COMPARISON OF BOND FAILURE AND ACCURACY OF TWO INDIRECT BONDING TECHNIQUES AND MATERIALS: AN IN-VIVO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"COMPARISON OF BOND FAILURE AND ACCURACY OF TWO INDIRECT BONDING TECHNIQUES AND MATERIALS: AN IN-VIVO STUDY"** is a bonafide record of work done by **Dr. FAYYAZ AHAMED. S** under my guidance during his postgraduate study period between 2008–2011.

This dissertation is submitted to **THE TAMIL NADU 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.

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CONTENTS

INTRODUCTION

Since the advent of the acid etch technique by **Buonocore**[12] in 1955 and the bonding of orthodontic brackets by **Newman**[53] in 1968, bonding research has strived to improve the delivery of orthodontic treatment. Orthodontic bonding gave rise to significant improvements in treatment such as greater patient comfort, elimination of the need for pretreatment tooth separation, improved oral hygiene and esthetics, and reduced chair time.

In an effort to produce a more accurate and efficient bracket placement system, **Silverman**[16] *et al.* developed the indirect bonding technique involving a two stage process in which the brackets are first placed in the laboratory on a plaster model and then are transferred to the patient's mouth by means of a tray, where they are bonded to the prepared enamel surface.

Indirect bonding even though requiring additional laboratory work and cost, has been reported to have many more advantages when compared to direct bonding including :

1) Accuracy of bracket placement particularly in the posterior area where access and vision are limited[47].

2) Reduced clinical chair side time for the doctor. **Aguirre**[43] *et al.* (1982) found that direct bonding took an average of 42.2 minutes while

indirect took only 23.9 minutes when considering the actual clinical time only.

3) Reduced stress for the doctor and clinical staff[31].

4) Easier clean up of any remaining resin when debonding the teeth[47].

5) Patients experience less trauma and discomfort[16].

6) Brackets adhered better to the teeth because of less breath condensation and subsequent moisture contamination of the etched and sealed teeth.

Initially, brackets were placed on the plaster model using sugar candy (**Silverman**[17] *et al.*,) or soluble cement (**Newman**[52]) which was later removed and a composite bonding agent placed at the time of bonding. **Thomas**[60] in 1979, used filled resin which was placed onto the retentive bracket bases which serves as an adhesive to attach the brackets to the stone model to form the custom base. Thomas technique became the foundation for contemporary indirect bonding.

Transfer trays which are fabricated after placing the brackets, should be rigid enough to hold the brackets in their position yet have enough flexibility to be easily removed once the brackets are attached to the teeth. The first material to be used as a transfer tray was a polyethylene plastic material

(**Silverman[16]** *et al.*). Later hard putty impression material was used[73]. Because of the force exerted during removal of these hard material and the risk of debonding brackets, **Moskowitz[50]** *et al.* in 1996 used vinyl polysiloxane impression material placed over the brackets followed by a 0.5mm hard thermoplastic material placed over it. This would provide rigidity to the tray for insertion and ease of removal after brackets are attached to the teeth.

However, most practitioners seem to prefer using vacuum formed resins which are easy to fabricate. Some use a 2 mm soft clear plastic sheet alone to provide adequate rigidity (**Myrberg and Warner[51]**, 1982; **Milne[47]** *et al.*, 1989; **Read and O'Brien[35],** 1990). **Kalange[33]** found that the two-part heavy viscosity putty is superior to transparent trays, which offers a reliable and inexpensive method for transferring accurately placed brackets to the teeth.

Larry white[38], Arturo fortini & Fabio giuntoli[8] described a new method of transfer tray made from polymer of ethylene vinyl acetate applied with a hot thermal glue gun which was rigid enough to provide stability and at the same time was inexpensive to make. **white[39]** suggested preparation of transfer tray made of Thermal Glue which were sectioned for individual tooth and used light cure for indirect bonding. Disadvantage of this technique was the procedure was time consuming and uncomfortable for patients. In our study we used a transparent thermal glue material tray which was not sectioned for individual teeth and we did not block the bracket slot or undercuts with medium viscosity putty material rather we extended the tray covering the gingival wing but not beneath it to increase flexibility and ease of removal after bonding.

The final step in indirect bonding is attaching the brackets to the teeth via an adhesive system. Over the years many adhesive materials have been used for indirect bonding most of which were the same materials used for direct bonding. Chemically cured two paste adhesives, however have limited working time as the setting reaction starts as soon as the mixing begins. To overcome this disadvantage a no mix adhesive with 2 components like Sondhi Rapid Set (3M Unitek, Monrovia, Ca, USA) was developed specifically for indirect bonding.

Chemical setting resin gives the clinician adequate working time as the material only starts setting when the bracket comes in contact with the tooth. Chemically cured composites have very similar components to those that are light cured and therefore have the same clinical working characteristics. Whereas Light-cured resins actually take much longer to cure at the chairside and thus detract from the efficiency of indirect bonding.

Evaluation of accuracy of bracket placement using photographic technique was described by **Aguirre king and Waldron**[43]**.** They suggested use of a jig attached to the camera at a standard distance to eliminate magnification and angulation errors during photography and then calculated the accuracy of bracket placement. However this method had a disadvantage of taking standardized photographs in the premolar region. In this study to overcome this disadvantage and to make the measurements direct and accessible, a digital vernier caliper attached to 19x25 Stainless steel straight archwires of 1 inch length was used to evaluate the linear measurements in the models and in patients after bonding.

No previous studies, to our knowledge have been done to evaluate the Clinical bond failure rates and accuracy of bracket placement comparing two indirect bonding techniques using two different chemical cure materials.

The purpose of this study was to compare and evaluate the clinical bond failure rates and accuracy of bracket placement between Polyvinyl Siloxane and Thermal Glue material transfer trays (stabilized with a 19 gauge round stainless steel wire) and between Sondhi Rapid Set and Custom IQ indirect bonding agents.

REVIEW OF LITERATURE

Elliot Silverman , Cohen M , Gianelly A , Dietz V S. [16](1972)

First to report an indirect bonding method. They used a methylmethacrylate "new experimental adhesive" and Ultraviolet- light-activated unfilled bis-GMA resin. Silverman and Cohen reported that the advantages of the indirect technique were (1) reduced chairtime for the patient, (2) reduced stress for the operator, and (3) increased accuracy of bracket placement. They cautioned, however, that the procedure was technique sensitive and could lead to reduced bond strengths if the timing and manipulation of materials were not carefully controlled.

Elliot Silverman & Morten Cohen [17](1975)

Updated their technique wherein brackets were fixed onto a cast with sticky glue. When set, a transfer tray or a bracket tray was fabricated that held the brackets. The teeth to be bonded were subjected to pumice prophylaxis and etching, then the transfer tray with a UV light cured composite resin on the bracket bases was placed on the arch and cured with a UV light.

Elliot Silverman & Morten Cohen [18](1976)

Described a technique where the brackets were secured onto the cast with Nuva tach, which is a sticky glue material. A transfer tray is made. After etching and drying the teeth to be bonded, Auto tach, which is a two-paste system, is mixed on a cold slab and applied to the bracket bases on the transfer tray. Since the setting time for Auto tach is limited, time should not be wasted after the two pastes are mixed to insert the tray into the mouth. The authors say 20 minutes is all that is required for a full strap-up.

Moin and Dogon[48] (1977)

In their article evaluating indirect bonding, they compared favorably to direct bonding in that it decreases chairside time. Another advantage according to the authors was the comparative ease of finishing with indirect bonding and therefore better post treatment result.

Zachrisson and Brokakken[73] (1978)

In their article compared clinically direct vs. indirect bonding with different bracket types and adhesives. Results showed that failure rates were low for the direct bonded attachments and overall. With direct bonding 6 of 243 and 28 of 201 with indirect bonding was the number of failures. The difference of 2.5 vs 13.9% was statistically significant. The most number of failures were seen in the premolar region in both mandibular and maxillary arches.

Royce G. Thomas[60](1979)

Introduced a new technique that involved the formation of a custom base on the brackets. The technique involved application of concise or Dyna bond, which are chemically cured resins on the brackets to secure them on to the study cast in their desired position. When set, a transfer tray was fabricated with a thermoformed tray material. Later applied concise or Dyna bond sealant; Universal resin part (A) on the teeth. The custom bases on the transfer tray were painted with liquid sealant catalyst resin part (B). The tray is then held in the mouth for 1 1/2 mins. The author says this technique can provide a simple no rush atmosphere as no polymerization can occur till the two liquid sealants (A) and (B) come in contact with each other. Another advantage is that the unpredictable nature of the previously used glue or tape material during bonding of brackets on the cast is eliminated.

Aguirre, King and Waldron [43] (1982)

Assessed accuracy of bracket placement and clinical failure rate comparing indirect and direct bonding techniques. The indirect bonding procedure employed was the Thomas technique. 11 patients were included in the study. Two measurements were made from photographs of the teeth including vertical and angular measurements. Maxillary and mandibular arches were divided into hemi arches and 1 technique was used on each arch as decided by the flip of a coin.

The direct technique was done with the help of visual inspection and the indirect technique involved ideally placing the brackets on the cast. A camera with a jig attached having a rectangular wire at its end was used where the rectangular wire engaged the bracket for the photograph. A vertical reference line was marked along the midline marker of the bracket and a horizontal plane on rectangular wire. A vertical measurement linear was made along the vertical plane and the measurement lay between the points at which the horizontal plane intersected the vertical plane and the incisal and cuspal margin of the dental unit in question. The angular measurement was made on the angle formed in the mesio occlusal margin where the vertical and horizontal planes intersected.

Results showed no statistically significant difference in vertical placement. Angular bracket placement showed statistically significant difference in the canines with indirect being more accurate. The bracket failures recorded 3 months after bonding showed 4.5% for indirect and 5.3% for direct.

N.E.A. Myrberg, Warner[51](1982)

Described a technique using rectangular wires welded at right angles of each other as positioning indicators. The desired positions of the brackets on models are marked with a pencil. The rectangular wire is then fitted on to the bracket slot and glued onto the model in their desired positions. Then the indicators are removed and a soft splint material is vacuum formed over the models.

P. Scholz [57](1983)

The transfer tray was made of silicon based material. The author has used a no mix bonding adhesive although some feel that it has a shorter working time and setting time. The author feels these can be used to speed up the procedure. Final results showed that out of 595 brackets bonded, 19 failed producing a failure rate of 3.7%.

Andrew. L. Sonis[3](1988)

Compared the effectiveness of a light activated system with an autopolymerizing resin system. The light cured group was bonded with Aura fill composite and bonding agent Curing was for 30secs each. The chemical cured group was bonded with SYSTEM 1 + bonding adhesive. Results showed that 7.7% of the chemically cured brackets failed as opposed to 4.5% of the light cured brackets. There was no statistically significant difference between the 2 groups.

Hocevar & Vincent [24] (1988)

In their study compared bond strengths and failure locations in indirect and direct bonding of orthodontic brackets through an in vitro study on extracted premolars. Inspection of the indirectly bonded brackets with transfer tray (Silicon based) and bonding on to the teeth with a two part unfilled resin showed voids in two-third of the teeth. There was no significant differences in strength between the direct, void free indirect and sealed indirect. Indirectly bonded teeth left with voids were only half as strong. This prompts the author to suggest that sealing of voids may be a worthwhile clinical procedure. The failure location showed 44% of direct bonds failed at the bracket, adhesive interface whereas 72% of indirect bonds failed mainly at the enamel resin interface that proved to be an advantage during debonding as there was less clean up required.

Milne, Andreasen and Jacobsen [47] (1989)

Studied the comparative bond strengths between a simplified indirect technique and a direct technique. 48 incisors and 48 premolars were used in the study. Half the sample was bonded by means of a highly filled BIS GMA adhesive through direct placement. The remaining teeth were bonded by an indirect technique suggested by Thomas. Tensile and bond strength determination showed no statistically significant differences between either of the two bonding techniques.

Read, O'Brien[35] (1990)

Carried out a trial to evaluate the clinical performance of a visible light cured adhesive when used with a foil mesh base in an indirect bonding technique. 37 patients were included in the study and a total of 407 brackets were placed. The incidence and site of bond failure were recorded.Thirteen patients had bond failures (35%). The overall failure rate showed no significant differences between upper and lower arches. Similarly no differences were noted between failures occurring in the anterior and posterior regions.

A.M.P Harris, V. P. Joseph [2](1992)

Studied shear peel bond strength of esthetic orthodontic brackets. The shear bond strength was calculated with and without silane. There were statistically significant differences between the shear peel bond strengths of metal brackets compared to Transcend 2000 and silicon brackets.

Brad burn and Pender [19] (1992)

In their study examined ways of improving the bond strength of the light cured resins. 2 resins were compared. Bracket was bonded on each of the 4 surfaces of the 50 extracted molar teeth. Results showed that the chemical properties of the 2 light activated resins were improved by precuring on the bracket base before bonding.

Nasib balut, sandrik, klapper, bowman [52] (1992)

Conducted a study to determine accuracy of the bracket placement with the direct technique. Results showed a mean of 0.34mm linear discrepancy and mean of 5.54^0 angular discrepancies. Lower anterior teeth showed least variation. Maximum angular variation was found in the upper anteriors and the lower canines. Maximum vertical discrepancy was found in the upper second premolars.

Wei Nan Wang, Chiang Liang Meng [69] (1992)

Studied comparative bond strength of light cured resins and chemically cured resins. The authors recommended usage of light cured resins with exposure times of 40 secs for optimal bonding.

Jing yi ; Shian, Rasmussen [31] (1993)

In their study have evaluated the bond strength of aged composites found in the brackets placed by an indirect bonding. The Thomas technique produces an interface not present in direct bonding. (i.e) an aged composite sealant interface. 60 bovine teeth stored in water were used in this study. No differences were found in the shear bond strength values between the direct and indirect bonding techniques. No evidence was found to suggest that an aged composite would predispose the enamel bracket system to fail at the sealant composite interface.

Ronald - B. Cooper, Nile Sorenson[59] (1993)

In their article described a clinical evaluation of the Thomas technique using adhesive precoated brackets (A.P.C). The 2 authors along with 6 other clinicians bonded 852 metal and 238 ceramic brackets.The technique was the same as the one proposed by Thomas except that A.P.C brackets were used. Transfer trays were formed with a Biostar. Their findings showed that of 1090 brackets bonded only 15 were lost in the first 24 hrs all during the bonding procedure. 13 of those were in the mandibular arch and every failure was at the adhesive enamel interface.The bond failure rate of 1.4% compared favorably with the 2.5% range found in most indirect bonding studies.

John H. Hickam[32] (1993)

In his article describes the fabrication of a dual tray as a transfer tray. The enamel is coated with sealant and the bracket bases conditioned with methyl methacrylate. A 2-paste composite is then mixed and loaded onto a syringe. This material is then applied on to the bracket bases and the tray transferred to the mouth. The author claims an excellent success rate with this procedure.

Sinha, Nanda and Ghosh[67] (1993)

In their article have described a technique for indirect bonding. They have used a thermal cured fluoride-releasing resin to secure the bracket onto the model. Curing consists of heating the model in an oven at 325 °c for 20 minutes.Transfer trays may be vacuum formed or may be a silicon based impression material. When etching is completed Maxicure sealants A & B are mixed. Since the setting time is only 60 seconds no time is to be wasted applying the sealant on the teeth and on the bracket bases and transferred to the mouth.

This maxicure sealant consists of hydrogen fluoride in its monomer. The tray is held firmly on the teeth for 2-3 minutes and then peeled away. The authors report that out of 920 brackets, 47 were lost (5 %) within 24 hrs presumably due to moisture contamination. This is consistent with the failure rates of 1-5% reported in the literature.

Bishara Olsen and Yon weld[72] (1997)

Authors found that bond strength of uncoated brackets was significantly higher than pre-coated brackets. This finding prompts the authors to summarize, conventional Transbond XT was the material of choice for direct bonding.

Hugo R. Armas, Lionel Sadowsky[26] (1998)

In their study compared a visible light cured bonding system and a chemically cured bonding system in vivo. The light cured composite used was (sequence) and the chemically cured composite (system 1+). Results showed that 62 brackets failed with failure rate of 11.3% for light cured resins and 12% for chemically cured resins. Data analysis with chi square test rated no statistically significant differences between the failure rates of light and chemically cured resins.

Anoop sondhi[4] (1999)

In his article has described a new system of indirect bonding. The technique is a variant of the Thomas technique (formation of a custom base). The transfer tray suggested by the author is a vacuum formed Biostar material on top of a 1mm bioplast material. Alternatively the authors also suggest using a putty transfer material to fabricate the transfer tray. The author describes a new resin (2 paste) designed specifically for indirect bonding. The new resin called Sondhi quick set has been designed having the following objectives in mind.

Increased viscosity with use of fine particle fumed silica to compensate for small imperfections in the formation of the custom base and to improve the fit on the enamel. The resin has a quick set time of 30secs significantly reducing the time taken to hold the bonding tray.

Koo, Chung and Vanarsdall[9] (1999)

In an in vitro study evaluated accuracy of bracket placement when comparing an indirect technique to a direct technique; 19 casts of a class 11 div 1 malocclusion were used in the study. The models were divided into 3 groups, 9 for direct bonding, 9 for indirect bonding and 1 for ideal bracket positioning. Faculty members of the department of orthodontics performed all the bonding procedures.

The bonding procedures were performed on mannequins that simulated clinical conditions. Once the bonding procedures were completed the teeth were sectioned individually. Care was taken not to damage the proximal regions. The sectioned teeth were then photographed with a 110mm-lens set at a magnification of 1: 1. The camera body was fitted with a jig containing a .019X.025 inch wire that engaged the bracket slot during the photographic procedure. This was for standardization of the photographic technique.

The photographs of all the teeth were traced on a tracing sheet and matched to one another and to the tracings from the model which contained the ideal bracket positioning.

Results showed that the indirect technique provided better bracket placement with regard to bracket height than direct bonding on the right upper second premolar and on the left lower central incisor. No statistically significant difference was found between these two techniques regarding angular errors or mesiodistal positioning of brackets.Neither technique yielded ideal bracket placement but the indirect technique was more accurate.

V. White[39] (1999)

Discovered a more rigid matrix material that still has enough elasticity and flexibility to permit easy removal after polymerization for a transfer tray. The surebonder DT-200 dual-temperature hot-glue gun uses a polymer of ethylene vinyl acetate.

