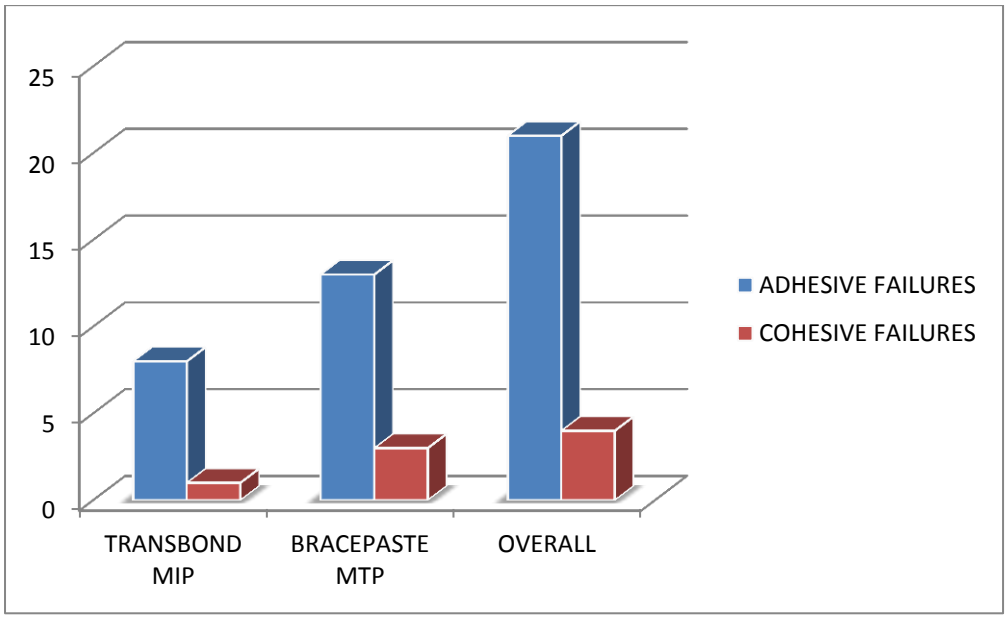
TABLE 5: COMPARISON OF ADHESIVE REMNANT INDEX

BETWEEN PRIMERS

ARI INDEX	FAILURE AND SUCCESS PERCENTAGE						p-value
	BRACEPASTE MTP FAILURES	PERCENTAGE	TRANSBOND MIP FAILURES	PERCENTAGE	OVERALL FAILURES	PERCENTAGE	
ADHESIVE FAILURE (ARI-5)	13	5%	8	3.3%	21	84%	0.882
COHESIVE FAILURE (ARI-4)	3	1.36%	1	0.45%	4	16%	
Total	16	3.63%	9	2.04%	25	5.68%	

Chi -square test- significant p value ≤ 0.05

GRAPH 5



Discussion

DISCUSSION

From the inception of fixed appliance treatment in orthodontics, the brackets are welded to the gold or stainless steel bands that pass circumferentially around the teeth for which interproximal separations had to be made between each tooth using either wires or elastomeric seperators. This causes discomfort to the patient and more over at the end of the treatment these spaces had to be addressed again to obtain proper finish.

To overcome this procedure clinicians preferred fixing bracket directly over the teeth which was put forward by **Dr. George Newman** and **Fujio Miura** who pioneered the bonding of orthodontic brackets to enamel[62]. This was followed by the introduction of acid etching technique by **Bunocure** that aided in increased patient compliance decreased chair side time and better esthetics[12].

