"COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF COLOR CHANGING ADHESIVE WITH CONVENTIONAL ADHESIVE USED TO BOND BRACKETS BY INDIRECT TECHNIQUE IN LINGUAL ORTHODONTICS"

Dissertation

Submitted to

BABU BANARASI DAS UNIVERSITY,

LUCKNOW, UTTAR PRADESH

In the partial fulfillment of the requirements for the degree

of

MASTER OF DENTAL SURGERY

In

ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS

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YEAR OF SUBMISSION: 2021 **BATCH: 2018-2021**

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I hereby declare that this dissertation entitled **"COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF COLOR CHANGING ADHESIVE WITH CONVENTIONAL ADHESIVE USED TO BOND BRACKETS BY INDIRECT TECHNIQUE IN LINGUAL ORTHODONTICS"** is a bonafide and genuine research work carried out by me under the guidance of ***Dr. Kamna Srivastava,*** Reader, Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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ACKNOWLEDGEMENT

The satisfaction and euphoria that accompany the successful completion of a task could be incomplete without mentioning the people who made it possible. I owe my immense respect to almighty God for residing in my heart and showering His choicest and divine blessings upon me always.

Language seems to have limitations to express my feelings of gratitude and reverence to ***Dr. Tripti Tikku****, MDS, Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Lucknow for providing me constant help, useful guidance and encouragement all throughout my work. Her frankness towards discussion, criticism and timely suggestions enabled me to complete this work. At every stage, her wise and logical suggestions and meticulous attention to the fine details have helped me give this dissertation its final shape. For her noble kindness, selfless generosity and everlasting helping nature, I shall remain ever-grateful to her.*

I find words insufficient to express my profound gratitude to my revered mentor, honorable guide and beloved teacher ***Dr. Kamna Srivastava****, MDS, Reader, Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Lucknow. It has been a great privilege to work under her able guidance and extraordinary command. Her intelligence and methodical approach to work, inculcated in me the spirit of research for which I shall always remain thankful and indebted. Her words of wisdom and encouragement will always be with me. She has guided me at every point with her valuable suggestions, concrete guidance, constructive criticism, meticulous attention, cosmic knowledge and immense patience. She has always been a source of encouragement, constant inspiration and the ultimate solution for all my queries which were never time bound. Without her support, the completion of this dissertation wouldn't have been possible. Apart from the subject of my research, I have learnt a lot from her, which I am sure, will be useful in different stages of my life.*

I owe my most sincere gratitude to respected Dean ***Dr. B Rajkumar****, for the permission, help and guidance during the conductance of this work.*

I am equally indebted to ***Dr. Rohit Khanna****, MDS, Professor, Department of Orthodontics and Dentofacial Orthopedics, for his valuable advice throughout, unbiased support and constant help rendered not just for the dissertation, but always.*

I gratefully acknowledge ***Dr. Rana Pratap Maurya****, MDS, Reader, Department of Orthodontics and Dentofacial Orthopedics, for his valuable suggestions, timely guidance and untired help during sample collection.*

I would also like to express my gratitude to ***Dr. Sneh Lata Verma,*** *MDS, Reader, Department of Orthodontics and Dentofacial Orthopedics, for her encouragement, constant moral support and inspiration.*

I also thank all the senior lecturers of my Department, ***Dr. Srishti Aditi, Dr. Ankita Jaiswal, Dr. Prateek Asthana, Dr. Shweta Pandey*** *and* ***Dr. Abhimanyu Singh*** *for their time to time support and constant motivation which always encouraged me to keep going through the hurdles.*

I would like to thank my seniors ***Dr. Medha Lakhanam, Dr. Rahul Anand, Dr. Priyanka Rai, Dr. Harmeet Kaur,*** *and my colleagues* ***Dr. Akshita Agarwal, Dr. Sanaf Zaman, Dr. Astha Baul Srivastava, Dr. Vandana Chauhan*** *and* ***Dr. Divya Tripathi,*** *for their valuable suggestions and support. I also express my special thanks to my juniors* ***Dr. Tanjula Shair, Dr. Akansha, Dr. Noor Zaman, Dr. Rigzing O Lepcha, Dr. Deepak Chandra, Dr. Deepa Soni, Dr. Swagat Verma, Dr. Haobam Minerva, Dr. Kamran Javed, Dr. Bhanu Pratap*** *and* ***Dr. Bivek Bijoy Senapati*** *for their consistent help. I would also like to thank the paradental staff of my department* ***Mr. Surender*** *and* ***Mr. Narender****.*

I would specially like to thank my friends ***Dr. Taruna Chaudhary, Dr. Srishti Beera, Dr. Nidhi Chaudhary, Dr. Sankalp Nigam, Dr. Shubham Gupta, Dr. Dibyajit Sur, Dr. Himanshi, Dr. Akanksha Raj, Dr. Prashant Sharma, Dr. Pratibha Kaushik, Dr. Mushahid Hasan****,* ***Dr. Abhimanyu Kochhar****,* ***Sonali Rastogi, Ridhvika Arora, Dharini Singh*** *and* ***Aakriti Singhal*** *for believing in me and always being my support.*

*A special mention for a word of thanks **to Dr. Avi Bansal, Dr. Pranshu Singh** and **Dr. Tamanna Aghi** for their support and assistance in times when I needed them the most.*

*Most of the results obtained in the thesis wouldn't have been possible without the cooperation of **Mr. Abhishek Rajvansh**, Deputy Director and in-charge at CIPET, Dehradun. I would also like to express my gratitude to my statistician, **Dr. Upendra Sir** for helping me to obtain the results for my dissertation.*

*I wish to thank my fiancé **Dr. Shobhit Garg** for his unbound faith, unflinching support, motivation, generous care, unending and fruitful advices, guidance and constant upliftment throughout my dissertation period that has helped me bring this dissertation to a successful completion. Thanking you for standing by my side like a pillar.*

*I dedicate this dissertation to the timeless efforts, blessings, prayers & good wishes of my parents **Mr. Surendra Arora** and **Mrs. Ranjana Arora** who have been a constant source of inspiration and encouragement to me always and without whom I am nothing. I would like to express my gratitude to my siblings **Neha A. Kumar** and **Rishabh Utreja** who have always been with me through thick and thin and have been a constant source of vigour, motivation to bring out the best in me and my brother-in-law **Saurabh Kumar** for his constant support, help and advice when need arose. I would like to thank my Massi **Mrs. Charu Utreja** and Mausa ji **Mr. Naveen Utreja** for always believing in me, guiding me through right and wrong and always encouraging me to keep going.*

*A special word of humble gratitude to my in-laws **Mr. Umesh Garg**, **Mrs. Seema Garg**, **Dr. Mohit Tayal** and **Dr. Sakshi Tayal** who have always motivated and uplifted me to be the best version of myself and have been a strong support in all my decisions.*

In the end, I would like to thank all those people who have directly or indirectly contributed to the completion of my dissertation.

Dr. Samiksha Arora

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LIST OF ABBREVIATIONS

SERIAL NUMBER	ABBREVIATION	FULL FORM
1.	SBS	Shear bond strength
2.	DT3C	Das Tip, Torque and Thickness Customization
3.	MPa	Mega Pascal
4.	CIPET	Central Institute of Plastic Engineering and Technology
5.	STB	Scuzzo Takemoto Bracket
6.	N/mm^2	Newton per square milimeter
7.	SEP	Self-Etch Primer
8.	CCA	Color Changing Adhesive
9.	SD	Standard Deviation
10.	CI	Confidence Interval
11.	NS	Not significant
12.	kN	Kilo Newton
13.	Fig	Figure
14.	etc	Etcetera
15.	et al	et alia (and others)
16.	°C	Degree Celsius
17.	LED	Light Emitting Diode
18.	nm	Nano meter
19.	mW/cm^2	Mili Watt per square centimeter
20.	mm/min	Milimeter per minute

ABSTRACT

Introduction: The purpose of this study was to evaluate the shear bond strength of a color changing adhesive (Grengloo) and its comparison with a conventional adhesive (Transbond XT) used to bond brackets by Indirect Technique in Lingual Orthodontics using Universal Testing Machine.

Material and method: The sample consisted of 50 extracted human premolar brackets divided equally and randomly into two groups, Group I consisted of 25 teeth bonded indirectly on lingual surface of teeth by Grengloo and Group II consisted of 25 teeth bonded indirectly on lingual surface of teeth by Transbond XT using Das' DT3C bracket positioning device and the shear bond strength was measured by Universal testing machine. Data was subjected to appropriate statistical analysis.

Result: Significantly higher values of shear bond strength was seen for Group I (13.07 $\pm$ 4.93 MPa) as compared to Group II (9.76 $\pm$ 2.75 MPa), however, both were above the clinically acceptable limits by Reynolds (5-7 MPa).

Conclusion: Grengloo had adequate shear bond strength, much above the clinically acceptable limits which advocates its use in lingual orthodontics. Also, its dual color-changing property will be extremely beneficial for adhesive removal from irregular lingual surfaces after completion of treatment.

Keywords: color changing adhesive, shear bond strength, universal testing machine, indirect bonding, lingual Orthodontics.

The technique of fixed Orthodontics evolved from banding of all teeth to bandless Orthodontics which involved bonding of attachments to tooth surface. Bond strength of brackets bonded to enamel should withstand occlusion forces and the stresses exerted by insertion of arch wires for tooth movement in all three planes of space. At the same time, bond strength should not be so much so as to cause damage to the enamel surface while debonding.

Bonding of attachments initially involved direct bonding, introduced in the year 1965 by Newman[1], where acid etch technique of Buonocore[2] was used followed by bonding of brackets to the teeth with an epoxy-derived resin.

Direct bonding involves manual positioning of the brackets on teeth and it provided esthetic alternative to fully banded appliance therapy. It was convenient for the operator as well as the patient and it became increasingly popular in labial Orthodontics. However, it had certain disadvantages like more chair-side time, increased risk of contamination by saliva causing bond failure, poor visualization of posterior teeth leading to difficulty in accurate positioning of the bracket, etc. To overcome these limitations, Indirect Bonding Technique was introduced by Silverman and Cohen[3] in 1972 and later modified by Thomson[4] in 1979. The Indirect Bonding Technique involves fabrication of a custom transfer tray after placement of the brackets on the hard stone models, thereby using the same for bonding it in the patient's mouth.

Shpack et al[5] conducted a study in 2007 to examine the accuracy of bracket placement in labial vs lingual systems and direct vs indirect bonding techniques and found out that for both systems i.e. labial as well as lingual, indirect bonding significantly reduced the absolute torque error and rotation deviation. The torque error could cause transverse discrepancy (scissor/ crossbite) combined with disclusion of antagonist teeth. The rotation deviation could cause irregular interproximal contact points.

The preference for esthetic alternatives to brackets placed labially, be it ceramic or polycarbonate bracket, led to the advent of lingual orthodontics. Lingual Orthodontics represents the best alternative for meeting the patient's expectations of invisible appliance without damaging the biomechanical efficiency. The first reference to lingual mechanics dates back to 1889 when John Farrar[6] introduced the 'Lingual Removable Arch.' Since then, clinicians have tried to utilize mechanical advantage of lingual aspect of teeth inorder to bring about desired tooth movements. The main advantages of using Lingual Orthodontics are that no damage is caused to the facial surfaces of the teeth from bonding, debonding and/or adhesive removal; facial and/or gingival tissues are not adversely affected; facial contours are truly visualized since the contour of the lips are not distorted due to protrusion caused by the labial appliances; inter-bracket width is reduced due to the smaller arch radius on the lingual aspect which is beneficial while using more resilient archwires[7].

For lingual Orthodontics, indirect bonding of the brackets is of utmost importance because great anatomical differences of lingual surfaces, especially of incisors and difficulty of the visualization of the lingual aspect of teeth and increased risk of contamination by saliva, direct bonding is not possible on lingual aspect.

The most important aspect of bracket placement in lingual orthodontics is that the required tip, torque, in-out considerations that are included in the bonded brackets are achieved by addition of adhesive of variable thickness beneath the bracket bases. For this, different devices like Torque Angulation Reference Guide (TARG), Fillion's lingual indirect bonding system, Customized lingual appliance setup service (CLASS), SLOT machine, Bonding with Equal Specific Thickness (BEST) system, HIRO system, Ray set system, Lingual bracket jig, Transfer Optimized Positioning (TOP/ INCOGNITO braces) system, Korean Indirect Bonding set-up (KIS) system, Hybrid core system, Orapix system, Das DT3C device etc. had been used. Amongst these, Das DT3C (Das' Tip Torque Thickness Customization Device) that enables transferring of tip and torque from labial to lingual side and can be done by the operator with no requirement of the laboratory was used in the present study.

Debonding is the removal of all Orthodontic attachments once the treatment is over. It involves removal of the remaining adhesive with minimum amount of damage to the surface enamel and restoring the enamel surface to its original state[2] without introducing iatrogenic damage. There are several procedures for bracket removal for both metal as well as ceramic brackets like using debonding pliers, thermal debonding, laser debonding, etc. Bracket removal using debonding pliers involves placing the tips of a twin-beaked plier against the mesial and distal edges of the bonding base and squeezing the bracket wings mesiodistally and lifting the bracket off with a peel force. Thermal debonding involves heating the tips of utility plier for ten seconds and then applying light rotational force on the bracket. In laser debonding, the laser energy degrades the adhesive resin by thermal softening of the bonding agent until the bracket drops off; thermal ablation occurs when the heat is fast enough to cause vaporization of the resin.

The main challenge after debonding is restoring the enamel surface as close as possible to the original texture of enamel. The removal of any excess adhesive can be done by scraping with a sharp instrument, band-removing plier, ultrasonic scaler, a suitable bur (eg. white stone finishing bur, dome-shaped tungsten coated bur), lasers, etc. After removal of the remnant adhesive, the tooth surface is polished to restore it to the original state. Several methods for polishing can be employed such as use of burs (composite bur, soflex discs, etc.) which is followed by the use of pumice paste and water with a rubber cup.

Most of the adhesives used for Orthodontic bonding are tooth colored, hence complete removal of the remaining adhesive without damaging the enamel is not easily achieved. To overcome this, color changing adhesives were introduced in Orthodontics like Transbond Plus (3M, for metal brackets), Blugloo (Ormco, for ceramic brackets), Grengloo (Ormco, for metal brackets)[2] etc.

Transbond Plus is a pink colored adhesive that allows easy removal of flash during bracket placement and after curing, it became tooth colored[2]. However, it did not offer any advantage of its color changing property during debonding. Grengloo, used for metal brackets possessed color changing property with the change of temperature[8]. Duers et al[9] reported that Grengloo has faster polymerization rate as compared to other light-cured bonding adhesives and therefore provides a higher percentage of total bond strength during the initial force loading. It is also designed with a patented ingredient to have upto 118% greater impact resistance and it also has a chemical affinity for meal brackets which ensures reliable bond strength of this color changing adhesive. The green color of Grengloo adhesive at lower temperature facilitated removal of excess flash and as the adhesive is cured or warmed to body temperature, its color disappeared and it remained tooth colored throughout the treatment[2,8]. After debonding of the brackets, with a short blast of cool air or water spray, its color changed to green again which allowed easy removal of the adhesive remnants from the tooth surface preventing damage to the enamel during adhesive removal. This property would be extremely helpful in lingual Orthodontics as well, where the removal of remaining adhesive from irregular lingual surface cannot be easily visualized. Similarly, Blugloo can be used with ceramic brackets.

Despite of the advantage of color changing ability of the orthodontic adhesives, the most important consideration while selecting any adhesive will be its bond strength. The clinically acceptable bond strength is necessary to withstand occlusal and masticatory stresses and forces exerted while applying different treatment mechanics. Reynolds proposed clinically acceptable bond strength to be in the range of 5.88-7.85 MPa[10]. Bond strength in fixed (labial and/or lingual) Orthodontics depends on a number of factors like adequately clean and properly conditioned enamel surface, type of adhesive used, surface area of the bracket and bracket mesh, type of curing light used, technique of bonding (direct/indirect), thickness of adhesive/bonding material used etc[11].

If these color changing adhesives provide adequate bond strength along with their ability to aid in easy removal of flash during bonding and removal of remaining adhesive after debonding, they will go a long way in Orthodontics. Since variable thickness of the composite pad is seen beneath the bracket base due to incorporation of tip and torque in bracket bases, hence, bond strength of the adhesive might be altered when used lingually.

A study done by Northrup et al[12] in 2007 showed the advantages of Blugloo (a color changing adhesive) over conventional adhesive with the advantage of easy clean up as a result of color change, improved esthetics along with 150% increased bond strength specially when used with a specific type of bracket. Ekhlassi et al[2] conducted a comparative study of shear bond strength of color changing and conventional adhesives in 2011 on extracted bovine incisors and found out that time had no significant effect on the shear bond strength of either Grengloo, Transbond Plus or Transbond XT. They also emphasized the importance of color changing adhesives used to bond brackets as the flash removal becomes easier, it is easier to visualize the remaining adhesive on the tooth surface after debonding, thus lesser chances of white spot lesions while using color-changing adhesives as compared to tooth-colored adhesives.

Few studies[2,8-10,12-19] have been done to evaluate the shear bond strength of Grengloo with conventional and other color changing adhesive i.e. Transbond Plus. Two of these studies[2,9] conducted on bovine incisors showed that the shear bond strength of Grengloo was lesser than Transbond Plus but still higher than clinically acceptable values given by Reynold (5.88-7.85MPa)[10]. A study done by Shamnur N, Prasad M and Jacob JJ[14] in 2011 evaluated the clinical performance of Grengloo in comparison to Transbond Plus in terms of bonding time, bond failure rate and time taken by each adhesive to change the color and they found similar clinical performance of both the adhesives. None of these studies had evaluated the shear bond strength of Grengloo when used on human teeth. Also, no study had been conducted to evaluate the shear bond strength of Grengloo when used in Lingual orthodontics. Considering this, the aim of this study was to evaluate and compare the shear bond strength of brackets bonded by indirect bonding technique in Lingual Orthodontics with two different light-cure adhesive systems i.e. a color changing adhesive, Grengloo and a conventional adhesive, Transbond XT.

AIM: To evaluate and compare the shear bond strength of Orthodontic brackets bonded by indirect technique in lingual fixed Orthodontic appliance using two different light-cure adhesive resin (Grengloo and Transbond XT).

OBJECTIVES:

1. To evaluate the shear bond strength of brackets bonded by Indirect bonding technique on the lingual surface of teeth by color changing light-cure adhesive resin, Grengloo.

2. To evaluate the shear bond strength of brackets bonded by Indirect bonding technique on the lingual surface of teeth by conventional light-cure primer adhesive resin, Transbond XT.

3. To compare the shear bond strength of brackets bonded by Indirect technique on lingual surface of teeth bonded by conventional adhesive (Transbond XT) and color changing adhesive (Grengloo).

Alexandre P, Young J, Sandrik JL, Bowman D (1981)[20] conducted a study on 108 extracted premolar teeth, randomly divided into 6 equal groups. Concise, Dyna Bond and Endur were used as bonding agents and each system was tested on 36 teeth equally divided into 1- and 27- day test period. A contoured stainless steel mesh-base bracket (Unitek Twin Torque) was bonded to each tooth. A shear load was applied by Universal testing machine, Instron and no significant difference was found in the bond strength at 24-hour interval. However, Concise and Dyna bond were significantly stronger than Endur when tested at 27-day interval. The interface was studied to determine the mode of failure and it was found that in all cases, bond failure occurred as mixed adhesive-cohesive phenomena.