The inexpensive Surebonder works with mini-glue sticks, whose flow is easier to control than that from the larger sticks. In effect, the gun is simply a heating element that liquefies the solid glue stick and then places the glue where it is needed. Although the gun has a dual temperature control, the higher temperature tends to produce bubbles within the molten matrix; the lower temperature is hot enough for indirect bonding. A small amount of Aleene's Tacky Glue, an inexpensive, water soluble adhesive was used to position the bracket to the cast instead of the custom base. Used the glue gun to form a molten matrix over the entire lingual and occlusal surfaces and part of the facial surfaces of the teeth and brackets. The brackets should be covered only partially, with care taken not to get hot glue in the Bracket Slots, this will make it much more difficult to remove the matrix and does not add much to its stiffness. After the glue cools and hardens, submerge the matrix and brackets in water for about 30 minutes to dissolve the Tacky Glue and separate the matrix and brackets from the cast. Soak the brackets and matrix for another hour or so; any remaining glue can then be easily brushed away with a soft-bristle toothbrush and cold water.

Mix two drops each of Excel A and B unfilled sealant, and paint this mixture over the teeth. The lower temperature slows the chemical curing of the composite and allows much more time for buttering the mixture over the bracket mesh with a toothpick. When the matrix is placed in the mouth, however, the sudden temperature change accelerates the setting time. Curing can be accelerated further by blowing warm air over the teeth and matrix. The transfer tray is removed using a hot water gargle. The hot-glue matrix offers a reliable and inexpensive method for transferring accurately placed brackets to the teeth.

Collins, J. [30](2000).

The adhesives used for indirect bonding setups have continued to be a problem, however. Bracket drift and mediocre bond strength are the major drawbacks of adhesives such as melted "Sugar Daddy" candy, wallpaper paste, school glues, alcohol-based adhesives, and light- and thermal-cured resins.

A new ultra-viscous, water-soluble, and tenacious bonding adhesive, JC Endirect, represents a major advance in indirect bracket placement. In a one-year field test conducted in the laboratory, this adhesive proved to have excellent viscosity, eliminating bracket drift on stone models. Bracket-to-cast bond strength was also consistently excellent. The adhesive demonstrated superior resistance to bracket displacement when vacuum-formed tray materials and polyvinyl siloxane trays were used.

Taeweon Kim[68] (2000)

Introduced a new indirect bonding method for lingual bonding, convertible resin core system. After placing the brackets on set up model the resin core is built up using a DuraLay material on each bracket individually.

Ryoon – ki Hong , Yong-Hwa Kim[61] (2000)

authors used a special bracket positioning device called the slot leveler they positioned the brackets (lingual) to the set up model using the Transbond XT light curing composite material.

Bulent Hayder[11] (2001)

Used indirect bonding technique to bond the fixed lingual retainer on 0.016 X 0.022 wire after adapting to the lingual surface the retainer is positioned in up model with a help of a composite and cured, a light body silicone based impression material with its activator is loaded in the 2ml syringe and applied over the retainer wire. After few minutes the putty material mixed with activator was used to cover the light body material and upto the incisal edges. The special tray after sandblast is positioned on the patients mouth and cured by regular bonding procedures.

This technique eliminates the difficulties encountered in direct bonding of the lingual fixed retainer which is challenging with upright mandibular incisors, salivary contamination, visibility and access. This technique is more precise than the regular system.

Larry white[38] (2001)

He used a water soluble Aleene tacky glue to position the brackets on the set up model and fabricated the special tray with a hot glue matrices. He compares the use of traditional enamel preparation of etch 20 seconds with 37% phosphoric acid, water rinse, air dry and by using ultra band lock compomer and curing light by caulk maxlite with conventional tip for 30 seconds for each tooth with that of Prompt-L-Pop application over the enamel, air dry and cured by power slot rip. Each tooth was cured for only 5 seconds.

So that means 20 minutes it took to cure the brackets in conventional way but it took only 7 minutes to cure Promt -L-Pop and power slot tips. He says the power slot tips are as effective as laser lights.

Brite Melsen and Piero Biaggini [42] (2002)

Ray Set is a bracket positioning device, This device is basically an upgrade of TARG system with a rotary base that provides precise control. It enables to bond the preadjusted edge wise brackets so the result reflect their prescribed values regardless of any variation in the tooth size, shape and surface.

H. Stuart McCrostie[22] (2003)

Compared the shear bond strength of orthodontic brackets bonded to teeth with either an indirect bonding technique and a new adhesive resin or a direct bonding technique and a light-activated adhesive – in vitro. Bonding of the bracket to the set up model remains the same except Methyl Ethyl Ketone (MEK) instead of ketone to remove the contaminants from the bracket base. Memosil "CD" is used as transfer tray of 2mm thick over the incisal, buccal and lingual sides. It is recommended to store the material in refrigerator to enhance the working time above 3 minutes. Since upper arch is slightly broad and less of salivary Contamination the tray need not be sectioned when compared to the lower.

In this study, no evidence suggests a difference in shear bond strength of orthodontic brackets bonded to tooth enamel, whether they are bonded with the direct or indirect technique.

P.G. Miles and R.J. Weyant [45] (2003)

Purpose of this study is to compare and evaluate the clinical failure rates of the chemically-cured composite bonding resins Sondhi Rapid Set (SD) and Maximum Cure (MC) when used in an indirect bonding technique. 40 patients were used in a split-mouth study design. Over a 5-months observation period, bond failure recorded and the data compared with a Wilcoxon sign-rank test.

SD adhesive had 9.9 % failure rate compared with MC group's 1.4 % failure rate. In the maxillary arch, 7 brackets from the SD quadrants came loose versus one for the MC. In the mandibular arch 29 brackets from the SD quadrants came loose compared with four from the MC quadrants. Both chemically-cured adhesives (SD and MC) examined in this study were suitable for the indirect bonding of brackets. SD adhesive had 7 times the number of breakages than the MC adhesive in both arches.

Klocke A, Shi J, Kahl-nieke B,Bismayer[7] (2003)

The aim of this in vitro investigation was to evaluate bond strength for a cyanoacrylate adhesive in combination with an indirect bonding technique. Eighty bovine permanent mandibular incisors divided in five groups of 20 teeth each were formed: (1) modified Thomas technique with thermally cured base composite (Therma Cure) and chemically cured sealant (Maximum Cure), (2) Thomas technique with thermally cured base composite (Therma Cure) and chemically cured sealant (Custom I Q), (3) Thomas technique with light-cured base composite (Transbond XT) and chemically cured sealant (Sondhi Rapid Set), (4) modified Thomas technique with chemically cured base adhesive (Phase II) and chemically cured sealant (Maximum Cure), and (5) control group directly bonded with light-cured adhesive (Transbond XT). Groups 1 and 2 showed significantly lower bond strengths than groups 3, 4, and 5 and a higher probability of bond failure. Both the original (group 2) and the modified (group 1) Thomas technique were able to achieve bond strengths comparable to the light-cured direct bonded control group.

Arndt Klocke, Jianmin Shi, Barbel Kahl-Nieke, Ulrich Bismayer[6] (2003).

The aim of this in vitro investigation was to evaluate bond strength for a custom base Indirect bonding technique using a hydrophilic primer on moisture tooth surfaces. Stainless steel brackets were bonded to 100 permanent bovine incisors using a light cured custom base composite adhesive, a chemically cured sealant and the hydrophilic primer Transbond MIP (3M-Unitek, Monrovia,Calif).

Five groups (A-E) of 20 teeth each were formed according to the time of contamination (before or after application of the primer) and the type of contaminated (distilled water or saliva): A, control group with no contamination; B, contamination with saliva before application of the primer; C, contamination with water before application of the primer; D, contamination with saliva before and after application of the primer; and E, contamination with water before and after application of the primer. The lowest mean bond strength was measured for group E and was significantly lower than for groups A, B, and C. Contamination after primer application resulted in an increased risk of bond failure at clinically relevant levels of stress.

Gia K. Yi[71] (2003)

Found no evidence suggesting a difference in shear bond strength of orthodontic bracket bonded to tooth enamel, whether they are bonded with the direct or indirect technique. Initially, bond failure rates for indirect bonding were higher (13.9%) when compared with direct bonding (2.5%). However, with modifications and improvements to the technique, the two systems now have similar bond strength and failure rates.

Peter G.Miles[45] (2003)

The aim of this study was to compare and evaluate the clinical failure rate between chemically cured composite bonding resin and the flowable light cure results showed that the failure rates were low for both adhesives, so either could be recommended for clinical use.

T. M. Hodge, A. A. Dhopatkar and W. P. Rock[25] (2004)

Their objective is to determine the accuracy of direct or indirect bracket placement. Before and after bond-up all brackets were photographed and measured from tracings to determine positional differences from the ideal. Bracket placement errors are greater in the maxillary arch than in the mandibular arch. There was no significant difference between the mean errors produced by the two methods of bracket placement.

Arndt Klocke[5] (2004)

Three base composite-sealant combinations were investigated composite, Custom I.Q sealant, Maximum cure sealant & transbond XT base composite, Sondhi rapid set sealant. Shear bond strength was for 3 different debonding time intervals. Time of transfer tray removal as recommended by the manufacturer & 30 minutes after bonding of the sealant after bonding of the sealant. Results showed, groups bonded with Maximum cure or sondhi rapid set sealants, no influence of debonding time on shear bond strength was found.

The custom I.Q sealant groups showed significantly lower bond strength when debonded at the recommended tray removal time. All base composite sealant combinations showed acceptable bond strength at 30minutes and 24hrs after bonding of the sealant.

Omur Polat[54] (2004)

For the in vitro study 60 extracted premolars were divided into 3 groups. In indirect group 1, therma cure laboratory resin / custom IQ resin for indirect bonding. For indirect group 2, Transbond XT / Sondhi rapid set. In the direct bonding group, the brackets were bonded to teeth directly using Transbond XT. The SBS were evaluated, and the comparasions were made.

Results showed there were no significant differences between indirect group 1 and direct group, but both yielded higher SBS values compared with indirect group 2. In vivo bond survival evaluation showed no differences between the two indirect bonding systems available.

Kim and Echarri[15] (2004)

They developed a double transfer tray system using a triad light cured acrylic for individual teeth, this gives more stability to the transfer tray than the green xantopren optosil material as second tray that covers all the acrylic individual tray. This is a flexible tray which can adapt easily while positioning and as well as removal.

Miyazawa K, Miwa H, Goto S, Kondo T[36] (2004)

Indirect bracket bonding methods that use individual tooth transfer trays offer several benefits compared to direct bonding techniques, as well as to indirect bonding systems that use transfer trays that include all of the teeth.

Precise and correct bracket position presents the most significant advantage of all indirect bonding procedures, but this new indirect bracket bonding technique also provides unprecedented enamel protection and caries prevention. In addition, it provides accuracy for the recommendation of any loose, broken, or lost brackets at their previous sites.

Michael Mayhew[44] (2005)

He describes the pros and cons of computer-aided indirect bonding, placement software. OrthoCAD software provides diagnostic model measurements, multiple diagnostic setups, allowing a quick different treatment approaches. OrthoCAD's bracket placement software shows the optimal bracket position and eventual alignment for each tooth.

G. Miklus, Jean-Paul Alibert, Shane N. White[28] (2005)

Brackets positioned on cast with adhesive resin paste. Ligature wire twisted around acrylic ring to make cutting system. Brackets covered with light bodied silicone material on cast cutting wire placed within light bodied silicone, directly above occlusal edges of brackets.

Light bodied tray and brackets covered with heavy bodied silicone material, Cutting wire brought around to anterior of tray and secured within heavy bodied silicone in incisor region clinical Procedure is similar to other indirect bonding techniques, by holding the Transfer tray supported in place until adhesive has set cutting wire pulled forward with acrylic ring while oral commissures are retracted and tray is held firmly at distal ends cutting wire almost completely removed. This cuts the special tray from posterior to anterior around the inciso-occlusal area of the special tray.

Scaler is used to lift away occlusal lingual portion of transfer tray. Buccal portion of tray gently peeled off bonded brackets. Excess adhesive removed with scaler .This procedure can be adapted to any labial or lingual indirect bonding technique that uses silicone or polyvinyl siloxane transfer trays. lt cannot be used to section thermoformed trays or other materials that are not easily sliced by a wire. This wire cutting method is simple, efficient, gentle & safe. It has the potential to reduce bond failures in most indirect technique as well as to improve patient comfort & practice efficiency.

Brandon James Linn[10] (2006)

Study was made to evaluate & compare the shear bond strength & the sites of bond failure for brackets bonded to teeth using two indirect bonding material protocols & a direct bonding technique. The study was concluded that strong correlation was found between bond strength & ARI (adhesive remnant index) scores within or between groups.

Jacob Daub et al[29] (2006)

A comparative study was done to evaluate the shear bond strength of one direct & two indirect bonding method/adhesives after thermocycling, it was concluded that no significant difference in SBS (shear bond strength) was found between teeth bonded directly & indirectly after thermocycling.

J. Spary, S.Thiyagarajah ,W. P. Rock[63] (2006)

Compared bond failure rates between direct and indirect techniques for bonding orthodontic brackets. A two-centre single blinded prospective randomized controlled clinical trial according to a split-mouth study design done in thirty-three subjects. The number and site of bracket failures between tooth was recorded over 1 year. Brackets were lost from 14 of the 553 teeth bonded, giving an mid failure rate of 2.5%. There were no significant differences in bond between direct and indirect bonding or in the tooth types of the failures.

Larry White[40] (2007)

He describes the advantage of accuracy and low cost, but additionally offers clinicians a method that allows them to bond teeth one by one, while placing individual pressure on each teeth. Individual transfer trays have been made in a variety of ways, but fabricating them from hot glue matrices has proven simple, quick, effective and inexpensive. Bracket placement occurs one tooth at a time, and total attention can be focused on that tooth to the exclusion of others but they are slower than bonding all of the teeth in one tray. The matrices are easily saved and can be re-cement broken brackets but. Firm pressure can be applied to the designated tooth without affecting adjacent bonding but the trays have more flexibility than a full-arch tray.

S. Thomas Deahl, N. Salome, J. P. Hatch, and John D. Rugh[64] (2007)

The purpose of this study was to compare bond-failure prevalences, number of appointments, and treatment times between direct and indirect bracket bonding for patients treated in private orthodontic practices. This practice-based study showed no difference in the failure rates and total treatment time between direct and indirect bonding.

Shpack N, Geron S, Floris I, Davidovitch M, Brosh T, Vardimon[66] (2007)

To examine the ultimate accuracy of bracket placement in labial vs lingual and direct vs indirect bonding techniques. Forty pretreatment dental cast of 20 subjects were selected. No Statistically Significant difference was found between labial and lingual systems for the same bonding technique. Labial and lingual systems have same accuracy. For both systems, indirect bonding significantly reduces absolute rotational and angulation errors.

Arturo Fortini, Fabio Giuntoli[8] (2007)

In this method modification Larry white method was used. A composite resin instead of the water soluble adhesive to bond the bracket to the working cast (custom base) helps in reducing the amount of excessive resin. They also used a flowable composite (tetric flow) as a bonding agent which allows the excess material around the bracket base to be easily removed with a help of ultrasonic scaler.

The recommendation of a thin layer of medium viscosity silicone impression material prevents the thermal glue from seeping into the undercuts of brackets. This layer facilitates removal of the transfer tray and reduce the risk of debonding. This extension of glue matrix to the buccal surface of the teeth increases the stiffness of the transfer tray and there by reduces the distortion and minimizes the mistake in bracket position.

David armstrong. Gang Shen, Peter Petocz and M.Ali Darendeliler[14] (2007)

The placement of orthodontic brackets is guided either by localizing the clinical crown (CC) or by measuring the distance from incisal edge (ME). The purpose of this study was to examine if there are any significant differences in the accuracy of bracket positioning between these direct and indirect techniques. Typhodont models were simulated with a Class I malocclusion with severe crowding. Bonded teeth were removed from the typodont and photographed for imaging analyis.

A significant vertical difference between the CC and ME method, with the ME method more accurate vertically but no significant differences for mesiodistal or for tip errors. Archwire bending or bracket repositioning is still necessary to compensate for the inaccuracies with both techniques.

B. Wendl , H. Droschl and P. Muchitsch[70] (2008)

In this study Aptus bonding device (ABD; Aptus, Papendrecht, The Netherlands), was used as the new transfer device for the indirect bonding. This is a horseshoe-shaped instrument with seven compressed air-driven pistons. Steel wires are bent from the pistons to the brackets, which are bonded onto the model, and are attached to the brackets using a silicone-based polymer. The ABD system is positioned between the upper and lower models by means of a bite registration device.

Next, the patient bites into the bite registration device attached to the ABD. The ABD is now activated with compressed air and the brackets are pressed onto the teeth with a continuous force by means of inward moving pistons. This pressure of 6 atmospheres is equivalent to the pressure of direct bonding and does not alter the bite position in the existing occlusal impressions. After polymerization of the adhesive, the wires are moved out of the way and the ABD is removed.

In this laboratory investigation, the ABD was found to provide an accurate transfer method for indirect bonding of brackets. This method enables the majority of commercially available bracket systems to be bonded and allows both dental arches to be bonded in one stage.

Akhter Husain, Tariq Ansari, Rohan Mascarenhas, Sandeep Shetty[27] (2009)

In addition to being a highly technique-sensitive procedure, indirect bonding has two significant disadvantages. First, the occlusogingival insertion of a transfer tray causes the adhesive-coated bracket to scrape along the long axis of each tooth, resulting in more uneven distribution of the adhesive compared with the perpendicular placement of direct bonding. Second, when opaque transfer trays are used, the putty covering the palatal surfaces prevents light-curing from the palatal or occlusal side.

A modified acrylic platform in which the putty is placed only on the labial and buccal surfaces, providing easier access for light-curing. Two L-shaped handles are squeezed together to flare out the transfer tray, allowing placement of the brackets at right angles to the tooth surfaces.

Larry White[41] (2009)

This article explains thermal glue indirect-bonding method that can be used to expedite bonding appointments and make them more pleasant for patients and clinicians alike.

Michael C. Alpern, Carolyn Primus,Ada Hinda Alpern[1] (2009)

The AccuBond* system uses two adhesives to construct a custom base for each bracket. The first, ultrafluid material creates an adhesive foundation that interlocks with the retentive elements in the bracket base. Another polymer covers this completely filled foundation to form the custom base.

The AccuBond tray material is not an acrylic, silicone, or polyvinyl siloxane. Its high elasticity enables the tray to conform tightly to the shape of the dental model, and its flexibility allows easy intraoral removal. The thinness of the material facilitates light-curing. Most important, the material does not warp after forming, nor does it distort after being removed from the dental cast.

The blue inner-tray material covers the bracket undercuts, so that the brackets are held in the transfer tray without being embedded in the outer tray material. The blue inner liner does not interfere with light curing. For bonding to the teeth, a fluoride-releasing adhesive was developed with a film thickness of less than 100 microns.

Mauro Cozzani, Anna Menini, Andrea Bertelli[13] (2010)

In this technique two transfer trays for each cast in a positive-pressure thermoformer was fabricated. Make the first tray out of a 0.5mm elastic material (Copyplast Soft) that holds the brackets securely yet is flexible and trim this tray halfway up the clinical crown on the lingual side and to the gingival edge of the bracket base on the buccal side. Use a harder material (0.6mm Duran Hard) to form a second tray over the first.