From then bonding of orthodontic brackets to the teeth is the key step in orthodontic treatment[106,75]. It is the most sensitive step since repeated bond failures can prolong the treatment duration and can affect the patient compliance. There are various factors that can promote bond failure during bonding procedure like , prophylaxis , isolation ,etching (type, concentration, duration), primers, adhesives, bracket base (dimension and mesh design) and curing (type, duration,). Among these factors, isolation plays a key role since moisture contamination has been the main threat during bonding. **Miura** found that the bond strength decreased with time as a result of exposure to oral

fluids[58]. Moreover conventional bonding systems are hydrophobic in nature so isolation plays a crucial part in bonding procedure. **Cacciafesta et al** and many others showed that the presence of water[13,44] or saliva[13,89] drastically reduces bond strength in orthodontic resin bonding systems. Moisture contamination at different steps during bonding procedure can have an impact over the bond strength.

Apart from the bonding procedure there are much more factors which also contribute to the bond failures like type of malocclusion[8,55] arches[49], tooth type[67,33,48] and enamel texture[105,53]. Many techniques have been developed and many modifications have been made in the bonding material. Despite of all these, bond failures still exist as a threat in delay of treatment duration. This in vivo study is to compare the bond failure rates of two different moisture insensitive primers having other factors constant to eliminate bias.

Reynolds et al stated that bond strength of 5.9-7.9 MPa was necessary for successful adhesion of brackets to the teeth[35]. Many in vivo studies showed bracket failure rate range from 0.5% to 16% in which the average bracket failure rate being 6% approximately. So various factors should be taken into consideration while bonding to achieve a better bond strength.

Initial step in the orthodontic bonding is prophylaxis. A pumice prophylaxis aids removal of smear layer or any organic pellicle which are thought 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. Pumice prophylaxis was carried out in our study before bonding.

Acid etching of enamel surface was introduced by **Bunocure** in 1955[12]. There are various factors associated with etching procedure that can contribute much to the success of orthodontic bonding like the type of etchant used, duration of etching, etch pattern and contamination of etched surface etc. Studies have found that etched enamel contaminated with saliva or blood weakens the bond strength to 50% by forming an organic layer which fills the etched surface[36]. Etched enamel samples that were only air dried after saliva contamination showed significantly less shear strength than etched enamel samples that were re-etched for 60 seconds, then washed and dried after the contamination with saliva.

Different concentration of different acids and their duration have been described in literature claiming to produce 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 been proved to be the ideal acid for etching[24,108]. One of the potential disadvantage of etching with phosphoric acid is that the acid causes demineralization of the most superficial layer. To control excessive enamel loss, Maleic[64,31] and polyacrylic acids have been used as alternatives for phosphoric acid. These have been found to result in a reduction in bond strength.

Many studies have analyzed the bond strength of various concentration of Phosphoric acid and it has been denoted that 35-37% is ideal to achieve adequate bond strength and the duration have been analyzed and found that 15-60 seconds can be the duration of application of Phosphoric acid[24]. **Gardner et al** suggested that etching with 37% phosphoric acid for 30 seconds should be considered as a gold standard for etching[24]. Accordingly, in this study 37% phosphoric acid was applied for 30 seconds, rinsed thoroughly and air dried after which isolation was maintained.

Moreover, etch pattern varies between teeth and it contributes to the success of bonded brackets. **Mattick and Hobson** (2000), modified the etch pattern system developed by **Galil and Wrights** into a four types of pattern (Types A to D)[22,53]. If greater area occupied by etch pattern A and B, then the bond survival rate is higher and in the etch pattern D the bond survival rate is decreased. They have reported that anterior teeth were most likely to have high-quality etching (types A and B), and posterior teeth were most likely to have no etching (type D)[53,35]. The reason for poor etching pattern of posterior teeth could be attributed to the absence of prismatic layer in the posterior teeth which shows a resistant layer for acid etching[34,105].

The adhesive systems can be broadly classified as Light cure resins, Chemical cure resins, Resin Modified Glass Ionomer Cements, Cyanoacrylates and Flowable Composites. Light cure resins offer effortless

application, lesser degree of polymerization shrinkage and increased bond strength.