King L, Smith RT, Wendt SL, Behrents RG (1987)[21] conducted a study to evaluate the tensile and shear strengths of direct bonded stainless steel lingual orthodontic brackets by means of chemically-cured composite resins and transilluminated light-cured composite resins. For this study, eighty bovine teeth were divided into ten groups of eight teeth each. Stainless steel, mesh-backed lingual orthodontic brackets were bonded to five groups of teeth by means of two chemically cured composite resins and three light-cured composite resins. These teeth were tested in the Instron universal testing machine for tensile bond strengths. Likewise, five groups were bonded with the same type brackets and composite resins. These teeth were tested in the Instron for shear bond strengths. Five composite resins were chosen for evaluation— two chemically cured resins, Concise orthodontic bonding resin and Right-On, and three light-cured composite resins, Silux, Heliosit, and Heliosit Ortho, in this study. Results of this investigation showed that the bond strengths of the orthodontic brackets bonded with light-cured composite resins were significantly less than the bond strengths of the orthodontic brackets cemented with traditional adhesives and orthodontic composite resins. However, there was no correlation of bond strengths of the brackets cemented with the transilluminated light-cured composite resins when compared to the faciolingual widths of the teeth.

Gwinnett AJ (1988)[22] conducted a study to evaluate and compare the shear bond strength of metal, ceramic and ceramic filled plastic brackets bonded to human incisor teeth with a heavily filled composite resin. Five groups of ten caries free incisor teeth were made which were divided as follows: A- Ormesh bracket (metal), B- Microlok bracket (metal), C- Allure bracket (ceramic), D- Mirage bracket (plastic/ceramic-fiiled), and E- Transcend (ceramic); bonded with Concise Orthodontic bonding system which included concise bracket primer for Group D plastic brackets. The difference among means was not statistically significant at 95% confidence level. The site of failure was commonly at the resin-bracket interface except for the ceramic filled plastic brackets which frequently showed failure of the bracket itself.

McAlarney ME, Brenn P (1993)[23] evaluated the bond strength in vitro for two methods of direct bonding on a sample of sixty human premolar teeth which were divided into two groups of 30 each. In group I the brackets were bonded with a two-paste adhesive by using the conventional direct method. In group II brackets were bonded with a newly developed modified direct technique. During the modified direct technique, unfilled resin catalyst liquid was applied to a bracket, which had a coating of hardened composite cured against the tooth. After the acid-etched tooth was coated with unfilled resin base liquid, the bracket was placed. Sealant was then placed at the periphery of the bracket/tooth interface. Thus, the major modification of the direct technique would entail fabrication by the manufacturer of a bracket with prehardened bis-GMA composite resin on its backing. Bond strengths were 155.2 (SD = 35.7) and 140.6 (SD = 30.1) kg/cm 2 for conventional and modified techniques, respectively. With the conventional method, failure occurred mainly at the tooth/composite interface. Failure seen with the modified technique was mixed, but the major mode was composite/bracket. Therefore, the modified bonding method showed similar bond strengths and some advantages over the conventional method including, elimination of composite flash from around the brackets, ample working time, consistent adhesive thickness, and reduction of porosity.

Wiechmann D (2000)[24] conducted a study to examine the influence of intraoral sandblasting prior to etching on the adhesive strength on indirect bonding. The shear bond strength of 20 cylinders made of composite was measured after 24 hours of bonding on enamel of bovine teeth. The enamel of these 20 teeth was prepared by sandblasting prior to etching, whereas another set of 20 teeth were used as a control group in which bonding was done without sandblasting the surface. The results showed that intraoral sandblasting prior to etching can significantly ($p<0.001$) increase the adhesive strength between enamel and bonding material.

Oesterle LJ *et al* (2001)[25] conducted a study on 100 extracted human premolar teeth to determine the transmittance of the curing light through human enamel and the effect of transillumination on the bond strength of orthodontic brackets. Brackets with orthodontic composite adhesive were placed on the labial surface of the incisors and light cured from either the labial or the lingual. The control sample was cured from the labial for a total of 40 seconds of light exposure and the experimental samples were cured from the lingual (transillumination) for 20, 30, 40 or 50 seconds. The shear-peel bond strengths were tested at 30 minutes and 24 hours after light application. The results of this study demonstrated no statistically significant difference between 40 seconds of labial curing and most of the lingually cured groups. The only experimental group that differed statistically from the control group was the 40-second lingual cure group tested at 30 minutes after light application. The samples tested at 24 hours that received 50 seconds of transillumination were nearly the same as the control values. This study demonstrated that transillumination of maxillary incisors is an acceptable method of curing orthodontic adhesive, particularly if the exposure time is increased from 40 to 50 seconds.

Toledano M, Osorio R, Osorio E, Romeo A, Higuera B, Godoy FG (2003)[26] conducted a study on 50 extracted human premolar teeth to evaluate the shear bond strength of directly bonded stainless steel orthodontic brackets. The teeth were randomly divided into five groups: (1) System One (chemically cured composite resin), (2) Light Bond (light-cured composite resin), (3) Vivaglass Cem (self-curing glass ionomer cement), (4) Fuji Ortho LC (light-cured glass ionomer cement) used after 37% orthophosphoric acid–etching of enamel (5) Fuji Ortho LC without orthophosphoric acid–etching. The brackets were placed on the buccal and lingual surfaces of each tooth, and the specimens were stored in distilled water

(24 hours) at 37 degree C and thermocycled. Teeth were mounted on acrylic block frames, and brackets were debonded using an Instron machine. Bonding failure site was recorded by stereomicroscope. System One attained the highest bond strength. Light Bond and Fuji Ortho LC, when using an acid-etching technique, obtained bond strengths that were within the range of estimated bond strength values for successful clinical bonding. Fuji Ortho LC and Vivaglass Cem left an almost clean enamel surface after debracketing.

Kalocke A, Shi J, Nieke BK, Bismayer U (2003)[27] conducted a study by bonding stainless steel brackets to 100 permanent bovine incisors using the Thomas technique, the modified Thomas technique, and light-cured direct bonding for a control group. The following 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). Mean bond strengths of groups 3, 4, and 5 were not significantly different from each other. 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.

Murray SD, Hobson RS (2003)[28] conducted a study on 20 volunteers who were asked to wear removable appliances containing orthodontic brackets bonded to enamel slabs for 12 weeks. Each appliance carried 3 brackets bonded with Transbond and 3 brackets bonded with Heliosit. The bond strengths were tested at intervals of 4, 8, and 12 weeks. Control specimens were stored in sterile water at 37°C and were debonded at the same time intervals. Transbond specimens debonded after 4 weeks in vivo had significantly lower bond strengths (9.78 MPa) than did the controls (14.34 MPa). In vivo, specimens bonded with Heliosit had significantly lower bond strengths after 4 weeks (8.16 MPa vs 10.96 MPa) and 8 weeks (9.96

MPa vs 13.61 MPa) than did the controls. These results indicated differences between bond strength testing in vitro and in vivo.

Klocke A, Shi J, Vaziri F, Nieke BK, Bismayer U, Nat R (2004)[29] conducted a study on 135 bovine permanent mandibular incisors was randomly divided into nine groups of 15 specimens each to determine the influence of a reduced time interval before debonding on shear bond strength of stainless steel brackets bonded with a custom base indirect technique. Three base composite-sealant combinations were investigated: (1) Phase II base composite, Custom I.Q. sealant, (2) Phase II base composite, Maximum Cure sealant, and (3) Transbond XT base composite, Sondhi Rapid Set sealant. Shear bond strength was measured for three different debonding time intervals: (1) time of transfer tray removal as recommended by the manufacturer, (2) 30 minutes after bonding of the sealant, and (3) 24 hours after bonding of the sealant. For 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 measurements when debonded at the recommended tray removal time, and the Weibull analysis indicated a higher risk of bond failure at clinically relevant levels of stress. All base composite-sealant combinations showed acceptable bond strength at 30 minutes and 24 hours after bonding of the sealant.

A**ttilio MD, Traini T, Iorio DD, Varvara G, Festa F et al(2005)**[1] conducted a study on 80 extracted human premolars divided into two groups to evaluate the bonding of orthodontic brackets by determining the shear bond strength (SBS) and the mode of bond failure after debonding by using Transbond XT (control) and Denfil flow (flowable composite resin). No significant difference was observed in the SBS between the groups, and a clinically acceptable SBS was found for the two adhesives. Bond failures occurred mostly at the bracket–adhesive interface, without significant differences between the groups. At SEM analysis, Denfil Flow showed a greater frequency of air bubbles within the resin than did Transbond XT**.**

Aksu B, Caniklioˇglu MC, Ozturk Y (2005)[30] conducted a study on 20 extracted mandibular premolars to investigate the shear bond strength of indirectly bonded Ormco lingual brackets using different composite bracket base preparation. In group 1, 1 mm composite base was constructed directly on the intact bracket base. In group 2, bracket bases were first sandblasted and then 1 mm composite base was constructed. The mean of shear bond strength was higher for group 2 (12.11 MPa) than group 1 (9.46 MPa). The results of this study support the recommendation of sand blasting in order to increase the shear bond strength and retention between the bracket and composite base.

Klocke A, Nieke BK (2005)[31] conducted a study to analyze the influence of debonding force location in shear bond strength testing of orthodontic brackets in vitro on ninety extracted permanent bovine mandibular incisors which were randomly divided into 3 groups of 30 specimens each. Teeth were bonded with stainless steel orthodontic brackets. Enamel surfaces were etched with 37% phosphoric acid for 30 seconds and bonded with Transbond XT adhesive. Debonding force measurements were performed with a universal testing machine. Location of the debonding force was at the bracket base for group A, at the ligature groove for group B, and at the occlusal bracket wings for group C. Maximum mean shear bond strength was found for group A (22.70 MPa), followed by group B (11.52 MPa) and group C (9.44 MPa).

Vicente A, Bravo LA, Romero M, Ortiz AJ, Canteras M et al (2005)[32] conducted a study on 75 extracted premolars to compare the shear bond strength and the quantity of adhesive remaining on the tooth after debonding of brackets bonded with two light-cured orthodontic resin adhesive systems (Transbond XT and Light-bond) and a dual cured resin cement (Rely X Unicem). Shear bond strength was measured using a universal test machine and adhesive remnant was quantified using image analysis equipment. The results showed that resin cement produced significantly lower mean bond strength of 8.16 as compared to the two orthodontic resin adhesive systems i.e. 12.27 MPa for Transbond XT and 14.93 MPa for Light-Bond. However, resin cement left relatively lesser remnant of adhesive than the other two.

Shpack N, Geron S, Floris I, Davidovitch M, Brosh T et al (2007)[5] conducted a study on 40 pre-treatment dental casts of 20 subjects to examine the accuracy of bracket placement in labial vs lingual systems and direct vs indirect bonding techniques. Direct bonding was performed on casts held in mannequin head. Labial brackets were oriented with a Boone gauge, and lingual brackets were oriented with a Lingual-Bracket-Jig System. Torque error (TqE) and rotation deviation (RotD) were measured with a torque geometric triangle and a toolmaker's microscope respectively. Both torque and rotational measurements were evaluated statistically as algebraic and absolute numeric values, using analysis of variance with repeated measures. Absolute Torque error and Rotation deviation were significantly higher in direct than in indirect bonding techniques. However, no statistically significant difference was found between labial and lingual systems for the same bonding technique.

Northrup RG, Berzins DW, Bradley TG, Schuckit W (2007)[12] conducted a study to evaluate and compare the shear bond strength of two adhesive systems (Transbond XT and Blugloo) on 60 premolars using two types of brackets: a conventional (Orthos) and a self ligating bracket system (Damon 2) by direct bonding. The mean shear bond strength was maximum for group 3 bonded with Blugloo i.e. 24.8 MPa and minimum for group 1 bonded with Transbond XT i.e. 15.2 MPa. However, no significant differences were seen in the shear bond strength between groups 2 and 3 (both bonded with Transbond XT; and conventional and self-curing backets respectively). All the groups provided bond strength with over 90% survival rate at normal masticatory and orthodontic force levels i.e. they demonstrated clinically acceptable bond strength.

Ostby AW, Bishara SE, Denehy GE, Laffoon JF, Warren JJ (2008)[33] conducted a study to determine whether the pH of Self-Etching Primers (SEPs) affects the shear bond strength of orthodontic brackets for which forty-five molars were cleaned, mounted, and randomly divided into 3 groups with different SEPs: in group 1 (control), 15 orthodontic brackets were bonded to the teeth with Transbond Plus with a pH of about 1.0; in group 2, 15 brackets were bonded with Adper Prompt L-Pop with a pH of 0.9 to 1.0; in group 3, 15 brackets were bonded with Clearfil S3 Bond, with a pH of 2.7. All teeth were bonded with Transbond XT paste. The teeth were debonded within half an hour after initial bonding by using a universal testing machine. The residual adhesive on each tooth was evaluated. Results showed that the SEP with the highest pH (least acidic), Clearfil S3 Bond, bonded brackets successfully and with the strongest SBS which suggested that the pH of the SEP is not the primary determinant of the SBS. The comparisons of the ARI scores between the 3 groups indicated that bracket failure mode was not significantly different.

Adanir N, Turkkahraman H, Gungor AY (2009)[34] conducted a study to evaluate the effect of enamel fluorosis on the shear bond strength (SBS) of orthodontic brackets and to determine whether adhesion promoter, Enhance LC, increases the bond strength of brackets to fluorosed enamel. For this purpose, forty-five (30 fluorosed and 15 non-fluorosed) non-carious extracted human premolar teeth were used in this study. The fluorosed teeth were selected according to the modified Thylstrup and Fejerskov index, which is based on the clinical changes in fluorosed teeth. In groups 1 i.e. fluorosed teeth and group 3 i.e. control, the brackets were bonded with Light Bond composite resin and cured with a halogen light. In group 2, Enhance LC was applied to fluorosed enamel before bonding. After bonding, the SBS of the brackets was tested with a universal testing machine. The results showed that while fluorosis significantly reduced the bond strengths of the orthodontic brackets, Enhance LC significantly increased bond strength on fluorosed enamel (mean 18.22 ± 5.97 Mpa). Groups 1 and 3 had greater bond failures at the composite – bracket interface, whereas group 2 showed bond failure primarily at the enamel – composite interface.

Vilchis RJS, Yamamoto S, Kitai N, Yamamoto K (2009)[35] conducted a study to compare the shear bond strength (SBS) of orthodontic brackets bonded with 4 self-etching adhesives for which a total of 175 extracted premolars were randomly divided into 5 groups (n=35). Group I was the control, in which the enamel was etched with 37% phosphoric acid, and stainless steel brackets were bonded with Transbond XT. In the remaining 4 groups, the enamel was conditioned with the following self-etching primers and adhesives: group II, Transbond Plus and Transbond XT; group III, Clearfil Mega Bond FA and Kurasper F; group IV, Primers A and B, and BeautyOrtho Bond; and group V, AdheSE and Heliosit Orthodontic. The teeth were stored in distilled water at 37 degree Celsius for 24 hours and debonded with a universal testing machine. The adhesive remnant index (ARI) including enamel fracture score was also evaluated. Additionally, the conditioned enamel surfaces were observed under a scanning electron microscope. Results of this study showed that the SBS values of groups I (19.0 MPa) and II (16.6 MPa) were significantly higher than those of groups III (11.0 MPa), IV (10.1 MPa), and V (11.8 MPa). Fluoride-releasing adhesives i.e. Kurasper F and BeautyOrtho Bond showed clinically acceptable SBS values. Also, significant differences were found in the ARI and enamel fracture scores between groups I and II.

Romano FL, Correr AB, Sobrino LC, Magnani MBBA, de' Siqueira VCV (2009)[36] conducted a study to assess the shear bond strength of orthodontic brackets on different enamel surfaces using the Transbond Plus Color Change composite, and to analyze the Adhesive Remnant Index (ARI) for which seventy-two human premolars were divided into six groups as follows: Group 1(control) - Transbond XT conventional; in Groups 2 to 6, TPCC was used under the following enamel treatment conditions: phosphoric acid and XT-primer; Transbond Plus Self-Etching Primer (TPSEP); phosphoric acid only; phosphoric acid, XT-primer and saliva; and TPSEP and saliva, respectively. Twenty-four hours post bonding, the brackets were debonded with an Instron machine, and ARI was evaluated. Results showed that the mean shear strength values for Group 1 had significantly higher shear bond strength values than Groups 3, 5, and 6 ($p < 0.05$), but did not differ significantly from Groups 2 and 4 ($p > 0.05$).

Turkkahraman H, Adanir N, Gungor AY, Alkis H (2010)[13] conducted a study to test whether the shear bond strengths (SBS) of three commercially available colour change adhesives i.e. Transbond Plus Color Change Adhesive, Grengloo, and Blugloo, was different and to compare their bond strengths with a traditional light cure adhesive, Light Bond. For this study, forty-eight human permanent premolar teeth extracted for orthodontic reasons were used and were divided equally into 4 groups. The brackets were bonded with Light Bond for group I, Grengloo for group II, Blugloo for group III, and Transbond Plus CCA for group IV. After bonding, the SBS of the brackets were tested with a Universal testing machine. The results obtained from the study showed a significant difference between the SBS of Transbond Plus CCA and Light Bond. Although Transbond Plus CCA yielded the lowest SBS values, no statistically significant difference was found between bond strength values of the three commercially available CCAs which concluded that all three CCAs can be safely used in orthodontic practice since they yielded acceptable bond strengths. Also, a higher incidence of ARI scores 4 and 5 revealed that bond failures in all test groups were mainly at the adhesive interface.

Shamnur N, Prasad M, Jacob JJ (2011) [14] Evaluated and compared the clinical performance of two color-changing bracket bonding adhesive (Transbond Plus and Grengloo) in terms of bond failure rate, bonding time and time taken by the adhesive to change color. Bonding was done using Cross arch Split mouth technique, which involves the placement of two varieties of bracket bonding adhesives in diagonally opposite quadrants and cured using a visible light curing unit. The time taken by the adhesive to change color during bonding and the bonding time was noted using a stop watch. The bond failure rates of both the adhesives were evaluated by a thorough follow up of individual case, as and when they reported to the department with a debonded bracket. The data collected were subjected to statistical analysis. The results showed that the overall bond failure rate for two color changing adhesives were 7.1 % and 8.6 %, bonding time was 59.1 seconds and 57.4 seconds per tooth and time to change color was 45.9 seconds and 46 seconds. There were no significant differences between the failure rates, bonding time and time taken by both the adhesives to change color showing that both are clinically efficient and effective and are preferred over non-color changing bracket bonding adhesive as their color changing property helps in easy flash removal while bonding brackets.

Ekhlassi S, English JD, Ontiveros JC, Powers JM, Bussa HI, Frey GN et al. (2011)[2] conducted a study on 180 extracted bovine incisors divided into nine groups of twenty teeth each to compare the shear bond strengths of two color changing adhesives (Transbond Plus and Grengloo) with a commonly used conventional light-cure adhesive to compare any changes in shear bond strengths over time. The teeth were debonded at three different time points (15 minutes, 24 hours, 1 week) using an Instron at 1.0 mm/min. Results showed that Transbond Plus at 1 week had the highest mean shear bond strength (14.7 MPa). Grengloo tested at 24 hours had the lowest mean shear bond strength (11.3 MPa). The mean shear bond strengths for the remaining seven groups had a range of 12–14.5 MPa.