This rigid tray will hold the brackets in position. Remove both trays from the cast with the brackets attached, and carefully separate the trays. Trim the rigid tray on the lingual to the gingival margin and on the buccal to the height of the bracket slots, thus making it easier to remove from the mouth. Use the cast to mold etching masks from a .5mm elastic material (Copyplast Soft). With a warmed #11 scalpel, contour each mask about 2mm apically from the cervical margin (partly covering the gingiva) and cut holes corresponding to the outlines of the bracket bases.

One of the most significant advantages of this technique is the use of etching masks limits the etched enamel surfaces to the required areas. These masks can be reused, even for single teeth, in case of accidental detachment. Other advantages of the method described here include the use of transparent transfer trays for homogeneous light-curing. The thinner trays are easier to insert and can be trimmed with a scalpel, thus avoiding the need for rotating instruments that can heat and deform the material.

Mark Joiner[34] (2010)

Described a modification of Kalange's technique to improve the accuracy and repeatability during bracket placement. The tools of this bracket placement technique are simple consisting of 2 bow compasses (model 508, Alvin, Boston, Mass) and 3 mechanical pencils (Draft/Matic, Alvin). The author concluded that this bracket placement technique has eliminated all wire bending or bracket repositioning problems with inaccurate bracket placement.

MATERIALS AND METHODS

The materials and methodology used in this study are described below.

MATERIALS

1. Transfer tray materials:

   a. Polyvinyl siloxane impression material (Silagum; DMG, Germany) (fig. 3)

   b. Thermal glue polymer (Polymer of ethylene vinyl acetate) (fig. 4)

2. Brackets:

Direct bond stainless steel pre adjusted fully programmed edgewise, Roth 0.022 slot brackets with metallic foil-mesh backing (Mini-Ovation; Dentsply, GAC) were used on all patients.

3. Adhesive: (fig. 2)

   a. Sondhi™ Rapid-Set (3M unitek)

   b. Custom IQ (Reliance orthodontics)

Transbond TM XT (Composite resin), a light-cured composite paste was used. (3M Unitek, Monrovia, Calif).

4. Light Cure Kit:

3M Ortholux ™ XT curing light, visible light range – 400 to 500 nm, light output power – 450 mw/cm^2.

5. Other materials and armamentarium used were: (fig. 1)

- Mouth mirror, Probe, Bracket Holder, Tweezer, MBT Bracket Positioning gauge, Marking pencil, BP blade.
- Thermal glue dispensing gun, Glue gun stick.
- Dispensing wells, Applicator tips.
- Cold mould seal (DPI)
- Compressed air/water facility with a 3-way syringe.
- Micro motor hand-piece with polishing cups and slurry of pumice.
- 37 % orthophosphoric acid gel.
- Suction unit.
- 19 gauge stainless steel round wire.
- 1 inch length rectangular straight wire (19x25 SS), Digital vernier caliper (Gros; General,USA) and cyanoacrylate adhesive. (fig. 5)

METHODOLOGY

Twenty patients who came for orthodontic treatment to the Dept. of Orthodontics, Ragas Dental College & Hospital, Chennai requiring fixed appliance therapy were included in the study. All patients participated were informed in detail about the study and were made to sign an informed consent form.

- All type of malocclusions were included.
- Teeth with crowns, bridges, veneers, restorations or with enamel hypoplasia anterior to the first permanent molars were not included.
- Severely rotated and blocked out teeth from the arch which needed bonded lingual button attachments were not included

Twenty patients were randomly divided into four groups: Group A, Group B, Group C & Group D.

- Group A consisted of twenty patients with Polyvinyl siloxane impression material transfer tray bonded with Sondhi™ Rapid-Set (3M unitek) on one quadrant;
- Group B consisted of twenty patients with Polyvinyl siloxane impression material transfer tray bonded with custom IQ (Reliance orthodontics) on one quadrant,

- Group C consisted of twenty patients with thermal glue material transfer tray bonded with Sondhi™ Rapid-Set (3M unitek) on one quadrant and

- Group D consisted of twenty patients with thermal glue material transfer tray bonded with custom IQ (Reliance orthodontics) on one quadrant.

The randomization was done using a flip of a coin. A split – mouth design was used. For each patient one quadrant was bonded with one of the four groups so that they were distributed equally for all the patients. All the teeth were pumiced and rinsed, and extra care was taken to remove any calculus.

A total of 326 teeth were bonded; out of which 80 teeth were bonded using Polyvinyl siloxane / Sondhi™ Rapid-Set (3M unitek) - (group A), 82 teeth were bonded using Polyvinyl siloxane / Custom IQ (Reliance) -(group B), 82 teeth were bonded using Thermal Glue / Sondhi™ Rapid-Set (3M unitek) - (group C) and 82 teeth were bonded using Thermal Glue / Custom IQ (Reliance) - (group D).

Indirect bonding transfer tray fabrication:

An accurate alginate impression of the arches were made and the models were poured without voids or air bubbles.

When the models were absolutely dry, the long axis of the teeth were marked and MBT bracket positioning gauge was used to mark the vertical height for individual teeth (parallelism was maintaining to the labial surface of the teeth while marking with the gauge). (fig. 6)

A thin coat of separating medium (cold mould seal) was diluted with water (1:2), applied evenly in thin coats and allowed to dry.

Transbond ^{TM} XT (3M Unitek) was evenly spread over the bracket mesh and placed onto the dental model with respect to the long axis and vertical height markings. (fig. 7,8) The excess flash was removed and each bracket was cured for 10 sec's on each side (mesial, distal, occlusal and gingival) to form the custom base.

Direct measurements were taken with the brackets bonded to the models using a digital vernier caliper. (fig. 9)

Transfer trays were constructed using Polyvinyl Siloxane impression material (Silagum; DMG, Germany) or Thermal Glue polymer (ethylene vinyl acetate). In this study the hot-glue gun was used along with polymer of ethylene vinyl acetate available in mini sticks (FDA-approved, non-toxic and non-carcinogenic). In effect, the gun used was simply a heating element that liquefies the solid glue stick. The liquefied hot glue was placed where it was needed and was allowed to set by manipulating with wet fingers.

The transfer tray for all the groups were extended starting from the buccal surface covering upto the gingival wings of the bracket (not below or under the wings), then over the occlusal surface and finally extended to the gingival margin on the palatal/lingual side. The transfer tray was also extended onto the extraction space. (fig.12)

Transfer tray modifications: (fig.12a & 12b)

In the Polyvinyl siloxane trays cuts were placed along the occlusal aspect of the material for about half of its thickness. This was done to reduce the stiffness of tray and ease during removal. In the Thermal glue transfer tray a 19 gauge round stainless steel wire was contoured and placed over the occlusal surface for additional stability in both upper and lower arches.

Transfer trays were constructed according to the quadrants assigned for that group. Once the tray was completely set, the excess tray material was cut and finally the tray was removed without any distortion.

Each of the custom base was cured for 10 sec and gently sandblasted with a microetching unit (50 µm of aluminum oxide) for 5 sec to remove the separating medium.

Care was taken to form a thin, uniform layer of custom base without any voids. The transfer trays were gently rinsed with water and made ready for bonding.

Indirect bonding with Sondhi™ Rapid-Set (3M unitek) & Custom IQ (Reliance orthodontics):

The arches for the indirect bonding were subjected to pumice prophylaxis with a prophy cup and pumice paste. (fig.13)

All the teeth to be bonded were etched with 37% orthophosphoric acid gel for the duration of 30 sec and rinsed thoroughly. The teeth were dried with oil and moisture free source of compressed air. (fig.14)

Manufacturer's instructions were followed all through the bonding procedure. The bonding arches were properly isolated and maintained dry till the end of the bonding procedure. Resin A (3M unitek) / Part A (Reliance orthodontics) was dispensed onto one side of the mixing well and Resin B (3M unitek) / Part B(Reliance orthodontics) onto the other side of the mixing well. A thin coat of Resin A / Part A was applied onto each tooth surface were the bracket was to be placed. Care was taken to remove any excess material which can lead to flash. A thin coat of Resin B / Part B was applied onto each of the custom bases. (fig.15,16)

The trays were then seated and held firmly in place for 30 seconds (Sondhi™ Rapid-Set/Custom IQ) with a gentle and uniform pressure applied over the occlusal and buccal surfaces of the teeth to be bonded.

The tray was removed after two minutes using a hand scaler to peel the tray from the palatal to buccal side. During polyvinyl siloxane tray removal the occlusal cut was deepened completely using a BP blade to split the tray into buccal and palatal halves. Thermal glue polymer tray removal was done with warm water given to the patient to rinse which made the tray soft, flexible and easy to remove. Extreme care was taken not to debond the brackets during removal.

After tray removal the excess resin was scaled from around the brackets and from the interproximal contacts. A dental floss was inserted to check that all contacts were open.

ASSESSMENT OF BRACKET PLACEMENT ACCURACY

Linear measurements were taken to determine the accuracy of bracket placement between the dental model and the patient using indirect bonding.

A digital vernier caliper with two 19 x 25 Stainless steel rectangular straight wires attached using cyanoacrylate adhesive to the outside jaws of caliper were used for measurement on the model after bracket placement and for the intra oral measurements after tray removal. Care was taken such that the attached 19x25 stainless steel wires were approximated to each other when the caliper reading was zero and when the outside jaws were approximated.

Vertical and horizontal measurements:

Vertical measurements were made from the first initial contact over the incisal/buccal cusp tip to the flat incisal side of the bracket base. (fig.10,19) (i.e., the inner surface of the 19x25 stainless steel wire attached to the stationary outer jaw touches the incisal surface whereas the outer surface of the 19x25 stainless steel wire attached to the movable outer jaw touch the incisal surface of the bracket base).

Horizontal measurements were made from the first initial contact over the mesial side of all the teeth bonded and to the flat mesial side of the bracket base. (fig.11,20) (i.e., the inner surface of the 19x25 stainless steel wire attached to the stationary outer jaw touches the mesial surface of the teeth whereas the outer surface of the 19x25 stainless steel wire attached to the movable outer jaw touch the mesial surface of the bracket base). For mesially rotated teeth the measurements were made on the distal side.

Parallelism was maintained while recording the measurement. All the measurements were made thrice and a mean for the three measurements were recorded for intra-observer variability.

Model measurements :

After the brackets were placed and cured onto the dental model the accuracy of bracket placement were measured.

Intra-oral measurements :

These measurements were taken immediately after the bonding procedure before initial wire placement.

The initial archwire placed was 0.14 Nickel-Titanium wire, followed by various combinations of round and rectangular Nickel-Titanium and Stainless Steel wires as treatment progressed. Recording of failed brackets involved only first time failures during the tray removal, initial arch wire placement and thereafter consecutive three appointments (30, 60 and 90 days).

The statistical analysis for the study was done with SPSS Version. 16.0 at 5% level of significance, the analysis done were

1. Chi – square test to compare the overall bond failure rates between the groups.
2. Chi – square test to compare the bond failure rate between the groups at different time duration.
3. The students – t test between the groups to compare the bracket placement accuracy between the groups.
4. The students – t test to compare the bracket placement accuracy between the quadrants within the group.

Figure 1 : Bonding armamentarium

Figure 2 : Indirect bonding resins

Figure 3 : Polyvinyl siloxane impression material (Silagum; DMG, Germany)

Figure 4 : Thermal glue dispensing gun

Figure 5 : Digital vernier caliper attached with 19x25 ss straight wire.

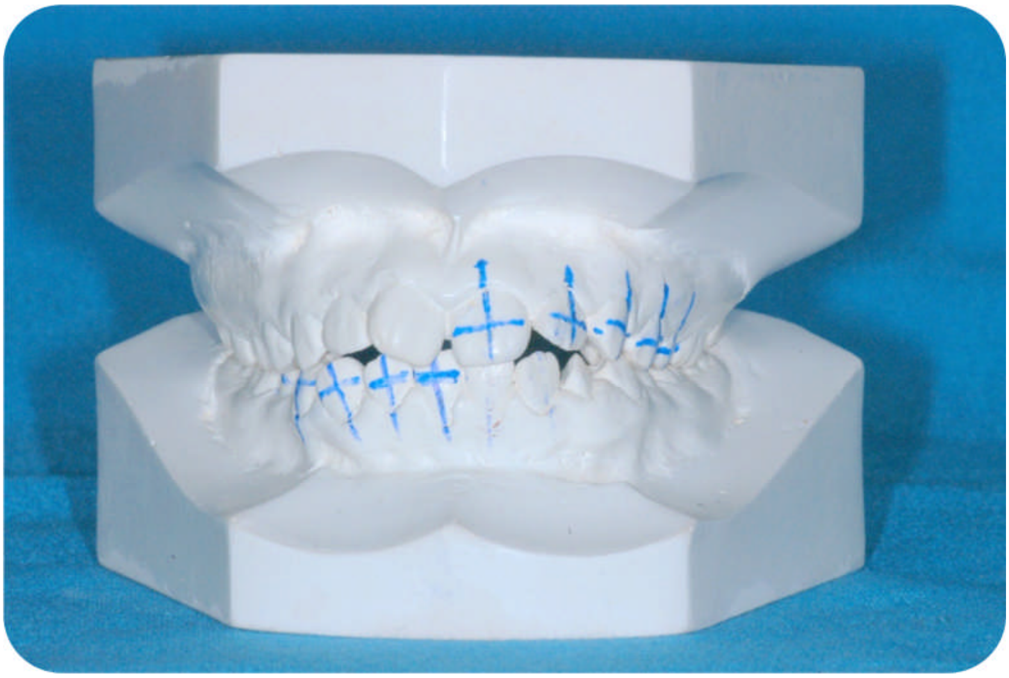


Figure 6 : Working model with long axis and vertical height marked

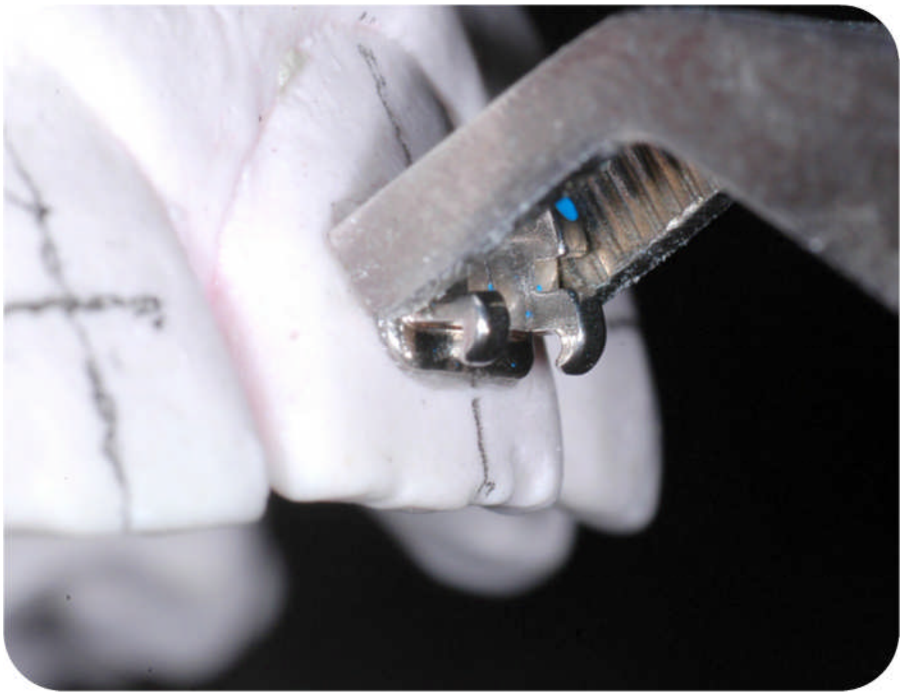


Figure 7 : Bracket placement with light cure adhesive

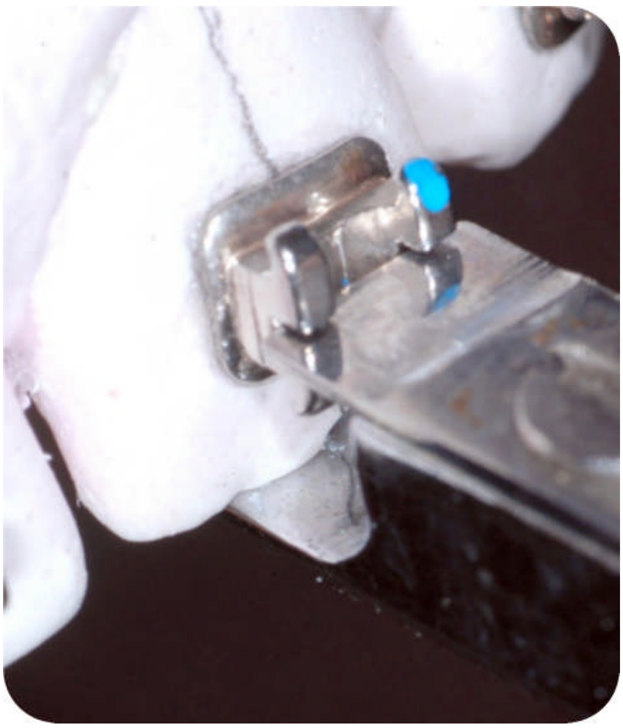


Figure 8 : Bracket positioning with MBT bracket positioning gauge.