In the early 1970s, **Miura** developed a technique for bonding polycarbonate plastic brackets to phosphoric acid etched enamel using a restorative filling material developed by **Masuhura et al**, which consisted of methyl methacrylate and polymethyl methacrylate with tri-n-butylborane as the catalyst[58]. This had many disadvantage but still it was preferred over banding around the teeth. To overcome this drawback, Retief et al developed an adhesive to bond metal brackets, based on research conducted by **Bowen** on epoxy resins. Epoxy resins did not experience significant polymerization shrinkage when setting, had the same coefficient of thermal expansion as enamel, and were cross-linked to minimize water absorption. These characteristics produced the strength needed to resist the inherent mechanical and masticatory forces.

Contamination being a major threat for the success of orthodontic bonding, isolation plays a critical role for which cotton rolls, saliva ejectors, soft tissue and tongue retractors, and high vaccum suction can be used to help keep the operating field as dry as possible. Even Anti sialogogues have been used in dentistry for many years to reduce salivary flow. They are usually administered one hour before the bonding procedure. But many studies conclusively proved their inefficiency in reducing bond failure[43,69].

After contamination had occurred there are various thought as to whether re etching or repriming has to be done. **Brauchli et al** stated that repriming is sufficient after saliva or blood contamination[11].

So there was greater demand for hydrophilic adhesive materials to overcome the problem of moisture contamination. Then it was glass ionomer cement (GIC), which is a hybrid of silicate and polycarboxylate cements aided in bonding brackets over the wet fields[70] and also these have advantage of fluoride releasing property but it lacks bond strength when compared with composite resin. Problems with the chemically cured glass ionomer cement are that working time is greatly reduced and it gains adequate strength for ligating only after 20 minutes. These drawbacks got rectified with addition of light activator which decreases the setting time, increases the working time. And combination of GIC and composite was developed which retain the positive attributes of GIC as well as improved bond strength.

Light activated RMGICs were formulated to overcome the problems of moisture sensitivity of composites and low early mechanical strength of glass ionomers while maintaining the clinical advantages of conventional glass ionomers. Silverman developed a technique of bonding to the wet enamel without acid etching which is Fuji ortho LC[87], dual cure glass ionomer cement. This system has powder and liquid which has to be mixed and placed on the bracket base and positioned over the tooth surface and light cured for 20 seconds. But the major drawback is that the bond strength is greatly reduced.

Hegaty et al compared the bracket retention between RMGIC and resin based adhesive and RMGIC showed that significantly higher bracket failure rate when compared with resin based adhesive system[29].

Light cure systems are easy to use and versatile, with extended working time where necessary. There are various light curing units that have been used for bonding brackets. Conventional blue halogen curing lights have been the mainstay of light cure systems for decades and then as a alternative, light emitting diodes (LEDs) and plasma lights[18] have been developed. Since plasma light holds the risk of damaging the pulpal tissue, Light-emitting diodes (LEDs) are reported to produce light of greater intensity[41,66] reduced curing time and enhanced bond strength[103]. A systematic review by **Flemming et al** comparing all these three curing system showed that there is no risk of bond failure between these three systems[20]. 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 [93,14].

Adhesive used in this study is Bracepaste and it is common for both the primer groups. It was introduced by American orthodontics and its major ingredients being BIS GMA and quartz silica and it shows increased viscosity property which is beneficial in positioning the bracket that can prevent drifting away of bracket. **Krishnaswamy et al** compared Transbond XT and Bracepaste and the results showed that both light cure composite resin

adhesive materials displayed adequate and optimal bond strength suitable for application in orthodontic bonding procedures[42].

Use of primers in orthodontic bonding is recommended since it is postulated that enamel adhesion is ensured by mechanical interlocking of etched surface with polymerised liquid primers. Various studies have showed increased failure rates in absence of primers[77,72]. **Nandhra et al** who reported a debond rate of 11.2 per cent with primer and of 15.8 per cent without primer[61]. **Bazargani et al** in a randomized trial reported that failure rate without primer was 5.5 per cent and with primer 3.1 per cent[6].