Lombardo L, Kaplan A, Lapenta R, Bratti E, Pera C, Scuzzo G, Siciliani G (2011)[37] compared the adhesive potential, the mechanics implicated in adhesive failure, and the effect on the enamel of four brands of lingual brackets on one hundred and sixty premolar teeth. Four types of commercially available lingual brackets (STB, ORG, Magic, and Stealth) were selected. Forty brackets per manufacturer were used, half bonded directly and half indirectly. Each of these bonding groups was further subdivided: 10 brackets were bonded without treatment, while the other 10 were sandblasted. Thus, a total of four groups were created for each type of bracket: (a) sandblasted and directly bonded, (b) sandblasted and indirectly bonded, (c) not sandblasted and directly bonded, and (d) not sandblasted and indirectly bonded. Immediately after bonding, each bracket was tested for adhesion strength, and each appliance was then examined via electron microscopy to calculate the ARI. Results showed a significant difference among the four bracket types; a general improvement in lingual appliance mechanical features provoked by sandblasting, and no significant effect of bonding method on the degree of bond strength. The ARI revealed that the most common area of adhesion crisis was at the adhesive-bracket interface. Overall, STB brackets performed better.

Maurya R, Tripathi T, Rai P (2011)[16] conducted a study to compare the shear bond strengths of light-cured orthodontic bonding agents namely glass ionomer, conventional composite resin i.e. Transbond XT, and color changing composite resin i.e. Transbond Plus, with conventional etch and self-etch primer i.e. Transbond Plus SEP. for this purpose 300 maxillary premolars were divided equally into five groups and bonding was done on the facial aspect. The following five groups of light-curing bonding agents were used namely, group I- Glass ionomer resin adhesive; group II- Composite resin with conventional etchant (Transbond XT); group III- Composite resin with self-etch primer (Transbond XT, Transbond Plus SEP); group IV- color changing composite resin with conventional etchant (Transbond Plus); group V- color changing composite resin with self-etch primer (Transbond Plus, Transbond Plus SEP). the sample was subject to Instron for shear bond strength testing and it was observed that Transbond XT with conventional etchant group (group II) had the highest bond strength whereas group I had the lowest.

Cal-Neto JP, Castro S, Moura PM, Ribeiro D, Miguel JAM (2011)[38] conducted a study to test the null hypothesis that there was no difference in the shear bond strength of indirectly bonded lingual brackets prepared with or without sand blasting prior to etching on 40 extracted premolar teeth divided into two groups of 20 each. Group I was the control group in which etching followed by indirect bonding was done with Maximum cure and Phase II; and group II in which sandblasting was done prior to etching followed by Indirect bonding. Instron was used to measure the shear bond strength and results showed that the bond strength for group II was comparatively higher than for group I but the clinical performance was not statistically different.

Duers MW, English JD, Ontiveros JC, Powers JM, Bussa HI, Frey GN et al (2011)[9] conducted a study on 240 bovine incisors divided into four groups to investigate whether three different color changing light-cured orthodontic bonding adhesives (3M Unitek Transbond PLUS, Ormco Grengloo and Ormco Bugloo) have comparable shear bond strength to a conventional light-cured orthodontic bonding adhesive (3M Unitek Transbond XT: control). The shear bond strength were tested at two different times (15minutes and 24 hours) post bond. Results showed that the average shear bond strength of Transbond PLUS, Ormco Blugloo and Transbond XT was greater at 24 hours than 15 minutes; whereas, for Grengloo, the average shear bond strength was greater at 15 minutes than 24 hours. Moreover, Grengloo tested at 15 minutes had the highest average shear bond strength of 9.91 MPa whereas the same had lowest average shear bond strength at 24hours i.e. 6.44 MPa. Thus, all four orthodontic bracket bonding adhesives demonstrated bond strengths considered to be clinically acceptable for orthodontic purposes.

Dalessandri D, Dalessandri M, Bonetti S, Visconti L, Paganelli C (2012)[39]**:** conducted a study to evaluate if the use of an indirect braces bonding protocol for localized enamel etching and adhesive application could help reduce plaque accumulation and demineralization around the brackets compared with a conventional direct-bonding technique. Thirty patients were bonded with a split-mouth approach: two randomly selected opposite quadrants were used as the test sides and the other two as control sides. During the first 6 months, the plaque presence around the braces was recorded monthly according to a plaque accumulation index (PAI), as was the presence of demineralization. PAI values were measured at each of the four bracket sides for every bonded tooth. Considering whole-mouth results, different bracket margin PAI scores did not differ significantly. PAI scores were higher at t1 (one month after bonding) and progressively decreased during the treatment. At debonding, the onset of 21 new white spots was recorded overall for the control sides and eight new white spots for the test sides.

Silva CFLM, Correa MA, Sobrinho LC, Moro A, Moresca RC, Correr GM (2012)[40] conducted a study to evaluate the bond strength of brackets fixed with different materials (two light-cured nanofilled resins - Transbond Supreme LV and Flow Tain LV, a light-cured resin - Transbond XT (control) and two chemically cured resins for indirect bonding - Sondhi Rapid- Set and Custom I.Q.) using the indirect bonding technique after 10 min and 24 h, and evaluate the type of failure. One hundred premolars were selected and randomly divided into groups (n=10) according to the material and fixation period. The brackets were bonded through the indirect technique following the manufacturer's instructions and stored in deionized water at 37 degree Celsius for 10 min or 24 h. After, the specimens were submitted to a shear bond strength (SBS) test (Instron) at 0.5 mm/min and evaluated for adhesive remnant index (ARI). Results showed that the light-cured nanofilled materials used in indirect bonding showed greater resistance than the chemically cured materials. The period of fixation had no influence on the resistance for different materials.

Izadi MI, Sherriff M, Cobourne MT (2012)[17] conducted a study to evaluate and compare the shear bond strength (SBS) and adhesive remnant index (ARI) of Damon3 and Damon3MX brackets bonded with their recommended primer/adhesive combination or Transbond XT primer/adhesive, with APC II brackets bonded using Transbond XT. Sixty non-carious human third molars were collected and randomly divided into six equal groups of 10. Amongst these, one group was used to standardize the testing methodology, with the remainder constituting the five experimental groups. Upper right central incisor brackets represented each bracket type. Specifically, Damon3 brackets were bonded using either OrthoSolo primer/Blugloo or Transbond XT primer/adhesive; Damon3MX brackets were bonded using OrthoSolo primer/Grengloo or Transbond XT primer/adhesive, and APC II brackets were bonded with Transbond XT primer. Brackets were debonded by shear force using an Instron machine and the SBS measured. Scores for ARI were determined for all groups after bracket failure by magnifi ed inspection of the tooth surface. Higher SBS was observed with Damon3 brackets bonded with OrthoSolo/Blugloo compared with Transbond XT, but no significant differences between the SBS of Damon3MX brackets bonded with OrthoSolo/Grengloo compared with Transbond XT. There were no significant differences in SBS of all three bracket types when bonded with Transbond XT.

Mati M, Elie AMM, Bouserhal J, Nassif NB (2012)[41] conducted a study to evaluate the effects of sandblasting on the initial shear bond strength and on the bracket/adhesive failure mode of orthodontic brackets bonded on buccal and lingual enamel using a self-etching primer (SEP). The brackets were bonded using a SEP and composite resin on the buccal and lingual surfaces of 30 premolars with intact enamel and 30 premolars pretreated by sandblasting with 50 mm aluminum-oxide. The results obtained after statistical analysis showed that sandblasting increased significantly SBS of the SEP on the buccal surfaces but the increase on the lingual surfaces was not statistically significant. A comparison of the adhesive remnant index scores indicated that there was more residual adhesive remaining on the teeth that were treated by sandblasting than on the teeth with intact enamel.

Chidipothu HR, Chandrasekhar S (2012)[42] conducted a study on forty human premolars, divided into Group I (n = 20) Transbond XT and Group II (n = 20) Transbond Plus Color Changing Adhesive (TPCCA); which were bonded with metal brackets using the adhesives. Brackets were debonded in shear on an Instron universal testing machine with a crosshead speed of 1 mm per minute. The mode of bond failure was determined by Modified ARI index and the Degree of Conversion (DC) was determined by FTIR analysis. Results showed no statistical significance between SBS of TPCCA [SD-8.87 (2.11)] and conventional Transbond XT [SD-10.54 (3.12)] and therefore was clinically acceptable. Both adhesives exhibited cohesive type of bond failure. A statistically significant lower percentage of DC was noted for TPCCA than Transbond XT, but it was within the range reported in the literature (55-75%).

Nichols DA, Gardner G, Carballeyra AD (2013)[43] used the cone-beam computed tomography and computer-assisted modeling software, to evaluate the consistency of orthodontists in placing orthodontic brackets at different times. For this, five orthodontists with experience in indirect bonding were selected to place brackets on 10 different casts at 3 time periods (n= 30 per orthodontist). Each participant completed an initial indirect bonding setup on each cast; subsequent bracket placements were completed twice at monthly intervals for comparison with the initial setup. The casts were scanned using an iCAT cone-beam computed tomography scanner and imported into Geomagic Studio software for superimposition and analysis. The scans for each time period were superimposed on the initial setup in the imaging software, and differences between bracket positions were calculated. For each superimposition, the measurements recorded were the greatest discrepancies between individual brackets as well as the mean discrepancies and standard deviations between all brackets on each cast. Results showed no statistically significant differences between time points of each orthodontist, or among the orthodontists for the parameters measured.

Bozelli JV, Bigliazzi R, Barbosa HAM, Ortolani CLF, Bertoz FA, Faltin JK (2013)[44] conducted a study to assess the time spent for DBB - direct bracket bonding and IBB - indirect bracket bonding techniques. The time length of laboratorial (IBB) and clinical steps (DBB and IBB) as well as the prevalence of loose bracket after a 24-week follow-up were evaluated on seventeen patients (7 men and 10 women) with a mean age of 21 years, requiring orthodontic treatment. A total of 304 brackets were used (151 DBB and 153 IBB) with same bracket type and bonding material in both the groups. Results showed that Indirect Bracket Bonding could be accepted as a valid clinical procedure since the clinical session was faster and the total time spent for laboratorial positioning of the brackets and clinical procedure was similar to that of Direct Bracket Bonding. Additionally, no difference was found as for the prevalence of loose bracket between both groups.

Stumpf ASG, Bergmann C, Prietsch JR, Vicenzi J (2013)[15] conducted a study on ninety metallic and ninety ceramic brackets which were bonded to 180 bovine incisors using two color change adhesives and a regular one. The teeth were randomly divided into 6 groups: Group 1 (G1) = metallic brackets bonded with Ortho Lite Cure; Group 2 (G2) = ceramic brackets bonded with Ortho Lite Cure; Group 3 (G3) = metallic brackets bonded with Transbond Color Change; Group 4 (G4) = ceramic brackets bonded using Transbond Color

Change; Group 5 (G5) = metallic brackets bonded with Transbond XT; and Group 6 (G6) = ceramic brackets bonded with Transbond XT. A tensile stress was applied by a universal testing machine and the teeth were observed in a microscope after debonding in order to determine the Adhesive Remnant Index (ARI). The statistical analysis demonstrated that the groups bonded with Transbond XT (G5 and G6) showed the highest adhesion, followed by the groups bonded with Transbond Color Change (G3 and G4). The worst results were obtained with the Ortho Lite Cure resin (G1 and G2). The results for the ARI showed no significant difference between the groups The most common ARI outcome was the entire adhesive remaining on the enamel.

Bayani S, Ghassemi A, Manafi S, Delavarian M (2015)[18] conducted a study to evaluate the effect of light-curing time on the shear bond strength of two orthodontic color-changing adhesives i.e. Grengloo and Transbond Plus for which 72 extracted premolars were randomly distributed in six groups of 12 teeth each. After the application of primer, a metal bracket was bonded to the buccal surface using an orthodontic adhesive. Grengloo and Transbond Plus were tested and one conventional light cured adhesive (Resilience) was used as a control. For each of the 1adhesive, the specimens were light-cured for 20 seconds and 40 seconds. The sample was then subjected to Universal Testing Machine to measure the SBS. Results showed that Grengloo had the highest SBS when light cured for 40 seconds and Transbond Plus showed the least when light-cured for 20 seconds. The ARI scores of Transbond Plus was significantly higher than the control group.

Ashtekar S, Shetty P, Deshpande R, Jadhav P (2016)[45] conducted a study to compare and evaluate the shear bond strength (SBS) of lingual brackets, manufactured by three different processes, that is, laser sintering, milling, and casting, bonded with two different adhesive primers. The study was done on one hundred and twenty premolars and three types of lingual brackets were used, namely, STB (milling), 7th Generation (casting), and lingual matrix (laser sintering). Forty brackets per system were used half of which were sandblasted while the other half were used as available. Further, these were subdivided and bonded with Transbond XT primer and adhesive and 3M ESPE primer and Transbond XT adhesive. Customization of STB and 7th Generation was done by TARG, Lingual matrix had bases customized by CAD/CAM. SBS was tested with universal testing machine and evaluated for adhesive remnant index (ARI). Results showed that surface treatment, use of different primers, method of customization influenced the SBS, and ARI suggested that the fracture occurred between composite and bracket interface. Lingual matrix bracket showed greater SBS as compared to STB and 7th Generation, and sandblasting increased SBS.

Imakami MB, Corotti KMV, Carvalho PED, Scocate ACRN (2016)[46] conducted a study to evaluate the shear strength of lingual metal brackets bonded to ceramic veneers. A total of 40 specimens were divided into four groups of 10, according to bonding material and ceramics preparation: Group I - Sondhi Rapid-Set resin and hydrofluoric acid, Group II - Sondhi Rapid-Set resin and aluminum oxide, Group III - Transbond XT resin and hydrofluoric acid, and Group IV - Transbond XT resin and aluminum oxide. Prior to bonding, the brackets were prepared with heavy-duty resin base and the ceramic veneers were treated with silane. The shear bond strength test was conducted with a Kratos testing machine. The results showed a statistically significant difference between groups I (2.77 MPa) and IV (6.00 MPa), and between groups III (3.33 MPa) and IV i.e. the bonding of lingual brackets to ceramic surfaces exhibited greater shear strength when aluminum oxide was used in association with the two resins utilized in this study, although Transbond XT showed greater shear strength than Sondhi Rapid-Set.

Youssefinia S, Mortezai O (2018)[19] conducted a study to evaluate and compare the shear bond strength of traditional adhesive (Transbond XT) with a color-changing adhesive (Transbond Plus) at different times. For this purpose, 72 extracted human premolar teeth were equally divided into two groups: Group I- brackets bonded with Transbond XT; and Group II- brackets bonded with Transbond Plus. Each of these groups were then further divided into three subgroups of 12 teeth each; representing three different time points to be tested i.e. at 15 minutes, 24 hours and 1 week. The shear bond strength was tested by the Universal testing machine and results showed that although Transbond XT showed lowest SBS at values at 1 week, but there was no significant difference between samples regarding their shear bond strength at different time nor any difference was seen in the Adhesive Remnant Index scores.

Pamukcu H, Ozsoy OP, Dagalp R (2018)[47] conducted a study to evaluate in vitro shear bond strength (SBS) and in vivo bond survival rates of brackets bonded using orthodontic indirect bonding resins. For the in vitro study, the first group was direct bonding control group. In Groups II and III, bonding was performed with indirect bonding resins that were either chemically or light-cured. The SBS of each sample was examined. For the in vivo study, full-mouth brackets were placed in 20 patients using a split-mouth approach, with either chemically-cured or a light-cured indirect bonding resin. The patients were followed for 12 months. Data were statistically evaluated and in vitro study showed lower SBS with chemically-cured indirect bonding resin than flowable light-cured resin and the control group, but in vivo failure rates of both indirect resins were found to be adequate for clinical usage.

Bolya P, Shukla C, Tiwari G, Bhatt S, Rathore S, Ali A (2018)[48] conducted a study on 50 extracted premolars to evaluate and compare the bond strength in various indirect bonding techniques when using different primers and adhesives. The sample was divided into five groups of 10 teeth each. Brackets of groups A, and B were bonded on the cast by Deli (water soluble glue), group C by Transbond Supreme LV, groups D and E by Tansbond XT. Indirect bonding on the teeth was done in groups A and C by Sondhi rapid set resin technique, groups B and D by Transbond XT and group E by Transbond LV Supreme. The overall comparison of all the techniques produced comparable mean bond strengths that were well within the clinically acceptable range. Group D produced the highest bond strength in comparison to other groups followed by Group E, B, C, and A. All the groups showed shear bond strength of more than 7.8 MPa. Hence, all the five techniques were suitable for clinical use.

Farhadian N, Miresmaeili A, Zandi VS (2019)[49] conducted a study to compare the shear bond strength (SBS) of orthodontic brackets bonded to enamel with conventional acid-etch (AE) technique and self-etching primers (SEP) on twenty-two patients, requiring extraction of two bicuspids for orthodontic reasons. In each individual, following blinding and allocation concealment, one intact premolar received conventional AE, whereas the contralateral premolar received SEP with a split-mouth design. Bonded brackets remained in the oral cavity for two months. Later, the teeth were extracted without debonding the brackets. SBS and adhesive remnant index (ARI) were measured using a Universal Instron machine and a stereomicroscope, respectively. The results showed that there was no statistical difference between the shear bond strengths of both the groups, however, the amount of residual adhesive on the enamel surface was significantly less with SEP than with conventional AE.

Singh P, Kumar CHS, Mohammed A, Sinha SK, Kalai P, Motghare R, Agarwal N (2019)[50] conducted a study to compare the accuracy, and time consuming between direct and indirect bonding by photographic method on 5 patients with split mouth technique in upper arch where brackets were bonded on one quadrant of orthodontic models for Indirect bonding one set as predetermined “ideal” bonding. A transfer tray was prepared and then placed into patients mouth and other half quadrant was directly bonded to patient’s teeth. The accuracy was checked using photographic method in three parameters bracket height, mesiodistal position and angulation. Time taken for bonding direct and indirect procedures were calculated. The statistical analysis showed significant difference in bracket height and angulation and was insignificant for mesiodistal position proving that indirect bonding is more accurate and less time consuming than the direct bonding of braces.

Delavarian M, Rahimi F, Mohammadi R, Imani MM (2019)[8] conducted a study on 120 extracted premolar teeth to compare the shear bond strength of metal and ceramic brackets used to bond enamel by using Grengloo and Transbond XT adhesive. The sample was divided into four groups, group 1- Grengloo with metal bracks; group 2- Grengloo with ceramic brackets; group 3- Transbond XT with metal brackets and group 4- Transbond XT with ceramic brackets. After bonding, the sample was subjected to 500 thermal cycles and incubated at 37 degree celcius. The effect of brackets did not give any statistical difference, however, the shear bond strength of Grengloo was higher than that of Transbond XT.

Knaup I, Boddeker A, Tempel K, Weber E, Bartz JR et al (2020)[51] conducted a study to analyse the effect of different innovative rebonding systems to identify optimised rebonding protocols for orthodontic patient care for which metallic brackets were bonded to the frontal enamel surfaces of 240 bovine lower incisors embedded in resin bases. Teeth were randomly divided into two major experimental groups: in group 1 a hydrophilic primer

(Assure™ PLUS) was compared to commonly used orthodontic adhesives (Transbond XT™, BrackFix®, Grengloo™) and a zero control. In group 2, different rebonding systems were analysed using a hydrophilic primer (Assure™ PLUS), a methyl methacrylate-consisting primer (Plastic Conditioner) and a conventional adhesive (Transbond XT™). All teeth were tested for shear bond strength, adhesive remnant index and enamel fracture rate. Based on the results obtained, it was found that rebonding strength could be compensated by the use of hydrophilic priming systems. The additional use of a methyl methacrylate-consisting primer did not seem to enhance shear bond strength. No etching approaches resulted in non-sufficient bond strength.