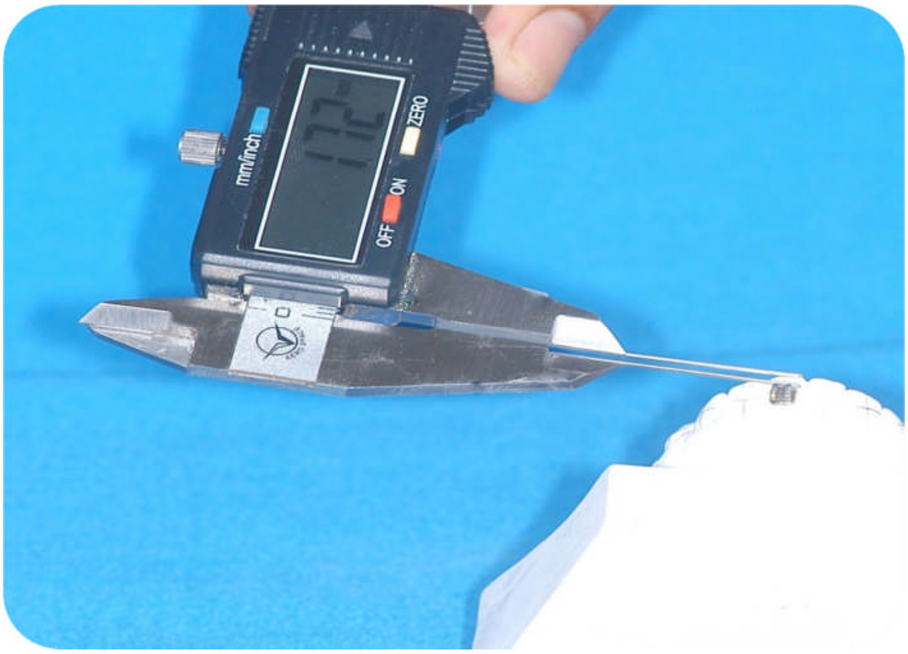


Figure 9 : Bracket accuracy measurement with modified digital caliper

Figure 10 : vertical measurement on the model

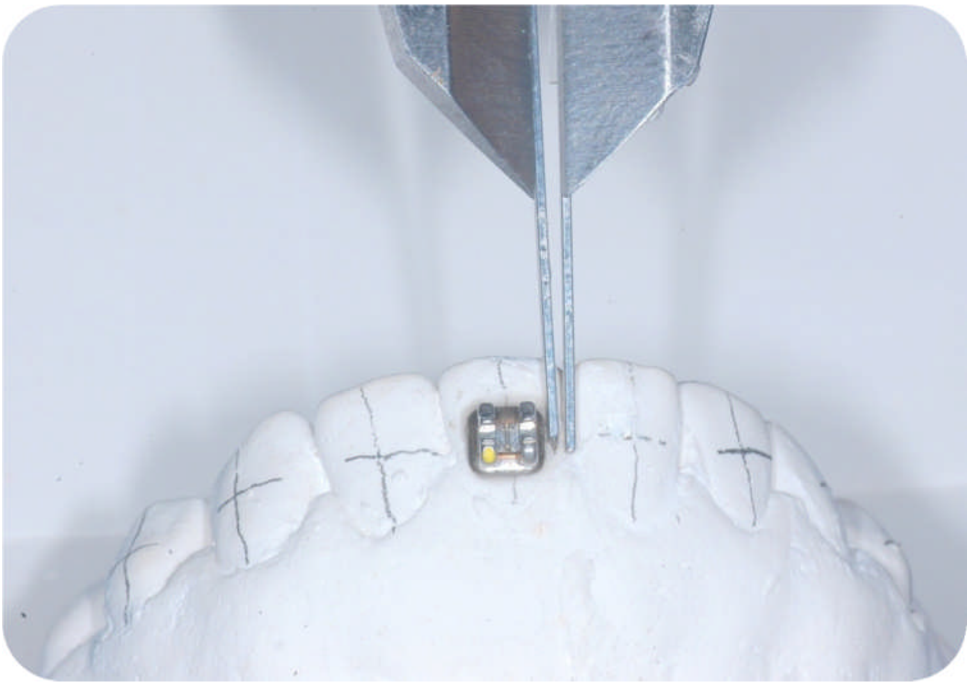


Figure 11 : Horizontal measurement on the model

Figure 12 : Tray fabrication - Polyvinyl siloxane impression material (Silagum; DMG, Germany) & Thermal glue material (polymer of ethylene vinyl acetate)

Figure 12 a: Tray fabrication - Thermal glue material reinforced with 19 gauge ss wire occlusally.

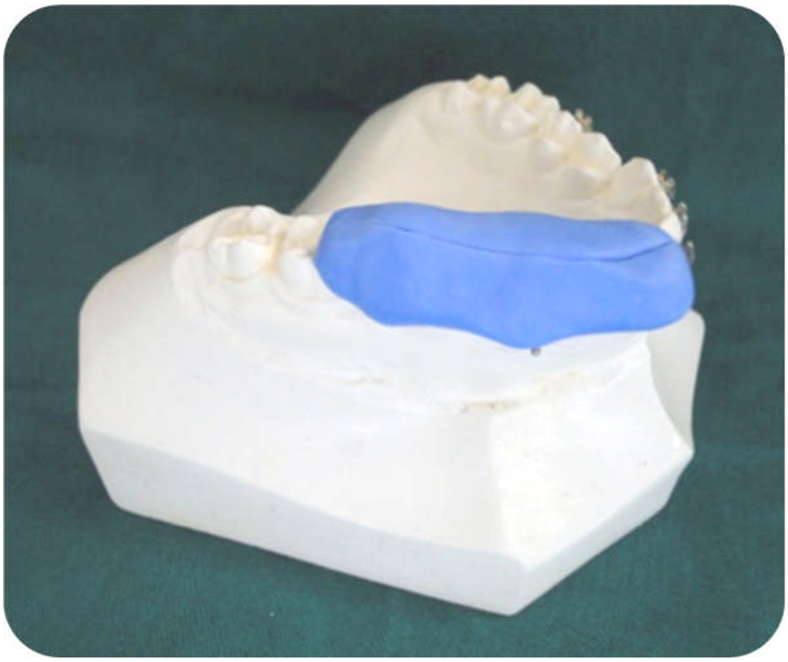


Figure 12 b: Tray fabrication – Polyvinyl siloxane material with occlusal cut

Figure 13 : pumice prophylaxis

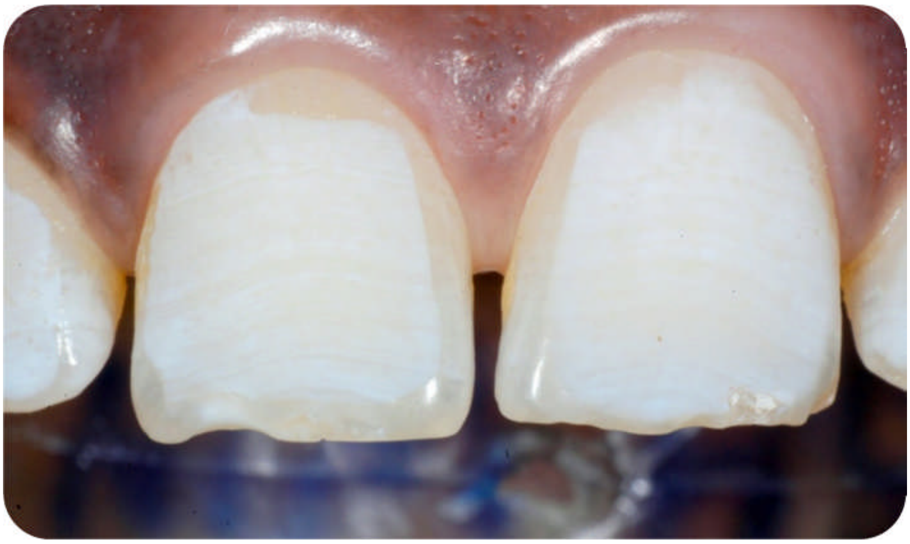


Figure 14 : After acid etch with 37% orthophosphoric acid

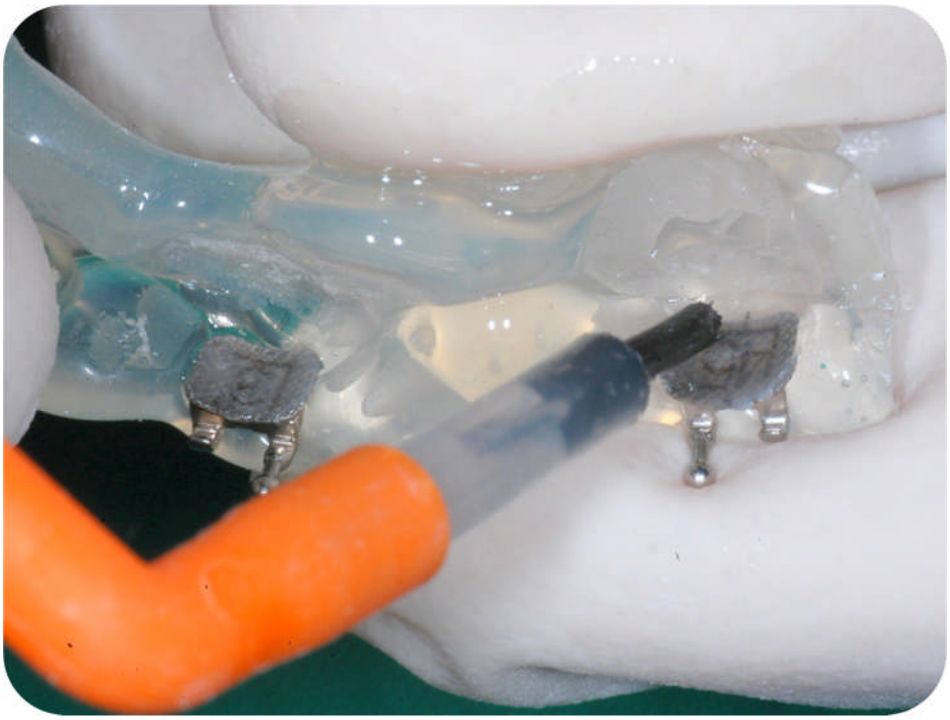


Figure 15 : Application of Resin B (3M unitek) / Part B (reliance orthodontics) to the bracket base

Figure 16 : Application of Resin A (3M unitek) / Part A (reliance orthodontics) to the bracket base

Figure 17 : Tray placement

Figure 18 : After tray removal

Figure 19 : vertical measurement – intraoral

Figure 20 : horizontal measurement - intraoral

RESULTS

In this study a total of 326 brackets were bonded to evaluate the clinical bond failure rate.

CLINICAL BOND FAILURE RATE

The parameter assessed were,

1. **Assessment of clinical bond failure of brackets at different time durations.**
2. **Assessment of clinical brackets bond failure between two different bonding techniques and materials.**
3. **To determine the teeth with most clinical bond failure rate.**

Group Vs Bond Failure at Tray Removal (TABLE I)

Polyvinyl Siloxane / Sondhi Rapid Set (Group A) had maximum bond failure rate of 12.7% (9 out of 80) during initial tray removal within the groups followed by 6.5% (5 out of 82) for Polyvinyl Siloxane/Custom IQ (Group B), 6.5% (5 out of 82) for Thermal Glue / Sondhi Rapid Set (Group C) and 5.1% (5 out of 82) for Thermal Glue / Custom IQ (Group D). The overall bond failure rate for all the groups was 7.6 % (23 out of 326). With Chi – square test showing no statistical significance differences in bond failure for all the groups during initial tray removal.

Group Vs Bond Failure at Initial Arch wire placement (TABLE II)

Polyvinyl Siloxane / Sondhi Rapid Set (Group A) showed the highest bond failure rate of 8.1% (5 out of 71) during the initial arch wire placement followed by 5.4% (4 out of 78) for Thermal Glue / Custom IQ (Group D), 2.8% (2 out of 77) for Polyvinyl Siloxane/Custom IQ (Group B) and 1.4% (1 out of 77) for Thermal Glue / Sondhi Rapid Set (Group D). The overall bond failure rate for all the groups was 4.3% (12 out of 303). Chi – square test showed no statistical significance differences in bond failure for all the groups during arch wire placement.

Group Vs Bond Failure at 30 days (TABLE III)

Polyvinyl Siloxane / Sondhi Rapid Set (Group A) showed the highest bond failure rate of 5.3% (3 out of 66) at 30 days followed by 2.8% (2 out of 76) for Thermal Glue / Sondhi Rapid Set (Group C) , 1.4%(1 out of 74) for Thermal Glue / Custom IQ (Group D) and 0% (0 out of 75) for Polyvinyl Siloxane/Custom IQ (Group B). The overall bond failure rate for all the groups at 30 days was 2.2% (6 out of 291) . Chi – square test showed no statistical significance differences in bond failure for all the groups during arch wire placement.

Group Vs Bond Failure at 60 days (TABLE IV)

Polyvinyl Siloxane / Sondhi Rapid Set (Group A) showed the highest bond failure rate of 1.9% (1 out of 63) at 60 days followed by 1.4% (1 out of 75) for Polyvinyl Siloxane/Custom IQ (Group B), 1.4% (1 out of 74) for

Thermal Glue / Sondhi Rapid Set (Group C) and no bond failure in Thermal Glue / Custom IQ (Group D). The overall bond failure rate for all the groups was very less 1.1% (3 out of 285) . Chi – square test showed no statistical significance differences in bond failure for all the groups during arch wire placement.

Group Vs Bond Failure at 90 days (TABLE V)

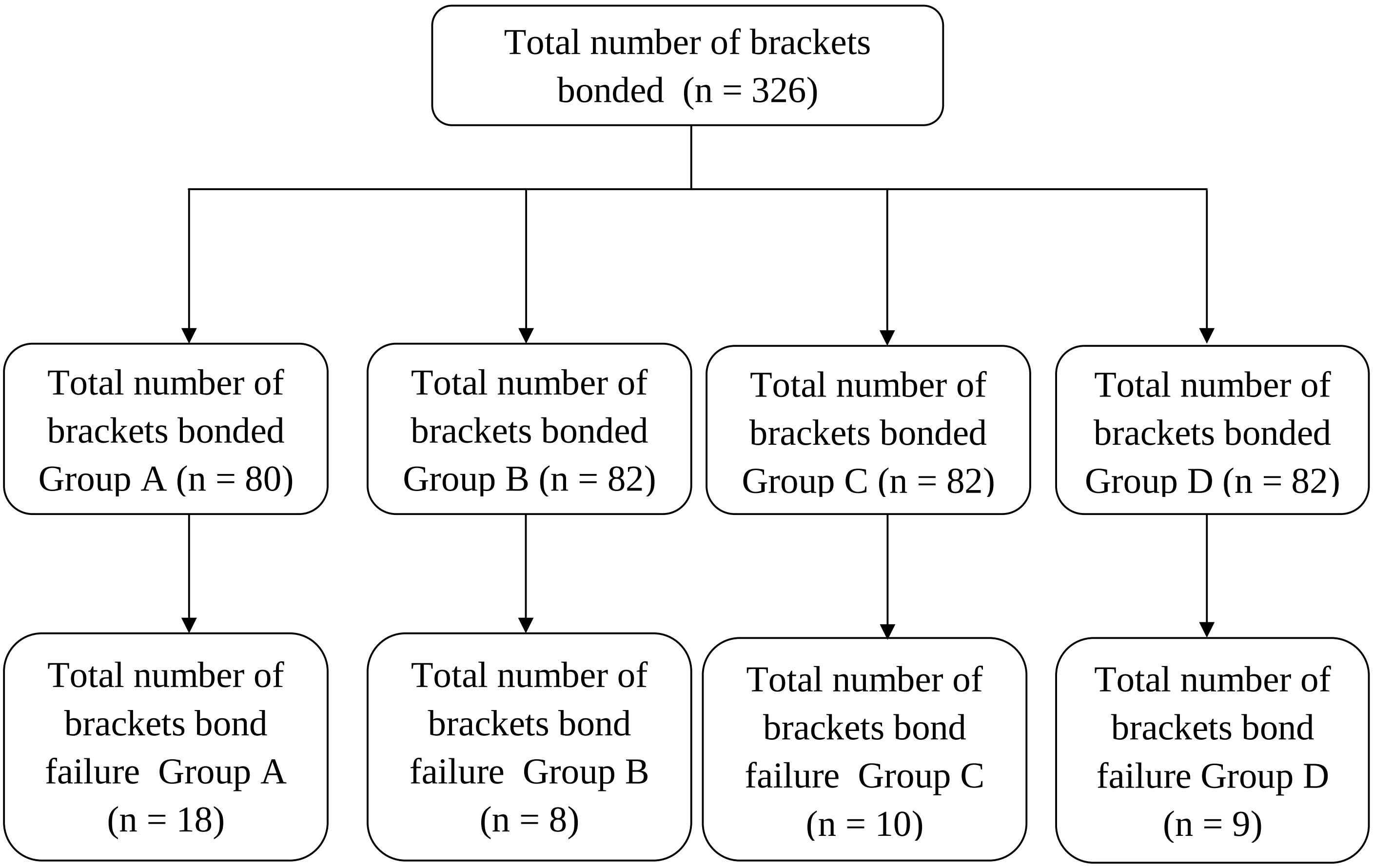
Thermal Glue / Sondhi Rapid Set (Group C) showed the highest bond failure rate of 1.5% (1 out of 73) at 90 days with no bond failure in the other groups. The overall bond failure rate for all the groups was very less 0.4% (1 out of 282). Chi – square test showed no statistical significance differences in bond failure for all the groups during arch wire placement.

Group Vs Bond Failure (TABLE VI)

Polyvinyl Siloxane / Sondhi Rapid Set (Group A) showed the maximum bond failure rate of 25.4% (18 out of 80) at all point of time followed by 13% (10 out of 82) for Thermal Glue / Sondhi Rapid Set (Group C) and 9% (9 out of 82) for Thermal Glue/Custom IQ (Group D). Polyvinyl Siloxane/Custom IQ (Group B) showed the least bond failure rate with 8% (8 out of 82). Chi – square test showed statistical significance differences $p = 0.040$ ($p < 0.05$) in bond failure for all the groups at all point of time.

In the study results showed increased bond failure rate when indirect bonding was done with Polyvinyl Siloxane/ Sondhi Rapid Set. In the number bracket failure between individual tooth, lower second premolars had maximum failure rate (22.2%) (10 out of 45) followed by lower central incisors (17.7%) (8 out of 45).

CONSORT DIAGRAM FOR BOND FAILURE



Total number of bracket bond failures = 45

Maximum number of bond failure Group **A** = 18

(Polyvinyl siloxane / Sondhi™ Rapid-Set)

Minimum number of bond failure Group **B** = 8

(Polyvinyl siloxane / custom IQ - Reliance orthodontics)

BRACKET PLACEMENT ACCURACY

In this study a total of 303 brackets were evaluate for accuracy of bracket placement when compared to 326 brackets for clinical bond failure. This was because of 18 brackets failed during initial tray removal which cannot be measured.

Parameters assessed were,

1. **Comparison of bracket placement accuracy within the groups.**
2. **Assessment of overall accuracy of bracket placement.**
3. **Relative accuracy of bracket placement within the quadrants.**

Group A - Polyvinyl Siloxane / Sondhi™ Rapid-Set (TABLE VIII)

Vertical measurement

The vertical measurements between the model and the intraoral values in Group A showed a mean difference of 2.03 mm. students paired T- test showed a statistically significant difference with P = 0.045 ($P < 0.05$) indicating the vertical bracket placement error in this Group.

No statistically significant differences were seen in the accuracy of vertical bracket placement in all the quadrants. **(TABLE XII)**

Horizontal measurement

The horizontal measurements between the model and the intraoral values in Group A showed a mean difference of 2.27 mm. Students paired T-test showed a statistically significant difference P = 0.026 (P <0.05) indicating the horizontal bracket placement inaccuracy in Group A.

No statistically significant differences were seen in the accuracy of horizontal bracket placement in all the quadrants. **(TABLE XII)**

Group B - Polyvinyl siloxane impression / Custom IQ (Reliance orthodontics) (TABLE IX)

Vertical measurement

The vertical measurements between the model and the intraoral values in Group B showed a mean difference of 3.5 mm. Students paired T- test showed a statistically significant difference P = 0.001 (P <0.05) indicating the vertical bracket placement error in Group B.