A reduction in bond strength of adhesive to etched enamel after moisture and saliva contamination has been reported by several authors[32,65,73]. An area for clinical improvement is the tolerance to moisture contamination during bonding to reduce the incidence of bond failures. So modifications were made in the primer material to make the traditional adhesives more hydrophilic by incorporating hydrophilic monomers (HEMA, 4-PENTA, etc.) and addition of alcohol or acetone to displace the moisture from the surface of the contaminated enamel to produce greater tolerance to wet conditions and to promote successful bonding[104]. **Nakabayashi** stated that Hydroxy Ethyl Methacrylate was found to be effective in improving the diffusivity of demineralized dentin[60]. Many studies have proved that the bonding efficiency of HEMA based hydrophilic primer over enamel surface as well[50]. Earlier In 1998, several hydrophilic primers were introduced like Ortho Solo (Ormco),

Assure (Reliance Orthodontic Products), and Transbond MIP (3MUnitek) were hydrophilic bonding resins that bonded well to wet or dry enamel, making the bonding procedure more forgiving.

Cacciafesta et al stated that bond strength of hydrophilic primer is significantly higher in dry field when compared with the moisture contaminated enamel surface[13]. **Sayinsu et al** showed that the moisture contamination after primer polimerisation showed greater bond strength than that of contamination before polimerisation[79]. So it was adviceable to re apply the primer if the polimerised primer gets contaminated with moisture.

In our study we compared the bond failure rates of two moisture insensitive primers, Bracepaste MTP and Transbond MIP which contains HEMA as the hydrophilic component. **Grandhi et al, nandhra et al** and various others have compared the efficiency of Transbond MIP[98,7,26,61,6] .Reports have proved the efficiency of the Transbond MIP over the moist or contaminated enamel surface[107]. We took up this study since Bracepaste MTP is a new product available in the market which is said to have similar properties. Both Transbond MIP and Bracepaste MTP contains ethyl alcohol as the base component and HEMA as the hydrophilic component, which shows the basic composition is similar. There are no previous studies available in the literature on comparison of Bracepate MTP with Transbond MIP.

Other than the bonding materials and the bonding procedures, bracket base and mesh design can reinforce the bond strength at the bracket enamel

interface[39,90]. **Shyagali et al** reported that, modifying the bracket mesh base by varying the diameter of the wire mesh significantly influences the amount of stress generated in the bracket-cement tooth continuum[86]. **Mitchel** was the one who used bracket with a retentive base[56]. Minimum of 6.82mm² dimension bracket base is required to achieve sufficient bond strength[51,17] and there were many modifications made in the mesh design like welded foil mesh with single or multiple layers. Comparing these two single foil mesh bases generate more stress than double foil mesh but these double foil mesh allows better penetration of adhesive and light during curing process[51]. Foil mesh bases have been known to withstand tensile forces better than other type mesh designs[96]. **Wang and Knox** show foil mesh designs to have better bond strength than integral meshes[100]. **Sorel** has stated that lasered base brackets have bond strength twice that of simple foil mesh brackets[91]. On comparing bracket prescription, commonly used prescriptions are MBT and ROTH in a clinical setting. Studies have shown that there is not much difference when comparing these prescription in terms of esthetics and torque efficiency [59,57]. The mean bracket base of the bracket used in the study was 9.42 mm^2 0.022 x 0.028 slot, Roth prescription, Mini Master Series, American orthodontics brackets were used in this study.

Other various factors that contribute to the success of bonding like the position of bonding, texture of the tooth, severity of malocclusion and even the masticatory force levels. **Proffit et al** reported that forces generated on brackets in the posterior quadrants exceeded 20 MPa.

There are various in vitro studies which evaluated the effectiveness of moisture insensitive primers by testing their shear bond strength. Even though in vitro studies promotes better standardization and results can be adequate to be used in a clinical setting, in vivo study promotes eradication of various bias and the study results obtained from oral environment are always reliable. In vivo study design helps us to examine and compare various parameters in intraoral setting which is considered more reliable.