Ramneez M, H Kiran, Alle RS, VS Bharathi, HS Dharmesh (2020)[10] conducted a study on 120 extracted premolar teeth to evaluate and compare the shear bond strength of color changing adhesives i.e. Transbond Plus, Grengloo and Blugloo. The sample was divided into 3 groups group I- Tansbond Plus, group II- Grengloo and group III-Blugloo and then further subdivided into A- no contamination; B- contamination with saliva before application of bonding agent; C- contamination with saliva after application of bonding agent; D- contamination with saliva before and after application of bonding agent. All teeth were individually mounted on acrylic jig and the process of etching and priming was carried out after which contamination with artificial saliva was done according to the above mentioned categories. The teeth were bonded with metal brackets with color changing adhesives for different groups (40 each) and then subjected to shear bond strength testing after 24 hours by a universal testing machine. The bond strengths of all the three color changing adhesives was within acceptable clinical limits, however, the shear bond strengths of Grengloo and Blugloo was more as compared to Transbond Plus.

Mohlhenrich SC, Alexandridis C, Peters F, Kniha K, Modabber A, et al (2020)[52] conducted a study to compare the bracket placement and excess bonding adhesive depending on different indirect bonding (IDB) techniques and bracket geometries for which four hundred eighty brackets without hook and 360 with hook were placed on 60 plaster models. Three IDB techniques were tested: A- polyvinyl-siloxane vacuum-form (PVS-VF), B- polyvinyl-siloxane putty (PVS putty), and C- translucence double-polyvinyl-siloxane (double-PVS). A and B were combined with chemically, and C was combined with light cured bonding adhesive. Virtual images of models before and after bracket transfer were generated, and computerized images were compared. Linear, angular deviations, and excess bonding adhesive were measured. The results obtained showed that the double-PVS group gave promising results with respect to transfer accuracy, whereas the PVS-VF group provided least excess bonding adhesive. Basically, hooks led to lower precision and higher excess bonding adhesive. PVS trays for IDB generated high bracket placement accuracy. PVS-putty was the easiest to handle with and also the cheapest, but led to large excess bonding adhesive, especially in combination with hooked brackets or tubes.

Niu Y, Zeng Y, Zhang Z, Xu W, Xio L (2021)[53] conducted a study to compare the transfer accuracy of two digital transfer trays, 3D printed tray and the vacuum-formed tray, in the indirect bonding of labial brackets. Ten digital dental models were constructed by oral scans using an optical scanning system. 3D printed trays and vacuum-formed trays were obtained through the 3Shape indirect bonding system and rapid prototyping technology (10 in each group). Then, the labial brackets were transferred to 3D printed models, and the models with final bracket positioning were scanned. Linear and angular transfer errors were measured using GOM Inspect software. The mean transfer errors and prevalence of clinically acceptable errors of two digital trays were compared and the 3D printed tray scored better in terms of transfer accuracy than did the vacuum-formed tray. However, both types of trays had better linear control than angular control of brackets.

MATERIAL & METHODOLOGY

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Dehradun with an aim to evaluate and compare the shear bond strength of Orthodontic brackets bonded by indirect technique in lingual fixed Orthodontic appliance using two different light-cured adhesive resin systems i.e. a color changing adhesive and a conventional adhesive.

1. COLLECTION OF SAMPLE (TEETH)

The sample consisted of 50 human premolar teeth extracted from the patients undergoing fixed Orthodontic treatment and in whom first premolar extraction was planned as a part of fixed Orthodontic treatment. The teeth were extracted and obtained from Department of Oral and Maxillofacial Surgery, Babu Banarasi Das College of Dental Sciences, Lucknow. Informed consent was taken from all the subjects for using their teeth for the study. The extracted teeth were thoroughly cleaned for any soft tissue debris or blood after extraction and then stored in 10% formalin at constant room temperature of 37ºC as shown in Fig 1 until they were subjected to shear bond strength (SBS) testing.

Fig. 1. COLLECTION OF SAMPLE

Criteria for sample selection:

Inclusion criteria:

The criteria for sample selection were as follows:

1) All premolar teeth had intact enamel, without the presence of hypoplastic areas, caries, fractures or cracks visible to the naked eye.

2) No previous history of bonding on the tooth surface.

3) No history of trauma or any structural alteration caused by mechanical procedure during extraction.

4) The teeth should have not been subjected to any chemical agent, eg. Hydrogen peroxide.

5) No history of restorative or cosmetic (i.e. bleaching etc.) dental treatment.

Exclusion criteria:

1) Premolars having abnormal morphology on the lingual surface.
2) Premolars of patients who had undergone orthodontic treatment.
3) History of restorative or cosmetic (i.e. bleaching etc.) dental treatment.

2) DISTRIBUTION OF SAMPLE:

Before bonding, the samples were randomly divided into two groups: Group I and Group II with 25 specimens in each group (Table 1) according to the adhesive resin system used for bonding.

TABLE 1: Shows the distribution of sample in groups according to the adhesive resin system used.

Groups	Sample Size (N= 50)	Adhesive resin system used
Group I	25	Indirect bonding done by using Transbond XT
Group II	25	Indirect bonding done by using Grengloo

3. MATERIALS USED FOR MAKING THE MOULD AND MOUNTING OF TEETH (Fig 2):

A. Dental stone – Type III dental stone (Denstone)

B. Rubber bowl, spatula

D. Vaccum sheets – Avac S clear thermoforming sheets of 2 mm thickness

E. Vaccumpress machine - Easy VAC vaccumpress machine of A Medes Company

F. Autopolymerizing Polymethyl Meth Acrylate – Pyrex rapid repair

G. Dapendish and wax spoon

H. Diamond disc bur and handpiece

4. MATERIALS USED FOR MAKING MODEL OF EXTRACTED TEETH (Fig 3):

A. **Polysiloxane impression material**- Soft body vinyl polysiloxane impression material of 3M, ESPE company

B. **Type III dental stone**- Type III Dental stone, Denstone

5. MATERIALS USED FOR BONDING (Fig 4):

A. **Etchant -** DPI etchant gel (White, India, 37% phosphoric acid)

B. **Primer -** Transbond XT Primer (3M Unitek Corporation, Monrovia, Calif)

- Ortho Solo Primer (Ormco Corporation)

C. **Adhesive -** Light curable orthodontic material Transbond XT adhesive (3M Unitek Corporation, Monrovia, Calif)

- Grengloo: a color changing adhesive (Ormco Corporation)

D. **Brackets** - STB brackets 7^{th} generation (Libral Traders) with 10.50 mm^2 mesh base surface area and a slot configuration 0.017″×0.025″.

E. **Applicator tip**

F. **Mouth mirror**

G. **Explorer**

H. **Three-way air water syringe**

I. **Light cure unit-** Woodpecker LED curing light unit with light Intensity of 1000mw/cm^2 - 1700mw/cm^2 and wavelength of 420nm - 480nm.

J. **DT3C (Das' Tip, Torque and Thickness Customization) Device (Fig 5)**: DT3C device was designed Dr Suryakant Das for customized Indirect bonding on lingual surface of teeth. It is a specialized Caliper with 5 labial insert tips with tips of +8, +4, 0, -4, -8 degrees and six lingual torque blades of 22, 17, 12, 7, 3 and -6 degrees. Unlike other devices, the lingual arm of DT3C Device can be adjusted to the desired vertical height; uses lingual torque blades for torque expression in the custom lingual brackets, thus omitting any vertical error due to change in torque expression. It helps in direct transfer of tip and torque from the labial surface of a tooth to the lingual side at a specific thickness.

K. **Sandblaster (Fig 6):** Microblaster (50 micron aluminium oxide particles Macrodent, Manikstar sandblaster).

6. MATERIALS USED FOR FABRICATION OF TRANSFER TRAY (Fig 7):

A. Separating media - Sodium alginate (cold mold seal)

B. Vaccum sheets - Avac S clear thermoforming sheets of 2 mm thickness

C. Vaccum press machine- Easy VAC vaccum press machine of A Medes Company

7. UNIVERSAL TESTING MACHINE (Fig 8):

The Universal testing machine which was used to measure the SBS was at Central Institute of Plastics Engineering and Technology, CIPET, Dehradun. The machine had working range 1-50 kN at temp 250̊ C, the crosshead motion was 0.5mm/min and accuracy was 1N.

Fig 2. MATERIALS FOR MAKING MOULD AND MOUNTING OF TEETH

a- Type III dental stone, b- rubber bowl, c- spatula, d- dental stone block, e- dapendish, f- wax spoon, g- separating media- cold mould seal, h,i- Pyrex rapid repair cold cure acrylic resin, j- mould prepared by stone block, k- disc bur, l- straight handpiece, m- vaccum sheet, n-vaccumpress machine

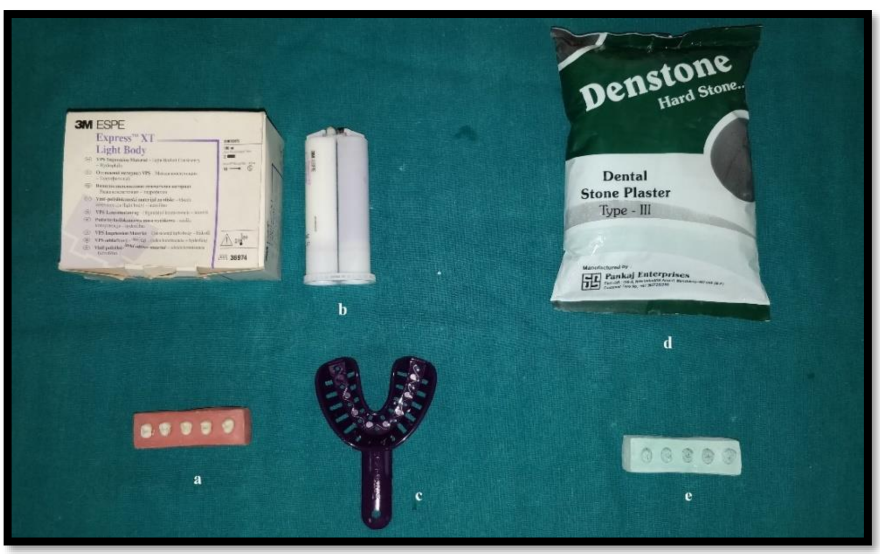

Fig 3. MATERIALS FOR MAKING WORKING MODEL

a- Acylic model with mounted teeth, b- soft body polysiloxane impression material, c- impression tray, d- Type III dental stone, e- working model

Fig 4. MATERIALS FOR BONDING OF TEETH

a- Etchant, b- Transbond XT primer, c- Transbond XT adhesive, d- OrthoSolo primer, e- Grengloo adhesive, f- applicator tip, g- mouth mirror, h- explorer, i- tweezer, j- LED light curing unit, k- three-way air water syringe, l- STB 7th generation lingual brackets (loose)

Fig 5. DAS DT3C DEVICE

Fig 6. MANIKSTAR SANDBLASTER

Fig 7. MATERIALS USED FOR MAKING TRANSFER TRAY

a- Separating media, b- thermoforming vaccum sheet, c- vaccumpress machine

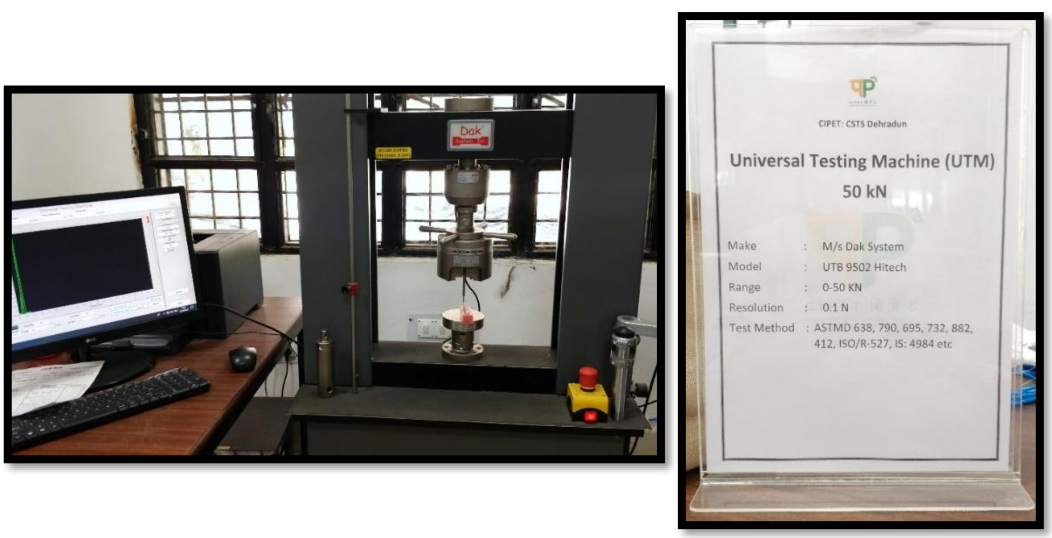

Fig 8. UNIVERSAL TESTING MACHINE

METHODOLOGY

1) **Making a mould for acrylic**

a) A dental stone block of dimension 3.5 inch × 1 inch was prepared and trimmed properly as shown in Fig. 9.
b) A thin layer of separating media diluted with water at 1:1 ratio was placed on the stone block and allowed to dry for 20 minutes.
c) The block was then placed in Easy VAC vaccumpress machine. Rubber vaccum sheet of 2 mm was fitted in the upper compartment of machine.
d) Vaccum sheet was heated and vaccum was released, upper compartment was brought down and the heated sheet was adapted over the stone block.
e) The sheet was then removed from the stone block and used as a mould for making acrylic models.

2) **Mounting of the teeth**

The extracted premolar teeth were grooved at cementoenamel junction using a water – cooled diamond disc before mounting them vertically in moulds with acrylic resin (Fig 10). Powder and liquid od autopolymerizing acrylic resin was mixed in a glass cup and then transferred to the mould of dimension 3.5 inch × 1 inch prepared by the thermoform sheet. The extracted teeth were mounted in this auto polymerizing resin in group of 5 at a time and allowed to set for 45 minutes (Fig 11). Ten such sets (Fig. 12) of mounted teeth with 5 teeth in each set were prepared and were stored in distilled water to keep them moist so that dessication did not affect the enamel surface. Out of these, five sets were reserved for indirect bonding on lingual aspect using Grengloo adhesive and the remaining five were reserved for indirect bonding on lingual aspect using Transbond XT adhesive.

3) **Indirect bonding on lingual surface**

This included four steps:

A. Fabrication of working model poured in stone for each set of mounted teeth

B. Placement of bracket on the working model using the DT3C bracket positioning device and curing the adhesive

C. Fabrication of the transfer tray

D. Indirect bonding using transfer tray in both the groups

A. Fabrication of working model poured in stone for each set of mounted teeth

a) A polysiloxane putty impression was made of the teeth mounted in acrylic.

b) Type III dental stone (Denstone) was mixed and a working model of the teeth mounted in acrylic was prepared.

c) Ten such models were prepared from the ten sets of autopolymerizing acrylic models (Fig. 13).

B. Placement of bracket on working model using the bracket positioning device and curing the adhesive

a) The pencil markings were made on the labial as well as lingual surface of the diestone model. The markings were done as per long axis of the premolar extending from labial to lingual side. Horizontal marking on the labial side was at the center of clinical crown whereas on the lingual side horizontal line was at a distance of 5mm from lingual cusp tip (Fig. 14).

b) After assembling the DT3C device with customized lingual arm having 0° tip and labial arm with -6° torque specific for the premolars, the lingual bracket was attached to labial arm with help of module.

c) Labial insert of DT3C device was placed at a point where horizontal and vertical lines meet on labial surface. Screw was tightened till the bracket attached to DT3C device approximated the lingual surface at a point marked for placement of bracket lingually.

d) Grengloo adhesive was placed on the attached brackets, and then Orthosolo primer was applied for Group I. Similarly, Transbond XT adhesive along with Transbond XT primer was used for Group II (Fig. 15).

e) The device was held firmly with thumb on the model and bracket was bonded with light cure (Fig. 16).

f) Similar procedure was repeated for making 10 working models i.e. 5 models using Orthosolo primer and Grengloo adhesive and 5 models using Transbond XT primer and adhesive.

Fig 9. MAKING A MOULD FOR MOUNTING OF TEETH

Fig 10. GROOVING OF TEETH AT THE CEMENTOENAMEL JUNCTION

Fig 11. MOUNTING OF TEETH VERTICALLY IN ACRYLIC

Fig 12. TEETH MOUNTED IN ACRYLIC

Fig 13. WORKING MODELS

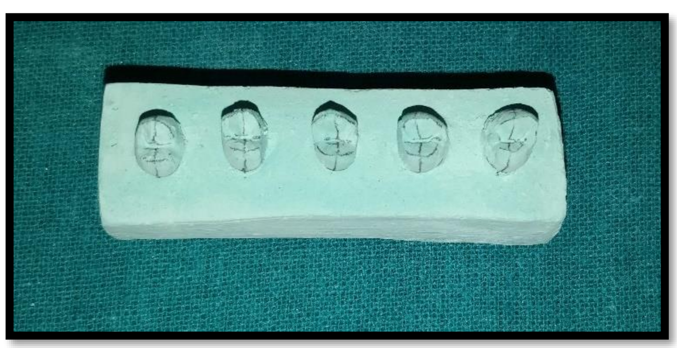

Fig 14. MARKING OF THE HORIZONTAL AND VERTICAL LINES ON THE STONE MODEL

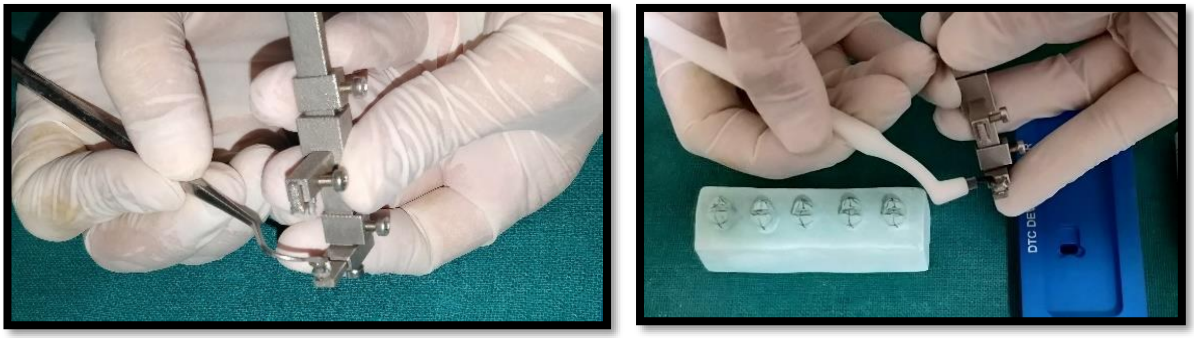

Fig 15. APPLICATION OF ADHESIVE AND PRIMER ON THE BRACKET BASE PLACED IN DT3C DEVICE

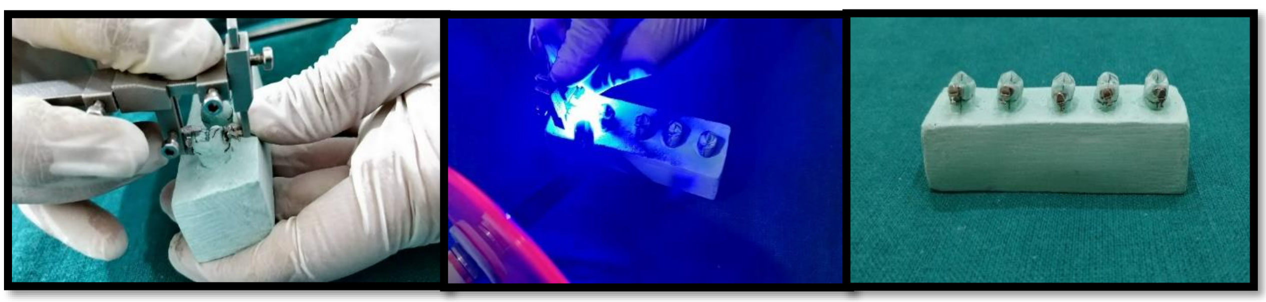

Fig 16. PLACEMENT OF BRACKET ON THE WORKING MODEL USING DT3C DEVICE

C. **Fabrication of the transfer tray:**

a) After the bracket positions are confirmed on the stone models, a thin layer of separating media diluted with water at 1:1 ratio was placed on each model and allowed to dry for 20 minutes.

b) Three working diestone model were placed in Easy VAC vaccumpress machine. Rubber vaccum sheet of 2 mm was fitted in the upper compartment of machine as shown in Fig. 17.

c) Vaccum sheet was heated and vaccum was released, upper compartment was brought down and the heated sheet was adapted over the working model.

d) The transfer tray was carefully removed from each of the working model and trimmed properly (Fig. 18).

e) The bracket bases were then sandblasted with aluminum oxide (20µm) particles using sandblaster and then washed with water jet and blown dry with oil-free air.