Statistically significant differences were seen in the accuracy of vertical bracket placement in the 1^{st} and 4^{th} quadrants indicating a vertical bracket placement error in these quadrants. **(TABLE XIII)**

Horizontal measurement

The horizontal measurements between the model and the intraoral values in Group B showed a mean difference of 0.92 mm. students paired T-test showed no statistically significant difference indicating the accuracy in horizontal bracket placement in Group B.

4th quadrants showed a statistically significant differences in the horizontal measurement indicating inaccuracy of bracket placement in Group B. **(TABLE XIII)**

Group C - Thermal glue / Sondhi™ Rapid-Set (3M unitek) (TABLE X)

Vertical measurement

The vertical measurements between the model and the intraoral values in Group C showed a mean difference of 0.5 mm. Students paired T- test showed a no statistically significant difference indicating the highest vertical bracket placement accuracy in Group C.

Statistically significant differences were seen in the accuracy of vertical bracket placement in the 3rd and 4th quadrants indicating a vertical bracket placement inaccuracy in these quadrants. **(TABLE XIV)**

Horizontal measurement

The horizontal measurements between the model and the intraoral values in Group C showed a mean difference of 1.71mm. Students paired T-test showed no statistically significant difference indicating the accuracy in horizontal bracket placement in Group C.

No statistically significant differences in the horizontal measurement were noted indicating accuracy of bracket placement in Group C for all the quadrants. **(TABLE XIV)**

Group D - Thermal glue / Custom IQ (Reliance orthodontics)

(TABLE XI)

Vertical measurement

The vertical measurements between the model and the intraoral values in Group D showed a mean difference of 2.14 mm. Statistically significant difference with P = 0.035 ($P < 0.05$) indicated vertical bracket placement inaccuracy in Group D.

Statistically significant differences were seen in the accuracy of vertical bracket placement in the 4th quadrants indicating a vertical bracket placement inaccuracy in these quadrants. **(TABLE XV)**

Horizontal measurement

The horizontal measurements between the model and the intraoral values in Group D showed a mean difference of 1.47mm. Students paired T-test showed no statistically significant difference indicating the accuracy in horizontal bracket placement in Group D.

No statistically significant differences in the horizontal measurement were noted indicating accuracy of bracket placement in Group D for all the quadrants. **(TABLE XV)**

Accuracy of bracket placement for the groups (TABLE VII)

Vertical measurement

The vertical bracket placement measurement had a mean difference of 0.87 mm. Students T- test with P = 0.381 showed no statistically significant difference in the vertical bracket placement for the overall groups.

Horizontal measurement

The horizontal measurements between the model and the intraoral values showed a mean difference of 2.38 mm. Students paired T- test showed statistically significant difference P = 0.017 (P < 0.05) indicating the inaccuracy in horizontal bracket placement for overall groups.

Cross tables for Bond failure

Table I

Group Vs Bond Failure at Tray Removal

	Bond Failure				Total		Chi-square value	P - Value
	Yes		No					
	n	%	n	%	n	%		
Group A	9	12.7	71	88.7	80	100	3.556	0.314
Group B	5	6.5	77	93.9	82	100		
Group C	5	6.5	77	93.9	82	100		
Group D	4	5.1	78	95.1	82	100		
Total	23	7.6	303	92.9	326	100		

Table II

Group Vs Bond Failure at Initial Arch wire placement

	Bond Failure				Total		Chi-square value	P - Value
	Yes		No					
	n	%	n	%	n	%		
Group A	5	8.1	66	92.9	71	100	4.256	0.235
Group B	2	2.8	75	97.4	77	100		
Group C	1	1.4	76	98.7	77	100		
Group D	4	5.4	74	94.8	78	100		
Total	12	4.3	291	96	303	100		

Table III

Group Vs Bond Failure at 30 days

	Bond Failure				**Total**		**Chi-square value**	**P - Value**
	Yes		**No**					
	n	**%**	**n**	**%**	**n**	**%**		
Group A	3	5.3	63	95.4	66	100	4.304	0.231
Group B	0	0	75	100.0	75	100		
Group C	2	2.8	74	97.3	76	100		
Group D	1	1.4	73	98.6	74	100		
Total	6	2.2	285	97.9	291	100		

Table IV

Group Vs Bond Failure at 60 days

	Bond Failure				**Total**		**Chi-square value**	**P - Value**
	Yes		**No**					
	n	**%**	n	%	**n**	**%**		
Group A	1	1.9	62	98.4	63	100	1.144	0.767
Group B	1	1.4	74	98.6	75	100		
Group C	1	1.4	73	98.6	74	100		
Group D	0	0.0	73	100.0	73	100		
Total	3	1.1	282	98.9	285	100		

Table V

Group Vs Bond Failure at 90 days

	Bond Failure				**Total**		**Chi-square value**	**p-value**
	Yes		**N o**					
	n	%	n	%	n	%		
Group A	0	0.0	62	100.0	62	100	2.820	0.420
Group B	0	0.0	74	100.0	74	100		
Group C	1	1.5	72	98.6	73	100		
Group D	0	0.0	73	100.0	73	100		
Total	1	0.4	281	99.6	282	100		

Table VI

Group Vs Bond Failure Cross tabulation

Groups	**Bond Failure**				**Total**		**Chi-square value**	**p-value**
	Yes		**No**					
	n	%	n	%	N	%		
Group A	18	25.4	62	77.5	80	100.0	8.292	0.040
Group B	8	10.4	74	90.2	82	100.0		
Group C	10	13.0	72	87.8	82	100.0		
Group D	9	11.5	73	89	82	100.0		
Total	45	14.9	281	86.1	326	100.0		

Cross tables for Bracket placement

Paired T-Test

Table VII

Paired Samples t-test

	Mean	N	Std. Dev.	t-value	p-value
Model value - Vertical	1.851	303	0.5701	0.877	0.381
Patient value - Vertical	1.831	303	0.6285		
Model value - Horizontal	1.329	303	0.5144	2.389	0.017
Patient value - Horizontal	1.381	303	0.5342		

Paired T-Test for groups

Table VIII

Paired Samples t-test

Group		Mean	N	Std. Dev.	t-value	p-value
Group A	Model value - Vertical	1.899	71	0.4194	2.037	0.045
	Patient value - Vertical	1.979	71	0.4680		
	Model value - Horizontal	1.300	71	0.4793	2.278	0.026
	Patient value - Horizontal	1.396	71	0.4475		

Table IX

Group		Mean	N	Std. Dev.	t-value	p-value
Group B	Model value - Vertical	1.803	77	0.5982	3.523	0.001
	Patient value - Vertical	1.704	77	0.6251		
	Model value - Horizontal	1.475	77	0.5510	0.923	0.359
	Patient value - Horizontal	1.441	77	0.6053		

Table X

Group		Mean	N	Std. Dev.	t-value	p-value
Group C	Model value - Vertical	2.001	77	0.6540	0.581	0.563
	Patient value - Vertical	2.038	77	0.7034		
	Model value - Horizontal	1.264	77	0.5407	1.717	0.090
	Patient value - Horizontal	1.341	77	0.5175		

Table XI

Group		Mean	N	Std. Dev.	t-value	p-value
Group D	Model value - Vertical	1.708	78	0.5400	2.148	0.035
	Patient value - Vertical	1.618	78	0.5927		
	Model value - Horizontal	1.277	78	0.4601	1.478	0.143
	Patient value - Horizontal	1.349	78	0.5519		

Paired T-Test for Group A

Table XII

Paired Samples t-test

Quadrant		Mean	N	Std. Dev.	t-value	p-value
First	Model value - Vertical	1.665	20	0.4891	1.111	0.281
	Patient value - Vertical	1.765	20	0.5687		
	Model value - Horizontal	1.485	20	0.6226	1.932	0.068
	Patient value - Horizontal	1.655	20	0.5266		
Second	Model value - Vertical	2.031	16	0.4078	1.861	0.083
	Patient value - Vertical	2.144	16	0.3577		
	Model value - Horizontal	1.556	16	0.3054	0.000	1.000
	Patient value - Horizontal	1.556	16	0.3723		
Third	Model value - Vertical	1.900	14	0.3351	0.101	0.921
	Patient value - Vertical	1.907	14	0.4891		
	Model value - Horizontal	1.043	14	0.3917	1.158	0.268
	Patient value - Horizontal	1.145	14	0.3440		
Fourth	Model value - Vertical	2.019	21	0.3265	1.060	0.302
	Patient value - Vertical	2.106	21	0.3464		
	Model value - Horizontal	1.100	21	0.3017	1.048	0.307
	Patient value - Horizontal	1.195	21	0.2872		

Paired T-Test for Group B

Table XIII

Quadrant		Mean	N	Std. Dev.	t-value	p-value
First	Model value - Vertical	2.254	24	0.6318	2.818	0.010
	Patient value - Vertical	2.149	24	0.6213		
	Model value - Horizontal	1.890	24	0.3545	0.401	0.692
	Patient value - Horizontal	1.871	24	0.4704		
Second	Model value - Vertical	1.844	16	0.4912	0.355	0.728
	Patient value - Vertical	1.822	16	0.5141		
	Model value - Horizontal	1.656	16	0.6345	1.773	0.097
	Patient value - Horizontal	1.759	16	0.7342		
Third	Model value - Vertical	1.505	19	0.4339	0.964	0.348
	Patient value - Vertical	1.426	19	0.5414		
	Model value - Horizontal	.974	19	0.3052	0.820	0.423
	Patient value - Horizontal	1.032	19	0.3250		
Fourth	Model value - Vertical	1.478	18	0.3843	5.105	0.000
	Patient value - Vertical	1.300	18	0.3597		
	Model value - Horizontal	1.289	18	0.3771	2.944	0.009
	Patient value - Horizontal	1.017	18	0.1295		

Paired T-Test for Group C

Table XIV

Quadrant		**Mean**	**N**	**Std. Dev.**	**t-value**	**p-value**
First	Model value - Vertical	2.132	19	0.6583	0.809	0.429
	Patient value - Vertical	2.005	19	0.8059		
	Model value - Horizontal	1.484	19	0.4285	0.940	0.360
	Patient value - Horizontal	1.571	19	0.3220		
Second	Model value - Vertical	2.195	19	0.8960	0.341	0.737
	Patient value - Vertical	2.226	19	0.8419		
	Model value - Horizontal	1.679	19	0.7028	0.098	0.923
	Patient value - Horizontal	1.689	19	0.7125		
Third	Model value - Vertical	1.758	24	0.4272	3.202	0.004
	Patient value - Vertical	2.104	24	0.4777		
	Model value - Horizontal	.942	24	0.2430	0.944	0.355
	Patient value - Horizontal	1.017	24	0.3212		
Fourth	Model value - Vertical	1.980	15	0.5074	3.267	0.006
	Patient value - Vertical	1.733	15	0.6388		
	Model value - Horizontal	.973	15	0.2251	1.951	0.071
	Patient value - Horizontal	1.127	15	0.1792		

Paired T-Test for Group D

Table XV

Quadrant		Mean	N	Std. Dev.	t-value	p-value
First	Model value - Vertical	1.412	16	0.5830	1.747	0.101
	Patient value - Vertical	1.256	16	0.4676		
	Model value - Horizontal	1.531	16	0.3092	1.385	0.186
	Patient value - Horizontal	1.663	16	0.4272		
Second	Model value - Vertical	1.550	22	0.6375	0.120	0.906
	Patient value - Vertical	1.541	22	0.6254		
	Model value - Horizontal	1.409	22	0.4830	2.617	0.016
	Patient value - Horizontal	1.636	22	0.6521		
Third	Model value - Vertical	1.881	21	0.3750	0.547	0.590
	Patient value - Vertical	1.829	21	0.6125		
	Model value - Horizontal	1.205	21	0.4522	0.679	0.505
	Patient value - Horizontal	1.148	21	0.2676		
Fourth	Model value - Vertical	1.947	19	0.3611	2.380	0.029
	Patient value - Vertical	1.778	19	.4947		
	Model value - Horizontal	.989	19	.3928	0.107	0.916
	Patient value - Horizontal	.977	19	.4399		

SILICONE MATERIAL TRANSFER TRAY / SONDHI RAPID SET (3M UNITEK)						
GROUP A						
TOTAL - 80						
PATIENT NAME	**BONDED ARCHES**	**BOND FAILURE**				
		TRAY REMOVAL	**INITIAL ARCHWIRE PLACEMENT**	**30 DAYS**	**60 DAYS**	**90 DAYS**
AB	LOWER R	41,45	42	43,44	--	--
BC	LOWER L	31	--	--	--	--
CD	LOWER L	--	32	--	--	--
DE	LOWER L	--	--	32	--	--
EF	LOWER L	33,35	--	--	--	--
FG	LOWER R	--	--	--	--	--
GH	LOWER R	--	--	--	--	--
HI	UPPER R	--	--	--	--	--
IJ	UPPER R	--	--	--	--	--
JK	LOWER L	--	32	--	--	--
KL	UPPER R	--	--	--	--	--
LM	UPPER R	--	--	--	--	--
MN	LOWER L	--	--	--	--	--
NP	LOWER L	--	--	--	--	--
PR	LOWER R	--	41	--	45	--
RO	UPPER R	--	--	--	--	--
OQ	LOWER L	--	--	--	--	--
QW	UPPER R	13,14	12	--	--	--
WS	LOWER R	44,45	--	--	--	--
SX	UPPER R	--	--	--	--	--
FAILURE		**9**	**5**	**3**	**1**	**0**

SILICONE MATERIAL TRANSFER TRAY /CUSTOM IQ (RELIANCE)						
GROUP B						
TOTAL - 82						
PATIENT NAME	**BONDED ARCHES**	**BOND FAILURE**				
		TRAY REMOVAL	**INITIAL ARCHWIRE PLACEMENT**	**30 DAYS**	**60 DAYS**	**90 DAYS**
AB	LOWER R	--	--	--	--	--
BC	LOWER L	--	--	--	--	--
CD	LOWER L	--	31	--	--	--
DE	UPPER R	--	--	--	--	--
EF	UPPER L	--	--	--	--	--
FG	UPPER L	--	--	--	--	--
GH	UPPER L	24,25	--	--	--	--
HI	LOWER L	35	--	--	--	--
IJ	LOWER L	--	--	--	--	--
JK	UPPER R	11	15	--	--	--
KL	LOWER L	--	--	--	--	--
LM	LOWER L	35	--	--	--	--
MN	UPPER L	--	--	--	--	--
NP	UPPER R	--	--	--	--	--
PR	UPPER R	--	--	--	--	--
RO	UPPER R	--	--	--	13	--
OQ	LOWER L	--	--	--	--	--
QW	UPPER R	--	--	--	--	--
WS	UPPER L	--	--	--	--	--
SX	LOWER L	--	--	--	--	--
FAILURE		**5**	**2**	**0**	**1**	**0**

THERMAL GLUE MATERIAL TRANSFER TRAY/ SONDHI RAPID SET (3M UNITEK)							
GROUP C							
TOTAL - 82							
PATIENT NAME	**BONDED ARCHES**	**BOND FAILURE**					
		TRAY REMOVAL	**INITIAL ARCHWIRE PLACEMENT**	**30 DAYS**	**60 DAYS**	**90 DAYS**
AB	LOWER L	33,35	--	--	--	--
BC	LOWER R	41,45	--	--	--	--
CD	LOWER L	--	--	31	--	--
DE	UPPER L	--	--	--	--	--
EF	UPPER R	--	15	--	--	--
FG	LOWER R	--	--	--	--	--
GH	UPPER L	21	--	--	--	--
HI	LOWER R	--	--	--	--	--
IJ	UPPER R	--	--	--	--	--
JK	UPPER L	--	--	--	--	--
KL	UPPER L	--	--	--	--	--
LM	LOWER R	--	--	--	--	--
MN	LOWER R	--	--	--	--	--
NP	UPPER R	--	--	--	--	--
PR	UPPER R	--	--	--	--	--
RO	UPPER L	--	--	--	23	--
OQ	UPPER L	--	--	--	--	--
QW	UPPER R	--	--	--	--	--
WS	LOWER L	--	--	--	--	35
SX	LOWER R	--	--	45	--	--
FAILURE		**5**	**1**	**2**	**1**	**1**

THERMAL GLUE MATERIAL TRANSFER TRAY /CUSTOM IQ (RELIANCE)						
GROUP D						
TOTAL - 82						
PATIENT NAME	**BONDED ARCHES**	**BOND FAILURE**				
		TRAY REMOVAL	**INITIAL ARCHWIRE PLACEMENT**	**30 DAYS**	**60 DAYS**	**90 DAYS**
AB	UPPER L	--	--	--	--	--
BC	LOWER R	--	41	--	--	--
CD	LOWER R	--	--	--	--	--
DE	LOWER R	--	44	--	--	--
EF	LOWER R	42	--	--	--	--
FG	LOWER L	--	--	32	--	--
GH	UPPER L	--	--	--	--	--
HI	LOWER R	41	42,43	--	--	--
IJ	UPPER L	--	--	--	--	--
JK	LOWER R	--	--	--	--	--
KL	LOWER R	--	--	--	--	--
LM	LOWER R	--	--	--	--	--
MN	UPPER L	--	--	--	--	--
NP	UPPER L	21	--	--	--	--
PR	LOWER L	32	--	--	--	--
RO	UPPER R	--	--	--	--	--
OQ	LOWER R	--	--	--	--	--
QW	LOWER L	--	--	--	--	--
WS	UPPER R	--	--	--	--	--
SX	UPPER L	--		--	--	--
FAILURE		**4**	**4**	**1**	**0**	**0**

TABLE XVI						
GROUP A						
SILICONE MATERIAL TRANSFER TRAY / 3M SONDHI						
TOOTH NO	**MODEL VALUE**		**PATIENT VALUE**		**DIFFERENCE**	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**
11	1.9	1.5	1.7	1.8	0.2	0.3
11	2	1.8	2.1	2.1	0.1	0.3
11	1.8	2.6	2.1	2.7	0.3	0.1
11	1.9	1.5	1.7	1.8	0.2	0.3
11	1.8	2.6	2.1	2.7	0.3	0.1
12	2	1.8	1.4	1.5	0.6	0.3
12	2.1	1.6	2.4	1.3	0.3	0.3
12	1.7	1	2.1	1.5	0.4	0.5
12	2	1.8	1.4	1.5	0.6	0.3
12	1.7	1	2.1	1.5	0.4	0.5
13	1.7	2.1	1.5	1.9	0.2	0.2
13	2.5	1.7	2.4	1.2	0.1	0.5
13	1.9	1.6	2.5	2.1	0.6	0.5
13	1.7	2	1.5	1.9	0.2	0.1
13	1.9	1.6	2.5	2.1	0.6	0.5
15	0.7	0.9	0.5	0.8	0.2	0.1
15	1.5	0.9	1.6	1.5	0.1	0.6
15	0.9	0.4	1.6	1.2	0.7	0.8
15	0.7	0.9	0.5	0.8	0.2	0.1
15	0.9	0.4	1.6	1.2	0.7	0.8
21	1.8	2.1	2.1	2.1	0.3	0
21	2	1.8	2.1	2.1	0.1	0.3
21	2.5	1.8	2.1	2.3	0.4	0.5
21	1.8	2.1	2.1	2.1	0.3	0
22	2.2	1.3	2.4	1.3	0.2	0
22	2.1	1.7	2.4	1.3	0.3	0.4
22	2.1	1.4	2.5	1.5	0.4	0.1
22	2.2	1.3	2.4	1.3	0.2	0
23	2.6	1.1	2.4	1.2	0.2	0.1
23	2.3	1.5	2.4	1.2	0.1	0.3
23	2.3	1.5	2.6	1.4	0.3	0.1
23	2.6	1.1	2.4	1.2	0.2	0.1
25	1.5	1.4	1.6	1.5	0.1	0.1