There are very few in vivo studies available in the literature comparing the hydrophilic primers [54,50,6]. Moreover this study was conducted in a split mouth design which is more reliable. The two materials are distributed equally between the arches and quadrants in the same patient, by which we could eliminate other factors like masticatory load, diet, hygiene maintenance etc.

Assessing the failure rates of the bonded brackets in a randomized sample is always a reliable tool that can show the accurate clinical efficiency of the compared materials.[6,54].

This study is a in vivo comparative study to assess the bond failure rates of two moisture insensitive primers Bracepaste MTP and Transbond MIP in a split mouth design in a dry field. We have compared the failure rates of these two primers with multiple variables like dental arches, teeth, anterior and posterior region and based on adhesive remanent index.

In this study total of 25 brackets failed of 440 bonded teeth which are 5.7%. This is in accordance with the previous in vivo studies which showed failure range from 5 to 16 % with the average of 6 %[106,35,94].

BETWEEN ARCHES:

This study showed a significantly higher bond failure in lower arch when compared with the upper arch. This was in accordance with the previous clinical studies done by **Bazargani and Barbosa** [6,5]. A study done by **Ahmed hasan** showed that bond failure rates are higher in maxillary arch which is contradictory to our study[27,74].

And between the primer materials, Bracepaste MTP showed increased failure rates in mandibular arch when compared with the maxillary arch, but the difference is not statistically significant. Whereas Transbond MIP showed a significantly higher failure rate only in the mandibular arch. Overall both the material showed high failure rates in the lower arch when compared with the upper arch.

This can be attributed to the increased masticatory load of the patients. Diet and chewing pattern differs between patients and these also have a significant impact on the increased failure rates of lower teeth[33].

Another reason could be 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 the failure of the brackets in the mandibular arch. In order to prevent this, authors have suggested a bite plane

or pads to create a space and thus preventing the brackets from direct contact of upper tooth cusps or incisal edges.

In certain cases with mild crossbite, bite blocks were given to relieve the occlusion and alignment was carried out. But contradicting to this, Studies by **Sunna et al, Aneel Bherwani et al** reported that there is no difference in the bond failure between arches when bite blocks or bite planes are placed to eliminate occlusal forces [8,94].

Apart from these, moisture contamination was reported as a cause for increased lower bond failure, but this study being a comparison between moisture insensitive primers which are said to have greater bond strength in a moist field than on a dry field, it can be said that heavy occlusal load and varying chewing pattern could have been the major etiology for increased lower arch bond failure.

BETWEEN REGION :

This study showed higher failure rates in the posterior region than anterior region. When compared between the materials, Bracepaste MTP showed higher failure rates in both the region than Transbond MIP.

Regions were then compared between maxillary and mandibular arches which showed that increased failure rates are seen in mandibular posterior region and least failure rates were observed in maxillary anterior region. When compared between materials Bracepaste MTP showed higher failures in the

posterior region of both the arches when Transbond MIP showeed significantly high failure rates only in posterior region of mandibular arch.

Increased failure rates of lower posterior teeth in this study was in accordance with previous studies by **Linklater, Ahmad hasan and Sunna et al**[48,27,94] which reported that brackets bonded to the posterior teeth have a shorter survival rates than those bonded to anterior teeth[62,106,39,33,28] , this was attributed to insufficient access to operation region[28], partial eruption of the teeth or aprismatic enamel of premolar teeth[105], salivary contamination[36] and occlusal force.

The maximum voluntary bite force or the chewing force is higher in posterior region of dentition. Teeth with occlusion on the brackets were 4 times more likely to produce bracket failures than those without occlusion[29]. In contrary, **Hobson** stated that in the lower arch bond strength was weaker on anterior teeth than posterior teeth[33].