The transfer tray was ready to be used for indirect bonding on mounted teeth in acrylic.

D. Indirect bonding using transfer tray in both the groups:

a) Palatal/lingual surfaces of teeth were pumiced (Fig. 19).

b) The etchant (37% orthophosphoric acid) was applied to the bonding area of the teeth for 15 seconds (Fig. 20 (a)), washed for 20 seconds, and then dried with an oil-free air source by a three-way syringe to see a white frosty appearance.

c) For bonding of brackets in Group I, minimal thin layer of Orthosolo primer and Grengloo adhesive was spread over the bracket base and the transfer tray was carried on to the mounted extracted teeth in acrylic model, inserted and held firmly in position by finger pressure from both labial and palatal/ lingual aspect (Fig. 20 (b)).

d) The labial and palatal/lingual margin of the tray were perfectly adapted on the mounted model and this confirmed the correct positioning of the tray.

e) Brackets were then light cured for 20 seconds (Fig. 20 (c)).

f) After this, the tray was carefully removed by cutting in the interdental areas and on the occlusal surface separating both the labial and lingual surfaces with light pressure on the transfer tray (Fig. 21).

g) The same process was repeated for bonding of the brackets in Group II by using Transbond XT primer and adhesive.

h) Thereafter, both the groups were subjected to Universal Testing Machine to measure the Shear bond strength.

Shear bond strength testing:

All the specimens of Group I and Group II were debonded using the Universal testing machine and shear bond strength (SBS) was measured (Fig. 22). Each set with five mounted teeth was placed on lower compartment of the machine and was held firmly with the hand. An occluso-gingval force was applied to the bracket, producing a shear force at the bracket-tooth interface. The shear force was applied using a chisel-edge plunger, mounted in the movable crosshead of the testing machine. The plunger was positioned such that the leading edge aimed at the bracket tooth interface before being brought into contact with it at a crosshead speed of 0.5mm/min. The force was increased till the brackets were debonded. The force producing for debonding was recorded in Newton (N) by a computer which was electronically connected with the testing machine. Force was converted into megapascal (MPa= N/mm^2) by dividing the measured force values (N) by the mean surface area of the brackets (mm^2). SBS calculated in MPa for all the samples was recorded.

The Shear bond strength thus obtained for both the groups was subjected to appropriate statistical analysis for evaluation and comparison.

Fig 17. FABRICATION OF TRANSFER TRAY

Fig 18. TRIMMED TRANSFER TRAY WITH BRACKETS IN POSITION

Fig 19. PUMICING OF LINGUAL SURFACE OF TEETH

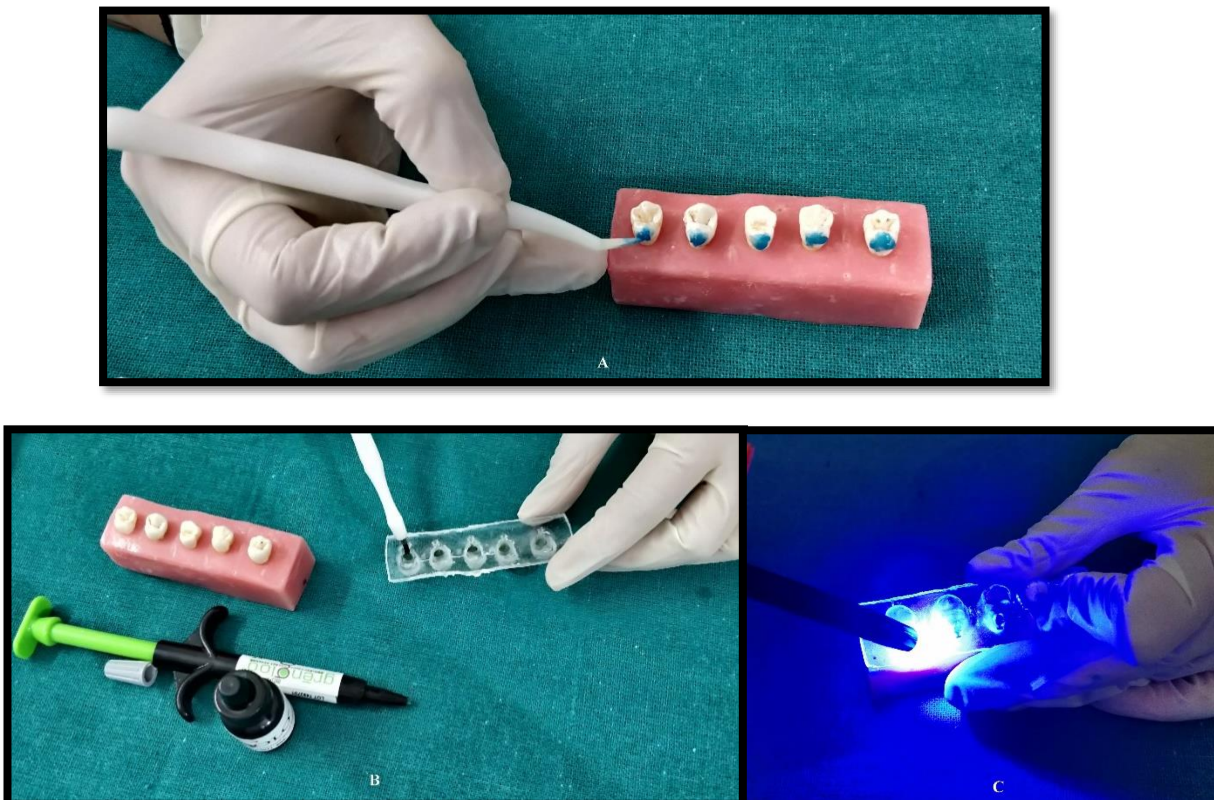

Fig 20. INDIRECT BONDING OF TEETH BY TRANSFER TRAY

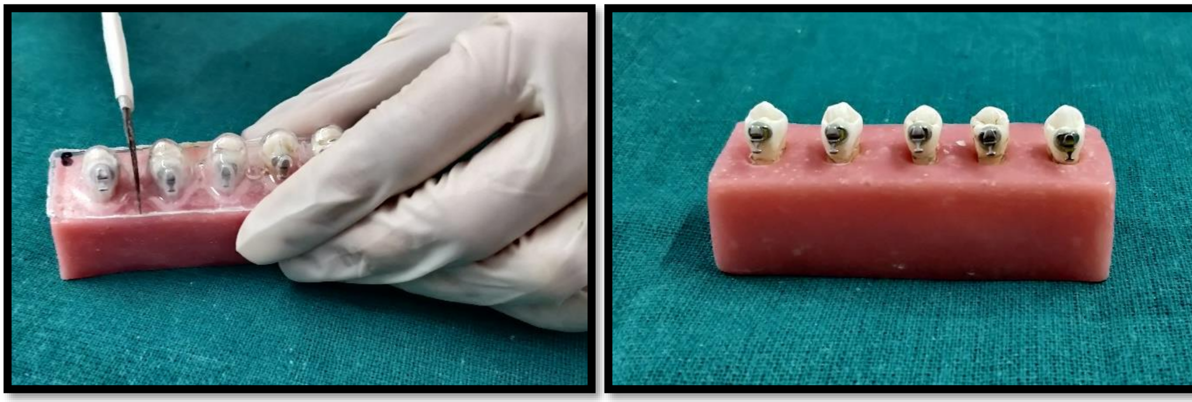

Fig 21. REMOVAL OF TRANSFER TRAY

Fig 22. DEBONDING OF BRACKETS BY THE UNIVERSAL TESTING MACHINE

STATISTICAL TOOLS EMPLOYED

The statistical analysis was done using Statistical Package for Social Sciences (SPSS, IBM version 20.0). The level of significance was fixed at 5% and $p \leq 0.05$ was considered statistically significant. Kolmogorov- Smirnov test and Shapiro-Wilks test were employed to test the normality of data. Mann Whitney U test was performed for quantitative variables.

The following Statistical formulas were used:

1 **Mean**: To obtain the mean, the individual observations were first added together and then divided by the number of observation. The operation of adding together or summation is denoted by the sign Σ.

The individual observation is denoted by the sign X, number of observation denoted by n, and the mean by $\overline{X}$.

$$\overline{X} = \frac{\Sigma X}{\text{No. of observations (n)}}$$

2. **Standard Deviation**: It is denoted by the Greek letter σ.

$$\sigma = \sqrt{\frac{\Sigma (X - \overline{X})^2}{n}}$$

3. **Mann Whitney U Test:**

$$U_1 = R_1 - \frac{n_1(n_1 + 1)}{2}$$

$$U_2 = R_2 - \frac{n_2(n_2 + 1)}{2}$$

Where, n_1 and n_2 are the sample sizes for Group I and Group II respectively, and R_1 and R_2 are the sum of the ranks in Group I and Group II.

4. Level of significance: "p" is level of significance

$p > 0.05$	Not significant
$p < 0.05$	Significant
$p < 0.01$	Highly significant
$p < 0.001$	Very highly significant.

MEASRUEMENT OF RELIABILITY

To check the intra operator error, ten extra premolar teeth were taken and new brackets were bonded following the same protocol as for Group I after a gap of ten days SBS was measured using Instron machine.

Table 2. Mean SBS of first and second set of readings:

Sample	First set of reading	Second set of reading	Mean difference	*p* value
1.	13.58	12.61		NS
2.	14.81	17.84		
3.	7.78	10.56		
4.	10.95	19.67		
5.	15.69	14.89		
6.	16.25	7.88		
7.	10.95	12.97		
8.	11.32	10.85		
9.	14.83	12.64		
10.	18.39	16.95		
Mean and SD	**M**=13.45 **SD**= 3.16	**M**= 13.77 **SD**= 3.46		

On comparing the result with Student 't' test, the mean difference between 1st and 2nd set of reading was statistically insignificant. Thus, the SBS obtained in the study were reliable.

OBSERVATION AND RESULTS

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Dehradun. The purpose of this study was to evaluate and compare the shear bond strength of Grengloo, a color changing adhesive (Ormco Corporation) with the conventional adhesive Transbond XT (3M) which were used in vitro for Indirect bonding on Lingual orthodontic brackets by a bracket positioning device (DT3C device).

The study comprised a total of 50 samples of extracted premolar teeth which were equally divided into two groups of 25 teeth each. For Group I, the brackets were bonded by Indirect bonding technique using Orthosolo primer Grengloo adhesive (Ormco Corporation) and for Group II, the brackets were bonded by indirect bonding technique using Transbond XT primer and adhesive (3M) (Fig 23).

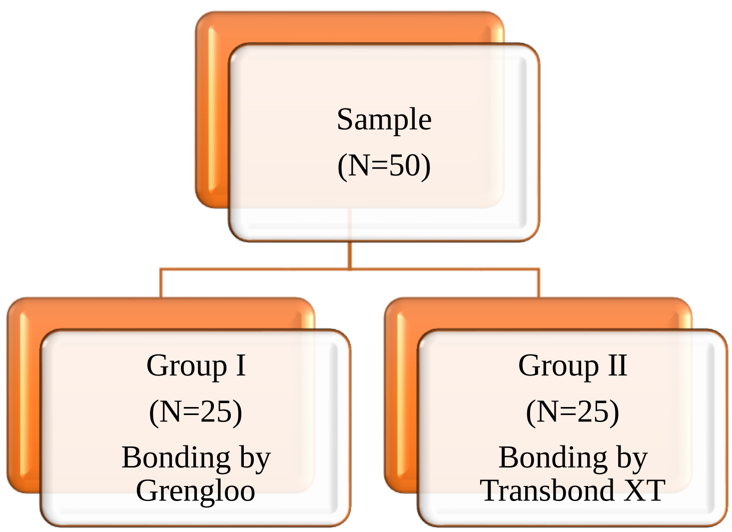

Fig 23: Distribution of sample

The amount of debonding force applied at the bracket-tooth interface by the piston of Universal Testing Machine (surface area= 1.5mm^2) was recorded in Newton. The pressure applied i.e. the shear bond strength was calculated by the following formula:

$$P = \frac{F}{a}$$

Where, P= pressure (N/mm^2)

F= force applied by the piston (N)

a= surface area of the bracket mesh base (10.50mm^2)

The Shear Bond Strength thus obtained was in N/mm^2 which was converted to MPa as:

1N/mm^2 = 1MPa

Table 3: Descriptive statistics for Group I and Group II

GROUP	MEAN SHEAR BOND STRENGTH (MPa)	STANDARD DEVIATION (S.D.)	MINIMUM VALUE (MPa)	MAXIMUM VALUE (MPa)	95% CI for MEAN	
					Lower Bound	Upper Bound
Group I	13.07	4.93	7.1	19.08	11.04	15.1
Group II	9.76	2.75	5.5	14.56	8.63	10.93

Table 3 shows the descriptive statistics for Group I and Group II. The mean shear bond strength of brackets bonded indirectly on lingual surface of teeth by Grengloo- a color changing adhesive (Group I) was 13.07 MPa with a standard deviation of 4.93 and for brackets bonded indirectly on lingual surface of teeth by Transbond XT adhesive (Group II) is 9.76 MPa with a standard deviation of 2.75; with the confidence interval at 95%. The minimum and maximum values of shear bond strength recorded for Group I were 7.1 MPa and 19.08 MPa respectively. The minimum and maximum values of shear bond strength recorded for Group II were 5.55 MPa and 14.56 MPa respectively.

Kolmogorov- Smirnov test and Shapiro-Wilks test were employed to test the normality of data. Mann Whitney U-test was performed for quantitative variables. The level of significance was fixed at 5% and $p \leq 0.05$ was considered statistically significant.

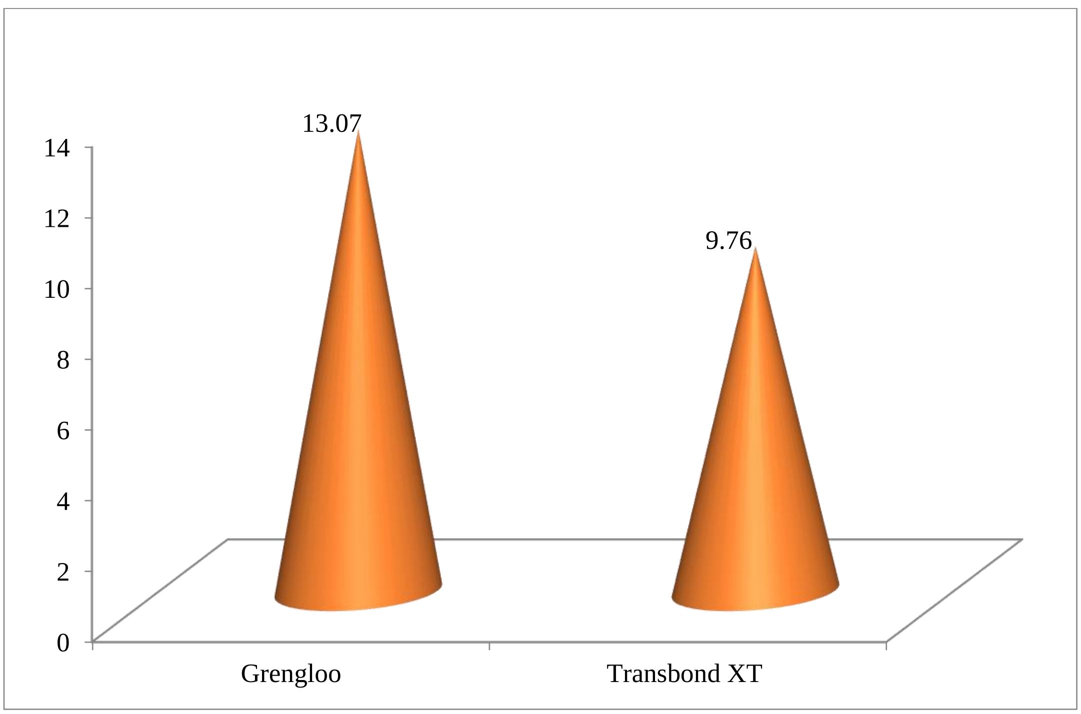

Fig 24: Graph: **Shear bond strength of Group I and Group II**

The graph depicts the mean Shear Bond Strength of Group I (Grengloo) and Group II (Transbond XT).

Table 4: Comparative evaluation of Shear Bond Strength between the two groups

Mean Difference of Shear Bond Strength of two groups Mean ± S.D. (MPa)	***p* Value**
3.31 ± 2.36	**.011* (s)**

$p > 0.05$ – non- significant

$p < .05$ – just significant*

$p < .01$ – highly significant

$p < .001$ – very highly significant

Table 4 shows the mean difference in the shear bond strength of brackets bonded by indirect bonding technique on the lingual surface of teeth by a color changing light-cure adhesive resin Grengloo for Group I and conventional adhesive resin Transbond XT for Group II. A comparative evaluation revealed significant difference between the two resins with significantly higher values (p value = .011) for Group I resin when compared with the Group II.

Direct bonding of teeth involved bonding of bracket attachments directly to the tooth surface which was introduced in the year 1965 by Newman[1], where acid etch technique of Buonocore[2] was used followed by bonding of orthodontic brackets to the teeth with an epoxy-derived resin and gradually replaced banding of all teeth. However, it had certain disadvantages like more chair-side time, increased risk of contamination by saliva, poor visualization of posterior teeth leading to difficulty in accurate positioning of the brackets, etc. To overcome these limitations, Indirect Bonding Technique was introduced by Silverman and Cohen[3] in 1972 which was more precise and less time consuming.