25	1.8	1.7	1.6	1.4	0.2	0.3
25	1.2	1.7	1.6	1.5	0.4	0.2
25	1.5	1.4	1.6	1.5	0.1	0.1
31	2	1.3	2.4	1	0.4	0.3
31	2	0.7	1.7	1.1	0.3	0.4
31	1.5	0.9	1.7	1.1	0.2	0.2
32	2.1	1.1	2.1	1.5	0	0.4
32	2	1.6	2.1	1.8	0.1	0.2
32	1.9	1.1	1.8	0.7	0.1	0.4
32	2	1	1.9	1.2	0.1	0.2
33	2.3	1.2	2.5	1.2	0.2	0
33	2.4	1.6	2.8	1.3	0.4	0.3
33	2.1	0.8	1.8	0.6	0.3	0.2
33	2	1.6	1.8	1.5	0.2	0.1
34	1.7	0.8	2	1.2	0.3	0.4
35	1.3	0.5	0.9	1.23	0.4	0.73
35	1.3	0.4	1.2	0.6	0.1	0.2
41	2.1	0.9	2.3	0.7	0.2	0.2
41	2.4	1.6	2.02	1.1	0.38	0.5
41	2.4	1.5	1.9	1.1	0.5	0.4
41	2.4	1.6	2.7	1.1	0.3	0.5
41	2.1	0.9	2.3	0.7	0.2	0.2
42	2	1.5	2.3	1.3	0.3	0.2
42	2	1.2	2.02	1.4	0.02	0.2
42	1.9	1.2	2.3	1.6	0.4	0.4
42	2	1.2	2.02	1.4	0.02	0.2
42	2.1	1.5	2.06	1.3	0.04	0.2
43	2.2	1.2	1.5	1	0.7	0.2
43	2.3	0.9	2.6	1.1	0.3	0.2
43	2.3	1.1	2.6	1.1	0.3	0
43	2.3	0.9	2.6	1.1	0.3	0.2
43	2.2	1.2	1.5	1	0.7	0.2
44	1.9	0.7	2.1	1.3	0.2	0.6
44	1.9	0.7	2.1	0.7	0.2	0
45	1.8	0.9	1.7	1.3	0.1	0.4
45	1.4	0.8	1.8	1.6	0.4	0.8
45	1.3	0.8	2	1.6	0.7	0.8
45	1.4	0.8	1.8	1.6	0.4	0.8

TABLE XVII						
GROUP B						
SILICONE MATERIAL TRANSFER TRAY / CUSTOM IQ (RELIANCE)						
TO0TH NO	MODEL VALUE		PATIENT VALUE		DIFFERENCE	
	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
11	2.8	1.9	3.1	2.1	0.3	0.2
11	3	2.6	2.7	2.9	0.3	0.3
11	2.9	2.1	2.7	2.1	0.2	0
11	2.4	1.9	2.5	1.8	0.1	0.1
11	2.8	1.9	2.8	2.1	0	0.2
11	3	2.6	2.7	2.9	0.3	0.3
12	3	1.7	2.9	1.8	0.1	0.1
12	2.6	1.9	2.1	2.2	0.5	0.3
12	1.8	2	1.7	2	0.1	0
12	2	1.15	1.9	1	0.1	0.15
12	3	1.7	2.9	1.8	0.1	0.1
12	2.6	1.9	2.1	2.2	0.5	0.3
13	2.6	1.9	2.4	1.5	0.2	0.4
13	2.4	2.4	2.4	2.3	0	0.1
13	1.8	1.6	1.8	1.6	0	0
13	1.8	1.7	1.7	1.6	0.1	0.1
13	2.6	1.9	2.4	1.5	0.2	0.4
13	2.4	2.4	2.4	2.3	0	0.1
15	1.9	1.7	2	1.3	0.1	0.4
15	1.2	1.8	1.04	1.8	0.16	0
15	1.3	1.9	1.3	1.7	0	0.2
15	1.1	1.2	1	1.3	0.1	0.1
15	1.9	1.7	2	1.3	0.1	0.4
15	1.2	1.8	1.04	1.8	0.16	0
21	2	1.9	2.4	2.1	0.4	0.2
21	3	2.6	2.7	2.9	0.3	0.3
21	2	1.9	2.4	2.1	0.4	0.2
21	2	1.9	2.1	2.1	0.1	0.2
22	1.7	2.1	1.9	2.4	0.2	0.3
22	2.6	1.9	2.1	2.2	0.5	0.3
22	1.7	2.1	1.9	2.4	0.2	0.3
22	1.9	2.1	1.9	2.4	0	0.3
23	1.7	1.5	1.6	1.2	0.1	0.3
23	2.4	2.4	2.4	2.3	0	0.1

23	1.7	1.5	1.6	1.2	0.1	0.3
24	1.5	0.6	1.3	0.6	0.2	0
24	1.5	0.6	1.5	1.05	0	0.45
25	1.3	0.8	1.01	0.7	0.29	0.1
25	1.2	1.8	1.04	1.8	0.16	0
25	1.3	0.8	1.3	0.7	0	0.1
31	1.2	0.8	0.9	0.6	0.3	0.2
31	1.6	0.6	2.3	0.7	0.7	0.1
31	1.2	1	0.9	0.6	0.3	0.4
31	1.2	0.8	0.9	0.6	0.3	0.2
31	1.7	1.3	1.4	0.9	0.3	0.4
32	1.4	0.9	1.4	1.1	0	0.2
32	1.7	0.7	2	1.6	0.3	0.9
32	1.4	0.9	1.4	1.1	0	0.2
32	1.6	0.9	1.4	1.1	0.2	0.2
32	1.7	1.5	1.5	1.2	0.2	0.3
33	2	0.8	1.6	0.8	0.4	0
33	2.2	1.5	2.9	1.7	0.7	0.2
33	2.1	0.8	1.6	0.8	0.5	0
33	2	0.8	1.6	1	0.4	0.2
33	1.9	0.8	1.6	0.9	0.3	0.1
34	0.9	0.5	1.1	1	0.2	0.5
35	0.9	1.4	0.9	1.4	0	0
35	0.7	1.4	0.9	1.4	0.2	0
35	1.2	1.1	0.8	1.1	0.4	0
41	1.7	1.3	1.4	0.9	0.3	0.4
41	1.4	2	1.4	0.9	0	1.1
41	1.5	2	1.4	0.9	0.1	1.1
41	1.5	1.9	1.4	0.9	0.1	1
42	1.7	1.5	1.5	1.2	0.2	0.3
42	1.6	1.5	1.5	1.2	0.1	0.3
42	1.6	1.2	1.5	1.2	0.1	0
42	1.9	1.5	1.5	1.2	0.4	0.3
43	1.9	1	1.6	0.9	0.3	0.1
43	1.6	0.8	1.6	0.9	0	0.1
43	1.9	0.9	1.6	0.9	0.3	0
43	1.6	0.8	1.6	0.9	0	0.1
43	2	1	1.6	0.9	0.4	0.1

45	1.2	1.1	0.8	1.1	0.4	0
45	0.8	1.2	0.5	1.1	0.3	0.1
45	0.9	1.2	0.8	1	0.1	0.2
45	0.9	1.1	0.8	1.1	0.1	0
45	0.9	1.2	0.9	1.1	0	0.1

TABLE XVIII

GROUP C

THERMAL GLUE MATERIAL TRANSFER TRAY / 3M SONDHI

TOOTH NO	**MODEL VALUE**		**PATIENT VALUE**		**DIFFERENCE**	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**
11	2.6	1.5	2.8	1.8	0.2	0.3
11	2.8	0.9	4	2	1.2	1.1
11	2.6	1.5	2.8	1.8	0.2	0.3
11	2.6	1.5	1.8	1.8	0.8	0.3
12	2.3	2.2	2.1	2.3	0.2	0.1
12	2.6	1.6	2.7	1.6	0.1	0
12	2.3	2.2	2.1	2.05	0.2	0.15
12	2.8	2.2	1.9	1.5	0.9	0.7
13	2.1	1.5	1.6	1.1	0.5	0.4
13	3.2	1.7	3.3	1.6	0.1	0.1
13	2.1	1.5	1.8	1.1	0.3	0.4
13	2.5	1.5	1.6	1.5	0.9	0
14	1.9	1.4	0.9	1.4	1	0
14	0.9	0.9	1.9	1.4	1	0.5
14	0.7	1.4	1.9	1.4	1.2	0
15	1.6	1.1	1.4	1.3	0.2	0.2
15	1.5	1.8	1.2	1.6	0.3	0.2
15	1.6	0.7	1.4	1.3	0.2	0.6
15	1.8	1.1	0.9	1.3	0.9	0.2
21	3.3	2.7	3.5	2.4	0.2	0.3
21	2.5	1.6	3.4	2.9	0.9	1.3
21	2.3	2.4	2.7	2.6	0.4	0.2
21	3.3	2.7	3.5	2.4	0.2	0.3
21	3.3	1.7	2.5	2.4	0.8	0.7
22	2.6	1.9	2.4	1.8	0.2	0.1
22	1.8	2.8	1.7	2.5	0.1	0.3
22	1.6	1.9	1.7	0.8	0.1	1.1

22	2.7	1.9	2.4	1.8	0.3	0.1
22	2.6	1.9	2.1	1.8	0.5	0.1
23	2.7	1.5	2.7	1.5	0	0
23	2.7	2	2.3	1.7	0.4	0.3
23	1.9	1.2	1.8	1.5	0.1	0.3
23	2.7	1.5	2.7	1.5	0	0
23	2.7	1.5	2.7	1.5	0	0
24	0.7	0.5	0.9	0.6	0.2	0.1
25	1	0.5	1.8	0.6	0.8	0.1
25	0.8	0.5	0.9	0.7	0.1	0.2
25	0.5	1.2	0.6	1.1	0.1	0.1
31	1.4	1.2	1.9	0.5	0.5	0.7
31	1.6	1.2	1.9	0.7	0.3	0.5
31	2.1	0.9	2.1	0.9	0	0
31	2.1	0.9	2.1	0.9	0	0
31	2.1	0.9	2.1	0.9	0	0
31	1.4	1.2	1.9	0.5	0.5	0.7
32	1.9	0.8	2.2	0.9	0.3	0.1
32	1.7	1	2.2	0.9	0.5	0.1
32	1.8	1.2	1.8	1.1	0	0.1
32	1.9	1.2	1.8	1.1	0.1	0.1
32	2	1.2	1.8	1.1	0.2	0.1
32	1.7	0.8	2.2	0.9	0.5	0.1
33	1.9	1.2	2.8	1.5	0.9	0.3
33	1.9	1.2	2.8	1.5	0.9	0.3
33	1.9	0.9	2.8	0.9	0.9	0
33	2.1	0.9	2.1	0.9	0	0
33	1.9	1.2	2.8	1.5	0.9	0.3
33	3	0.9	2.8	0.9	0.2	0
34	1.3	0.5	2	1	0.7	0.5
34	1.2	0.7	1.8	0.7	0.6	0
34	1.9	0.9	0.6	1.9	1.3	1
34	1.1	0.5	2	1.1	0.9	0.6
34	1.1	0.5	2	1.1	0.9	0.6
35	1.2	0.7	2	1	0.8	0.3
41	1.8	0.9	1.2	1	0.6	0.1
41	2.1	1	1.4	1.5	0.7	0.5
41	1.8	0.9	1.2	1	0.6	0.1
42	1.9	1.1	1.4	0.9	0.5	0.2
42	2	1.2	1.8	1.1	0.2	0.1

42	1.9	1.1	1.4	0.9	0.5	0.2
42	2.1	1.2	1.8	1.1	0.3	0.1
43	2.1	0.9	2.3	1.4	0.2	0.5
43	2.9	0.8	2.8	1	0.1	0.2
43	2.1	0.9	2.3	1.4	0.2	0.5
43	2.9	0.8	2.8	1.2	0.1	0.4
44	2	1.3	2	1.1	0	0.2
44	2	1.3	2	1.1	0	0.2
45	1.2	0.6	0.8	1.1	0.8	0.5
45	0.9	0.6	0.8	1.1	0.1	0.5

TABLE XIX

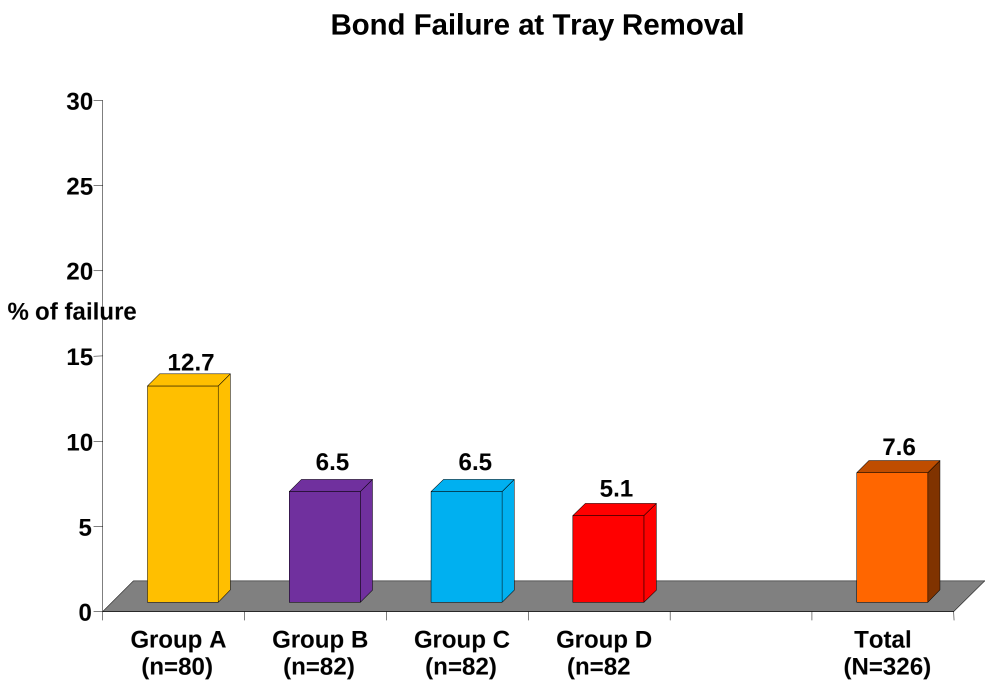
GROUP D

THERMAL GLUE MATERIAL TRANSFER TRAY / CUSTOM IQ (RELIANCE)

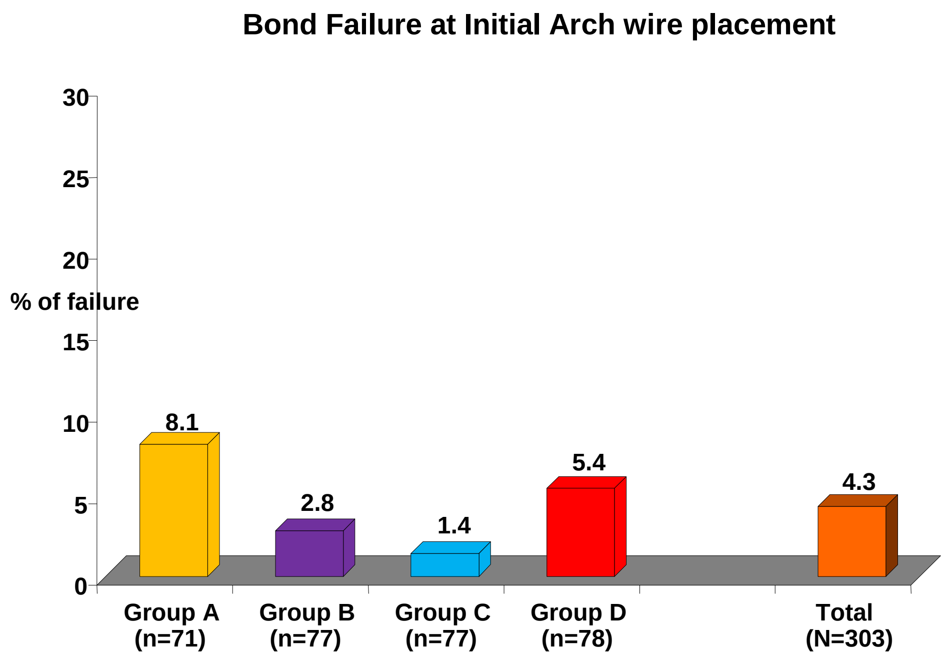
TOOTH NO	**MODEL VALUE**		**PATIENT VALUE**		**DIFFERENCE**	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**
11	2.7	1.3	1.6	2.5	1.1	1.2
11	2.1	1.4	1.6	2	0.5	0.6
11	1.5	1.3	1.9	1.8	0.4	0.5
11	2	2	1.6	2	0.4	0
12	1.6	1.4	1.6	1.5	0	0.1
12	1.6	1.4	1.6	1.5	0	0.1
12	2	1.4	1.6	1.5	0.4	0.1
12	1.6	1.4	1.6	1.5	0	0.1
13	1.2	2	1.2	2.1	0	0.1
13	1.2	1.7	1.2	1.9	0	0.2
13	0.8	2	1.2	2	0.4	0
13	1.2	2	1.2	1.9	0	0.1
14	0.7	1.4	0.5	1.1	0.2	0.3
14	0.9	1.4	0.7	1.1	0.2	0.3
15	0.8	1	0.5	1.1	0.3	0.1
15	0.7	1.4	0.5	1.1	0.2	0.3
21	1.8	1.3	1.6	2	0.2	0.7
21	2.7	1.9	2.5	3.2	0.2	1.3
21	1.7	1.5	1.8	2	0.1	0.5
21	1.8	1.3	1.6	2	0.2	0.7
21	2.5	1.6	1.4	2.2	1.1	0.6