So overall mandibular posteriors and anteriors are more prone for bond failures and higher bond success was observed in anterior region of maxilla.

BETWEEN TEETH:

In this study, mandibular arch exhibited increased failure rates in all types of teeth. Highest failure is observed in 2nd premolars and central incisors. Following which 1st premolars, lateral incisors and canines exhibited similar number of failures.

In maxillary arch failure rates were very minimal in all types of teeth, of which highest number of failures were observed in 2nd premolar followed by 1st premolar and lateral incisors. No failures were observed in maxillary canine.

So on the whole highest failure was observed in mandibular 2nd premolars and least bond failures were seen in maxillary canines and this was in accordance with the previous studies[55,1,83,99].

In this study highest failure rates were observed in 2nd premolars and central incisors irrespective of arches. But when compared between arches, both types of teeth showed increased failure rates in the mandibular arch. Then it was 1st premolars followed by lateral incisors which showed relatively less failure rates and the least bond failure rate was observed in canines

Whittaker found that the extent of aprismatic enamel is higher on the posterior teeth. So this affects the acid etching efficiency of the posterior teeth which in turn affects their bond strength and survival rates of the brackets[105]. This was supported by **Mattick and Hobson** in their micro topographic study of buccal enamel[53]. This can be one of the reasons for the decreased bond strength in lower premolar region in our study.

Incorrect brushing technique and more importantly the impingement of hard food substances on the premolars and molar as they are most commonly used for crushing and tearing, and it have been showed as a major reason for bond failure[49,106].

Unlike other studies by **Adolfson and DT Millet**, our study showed comparatively decreased failure rates in mandibular 1st premolars, this can be attributed to the decreased arch length tooth size discrepancy seen among our study sample.

Study by **Hobson and Mattick** have reported that lower incisors have greater bond strength owing to their type A, B etch pattern and smaller tooth surface area[35,53]. But in contrast to this, our study showed increased bond failure in lower central incisor, this was in accordance with a study **by Bora ozturk and Hobson** who found decreased shear bond strength in the lower anterior teeth [24,67].

ADHESIVE REMANENT INDEX :

For our study, the modified 5 scale classification of **Bishara and Truelove**[10] seemed more illustrative and fitting to describe the remnant on the failed brackets. Two types of failures have been discussed; adhesive failure which denotes failure between two interfaces (figure 5) and cohesive failure which denotes failure within the adhesive (figure 6).

This study showed increased adhesive failure than cohesive failure. All failed bracket fell under ARI 4 or 5. And when compared within the materials, both showed high adhesive failure. (ARI 5)

Several authors have denoted that the failure mostly occurs at the bracket-adhesive interface[4]. However, our study results were in correlation

with studies by **Sfondrini et al and Henkin et al** who claimed that the bond failure occurred more predominantly at the enamel-adhesive interface[30, 82].

Fox et al suggested that it would be preferable for bonds to fail at the enamel–adhesive interface as this would reduce the need for removal of composite from the tooth surface during the time of debonding after completion of fixed appliance treatment[21]. However, if the bond between bracket and composite is greater than that of between composite and enamel, there is an increased possibility for the enamel to fracture during debonding.

LIMITATIONS

This study was carried out only till leveling and aligning phase and hence the failure rates with higher dimensional wires were not evaluated.

Future studies with other parameters like age, gender and type of malocclusion may provide a better knowledge about the clinical performance of these materials.

Moreover, studies incorporating moisture contamination while clinical bonding procedure, can elicit the exact clinical performance of such moisture insensitive primers.

Summary & Conclusion

SUMMARY AND CONCLUSION

Even though bonding in orthodontics appears to be a simple technique, there are lot of factors that affect the bond strength like effective isolation, type and time of etching, bracket base and material, types of primers and adhesives, type of curing system etc. Even after various modifications and controlled bonding techniques, there are various clinical factors which also affects the bond failure rate such as tooth texture, masticatory force, diet, chewing cycle, brushing technique etc. Control of moisture contamination is considered to be the most challenging factor among all these. Based on this we clinically compared the bond failure rates of two moisture insensitive primers, Bracepaste MTP (Ormco) and Transbond MIP (3M Unitek).