With the increase in the preference for esthetics, Lingual Orthodontics offers a great advantage in comparison to Labial Orthodontics. The main advantages of lingual appliance therapy are that the facial surfaces of the teeth are not damaged from bonding, debonding and/or adhesive removal; gingival tissues are not adversely affected; facial contours are better visualized since the contour of the lips are not distorted by protrusion caused due to the labial appliances[7]. The inter-bracket width is reduced due to the smaller arch radius on the lingual aspect which is beneficial while using more resilient archwires, the esthetic demands of the patients are met along with similar results as offered by conventional labial appliance therapy. Bite plane effect produced by lingual brackets offers greater advantage in treating low angle deep bite cases as it causes intrusion of anterior teeth and extrusion of molars.

Direct bonding technique in lingual orthodontics was initially introduced in 1984 by Dr Michael Diamond when he devised a Peri/ reflector for bonding in the upper arch[54]. However, Indirect bonding is a must in lingual orthodontics due to greater anatomical differences of lingual surfaces of teeth, especially the incisors, difficulty of the visualization of the lingual aspect of teeth and increased risk of contamination by saliva. Various techniques for indirect bonding have been developed over the years which take into consideration the required tip, torque and in-out values that are achieved by addition of adhesive of variable thickness beneath the bracket bases while bonding. For this, different devices like Torque Angulation Reference Guide (TARG), HIRO system, Lingual bracket jig, Transfer Optimized Positioning (TOP/ INCOGNITO braces) system, Orapix system, Das DT3C device etc. have been devised and are being used. Amongst these, the Das DT3C device i.e. Tip, Torque and Thickness Customization device, designed by Dr Suryakant Das, which allows customized Indirect bonding on lingual surface of the teeth without the use of a laboratory, as it has a specialized caliper with five labial insert tips with tips of +8, +4, 0, -4, -8 degrees and six lingual torque blades of 22, 17, 12, 7, 3 and -6 degrees, was used in our study.

After completion of treatment, the main challenge for any Orthodontist is restoring the enamel to its original form with minimal damage to the tooth surface[2] after debonding. The tooth surface is restored to its original state by using various finishing and polishing methods like the use of soflex discs, composite burs etc.

Most of the adhesives used in current Orthodontic practice are tooth colored. Hence, their complete removal after debonding without damaging the tooth surface is nearly not possible[2]. To overcome this, various color changing adhesives were introduced in Orthodontics like Transbond Plus (3M, for metal brackets), Blugloo (Ormco, for ceramic brackets), Grengloo (Ormco, for metal brackets) etc. Transbond Plus is a pink colored adhesive that allows easy removal of flash during bracket placement and after curing, it becomes tooth colored. Grengloo had the added advantage that it changes back to green color on subjecting the teeth to a short blast of air or water spray after debonding which helps in easy removal of remaining adhesive on the tooth surface after debonding[8].

Inspite of the color changing ability of Orthodontic adhesive resins, the most important factor to be considered is the bond strength that the material possesses. Reynolds proposed clinically acceptable bond strength to be in the range of 5.88-7.85 MPa[10]. The shear bond strength of any adhesive depends on a number of factors[11] such as adequately clean and properly conditioned enamel surface, type of adhesive used, bracket material and design, type of curing light used, effect of primer, technique of bonding (direct/indirect), thickness of adhesive/bonding material used, sandblasting in indirect bonding, sandblasting in recycled metal brackets, etc.

Since the thickness of the composite pad (adhesive) beneath the bracket base is variable in Lingual Orthodontics, there is a chance that the shear bond strength of these adhesives might be altered. A lot of studies[2,8-10,12-19] have been conducted to evaluate and to compare the shear bond strength of Grengloo in vitro with the other color changing adhesives as well as with the conventional adhesives on labial surface of teeth. No study till date has been conducted to evaluate the shear bond strength of this color changing adhesive Grengloo on the lingual surface of teeth. Considering this, the aim of this study was to evaluate and compare the shear bond strength of the color changing adhesive, Grengloo (Ormco Corporation) with the conventional adhesive, Transbond XT (3M).

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with CIPET, Dehradun.

For this study, a sample of 50 non-carious maxillary and/or mandibular human premolar teeth, extracted for orthodontic purpose were taken and divided randomly and equally into two groups of 25 teeth each. The STB 7th generation lingual brackets in GROUP I were indirectly bonded by Grengloo (color-changing) adhesive, where as in GROUP II, were bonded indirectly by the conventional Transbond XT adhesive. The teeth were mounted in acrylic models vertically, in groups of 5 teeth each. From these acrylic models, the working models were prepared in Type III dental stone on which bracket placement on the lingual aspect was done by using Das DT3C device, followed by fabrication of vaccum-formed transfer tray. The brackets on the transfer tray were then transferred to the extracted teeth mounted in acrylic and were bonded in groups of 25 teeth by Grengloo and Transbond XT respectively. After removal of the transfer tray from the acrylic models, the brackets were subjected to the Universal Testing Machine for debonding and the shear bond strength of both the groups was evaluated.

The results of the present study indicated that there was a statistically significant difference ($p < 0.05$) amongst the shear bond strength of Group I and Group II. The mean shear bond strength for Group I was 13.07 $\pm$ 4.93 MPa which was much higher than that of Group II i.e. 9.76 $\pm$ 2.75 MPa.

None of the previous studies evaluated the shear bond strength of Grengloo by indirect technique on the lingual surface of human premolar teeth, hence the results of the present study were compared to studies conducted to evaluate the shear bond strength of directly bonded lingual brackets or to studies showing the comparison of the SBS of various color changing adhesives (Delavarian M et al, Turakkahraman H et al, Duers MW et al, Ekhlassi S et al, Rameez M et al, Shamnur N et al, Bayani S et al, Izadi MI et al, Knaup I et al, Northrup RG et al, Stumpf ASG et al, Youseffinia S et al, Maurya R et al), or a study done by Lombardo et al to compare the tensile strength of different lingual brackets or studies comparing SBS during the use of different surface treatment methods (Wiechmann D).

An in-vitro study was conducted by Delavarian M et al[8] in 2019 to compare the shear bond strength of metal and ceramic bonded on the labial aspect of 120 extracted human premolar teeth with Grengloo (color-changing adhesive) and Transbond XT (conventional adhesive). They found that maximum shear bond strength when Grengloo was used with ceramic brackets (23.55 ± 5.14 MPa), followed by SBS of Grengloo on metal brackets (22.94 ± 5.20 MPa), then Transbond XT with ceramic brackets (14.62 ± 4.30 MPa) and least of Transbond XT with metal brackets (13.71 ± 3.54 MPa). The effect of bracket type on SBS was not significant in any composite group. For metal brackets, Grengloo had statistically significant SBS in comparison to Transbond XT and same for ceramic brackets. On comparison of results of their study for metal brackets with our study where we bonded metal brackets on the lingual side using Indirect technique with similar adhesives, the shear bond strength of Grengloo was 22.94 ± 5.20 MPa in comparison to 13.07 ± 4.93 MPa obtained in our study. Similarly, SBS of Transbond XT group in their study (13.71 ± 3.54 MPa) was higher than the shear bond strength of Transbond XT (9.76 ± 2.75 MPa) obtained in our study. This difference could be attributed to the difference in the bonding surface i.e. labial versus lingual, type of technique used i.e. direct versus indirect.

In a study conducted by Turkkahraman H et al[13] in 2010, SBS was measured for metal brackets bonded on labial surface 48 human premolar teeth using three color-changing adhesive namely Transbond Plus, Grengloo and Blugloo and one conventional adhesive (Light bond). Maximum shear bond strength was seen for conventional adhesive (22.1 ± 2.5 MPa) followed by Grengloo (19.2 ± 3.3 MPa), then Blugloo (18.7 ± 2.8 MPa) and least for Transbond Plus color changing adhesive (16.0 ± 4.4 MPa). However, difference was statistically significant only between shear bond strength of conventional adhesive and Transbond Plus, the color-changing adhesives did not show any statistical difference between them. The SBS of Grengloo and that of Transbond XT in our study was lesser than the Grengloo group and conventional adhesive group of their study. This could be because we did bonding on the lingual surface of teeth by indirect technique. Also, the surface area of the brackets used in our study was more (10.50 mm^2) as compared to the one used in this study (9.63 mm^2).

Another study was conducted by Duers MW et al[9] (2011) where metal brackets were bonded on labial aspect of 240 extracted bovine incisors to compare the shear bond strengths of Transbond Plus, Grengloo and Blugloo with the conventional adhesive Transbond XT at 15 minutes and at 24 hours. Amongst different adhesives, Grengloo had highest shear bond strength at 15 minutes (9.91 ± 4.69 MPa), followed by Transbond XT (7.56 ± 2.88 MPa), then Blugloo (7.31 ± 2.71 MPa) and least was seen for Transbond Plus (6.59 ± 3.05 MPa); whereas Grengloo had the least shear bond strength at 24 hours (6.44 ± 3.04 MPa), followed by Transbond Plus (7.69 ± 3.71 MPa), then Transbond XT (7.82 ± 3.97 MPa) and maximum SBS at 24 hours was seen for Blugloo (8.18 ± 1.82 MPa). There was no significant difference statistically in SBS at two time intervals for all the adhesives except for Grengloo which showed significantly higher SBS at 15 minutes in comparison to SBS at 24 hours. According to the authors, the mean SBS for all the groups was 7.69 MPa which was well within clinically acceptable limits as suggested by Reynolds (6-8 MPa). The shear bond strength at 15 minutes for Grengloo was comparable to our study where SBS at 24 hours was much lesser. Values for Transbond XT at both time intervals were lesser than our study. The lesser SBS of Transbond XT and Grengloo at 15 minutes and at 24 hours in their study in comparison to our study could be because of the difference in the use of bovine incisors in their study and human premolars in our study.

In a study conducted by Ekhlassi S et al[2] (2011), 180 extracted bovine incisors were directly bonded to compare the shear bond strength of two color-changing adhesives Transbond Plus and Grengloo with a conventional adhesive i.e. Transbond XT using a self-etch primer at different time intervals of 15 minutes, 24 hours and at 1 week. They found out that the shear bond strength for Transbond XT was maximum at 15 minutes (14.4 ± 3.7 MPa) and least at 1 week (13.5 ± 5.2 MPa); whereas for Grengloo, the shear bond strength increased from 12.0 ± 5.9 MPa at 15 minutes to 14.3 ± 5.1 MPa at 1 week. There was no significant difference in SBS in regard to time, however, there was a significant difference among the adhesives ($p = 0.04$) as also seen in our study where SBS of Grengloo and Transbond XT showed statistically significant difference. The SBS for all the groups ranged from 11.3 MPa – 14.7 MPa. In their study, the values of SBS were higher than that obtained in our study for both Grengloo as well as Transbond XT, this could be due to the fact that they used bovine incisors and self-etching primer in their study.

Another study was conducted by Rameez M et al[10] (2020) to compare the shear bond strength of three color-changing adhesives namely Transbond Plus, Grengloo and Blugloo used for bonding metal brackets on labial aspect on 120 extracted maxillary premolars under non-contaminated and contaminated conditions. Contamination conditions were simulated by contamination of sample before applying the bonding agent, after applying bonding agent or both before and after the bonding agent was applied, using artificial saliva. As Blugloo is recommended for ceramic brackets only, the results of Transbond Plus and Grengloo will be discussed for comparison with our study. The shear bond strength of each adhesive group showed maximum SBS in non-contaminated conditions in comparison to contaminated conditions. For Grengloo, SBS under non-contaminated conditions (9.67 ± 0.28 MPa) was significantly higher than contamination before bonding (8.27 ± 0.31 MPa; $p < 0.001$), after bonding (8.41 ± 4.42 MPa; $p = 0.001$) and also, contamination before as well as after bonding (8.19 ± 0.40 MPa) at $p < .001$. Similarly, for Transbond Plus, the mean SBS was significantly higher under non-contaminated conditions (8.82 ± 0.18 MPa) than before bonding (7.94 ± 0.48 MPa at $p < 0.001$), after bonding (8.24 ± 0.28 MPa at $p = 0.007$) and contamination before and after bonding (7.68 ± 0.45 MPa at $p < 0.001$). No difference was seen in these two adhesive on comparing contamination before bonding to contamination after bonding and contamination before as well as after bonding. The shear bond strength of Grengloo group was lesser than that obtained in our study the difference could be due to the direct bonding in their study in comparison to the indirect bonding in our study and also due to the surface area of the bracket (9.806 mm^2) which was lesser as compared to our study (10.50 mm^2).

Shamnur N et al[14] (2011) did not evaluate or compare the shear bond strength of color changing adhesives (Transbond Plus and Grengloo), however they evaluated bond failure rates of brackets bonded with these adhesives which indirectly depends on shear bond strength only. Less bonding failure was observed if the shear bond strength was within clinically acceptable limits of 5-7 MPa. There was no difference between the two color-changing adhesives, which suggests that both the adhesives were comparable in terms of bond failure rates. Even the shear bond strength of Grengloo was 13.07 ± 4.93 MPa in our study which is higher than the clinically acceptable limits as suggested by Reynolds (5-7 MPa).

In a study conducted by Bayani S et al[18] (2015) done on the labial surface of 72 extracted human premolars, they evaluated the effect of light-curing time on the shear bond strength of two color-changing adhesives namely Grengloo and Transbond Plus keeping one conventional light-cured adhesive i.e. Resilience as the control group. They divided the sample into 6 groups consisting 12 teeth in each group and each adhesive was light cured for 20 and 40 seconds. Their results showed that Grengloo adhesive had highest SBS value of 31.25±2.43 MPa when light-cured for 40 seconds, followed by Grengloo at 20 seconds (27.55 + 3.47 MPa), then Resilience at 40 seconds (20.54 + 3.23 MPa), followed by Transbond Plus at 40 seconds (19.64 + 3.76 MPa), then Resilience at 20 seconds (17.24 + 3.48 MPa) and least SBS was shown by Transbond Plus at 20 seconds (14.05±4.24 MPa).

In a study conducted by Izadi MI et al[17] (2012), they aimed to measure the SBS values of Damon3 and Damon 3MX brackets with Blugloo and Grengloo respectively (as recommended) with Transbond XT and the result was then compared with conventional APC brackets which were bonded with Transbond XT when bonded on labial aspect of 30 human mandibular 3rd molars. Amongst the 5 groups included in the study, maximum value of SBS was seen when Damon3 brackets were bonded with orthosolo primer and Blugloo (69.19±5.96 N) followed by Damon 3MX brackets bonded with Grengloo (62.08±20.01 N), followed by the same brackets with Transbond XT (51.52 ± 16.04 N) followed by Damon 3 brackets with Transbond XT (42.96 ± 16.54 N) and least was seen on APC brackets bonded with Transbond XT (42.59±12.35 N). It was seen that there was a significant difference amongst the five groups ($p < 0.005$). On comparison of the SBS of Transbond XT with Grengloo for the same type of brackets i.e. Damon3MX, it was seen than Grengloo showed higher values of SBS (62.08±20.01 N) as compared to Transbond XT (51.52±16.04 N). The values of SBS are much higher than our study as they considered the force obtained to debond a bracket using Instron as the shear bond strength, whereas the SBS is generally calculated in all the studies as force divided by basal surface area of the brackets.

Another study, by Knaup I et al[51] in 2020, was done on extracted bovine lower incisors to evaluate the SBS of different adhesives on bonding and rebonding of metal brackets. Firstly, the SBS was evaluated and compared for Transbond XT primer and adhesive, Brackfix primer and adhesive, orthosolo primer and Grengloo adhesive and Meron glass ionomer luting cement. The brackets were rebonded using different combination of primers with Transbond XT. Considering the results of part 1 of this study, it was seen that the mean SBS of Transbond XT primer and adhesive (18.45±2.56 MPa), Brackfix (17.25±5.2 MPa) and Grengloo (19.08±3.19 MPa) was within clinically acceptable limits and all the three had statistically non-significant difference among them but had higher SBS than the group where Meron glass ionomer luting cement was used (8.7 ± 3.6 MPa). On evaluation of the results of just part 1 of the study, we see that although there was no significant difference in the mean SBS of Transbond XT and Grengloo but Grengloo showed higher bond strength in comparison to Transbond XT. Similar trend of higher bond strength of Grengloo as compared to Transbond XT was seen in our study but with statistically significant difference.

Another study conducted by Northrup RG et al[12] in 2007 was done on labial surface of 60 extracted human premolar teeth to compare the SBS of Damon 2 self-ligating brackets bonded with Transbond

XT (conventional adhesive) and Blugloo (color-changing adhesive) with conventional stainless steel brackets bonded by Transbond XT adhesive by direct technique. In all the three groups, highest bond strength was seen when Damon 2 brackets were bonded with Blugloo (24.8±4.2 MPa) followed by Damon 2 brackets bonded with Transbond XT (22.32 ± 5.3 MPa) and least was seen when conventional Orthos brackets were bonded by Transbond XT (15.2 ± 4.5 MPa). This showed that Orthos bracket groups had statistically lower SBS values as compared to Damon 2 with Blugloo (p <.001), however no significant difference was observed between the two Damon groups (p >.05). they got clinically acceptable values of SBS of color-changing adhesive, Blugloo in their study.

Similarly, in a study conducted by Stumpf ASG[15] et al (2013), on extracted bovine lower incisors, 90 metallic and 90 ceramic brackets were bonded on the labial surface by using two color changing adhesive and conventional adhesives for which they used Ortho Light cure for Group 1 and 2 (metal and ceramic brackets respectively), Transbond Plus for groups 3 and 4 and Transbond XT for groups 5 and 6. Among all the six groups, the tensile stress of Transbond XT was highest when bonded with ceramic brackets i.e. 5.95 ± 0.91 MPa, followed by Transbond XT with metallic brackets (5.62 ± 0.75 MPa), followed by groups bonded using Transbond Plus and metal bracket i.e. 4.26 ± 1.20 MPa and 4.20 ± 1.12 MPa for ceramic brackets bonded using Transbond Plus and least by Ortho lite cure resin group (2.75 ± 1.64 MPa for ceramic and 2.47 ± 1.66 MPa for metallic brackets). No significant difference was seen in the type of bracket used for each adhesive, however, significant differences were seen when the adhesives were compared and it shows that Transbond XT had the highest adhesion in comparison to the other color changing adhesive groups. The values for Transbond XT are lesser than our study as they measured tensile strength and not shear bond strength.

An in-vitro study was conducted by Youssefinia S et al[19] in 2018 on labial surface of 72 extracted human premolars to compare the SBS of color changing adhesive (Transbond Plus) with traditional Transbond XT adhesive at 15minute, 24 hours and 1 week. Maximum SBS was seen of Transbond Plus at 1 week (15 MPa) followed by the same at 24 hours (14.8 MPa), followed by Transbond XT at 15 minutes (14.7 MPA) and Transbond Plus at 15 minutes (14.6 MPa) and least by Transbond XT at 1 week (13.8 MPa). There was not much difference in the mean SBS of the two groups statistically. However, in our study, statistically significant difference was seen in the SBS of Transbond XT with Grengloo: color changing adhesive.