22	1.6	1.8	1.6	1.5	0	0.3
22	2.1	2.1	2	2.2	0.1	0.1
22	1.5	1.1	1.9	1.5	0.4	0.4
22	2.1	2.1	1.9	2.2	0.2	0.1
22	1.6	1.8	1.6	1.5	0	0.3
22	1.5	1.1	1.9	1.5	0.4	0.4
23	1.4	1.8	1.2	1.9	0.2	0.1
23	2.3	2	2.4	2	0.1	0
23	1.5	1.4	2	1.8	0.5	0.4
23	2.3	2	2.4	2	0.1	0
23	1.5	1.4	2	1.8	0.5	0.4
24	0.7	0.8	0.6	0.5	0.1	0.3
24	0.6	0.7	0.9	0.8	0.3	0.1
24	0.7	1	0.7	0.5	0	0.5
24	0.6	0.7	0.9	0.8	0.3	0.1
25	0.9	0.8	0.5	1	0.4	0.2
25	0.7	0.8	0.5	1.1	0.2	0.3
31	2.3	1.5	2.2	1.2	0.1	0.3
31	1.5	1.5	2	1.1	0.5	0.4
31	1.8	1.2	2	1.1	0.2	0.1
31	1.8	1.5	2	1	0.2	0.5
31	2.3	1.5	2.2	1.2	0.1	0.3
32	1.9	1.6	1.7	1.2	0.2	0.4
32	2.4	0.9	1.6	0.9	0.8	0
32	2.4	0.9	1.6	0.9	0.8	0
32	1.9	1.6	1.7	1.2	0.2	0.4
33	1.9	1.8	2.2	1.6	0.3	0.2
33	2.3	1.6	2.9	1.2	0.6	0.4
33	2	1.6	2.8	1.5	0.8	0.1
33	2.3	1.6	2.9	1.2	0.6	0.4
33	2.2	1.8	2.2	1.6	0	0.2
34	1.4	0.7	1.1	1.1	0.3	0.4
34	1.6	0.6	1.4	0.8	0.2	0.2
34	1.7	0.6	1.4	0.9	0.3	0.3
34	1.6	0.6	1.4	0.8	0.2	0.2
34	1.4	0.7	1.1	1.1	0.3	0.4
35	1.1	0.6	0.5	1.7	0.6	1.1
35	1.7	0.9	1.5	0.8	0.2	0.1
41	1.9	0.7	1.9	1.4	0	0.7
41	2	0.7	1.8	0.6	0.2	0.1

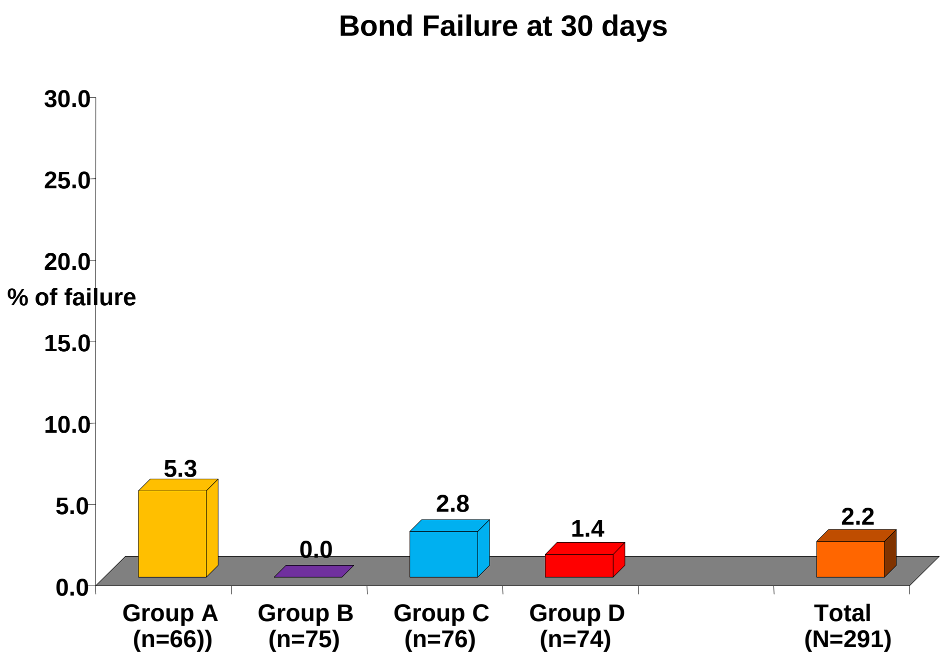
41	2.1	1.8	1.4	1.06	0.7	0.74
41	2	1	1.9	1.2	0.1	0.2
41	2	0.6	2.1	0.7	0.1	0.1
42	2.5	0.9	2.3	1.5	0.2	0.6
42	1.8	1.5	1.3	1.1	0.5	0.4
42	2	1.6	1.8	1.4	0.2	0.2
42	1.8	1.5	1.3	1.1	0.5	0.4
43	2.2	1.5	2.1	1.3	0.1	0.2
43	2.2	0.8	2.1	0.5	0.1	0.3
43	2.8	1.1	2.8	1.1	0	0
43	2	0.9	1.9	0.8	0.1	0.1
43	2.2	0.8	2.1	0.5	0.1	0.3
44	1.5	0.5	2.1	1.5	0.6	1
45	1.6	0.8	1.6	0.3	0	0.5
45	1.4	0.7	1.09	0.5	0.31	0.2
45	1.4	0.6	0.6	1.7	0.8	1.1
45	1.6	0.8	1.6	0.3	0	0.5

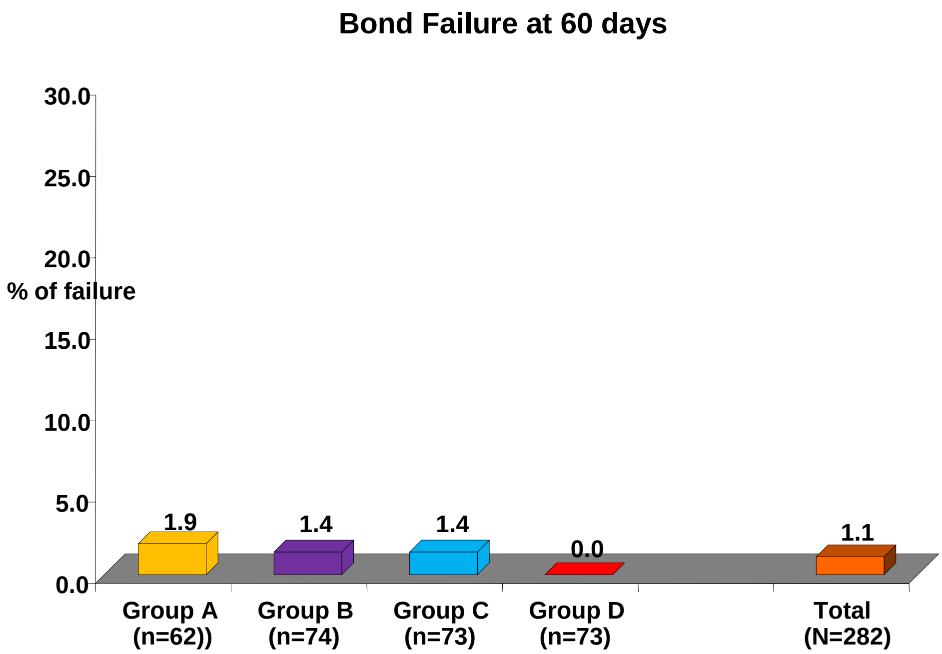


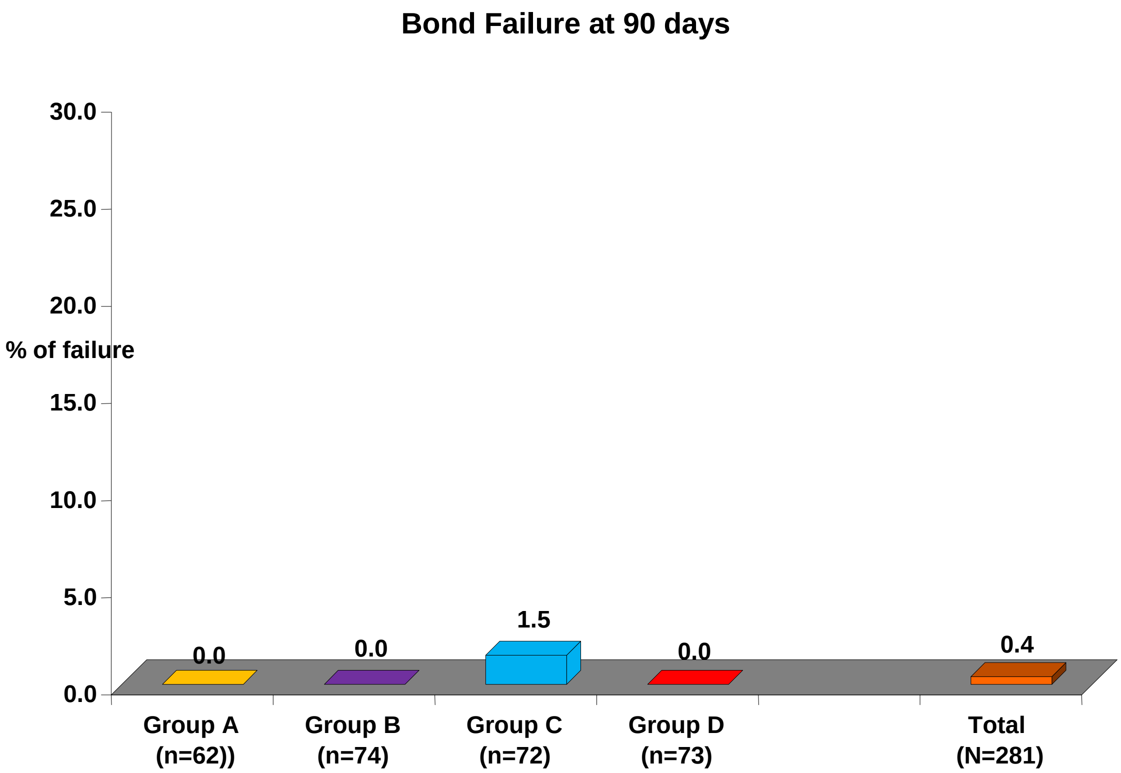
Bond Failure at Tray Removal
30
25
20
% of failure
15
10
5
0
12.7
6.5
6.5
5.1
7.6
Group A
(n=80)
Group B
(n=82)
Group C
(n=82)
Group D
(n=82
Total
(N=326)

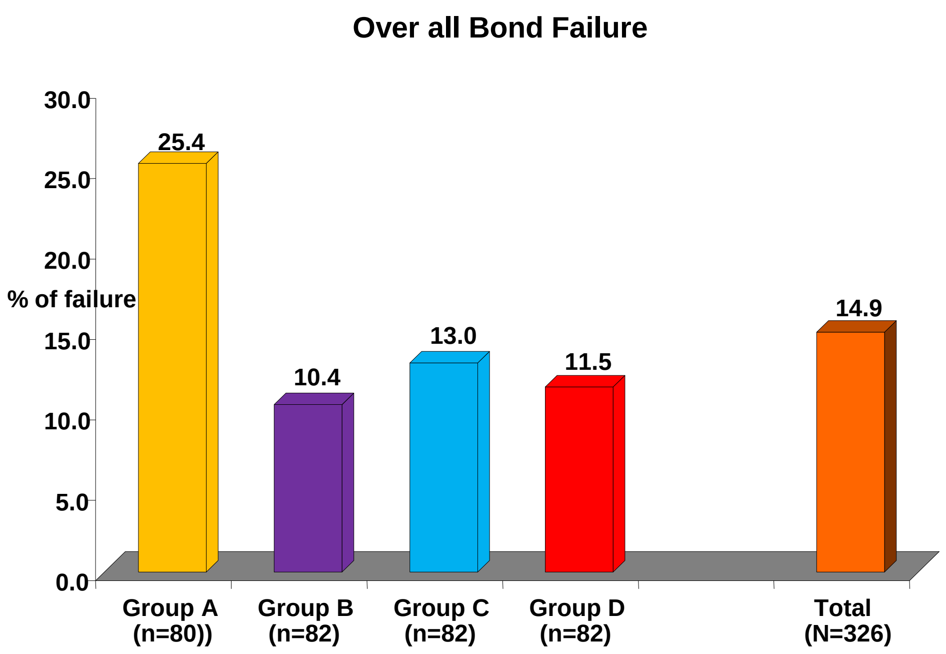


Bond Failure at Initial Arch wire placement
30
25
20
% of failure
15
10
5
0
8.1
2.8
1.4
5.4
4.3
Group A
(n=71)
Group B
(n=77)
Group C
(n=77)
Group D
(n=78)
Total
(N=303)

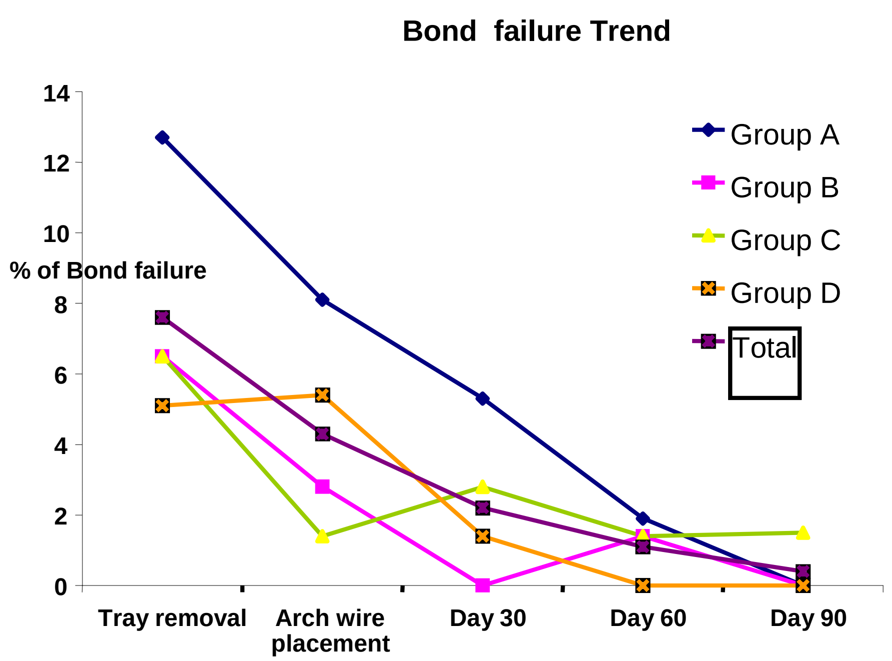

Bond Failure at 30 days
30.0
25.0
20.0
% of failure
15.0
10.0
5.0
0.0
5.3
0.0
2.8
1.4
2.2
Group A (n=66))
Group B (n=75)
Group C (n=76)
Group D (n=74)
Total (N=291)


Bond Failure at 60 days
30.0
25.0
20.0
% of failure
15.0
10.0
5.0
0.0
1.9
1.4
1.4
0.0
1.1
Group A (n=62))
Group B (n=74)
Group C (n=73)
Group D (n=73)
Total (N=282)

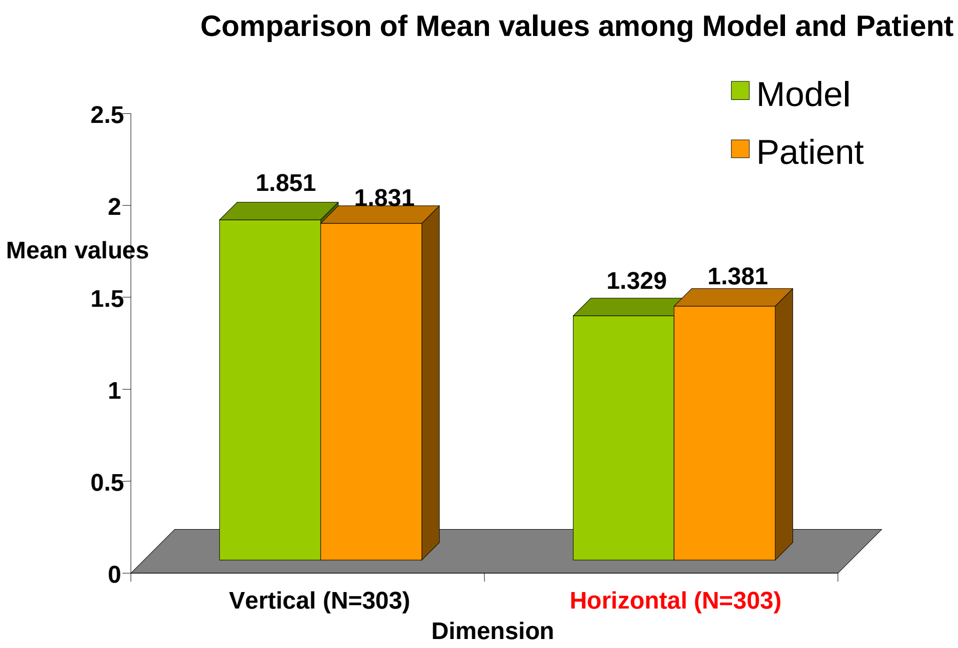

Bond Failure at 90 days
30.0
25.0
20.0
% of failure
15.0
10.0
5.0
0.0
0.0
0.0
1.5
0.0
0.4
Group A (n=62))
Group B (n=74)
Group C (n=72)
Group D (n=73)
Total (N=281)

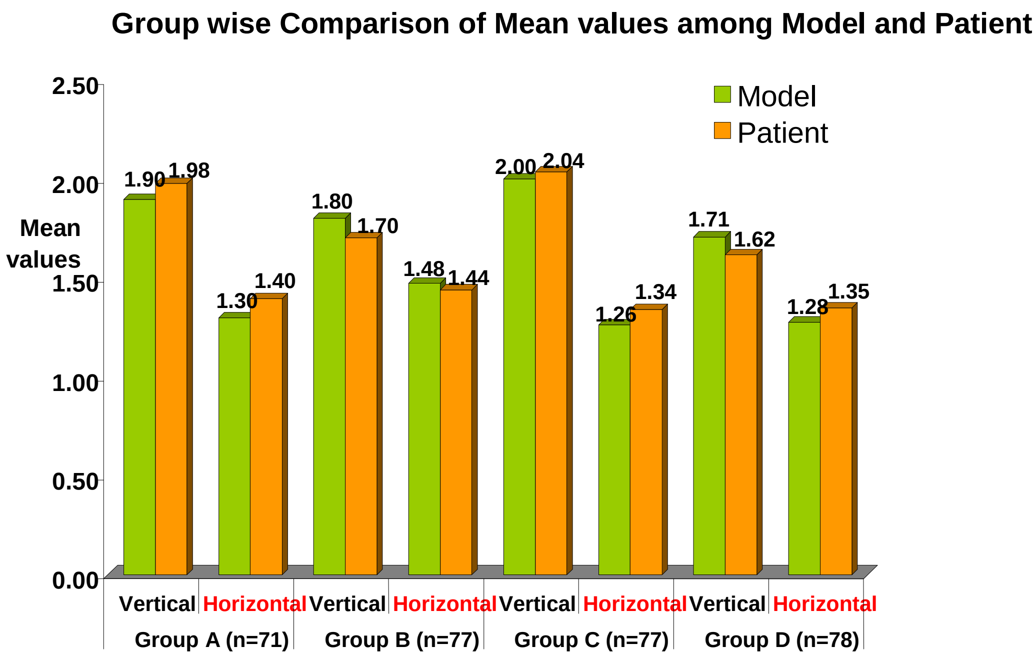


Over all Bond Failure
30.0
25.0
20.0
% of failure
15.0
10.0
5.0
0.0
25.4
10.4
13.0
11.5
14.9
Group A (n=80))
Group B (n=82)
Group C (n=82)
Group D (n=82)
Total (N=326)



Bond failure Trend
14
12
10
% of Bond failure
8
6
4
2
0
Tray removal
Arch wire placement
Day 30
Day 60
Day 90
Group A
Group B
Group C
Group D
Total


Comparison of Mean values among Model and Patient
Model
Patient
2.5
2
1.5
1
0.5
0
Mean values
1.851
1.831
1.329
1.381
Vertical (N=303)
Horizontal (N=303)
Dimension


Group wise Comparison of Mean values among Model and Patient
Model
Patient
Mean values
2.50
2.00
1.50
1.00
0.50
0.00
1.90
1.98
1.30
1.40
1.80
1.70
1.48
1.44
2.00
2.04
1.26
1.34
1.71
1.62
1.28
1.35
Vertical
Horizontal
Vertical
Horizontal
Vertical
Horizontal
Vertical
Horizontal
Group A (n=71)
Group B (n=77)
Group C (n=77)
Group D (n=78)

DISCUSSION

Ever since the straight wire appliance (**Andrews,** 1972) was introduced in orthodontics, it became widely recognized that accurate bracket placement is of critical importance in the efficient application of biomechanics and in realizing the full potential of a preadjusted edgewise appliance[4]. Direct bonding had been the only technique used to bond orthodontic brackets for many years. Earlier many orthodontists considered that direct bonding did not provide accuracy during bracket placement and thus the efficacy of the mechanotheraphy was lost.