Even though the study started with 32 patients, finally we evaluated 440 teeth from 22 patients using split mouth design to assess the bond failure rate between two moisture insensitive primers during the leveling and aligning phase. Primary aim was to find out the overall bond failure rate between materials. The other variables considered were comparison between arches, regions, teeth and type of failures.

Overall comparison of bond failure rate between the primers showed higher failure rate in Bracepaste MTP when compared with Transbond MIP, which was statistically insignificant.

When comparison was made between arches irrespective of the primers, mandibular arch showed statistically significant bond failure rate. And when primers were compared with arches, Bracepaste MTP showed similar failures in both the arches whereas Transbond MIP had significant failure rate only in the mandibular arch which was clinically and statistically significant.

When teeth were compared, 2nd premolars showed highest failure rate with both the primers irrespective of arches. When these failure rates were compared with the primers and arches, Bracepaste MTP showed similar failure rate between the arches, whereas Transbond MIP showed significantly higher failure rate only in the mandibular arch.

On comparison of anterior and posterior region, posterior region showed higher number of bond failure irrespective of arches. And when compared between the arches, mandibular posteriors showed higher failure rate in both the primer groups. Bracepaste MTP showed high failure rate in both maxillary and mandibular posteriors, while Transbond MIP showed high failure rate only in the mandibular arch which was statistically significant.

When the types of bond failures were compared between primers, it showed high adhesive failure (ARI 5) in both the primer groups. Overall comparison showed no statistical significant difference between the groups.

1. From this clinical trial, it was evident that there seems to be a very little difference in the clinical performance of the two primers. Despite the fact that there were slightly more failures in Bracepaste MTP group which seems to be statistically insignificant.
2. Clinically and statistically both Transbond MIP and Bracepaste MTP showed significant failures in mandibular 2nd premolars. One of the inherent drawbacks of bonding mandibular premolar was its lower bond strength due to the presence of aprismatic enamel. Hence, the future lies in the invention of newer materials with better physical properties to overcome this problem.

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Annexures

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 WHOM SO EVER IT MAY CONCERN

Date: 29/01/2020

Place: Chennai

From
The Institutional Review Board,
Ragas Dental College and Hospital,
Uthandi,
Chennai- 119

The project titled "**A COMPARATIVE IN VIVO ASSESSMENT OF BRACKET BOND FAILURE RATE WITH TWO MOISTURE INSENSITIVE PRIMERS**" submitted by **Dr Muthu Pradeep R.L** has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

DR. N.S. AZHAGARASAN, MDS
Member secretary,
The Institutional Review Board
Ragas Dental College and Hospital
Uthandi,
Chennai-119

ANNEXURE – II

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.

1. The importance of the present treatment in relation to the overall health and
   development has been explained
2. 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.
3. I assure that I/he/she shall come for each and every sitting without fail.
4. I authorize the doctor to proceed with further treatment according to his study
   protocol.
5. I have given voluntary consent to undergo treatment without any individual
   pressure or duress.
6. 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

ANNEXURE – III

URKUND

Urkund Analysis Result

Analysed Document:	for pliagarism.docx (D63358982)
Submitted:	2/3/2020 10:59:00 AM
Submitted By:	Pradeep.muthu152@gmail.com
Significance:	3 %

Sources included in the report:

https://www.slideshare.net/fari432/bonding-in-orthodontics-127316707
https://www.researchgate.net/publication/8395975_Comparison_of_bond_strength_between_a_conventional_resin_adhesive_and_a_resin-modified_glass_ionomer_adhesive_An_in_vitro_and_in_vivo_study

Instances where selected sources appear:

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