Another study conducted by Maurya R et al[16] (2011) on the labial aspect of 300 extracted human premolar teeth to compare the shear bond strength of various light-cure bonding agents namely, glass ionomer, Transbond XT and Transbond Plus CCA with a conventional etch and self-etch primer. The highest mean SBS was seen for Transbond XT with conventional etch technique (8.33 $\pm$ 2.19 MPA) followed by Transbond Plus with Transbond Plus SEP (7.47 $\pm$ 1.80 MPa) then of Transbond Plus with conventional etch technique (7.30 $\pm$ 1.71 MPa) followed by Transbond XT with Transbond Plus SEP 3 (6.97 $\pm$ 2.08 MPa) and the least was seen for glass ionomer (5.63 $\pm$ 1.98 MPa). Significant difference was seen in the group bonded with Transbond XT using a conventional etchant and glass ionomer. Also, the SBS of Transbond XT was more than Transbond Plus CCA when conventional etching was done. However, in our study, using conventional etchant, the SBS was significantly lesser of Transbond XT as compared to the color changing adhesive used Grengloo.

A study conducted by King L et al[21] (1987) on eighty bovine teeth divided into ten groups of eight teeth each, to evaluate the tensile and shear bond strengths of direct bonded stainless steel lingual brackets by means of 2 chemically cured composite resins (Concise and Right on) and three light-cured composite resins (Silux, Heliosit and Heliosit Ortho). The chemically-cured composite were thermocycled and stored in an incubator for 6 days. The tensile strengths observed was maximum for Right-On (15.49 MPa) followed by Concise Ortho (14.41 MPa), then of Heliosit (13.82 MPa), followed by Heliosit Ortho (12.94 MPa) and least was for Silux (12.65MPa). The shear bond strength observed was maximum for Right-On (6.47 MPa) followed by Concise Ortho (5.98 MPA), followed by Heliosit Ortho (5.59 MPa) then Silux (5.49 MPa) and least was for Heliosit (4.80 MPa).

In a study conducted by Lombardo L et al[37] in 2011 on the lingual surface of 160 extracted human premolar teeth, to compare the tensile strength of four different brands of lingual brackets namely STB, ORG, Stealth and Magic both with and without sandblasting in all the groups. It was observed that maximum tensile strength was seen with sandblasted-directly bonded STB brackets group (229.5 N) followed by sandblasted-indirectly bonded STB brackets (208.1 N) > sandblasted and directly bonded ORG group (182.8N) > sandblasted and indirectly bonded Magic brackets (181.0 N) > sandblasted and indirectly bonded Stealth group (172.7 N) > sandblasted and indirectly bonded ORG brackets (168.4 N) > sandblasted and directly bonded Stealth brackets (167.0 N) > sandblasted and directly bonded Magic group (166.1 N). Thus,the tensile strength of the directly or indirectly bonded, non-sandblasted brackets was lesser as compared to the sandblasted groups.

On comparison of our study with the above mentioned studies, it can be seen that the shear bond strength of Grengloo was within clinically acceptable limits as also seen in other studies. The shear bond strength of Grengloo was significantly more than other conventional adhesives in these studies where brackets were directly bonded on labial aspect. Similar finding was seen when brackets were bonded on lingual aspect by using indirect bonding technique. This is due to the fact that the manufacturer claims that Grengloo has a chemical affinity for metal brackets and provides higher bond strength due to the Ortho Solo sealant present in its composition which has fluoride-releasing potential with a unique form of glass fillers which act as shock absorbers and prevent the crack formation. Also, according to the manufacturers, Grengloo is designed with a patented ingredient which increases the traumatic impact resistance by 118% for reducing bond failures from traumatic impact, and due to the property of quick-cure polymerization, it provides greater shear bond strength seen at initial force loading, greater impact resistance as well as superb handling characteristics

Few studies (Shpack N et al, Singh P et al, Bozelli JV et al) stressed on importance of indirect bonding technique in Lingual Orthodontics as was done in our study.

A study conducted by Shpack N et al[5] (2007) on 40 pre- treatment dental casts of 20 patients to compare the torque error and rotation deviation between labial and lingual bracket system both by direct and indirect bonding techniques. The sample was divided into four groups namely, LbD- brackets bonded directly on the labial surface of tooth, LbI- brackets bonded indirectly on labial surface of toot, LgD- brackets bonded directly to lingual surface, and LgI- brackets bonded indirectly on the lingual surface. The results of this study showed significant absolute torque error (TqE) difference between direct and indirect techniques and between labial and lingual systems. The mean TqE was as follows: LgD > LbD > LgI > LbI. With reference to rotation deviation errors (RotD), it was in the following sequence: LgD > LbD >LgI > LbI. This signifies that absolute TqE as well as RotD were significantly more accurate ($p < 0.001$) in direct rather than indirect technique in labial as well as lingual systems. On comparison of labial versus lingual system, no difference was observed significantly in the TqE and/or RotD. In this, indirect bonding on lingual surface was done using Lingual bracket Jig system whereas in our study, we used the Das DT3C device for indirect positioning of teeth which takes into account the tip and torque values for each individual tooth and helps in better precision bonding.

Singh P et al[50] (2019) did a similar in-vivo study on five patients with midline diastema to compare the accuracy and time duration taken to bond brackets labially by direct as well as by indirect bonding techniques by photographic method. They divided the maxillary arch into two sections- right and left and teeth from central incisor to the 2nd premolar were bonded on the left side by indirect technique and right side by direct bonding technique. In the direct technique, MBT prescription brackets were bonded with Transbond XT adhesive manually using MBT gauge and visual inspection; whereas in indirect bonding technique, after drawing the long axis of teeth on the working model, the brackets were positioned according to MBT prescription by a double-sided tape, following which a soft tray was made with silicone glue gun and a hard tray by 1.5 mm thick biostar sheet. The excess of the tray was trimmed and brackets were washed and dried before placing in the patient's mouth. Time taken for both the methods was recorded and accuracy of angular and linear measurements as well as time measurement was done. All the variables were evaluated by drawing horizontal reference lines and their comparison between the positioning of brackets in the two segments was done by taking photographs of the same. It was observed that there was a significant difference in the mean bracket height of the 1st premolars ($p = 0.008$), the angular measurement of 2nd premolars were highly significant ($p = 0.004$) i.e. with the use of indirect bonding technique, there was better and accurate placement of brackets w.r.t. bracket height and angulation than the direct bonding technique. Similarly a highly significant difference ($p < 0.001$) was seen in the time taken by both the techniques i.e. the chair-side time taken by the operator for indirect bonding technique was much lesser than that taken by the direct bonding technique. However, more laboratory work time was required with the indirect bonding technique.

Bozelli JV et al[44] (2013) conducted a similar in-vivo study on 17 patients to compare the clinical as well as laboratory time spent for Direct Bracket Bonding (DBB) and Indirect Bracket Bonding (IBB). It was observed that the overall clinical and laboratory time was more for IBB (1167.20 $\pm$ 239.39 seconds) than DBB (892.73 $\pm$ 116.21 seconds). However, the clinical time taken for IBB (380.13 $\pm$ 47.59 seconds) was much lesser as compared to DBB (892.73 $\pm$ 116.21 seconds) which is advantageous since reduction in chair-side time reduces the clinical stress for the operator and also increases the patient comfort.

As seen the above mentioned studies, it can be concluded that indirect bonding technique saves chair-side time for the clinician and is more comforting for the patient. Also, uniform spread of adhesive with less voids and lack of movement of brackets is seen when customized transfer tray is used for indirect bonding, improving the shear bond strength.

Many studies have highlighted the importance of sandblasting in improving the shear bond strength. As per Lombardo et al, STB brackets showed stronger resistance when sandblasted and bonded directly or indirectly.

Weichmann D[24] (2000) conducted a study on bovine teeth to evaluate the effect on intraoral sandblasting before etching the tooth surface on the strength of the adhesive in indirect bonding. The results showed that intraoral sandblasting before etching, significantly increased the adhesive strength ($p < 0.001$) between enamel and the bonding material. In our study, we sandblasted the bracket bases during indirect bonding on the lingual surface of teeth to increase the bond strength.

As seen in the above mentioned studies, evaluating the efficacy of sandblasting, it can be inferred that sandblasting improves the shear bond strength of brackets. This justifies the use of sandblasting in indirect bonding technique when used for Lingual Orthodontics.

The drawback of any in-vitro study is the inability to reproduce in-vivo environment. The effect of occlusal masticatory and muscular forces, the pH of saliva and oral environment, temperature of the oral cavity, oral hygiene conditions, biodegradation of material in the oral cavity over a period of time, were not simulated in in-vitro studies, hence these factors can alter the mechanical properties of these adhesives thus affecting the bond strength. Also, the difference in the shear bond strength in different in-vitro studies could be due to the difference in the Universal Testing machine and their cross-head speed or surface area of the piston.

Within the limitations of this study, it can be seen that Grengloo had adequate shear bond strength, much above the clinically acceptable limits suggested by Reynolds (5-7 MPa) which advocates its use in Lingual Orthodontics. The main clinical implication will be that Grengloo with its adequate shear bond strength will ensure lesser bond failure when subjected to occlusal and masticatory stresses. Also, its dual color-changing property will be beneficial for adhesive removal from irregular lingual surfaces after completion of treatment using lingual technique and will also ensure lesser bond Grengloo gave adequate shear bond strength even in contaminated field in one of the studies (Rameez et al[10]), hence its use in Lingual Orthodontics where there are more chances of saliva contamination will be beneficial.

Future scope of the study involves increasing the sample size for the study and validating our results. Also, any microcracks on enamel or the surface roughness after using Grengloo on the lingual aspect of teeth can be evaluated. Shear bond strength can be calculated for different conventional adhesives or color changing adhesives or different types of brackets used in Lingual Orthodontics.

CONCLUSION

The present study was conducted to evaluate the shear bond strength of Grengloo: a color changing adhesive (Ormco Corporation) and its comparison with a conventional adhesive Transbond XT (3M) when they were used to bond brackets by indirect technique in Lingual Orthodontics. The following conclusions were drawn from this study:

1. The shear bond strength of both the adhesives (Grengloo and Transbond XT) were above clinically acceptable limits as suggested by Reynolds.
2. The shear bond strength of Grengloo adhesive was significantly higher than that of Transbond XT advocating its use in Lingual Orthodontics.

The main clinical implication of this study is that Grengloo with higher shear bond strength will be helpful in withstanding occlusal and masticatory forces in Lingual Orthodontics. Also, dual color changing property of this adhesive will be helpful in removal of remaining adhesive after debonding or post-treatment in Lingual Orthodontics.

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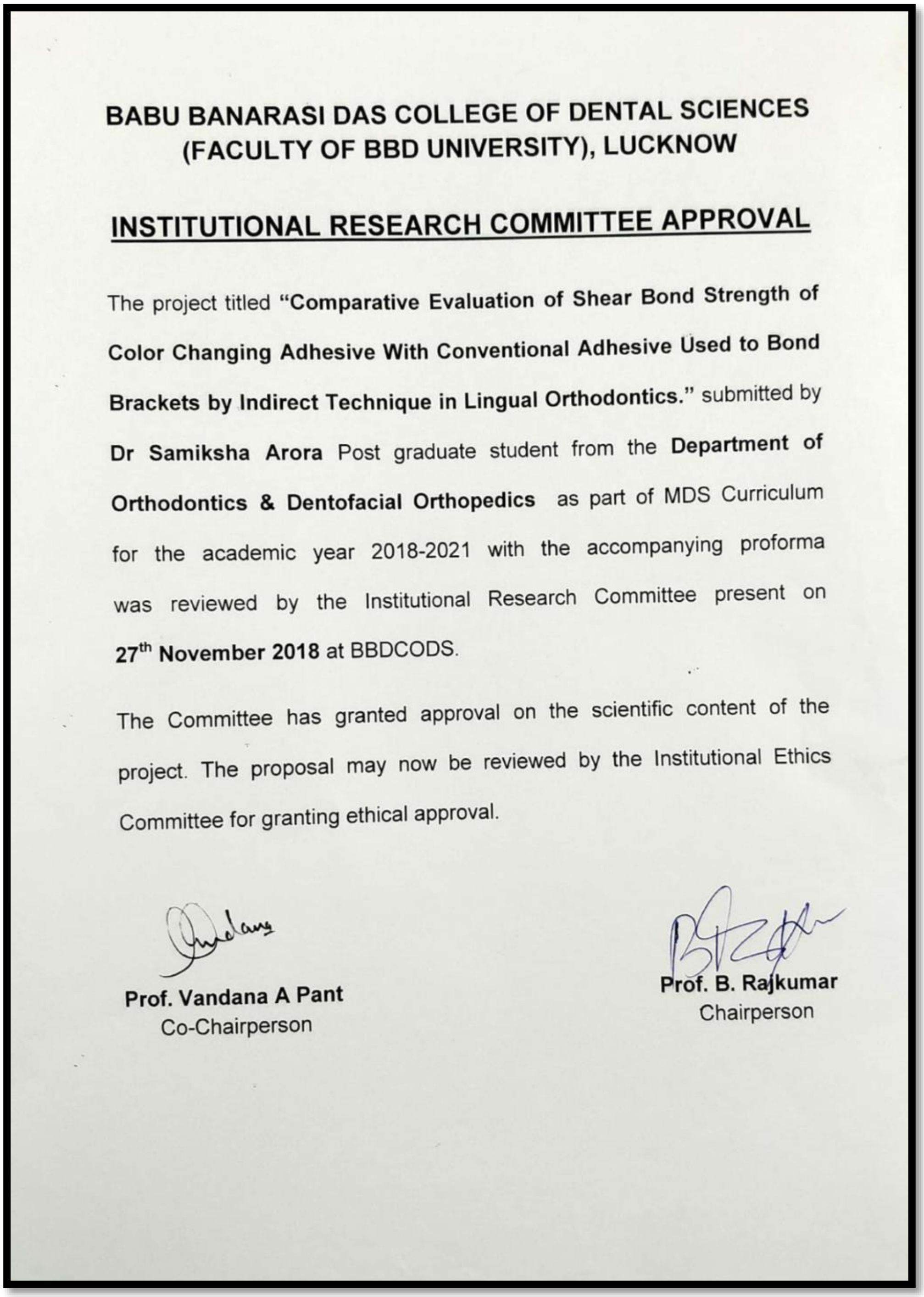
APPENDIX- I



BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES
(FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"Comparative Evaluation of Shear Bond Strength of Color Changing Adhesive With Conventional Adhesive Used to Bond Brackets by Indirect Technique in Lingual Orthodontics."** submitted by **Dr Samiksha Arora** Post graduate student from the **Department of Orthodontics & Dentofacial Orthopedics** as part of MDS Curriculum for the academic year 2018-2021 with the accompanying proforma was reviewed by the Institutional Research Committee present on **27th November 2018** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

APPENDIX- II

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the VIIth Institutional Ethics Sub-Committee

IEC Code: 02 **BBDCODS/01/2019**

Title of the Project: Comparative Evaluation of Shear Bond Strength of Color Changing Adhesive With Conventional Adhesive Used to Bond Brackets by Indirect Technique in Lingual Orthodontics.

Principal Investigator: Dr. Samiksha Arora **Department:** Orthodontics & Dentofacial Orthopedics

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: New, MDS Project Protocol

Dear Dr. Samiksha Arora,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 10th January 2019.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics & Dentofacial Orthopedics, BBDCODS, Lucknow
4.	Dr. Sumalatha M.N. Member	Reader, Department of Oral Medicine & Radiology, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala
22/01/19

(Dr. Lakshmi Bala)
Member Secretary
IEC

Member Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Dr. B. Rajkumar)
Principal
BBDCODS

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-226028

APPENDIX- III

सेन्ट्रल इंस्टिट्यूट ऑफ पेट्रोकेमिकल्स इंजीनियरिंग एण्ड टेक्नॉलाजी
सिपेट : सेन्टर फॉर स्किलिंग एण्ड टेक्निकल सपोर्ट (सी एस टी एस)
रसायन एवं पेट्रोरसायन विभाग,
रसायन एवं उर्वरक मंत्रालय, भारत सरकार
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CIPET सिपेट
probe - perform - practice - Plastics

CENTRAL INSTITUTE OF PETROCHEMICALS ENGINEERING & TECHNOLOGY
CIPET : CENTRE FOR SKILLING AND TECHNICAL SUPPORT (CSTS)
Department of Chemicals & Petrochemicals
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E-mail : cipetdehradun@gmail.com
Website : www.cipet.gov.in
Head Office : CIPET, Guindy, Chennai - 600 032

CIPET: CSTS/DDN/Testing/2021-22/30

Date: 03/07/2021

TO WHOM IT MAY CONCERN

This is to certify that Dr. Samiksha Arora has carried out Shear Bond Force test on Universal Testing machine for her thesis **"Comparative Evaluation of Shear Bond Strength of color changing adhesive with conventional adhesive used to bond brackets by indirect technique in lingual Orthodontics"** at CIPET: CSTS Dehradun.

Authorized Signatory

केन्द्र : अहमदाबाद, अमृतसर, औरंगाबाद, अगरतला, बद्दी, बालासोर, बेंगलुरु, भोपाल, भुवनेश्वर, चन्द्रपुर, चेन्नई, देहरादून, गुरूग्राम, गुवाहाटी, ग्वालियर, हैदराबाद, हाजीपुर, हल्दिया, इम्फाल, जयपुर, कोच्चि, कोरबा, लखनऊ, मदुरै, मुरथल, मैसूरू, रायपुर, राँची, वलसाड एवं विजयवाड़ा

Centres : Ahmedabad, Amritsar, Aurangabad, Agartala, Baddi, Balasore, Bengaluru, Bhopal, Bhubaneswar, Chandrapur, Chennai, Dehradun, Gurugram, Guwahati, Gwalior, Hyderabad, Hajipur, Haldia, Imphal, Jaipur, Kochi, Korba, Lucknow, Madurai, Murthal, Mysuru, Raipur, Ranchi, Valsad & Vijaywada

APPENDIX- IV

Babu Banarasi Das College of Dental Sciences

(A constituent institution of Babu Banarasi Das University)

BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

Participant Information Document (PID)

1. **Study title**

   Comparative evaluation of shear bond strength of color changing adhesive with conventional adhesive used to bond brackets by indirect technique in lingual orthodontics.

2. **Invitation paragraph**

   You are being invited to take part in a research study, it is therefore important for you to understand why the study is being done and what it will involve. Please take time to read the following information carefully. Ask us for any clarifications or further information. Whether or not you wish to take part is your decision.

3. **What is the purpose of the study?**

   The purpose of this study is to evaluate and compare the shear bond strength of Orthodontic brackets bonded by indirect technique in lingual fixed Orthodontic appliance using two different light-cure adhesive resins (Grengloo and Transbond XT).

4. **Why have I been chosen?**

   You have been chosen for this study as you are fulfilling the required criteria for this study.

5. **Do I have to take part?**

Your participation in the research is entirely voluntary. If you do, you will be given this information sheet to keep and will be asked to sign a consent form. During the study you still are free to withdraw at any time and without giving a reason.

6. What will happen to me if I take part?

You will have to give consent to use your extracted premolar teeth.

7. What do I have to do?

You do not have to change your regular lifestyles for the investigation of the study.

8. What is the procedure that is being tested?

The procedure will involve evaluating and comparing the shear bond strength of two different types of adhesives.

9. What are the interventions for the study?

Premolar teeth will be collected from patients who will be indicated for premolar extraction during their fixed orthodontic treatment. Shear bond strength will be calculated and evaluated in Central Institute of Plastic Engineering and Technology (CIPET), Lucknow. However you will not have any side effect on your health. This will be done only once in the study.