To overcome this, **Silverman** et al. (1972)[16] introduced the indirect bonding technique. As accurate bracket placement was essential for the proper functioning of a pre-adjusted appliance, indirect bonding technique involves placement of brackets in optimal positions on plaster models of the patient's dentition, and then transferring them to the mouth via a tray so that they can then be bonded to the teeth in positions predetermined in the laboratory[63].

Indirect-bonding techniques were developed to improve the accuracy of bracket placement, reduced chairtime, and avoid bond failures, thus shortening treatment time. However these systems have not always demonstrated such results[38,63,66]. Despite the advantages of indirect bonding, difficulty in isolating posterior teeth and problems with resin flash and inadequate bond strength had slowed its adoption[20].

Silverman et al[16] used an unfilled methylmethacrylate-based adhesive (BisGMA) in order to bond plastic brackets onto a model. **Silverman and Cohen**[18] improved this technique by using a perforated mesh base and ultraviolet (UV) cured BisGMA resin. Most indirect bonding can be traced back to a previously developed process (**Thomas**[60], 1978). A liquid catalyst resin was applied during chairside bonding onto a composite layer that had been pre-cured in the laboratory (filled BisGMA adhesive). A thin layer of sealer was additionally bonded onto the enamel. The chemical curing process begins when both components were brought into contact with each other on placement of the tray. The transfer tray was removed after polymerization. Using this technique, bond strength similar to direct bonding was achieved (**Hocevar and Vincent**[24], 1988). One of the criticisms of this method was that complete polymerization did not occur. For this reason, a modified technique was developed, with both components mixed before application (**Hickham**[32], 1993 ; **Moskowitz** et al[50] , 1996 ; **Miles**[46], 2002). Unfortunately this technique did not provide adequate working time compared to no mix adhesives. Other techniques make use of water-soluble adhesives for placing the brackets in the laboratory setting. This adhesive was removed after creation of the transfer tray (**White**[39], 1999). Apart from the use of chemically and thermally cured composites (**Sinha** et al[55], 1995), translucent transfer trays also allow light-cured composite adhesive to be used for coating the bracket base.

There are so many products coming in the market in relation to the bracket positioning devices, newer adhesives, advanced light cured system but the challenge remains in choosing the best and superior technique[33]. Continuous efforts are being made to make the indirect bonding superior and efficient from the previous debacles which it suffered during the yester years.

White[38] used a small amount of Aleene's Tacky Glue (Aleene's, Buellton, CA) to place the brackets on the cast instead of sugar candy and other substances. The custom bases in this study were made based on Thomas technique developed by **Roycee Thomas**[60] involving bonding the bracket on to the study model by means of light cured resin. In a clinical study to compare thermally cured and light cured resin, for custom base it was demonstrated that there were significantly more bond failures in the thermally cured resin group (**Miles** et al[46]). The light cure custom base provides custom fit onto the patient's tooth as well as greater reliability in securing the brackets onto the model avoiding bracket float. Custom bases made with light cure are far more superior to thermal cured custom base brackets as employed by **Nanda, Sinha and Duncanson**[67]**,** as this thermal cured custom bases involve heating the cast in a furnace for 30 minutes during which bracket float was common. In this study to achieve a complete cure each custom base was light cured for 10 sec after tray removal. **John hickham**[32] recommeded procuring before transferring to increase the success rate.

There have been a multitude of materials used for the construction of transfer trays, the extent of which has been left only to the imagination[33]. The tray materials used in this study were Polyvinyl Siloxane impression material (Silagum; DMG, Germany) and Thermal Glue Gun material (Polymer of ethylene vinyl acetate). **Kalange**[33] preferred a two-part heavy viscosity putty after trying all possible techniques and materials for transfer tray including single light cure and dual cure clear silicones, two-part liquid/putty silicones, single and dual clear Biostar® trays (Great Lakes Orthodontics, Tonawanda, NY), and found two-part heavy viscosity silicone putty superior to other materials. The Polyvinyl Siloxane trays were cut interproximally from the lingual to the level of the contacts as advocated by **Kalange**[33]. It has been found to be a major improvement in the tray design and to greatly facilitate removal of the trays.

The other tray material used in the study was Thermal Glue Gun material (Polymer of ethylene vinyl acetate) which is a flexible, in expensive and were available in different colors. **Larry White**[38,39,40]**, Arturo Fortini and Fabio Giuntoli**[8] used this material because of its above benefits. Thermal glue material is flowable when it is thermally hot and this property of the material provides close adaptation as well as good retention for the brackets.

In the pilot study done in our department we found increased bond failure rate when Polyvinyl Siloxane transfer trays was constructed as advocated by **Kalange**[33]. The stiffness of Polyvinyl Siloxane caused the increased bond failure rate during tray removal and therefore a modification was introduced wherein an occlusal cut was placed which extended only upto half the thickness of the tray aiding in easy tray removal without compromising the stability of the material. During tray removal this cut was deepened to split the tray into buccal and palatal halves.

The pilot study also revealed that flexibility of Thermal Glue material resulted in deformation of the tray during tray placement and removal. It was decided to place a 19 gauge stainless steel round wire and reinforce the Thermal Glue tray over the occlusal surface to provide additional stability of the transfer tray.

Both the transfer trays were not extended to cover the entire buccal surface but were extended only upto the bracket gingival wings (not under it) for ease of removal. Care was taken to maintain the adequate thickness of the tray to provide desired dimensional stability of the transfer tray.

Kalange[31] found that Chemically cured composites had very similar components to those that are light cured and therefore had the same clinical working characteristics. Light-cured resins actually take much longer to cure at the chairside and thus detract from the efficiency of indirect bonding. Hence in this study we used two different types of indirect bonding materials - Sondhi™ Rapid-Set (3M unitek) and custom IQ (Reliance orthodontics). The indirect bonding procedure was carried out according to the manufacturer's instructions.

Initially, bond failure rates for indirect bonding (13.9%) were higher when compared with direct bonding (2.5%)[73]. However, with modifications and improvements to the techniques, the two systems now have similar bond strengths and failure rates.

In an in-vitro study by **Polat** *et al*[54]., the mean shear bond strength associated with the use of the sondhi adhesive was only 6.1 MPa and was shown to have a significantly lower bond strength compared to direct bonding using light cured adhesive[54]. In a split mouth technique, **Miles and Weyant**[43] demonstrated a significant difference between Sondhi Rapid Set and Maximum Cure® (Reliance Orthodontic Products, Inc., Itasca, IL) sealants, with Sondhi Rapid Set having seven times the number of breakages (9.0% vs 1.4%) over a 6-month observation period. Both these studies however, associated the failure with the material itself and have not investigated possible other causes including the preparation technique and severity of the cases treated (malocclusion).

Most clinical studies on bond failure with indirect bonding attributed the failure to the adhesive material without taking into consideration the effect of the transfer tray in case of severe malocclusion (**Read and O'Brien**[35], 1990; **Mile and Weyant**[45], 2003).

There are no previous studies to assess the clinical bond failure rate and accuracy of bracket placement between Polyvinyl Siloxane and Thermal Glue, and using two different bonding materials namely Sondhi™ Rapid-Set (3M unitek) and custom IQ (Reliance orthodontics) .

Therefore a study was designed and carried out in our department to assess the accuracy and bond failure rate of the above two indirect bonding materials and transfer trays. The sample size consisted of a total of 326 brackets bonded in 20 patients. The sample was divided into four groups and a flip of a coin determined the quadrant for the bonding procedure. The same procedure was employed by **Trimpeneers and Dermaut**[35] as it was considered an unbiased procedure as any.

In the first part of the study the clinical bond failure rate for each group was assessed at five different time durations starting from the bracket bond failure during tray removal, initial arch wire placement, 30 days, 60 days and finally after 90 days.

The clinical bond failure rate in this in-vivo study showed increased bond failure rate with Polyvinyl siloxane / Sondhi™ Rapid-Set (3M unitek)

(25.4% failure rate). The bond failure rate in the other groups were much lesser when compared to Polyvinyl siloxane / Sondhi™ Rapid-Set (3M unitek). In Polyvinyl siloxane / Sondhi™ Rapid-Set (3M unitek) group the Polyvinyl Siloxane material was stiff enough during tray removal despite the fact that additional occlusal cuts were placed for ease of removal and when used along with Sondhi™ Rapid-Set (3M unitek) the bond failure rate increased. Previous studies by **Polat** et al[54] and **Miles and Weyant**[45] showed significantly increased bond failure rate with Sondhi™ Rapid-Set (3M unitek). In this study it was easy to remove the Thermal Glue tray as the material softens with warm water and significant reduction in bond failure were noted in this groups. **Arndt Klocke** et al[5] in his study concluded that Custom I.Q. sealant groups showed significantly lower bond strength measurements when debonded at the recommended tray removal time when compared with Sondhi™ Rapid-Set (3M unitek) and Maximum cure sealant (Reliance orthodontics). However this study was not representative of a real clinical situation as it was an in-vitro study, but in our in-vivo study custom IQ (Reliance orthodontics) showed superior bond strength compared to Sondhi™ Rapid-Set (3M unitek). The malocclusion and salivary contamination were the other factors which might have contributed to the bond failure rate. Moisture control was an important factor for clinical bond strength. The use of antisialogogues has been recommended to reduce moisture contamination when using the indirect bonding technique[4,60].

The bond failure rate was higher during the transfer tray removal (7.6% bond failure) and gradually declined during consecutive time durations for all the groups (0.4 % bond failure at 90 days). So it was necessary to carefully remove the transfer tray to minimize the bond failure. Considering the individual tooth lower second premolars (22.2% bond failure) showed increased bond failure rate. In a clinical trial comparing direct and indirect bonding bond failure rate **Zachrisson and Brobakken** concluded that indirect bonding showed increased bond failure occurred in the lower second premolar region. This might be because of inadequate isolation in the posterior arch segment. **Geenty**[20] while enumerating the disadvantages of indirect bonding, mentioned difficulty in isolating posterior teeth with this technique. Interestingly in our study it was noted that the lower central incisors and lateral incisors showed increased bond failure rate (17.7% bond failure) second only to lower 2nd premolars. This bond failure in the lower anterior segment was probably because of the crowding present in this region in most of the samples. To minimize bond failure in crowding cases it was recommended to section the tray for ease of isolation, tray placement and tray removal. All the failed brackets were bonded with direct bonding technique.

In the second part of the study the accuracy of bracket placement was assessed using calibration certified vernier caliper (Gros; General, USA). **Santoro**[62] concluded that digital caliper was considered to be an accurate, reliable and reproducible device for dental measurements. Previous studies by

Aguirre King and Waldron[43] and **Koo** et al[9] suggested a jig made of 19X25 stainless steel wire attached to a tripod onto the camera. This jig engages the bracket slot during photography to provide a standardized image for measurement on the patient.

There are no studies in the literature other than photographic method to assess the accuracy of bracket placement. Even the photographic method using a jig for intraoral photography proved to be difficult in the premolar region[43]**.** The other shortcomings were that no direct measurements can be made on the teeth and always there was an element of inaccuracy in the measurements because of magnification with the photographs. The procedure was also cumbersome as the photography needed parallelism which proved to be difficult in the posterior segment of the arch and later the need for tracing to determine the measurements.

Hence digital vernier caliper was used as an alternative for assessing the accuracy of bracket placement in this study as it was more convenient to be used as a direct measuring tool. Two 19x25 stainless steel straight wires of 1 inch length were attached parallel to each other to the caliper ends to increase the accessibility and to maintain the parallelism during vertical and horizontal measurements.

The same operator made all the measurements. Every measurement was made thrice and a mean value was recorded for all the teeth measured.

Statistically significant difference (mean - 1.32mm) ($p < 0.05$) was found in overall horizontal measurement revealing inaccuracy in the mesio-distal dimension whereas no statistical significant difference was found in the overall vertical measurement (mean - 1.85mm). This results were similar to the finding by **Koo** et al[9]., on individual teeth, where there was no statistically significant difference in the accuracy of bracket placement between direct and indirect bonding techniques except for upper right second premolar and lower left central incisor, where indirect bonding showed better bracket placement in bracket height when compared to mesiodistal and angular measurements.

Statistically significant difference was seen among all the groups regarding accuracy of bracket placement except in Thermal glue / Sondhi Rapid set group where it was insignificant (vertical – $p = 0.563$, horizontal - $p = 0.090$), which means that this group was efficient in accurate transfer of the brackets.

The Accuracy of bracket placement among the quadrants, fourth quadrant showed highest bracket placement error especially in the vertical measurements. **Aqiurre King and Waldron**[43] in their study concluded that in the lower arch there was a statistically significant difference in bracket placement on the second premolars ($p < 0.01$), on which the direct-bonded brackets were placed closer to the ideal, both angular and linear measurements demonstrated that neither the direct nor the indirect bonding techniques was 100 percent accurate. No study has been published till date related to comparison of bracket placement accuracy between two indirect bonding techniques.

The other possible reason for the bracket placement error in this study may be due to the dimensional stability of the transfer tray materials used which has to be evaluated in future studies.

As mentioned earlier most clinical studies on bond failure with indirect bonding attributed the failure to the adhesive material without taking into consideration the effect of the transfer tray in case of severe malocclusion and salivary contamination. In our study most number of brackets failure in the lower second premolars (22.2%) and incisors (17.7%) might be because of these factors. Most authors recommend sectioning the tray in case of malocclusion and some contraindicate the use of indirect bonding (**white**[40]). Further studies are needed to evaluate the effects of malocclusion and salivary contamination with indirect bonding.

There has been an increased interest in the use of self etching primers (SEP) and moisture insensitive primers (MIP) with direct bonding which not only have been reported to produce comparable bond strengths to traditional bonding (**Aljubouri** et al., 2004) but also have been reported to reduce the average time needed to bond orthodontic brackets. **White**[38] recommended use of Prompt L-Pop a self etching primer with indirect bonding technique. **Arndt klocke**[6] et al used Transbond MIP with indirect bonding technique. In orthodontic literature very few studies to our knowledge has been reported on the use of self etching primers (SEP) and moisture insensitive primers (MIP) with indirect bonding in relation to treatment time and efficiency of the bond. It has to be evaluated that using these primers will further reduce the treatment time, minimize the number of procedures involved with indirect bonding and also prove to be a viable option.

The findings of this in-vivo study reveal that the bond failure does exist and bracket placement errors are common even with indirect bonding procedure. It has been shown that modified digital vernier caliper can be a viable alternative method for assessing the accuracy of bracket placement. These findings need to be confirmed in the future studies with larger sample size over a longer period of time and should be tried with multiple and more experienced operators.

SUMMARY

The purpose of this study was to compare and evaluate the clinical bond failure rate and accuracy of bracket placement of two indirect bonding materials and transfer trays.

A split mouth technique was used in this study in which twenty patients were randomly divided into four groups: Group A - Polyvinyl siloxane / Sondhi™ Rapid-Set (3M unitek), Group B - Polyvinyl siloxane / custom IQ (Reliance orthodontics), Group C - Thermal glue / Sondhi™ Rapid-Set (3M unitek) & Group D - Thermal glue / custom IQ (Reliance orthodontics).

A total of 326 brackets were bonded and bond failure of brackets involved only first time failures during the tray removal, initial arch wire placement and thereafter three consecutive appointments (30,60 and 90 days).

Accuracy of bracket placement was measured with modified digital vernier caliper. Vertical and horizontal measurements were taken both on the models and intraorally in the patients and were evaluated for accuracy.

CONCLUSION

The findings of the study showed Polyvinyl Siloxane / Sondhi Rapid Set had maximum bond failure rate (25.4%) when compared with other groups. The bond failure rate was higher during the transfer tray removal (7.6%) which gradually declined in consecutive appointments.

Thermal glue transfer tray and Custom IQ (Reliance orthodontics) resin proved to be superior with minimum bond failure. Mandibular second premolars (22.2%) and lower incisors (17.7%) showed increased bond failure rates.

Indirect bonding was accurate in vertical dimension and fourth quadrant showed least accuracy. Thermal glue / Sondhi Rapid set (3M unitek) group was efficient in accurate transfer of the brackets.

Thermal Glue found to be an inexpensive and a better transfer tray material when compared to Polyvinyl Siloxane. Thermal Glue tray reinforced with 19 gauge wire proved to be more effective. In case of malocclusions it was recommended to section the tray to minimize bond failure.

Modified Digital vernier caliper can be a reproducible and convenient method for measuring bracket placement accuracy. These findings need to be confirmed in future studies with larger samples over a longer period of time.

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