10. What are the side effects of taking part?

There are no side effects on patients of this study.

11. What are the possible disadvantages and risks of taking part?

There are no risk or disadvantages of taking part in this study.

12. What are the possible benefits of taking part?

This study will help us to know that whether the color changing adhesive helps us in achieving the shear bond strength that is equal to or greater than the clinically acceptable limits as proposed by Reynolds. If found so, the use of these adhesives would increase greatly in dental clinics for Orthodontic treatment as they can be removed easily without causing damage to the tooth surface.

13. What if new information becomes available?

If additional information becomes available during the course of the research you will be told about these and you are free to discuss it with your researcher, your researcher will tell you whether you want to continue in the study. If you decide to withdraw, your researcher will make arrangements for your withdrawal. If you decide to continue in the study, you may be asked to sign an updated consent form.

14. What happens when the research study stops?

If the study stops/finishes before the stipulated time, this will be explained to the patient/volunteer.

15. What if something goes wrong?

If any severe adverse event occurs, or something goes wrong during the study, the complaints will be handled by reporting to the institution (s), and Institutional ethical community.

16. Will my taking part in this study be kept confidential?

Yes it will be kept confidential.

17. What will happen to the results of the research study?

The results of the study will be used to assess the shear bond strength of the color changing adhesive. Your identity will be kept confidential in case of any report/publications.

18. Who is organizing the research?

This research study is organized by the academic institution (BBDCODS).

19. Will the results of the study be made available after study is over?

Yes.

20. Who has reviewed the study?

The study has been reviewed and approved by the Head of the Dept, and the IEC/IRC of the institution.

21. Contact for further information

Dr. Samiksha Arora

Department of Orthodontics and Dentofacial Orthopedics

Babu Banarasi College of Dental Sciences.

Lucknow-227105

Mob- 9837612630

Dr.Tripti Tikku (HOD)

Department of Orthodontics and Dentofacial Orthopedics

Babu Banarasi College of Dental Sciences.

Lucknow-227105

Mob- 9554832799

Dr. Laxmi Bala,

Member Secretary,

Babu Banarasi College of Dental Sciences.

Lucknow

bbdcods.iec@gmail.com

Signature of PI…………………………………………………….

Name………………………………………………………………

Date ……………………………………………………………….

APPENDIX- V

बाबू बनारसी दास कॉलेज ऑफ डेंटल साइंसेज

(बाबू बनारसी दास विश्वविद्यालय का एक घटक संस्थान)

बीबीडी सिटी, फैजाबाद रोड, लखनऊ - 227105 (भारत)

प्रतिभागी सूचना दस्तावेज (पीआईडी)

1- अध्ययन शीर्षक

लिंगुअल ऑर्थोडोंटिक्स में ब्रैकेट को चिपकाने वाले दो पदार्थों की ना टूटने की क्षमता का तुलनात्मक मूल्यांकन।

2- आमंत्रण अनुच्छेद**?**

आपको एक शोध अध्ययन में भाग लेने के लिए आमंत्रित किया जा रहा है, इसलिए यह समझना आपके लिए महत्वपूर्ण है कि अध्ययन क्यों किया जा रहा है और इसमें क्या शामिल होगा। कृपया निम्नलिखित जानकारी को ध्यान से पढ़ने के लिए समय दें। किसी भी स्पष्टीकरण या आगे की जानकारी के लिए हमसे पूछें। चाहे आप भाग लेना चाहते हैं या नहीं, आपका निर्णय है।

3- अध्ययन का उद्देश्य क्या है**?**

इस अध्ययन का उद्देश्य ब्रैकेट को चिपकाने वाले रंग बदलने वाले पदार्थ की ना टूटने की क्षमता का मूल्यांकन करना है।

4- मुझे क्यों चुना गया है**?**

इस अध्ययन के लिए आपको चुना गया है क्योंकि आप इस अध्ययन के लिए आवश्यक मानदंडों को पूरा कर रहे हैं।

5- क्या मुझे भाग लेना है**?**

शोध में आपकी भागीदारी पूरी तरह से स्वैच्छिक है। यदि आप करते हैं**,** तो आपको यह जानकारी पत्र दिया जाएगा और सहमति फॉर्म पर हस्ताक्षर करने के लिए कहा जाएगा। अध्ययन के दौरान आप अभी भी किसी भी समय बिना किसी कारण के वापस लेने के लिए स्वतंत्र हैं।

6- अगर मैं भाग लेता हूं तो मेरे साथ क्या होगा**?**

आपको इस अध्ययन में अपने फ़िक्स्ड ऑर्थोडोंटिक उपचार के दौरान निकाले गए दांत देने होंगे।

7- मुझे क्या करना है**?**

अध्ययन की जांच के लिए आपको अपने नियमित जीवन शैली को बदलने की ज़रूरत नहीं है।

8- परीक्षण की जा रही प्रक्रिया क्या है**?**

इस अध्ययन में हम ब्रैकेट को चिपकाने वाले दो पदार्थों की ना टूटने की क्षमता का तुलनात्मक मूल्यांकन करेंगे।

9- अध्ययन के लिए हस्तक्षेप क्या हैं**?**

न्यूनतम हस्तक्षेप किया जाएगा।

10- भाग लेने के दुष्प्रभाव क्या हैं**?**

इस अध्ययन के कोई दुष्प्रभाव नहीं हैं।

11- भाग लेने के संभावित नुकसान और जोखिम क्या हैं**?**

इस अध्ययन में कोई जोखिम शामिल नहीं है।

12- भाग लेने के संभावित लाभ क्या हैं**?**

यह अध्ययन के द्वारा हमें ब्रैकेट को चिपकाने वाले रंग बदलने वाले पदार्थ की ना टूटने की क्षमता के बारे में पता चलेगा। यदि परिणाम सही निकला तो इस पदार्थ का प्रयोग और भी अधिक किया जा सकता है क्योंकि यह पदार्थ दांतो से सरलता से हट जाता है।

13- क्या होगा अगर नई जानकारी उपलब्ध हो जाए**?**

यदि शोध के दौरान अतिरिक्त जानकारी उपलब्ध हो जाती है तो आपको इनके बारे में बताया जाएगा और आप अपने शोधकर्ता के साथ चर्चा करने के लिए स्वतंत्र हैं**,** आपका शोधकर्ता आपको बताएगा कि आप अध्ययन में जारी रखना चाहते हैं या नहीं। यदि आप वापस लेने का निर्णय लेते हैं**,** तो आपका शोधकर्ता आपके वापसी के लिए व्यवस्था करेगा। यदि आप अध्ययन में जारी रखने का निर्णय लेते हैं**,** तो आपको एक अद्यतन सहमति फॉर्म पर हस्ताक्षर करने के लिए कहा जा सकता है।

14- शोध अध्ययन बंद होने पर क्या होता है**?**

यदि अध्ययन निर्धारित समय से पहले समाप्त / खत्म हो जाता है**,** तो यह रोगी / स्वयंसेवक को समझाया जाएगा।

15- क्या होगा अगर कुछ गलत हो जाए**?**

यदि कोई गंभीर प्रतिकूल घटना होती है**,** या अध्ययन के दौरान कुछ गलत हो जाता है**,** तो शिकायतों को संस्था (ओं)**,** और संस्थागत नैतिक समुदाय को रिपोर्ट करके संभाला जाएगा।

16- क्या इस अध्ययन में मेरा हिस्सा गोपनीय रखा जाएगा**?**

हां इसे गोपनीय रखा जाएगा।

17- शोध अध्ययन के नतीजों का क्या होगा**?**

इस अध्ययन के परिणाम से ब्रैकेट को चिपकाने वाले रंग बदलने वाले पदार्थ की ना टूटने की क्षमता का मूल्यांकन होगा। आपको यह समझना होगा कि आपकी पहचान किसी भी रिपोर्ट**/** प्रकाशन में नहीं की जाएगी।

18- शोध का आयोजन कौन कर रहा है**?**

यह शोध अध्ययन अकादमिक संस्थान द्वारा आयोजित किया जाता है। आपको शामिल किसी भी प्रक्रिया के लिए भुगतान नहीं करना है।

19- क्या सेवाएं शोध खत्म हो जाने के बाद उपलब्ध रहेंगी या नहीं**?**

हाँ।

20- अध्ययन की समीक्षा किसने की है**?**

इस अध्ययन की समीक्षा विभाग के प्रमुख और संस्थान के आईईसी / आईआरसी द्वारा की गई और अनुमोदित की गई है।

21- अधिक जानकारी के लिए संपर्क करें

डॉ. समीक्षा अरोड़ा

ऑर्थोडोंटिक्स एवं डेंटोफेशियल एस्थेटिक्स विभाग

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज

लखनऊ- 227105

9837612630

डॉ. तृप्ति टिक्कू

प्रोफेसर और हेड

ऑर्थोडोंटाइक्स एवं डेंटोफेशियल एस्थेटिक्स विभाग

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज

लखनऊ- 227105

9554832799

डॉ. लक्ष्मी बाला

सदस्य सचिव

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज

लखनऊ

bbdcods.iec@gmail.com

पीआई का हस्ताक्षर ....

नाम ....

दिनांक ....

APPENDIX- VI

Babu Banarasi Das College of Dental Sciences

(Babu Banarasi Das University)

BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

Consent Form (English)

Title of the Study -: **Comparative evaluation of color changing adhesive with conventional adhesive used to bond brackets by indirect technique in lingual Orthodontics**

Study Number……..

Subject's Full Name……….

Date of Birth/Age ………

Address of the Subject…………………….

Phone no. and e-mail address………………

Qualification ………………………………

Occupation: Student / Self Employed / Service / Housewife/ Other (Please tick as appropriate)

Annual income of the Subject………………

Name and of the nominees(s) and his relation to the subject……………… (For the purpose of compensation in case of trial related death).

1. I confirm that I have read and understood the Participant Information Document dated ……..for the above study and have had the opportunity to ask questions. OR I have been explained the nature of the study by the Investigator and had the opportunity to ask questions.

2. I understand that my participation in the study is voluntary and given with free will without any duress and that I am free to withdraw at any time, without giving any reason and without my medical care or legal rights being affected.

3. I understand that the sponsor of the project, others working on the Sponsor's behalf, the Ethics Committee and the regulatory authorities will not need my

permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the trial. However, I understand that my Identity will not be revealed in any information released to third parties or published.

4. I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).

5. I permit the use of stored sample (tooth/tissue/blood) for future research. Yes [ ] No [ ] Not Applicable [ ]

6. I agree to participate in the above study. I have been explained about the complications and side effects, if any, and have fully understood them. I have also read and understood the participant/volunteer's Information document given to me.

Signature (or Thumb impression) of the Subject/Legally Acceptable

Representative:……………..

Signatory's Name……………. Date ……….

Signature of the Investigator………………… Date………..

Study Investigator's Name.......................... Date………..

Signature of the witness…………………… Date………..

Name of the witness…………………………

Received a signed copy of the PID and duly filled consent form Signature/thumb impression of the subject or legally Date……..

APPENDIX- VII

Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

सहमति पत्र

अध्ययन शीर्षक - लिंगुअल ऑर्थोडोंटिक्स में ब्रैकेट को चिपकाने वाले दो पदार्थों की ना टूटने की क्षमता का तुलनात्मक मूल्यांकन।

अध्ययन संख्या......................

प्रतिभागी के पूर्ण नाम......................

जन्म तिथि / आयु......................

प्रतिभागी का पता......................

फोन नं. और ई-मेल पता ....

व्यवसाय: छात्र / स्व कार्यरत / सेवा / ग्रहिणी......................

अन्य (उचित रुप मे टिक करें) ....

प्रतिभागी की वार्षिक आय......................

प्रत्याशीयो के नाम और प्रतिभागी से संबंध...(परीक्षण से संबंधित मौत के मामले मे मुआवजे के प्रयोजन के लिए)

1. मेरी पुष्टि है कि मैने अध्ययन हेतु सुचना पत्र दिनांक .... को पढ़ व समझ लिया तथा मुझे प्रश्न पुछने

या मुझे अध्ययन अन्वेषक ने सभी तथ्यों को समझा दिया है तथा मुझे प्रश्न पुछने के समान अवसर प्रदान किए गये।

2. मैंने यहाँ समझ लिया कि अध्ययन में मेरी भागीदारी पूर्णतः स्वैच्छिक है और किसी भी दबाव के बिना स्वतंत्र इच्छा के साथ दिया है किसी भी समय किसी भी कारण के बिना , मेरे इलाज या कानूनी अधिकारो को प्रभावित किए बिना अध्ययन में भाग न लेने के लिए स्वतंत्र हुँ

3. मैंने यह समझ लिया है कि अध्ययन के प्रायोजक , प्रायोजक की तरफ से काम करने वाले लोग, आचार समिति और नियामक अधिकारियों को मेरे स्वास्थ्य रिकार्ड को वर्तमान अध्ययन या आगे के अध्ययन के सन्दर्भ देखने के लिए मेरी अनुमति की जरूरत नही हैं, चाहे मैने इस अध्ययन से नाम वापस ले लिया है। हॉलाकि मै यह समझता हूँ कि मेरी पहचान को किसी भी तीसरे पक्ष या प्रकाशित माध्यम में नहीं दी जायेगी।

4. मै इससे सहमत हूँ कि कोई भी डेटा या परिणाम जो इस अध्ययन से प्राप्त होता है उसका वैज्ञानिक उद्देश्य (ऑ) के उपयोग के लिए मेरी तरफ से कोई प्रतिबंध नही है।

5. भविष्य के अनुसंधान के लिए भंडारित नमूना (ऊतक /रक्त) पर अध्ययन के लिए अपनी सहमति देता हूँ।
हों [ ] नहीं [ ] अनउपयुक्त [ ]

6. मै परीक्षण की अनुमति देता हुँ। मुझे इसके द्वारा यदि कोई परेशानी होती है, इसके बारे में जानकारी दे दी गई है। मैने रोगी जानकारी सूचना पत्र को पढ़ तथा समझ लिया है।

प्रतिभागी / कानूनी तौर पर स्वीकार्य प्रतिनिधि का हस्ताक्षर (या अंगूठे का निशान---------------------- --------------------------------हस्ताक्षरकर्ता का नाम -------------------------------------- ---------------- दिनांक -- अध्ययन अन्वेषक का नाम------- गवाह के हस्ताक्षर.. दिनांक---------------------- -------------------- गवाह नाम.................................

मैनें पीआईडी और विधिवत भरे सहमति फार्म का एक हस्ताक्षर की नकल प्राप्त की.

प्रतिभागी कानूनी तौर पर प्रतिनिधि का हस्ताक्षर / अंगूठे का निशान .... दिनांक

APPENDIX- VIII

Babu Banarasi Das College of Dental Sciences

(Babu Banarasi Das University)

BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

Child Assent Form

Study Title -: **Comparative evaluation of shear bond strength of color changing adhesive with conventional adhesive used to bond brackets by indirect technique in lingual Orthodontics**

Study Number ____

Subject's Full Name

____

Date of Birth/Age____

Address____

____

____

I____, exercising my free power of choice, hereby give my consent for participation in the study entitled: "Quantitative analysis of enamel surface roughness using a colour changing adhesive for bonding – A Comparative Study" I have been informed, to my satisfaction, by the attending physician, about the purpose of the study and the nature of the procedure to be done. I am aware that my parents/guardians do not have to bear the expenses of the treatment if I suffer from any trial related injury, which has causal relationship with the said trial drug. I am also aware of right to opt out of the trial, at any time during the course of the trial, without having to give reasons for doing so

Signature of the study participant ______________________

Date:___________________

Name of the study participant_________________________

Signature of the Witness ______________________________

Date_________________________

Name of the Witness _______________________________

Signature of the attending Physician _____________________

Date ________________________

Name of the attending Physician ________________________

APPENDIX- IX

Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

शिशु सहमति पत्र

मैं "लिंगुअल ऑर्थोडोंटिक्स में ब्रैकेट को चिपकाने वाले दो पदार्थों की ना टूटने की क्षमता का तुलनात्मक मूल्यांकन" में भाग लेने के लिए अपनी सहमति प्रदान करता हूँ | मुझे इस अध्ययन के हेतु और उसमे की जाने वाली प्रक्रिया के बारे में चिकित्सक द्वारा बता दिया गया है| मुझे पता है कि अध्ययन सम्बन्धी किसी हानि जिसका अध्ययन की दावा से सम्बन्ध है उसका खर्च मेरे माता पिता अथवा अभिवाहक को नहीं वहां करना है | मुझे यह भी पता है कि मैं इस अध्ययन से किसी समय बिना कोई कारण बताये बाहर हो सकता हूँ ।

अध्ययन में भाग लेने वाले का नाम और हस्ताक्षर ___________ दिनांक ___

गवाह के हस्ताक्षर ___ दिनांक___

गवाह का नाम ___

चिकित्सक का नाम और हस्ताक्षर ___ दिनांक ___

APPENDIX- X

MASTER CHART

SAMPLE No.	GROUP 1 (in MPa)	SAMPLE No.	GROUP 2 (in MPa)
1	13.58	1	1.25
2	14.81	2	7.64
3	7.1	3	8.89
4	10.95	4	12.12
5	27.22	5	5.64
6	16.25	6	7.79
7	10.95	7	14.4
8	7.78	8	6.62
9	7.7	9	6.78
10	19.08	10	8.01
11	11.32	11	11.17
12	8.66	12	10.20
13	15.16	13	5.55
14	9.96	14	8.95
15	6.67	15	9.12
16	14.83	16	8.74
17	16.23	17	13.65
18	18.39	18	9.27
19	19.99	19	10.43
20	8.77	20	9.82
21	15.69	21	12.87
22	13.86	22	13.24
23	10.52	23	8.67
24	14.08	24	9.84
25	7.32	25	14.65
Mean ± SD	**13.07 ± 4.93**	**Mean ± SD**	**9.76 ± 2.75**

APPENDIX- XI

Curiginal

Document Information

Analyzed document	4. ABSTRACT-merged.pdf (D110137944)
Submitted	7/5/2021 6:20:00 AM
Submitted by	Kamna srivastava
Submitter email	dramitn99@bbdu.ac.in
Similarity	4%
Analysis address	dramitn99.bbduni@analysis.urkund.com

Sources included in the report

W	URL: https://www.researchgate.net/publication/6938056_Comparison_of_the_shear_bond_strength_of_2_self-etch_primeradhesive_systems Fetched: 1/22/2020 4:24:33 PM	1
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W	URL: https://www.researchgate.net/publication/236879347_Bond_strength_comparison_of_color-change_adhesives_for_orthodontic_bonding_using_a_self-etching_primer Fetched: 11/14/2020 9:59:06 AM	1
W	URL: https://worldwidescience.org/topicpages/c/ceramic%2Bbracket%2Bdebonding.html Fetched: 6/14/2021 9:12:39 PM	3
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W	URL: https://www.researchgate.net/publication/6938054_Shear_bond_strength_of_orthodontic_brackets_bonded_with_light-emitting_diode_curing_units_at_various_polymerization_times Fetched: 11/8/2019 5:53:51 AM	1
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SA	**9.INTRODUCTION-converted-merged.pdf** Document 9.INTRODUCTION-converted-merged.pdf (D46671908)	1
W	URL: https://www.researchgate.net/publication/7340907_Adhesion_promoters_Effects_on_the_bond_strength_of_brackets Fetched: 1/11/2021 3:12:41 PM	1

1/22