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Effect of Repeated Bonding on the Shear Bond Strength of Transbond XT (3M Unitek)

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Abstract:*Direct bonding of brackets to teeth has brought a revolution in the field of Orthodontics. Despite material advancement for direct bonding to increase efficacy of treatment, bond failures continues to be a challenge in clinical practice. This study was undertaken to measure Shear Bond Strength with Transbond XT first bonding and after debonding and repeated bonding twice. 30 test specimens were prepared from extracted maxillary and mandibular premolar teeth, which were subjected to repeat bonding (2 repetitions) using Transbond XT and Shear Bond Strength was measured for each of them. Mean Shear Bond Strength of 9.89 MPa ± 3.25 was obtained after first bonding. Mean Shear Bond Strength of 7.73 MPa ± 3.55 and 7.32 MPa ± 2.06 was obtained after first and second rebonding respectively. Transbond XT has higher Shear Bond Strength at initial bonding than first and second debonding-rebonding but shows Shear Bond Strength to be adequate for most Orthodontic needs even after debondingrebonding procedures.*

Keywords: *Direct bonding, Shear Bond strength, Debonding, Rebonding, Transbond XT*

I. Introduction

Direct bonding of brackets to teeth has brought a revolution in the field of Orthodontics. Since Buonocore introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel has developed applications in all fields of dentistry[1], including the bonding of Orthodontic brackets[2,3]. This approach has several advantages, i.e. enhanced ability for plaque removal by the patient, minimized soft-tissue irritation and hyperplastic gingivitis, elimination of the need for separation, absence of post treatment band spaces, facilitation of application of attachments to partially erupted teeth, minimal danger of decalcification with loose bands, easier detection and treatment of caries, and a more esthetic appearance for the patient[4].

Various materials have been introduced since the advent of direct bonding, mainly composite materials based on acrylic or diacrylate resins to be bonded chemically or light cured[5,6].Despite the material advancement for direct bonding to increase efficacy of treatment, bond failures continue to be a challenge in clinical practice[7]. Thus, a significant number of teeth need to be rebonded in a busy Orthodontic practice. This can prolong the total treatment time. Bond failure consumes increased chair side time as it needs time to clean, prepare and rebond the debonded bracket. This can cause change in the Bond Strength. The changes in Bond Strength after repeated bonding may be related to changes in the morphologic characteristics of the tooth surface caused by adhesive remnants[8] along with residue on the bracket bases[9]. Studies by various authors indicate that aluminium oxide air abrasion is efficient, technically simple and provides good Shear Bond Strength in addition to cost reduction both for Orthodontist and patient alike[9-11]. It is therefore important to understand what to expect when a tooth is rebonded more than once, because the literature provides contradictory findings about the Shear Bond Strength of rebondedattachments[12,13].

With this view in mind, this study was undertaken to measure Shear Bond Strength with Transbond XT first bonding and after debonding and repeated bonding twice.

II. Review Of Literature

In 1955, Buonocore[1] was the first to demonstrate that the bonding of acrylic restorative material was substantially increased by conditioning the enamel surface with 85% phosphoric acid for 30 seconds. It was suggested that the increased adhesion would be due to an increased surface area created by acid etching. Also the treatment increased the wettability of the adherent surface allowing for more intimate contact with the adhesive.

In 1964, Newman[14] was the pioneer in successfully bonding Orthodontic attachment to the teeth by means of epoxy resin. He used a mixture consisting of equal parts of low molecular weight epoxy liquid and a high molecular weight epoxy solid with a polyamide curing agent and also showed that pre-treating the tooth surface by pumicing and by applying 40% phosphoric acid will enhance the joint strength.

In 1965, Bowen[15] developed a new resin system Bisphenol-A- Glycidyldimethacrylate commonly known as BIS-GMA. He demonstrated that the incorporation of vinyl silane treated silica powder into the adhesive material improved its physical properties.

In 1968, Buonocore[16] et al examined the penetration of several resin dental material into enamel surface. They demonstrated resin tags projecting from all resin interfaces which had been in contact with conditioned enamel surface. The tags ranged upto 25 µm in length.

In 1971, Gwinnett et al[17] studied the nature and extent of surface changes produced on the enamel surface etched with phosphoric acid and observed that concentrated phosphoric acid solution resulted in reduced etching of enamel compared to that of dilute solutions.

In 1975, Reynolds[18] reported that the bonded brackets should be able to withstand forces generated by treatment mechanics and occlusion clinically. On the other hand, one should be able to debond the brackets without damaging enamel. He has reported that maximum tensile Bond Strength of 5.9 to 7.9 MPa would be able to resist treatment forces. He also said that an in vitro tensile strength of 4.9 MPa has proved to be clinically acceptable.

In 1977 Reynolds et al[19]made an in vitro comparative study of Bond Strength of attachments with various type of bases i.e. plastic brackets, metal brackets with mesh and polymer coated brackets base. They concluded that plastic brackets showed a greater resistance to tensile forces than metal brackets with mesh and polymer coated metal bracket bases.

In 1981, Alexandre P et al[20] concluded from their study that bond failure, inevitably occurred as mixed phenomenon i.e. at the enamel adhesive interface, bracket adhesive interface as well as through the adhesive.

In 1981, Jassem HA et al[21] conducted a study to measure Tensile and Shear Strengths of bonded and rebonded Orthodontic attachments. The results showed that temperature cycling adversely affected tensile Bond and Rebond Strengths, while the sealing resin had no additional effect on tensile and Shear Bond and Rebond Strengths.

In 1993, Leas T.J. et al[22] conducted a study on the effect of rebonding on the Shear Bond Strength of Orthodontic brackets. The purpose of this study was to determine the effects of two techniques on the Shear Bond Strengths of the rebonded Orthodontic appliances when compared with their original Shear Bond Strengths. Comparisons of the original and rebonded Bond Strengths showed that the rebonded Orthodontic appliances had higher mean Shear Bond Strengths than when they were originally bonded.

In 1998, Bishara et al[23] evaluated the effects on the Shear Bond Strength and the bracket adhesive failure mode when an acidic primer and other enamel etchant were used to condition the enamel. They concluded that, the use of acidic primer to bond Orthodontic brackets to the enamel surface, provided clinically acceptable Shear Bond Strength when used with high filled (77%) adhesive. Also, there was less residual adhesive remaining on the tooth surfaces when an acidic primer was used.

In 1999, Mui et al[12] performed a study for optimization of a procedure for rebonding dislodged Orthodontic brackets. The results revealed that the light-cured system produced higher Shear Bond Strength in the initial bond than the self-cured system ($p<0.005$). Reconditioning the enamel surfaces using a tungsten carbide bur and acid-etching gave the highest Shear Bond Strength (difference 5.8 MPa; $p<0.01$) and clinically favourable fracture characteristics. The data suggest that the optimal procedure for rebonding dislodged Orthodontic brackets is to resurface the enamel using a tungsten carbide bur, acid-etch the enamel, and use a new or re-use an old bracket after microetching.

In 2006, Tavares et al[10] conducted a study on Shear Bond Strength of new and recycled brackets to enamel. In conclusion, the outcomes of this study showed that bracket recycling using aluminium oxide particle air-abrasion was efficient and technically simple, and might provide cost reduction for Orthodontists and patients alike.

In 2009, Ana Nicolas et al[24] carried out a study to evaluate the in vitro effect of repeated bonding on the Shear Bond Strength with different enamel conditioning procedures. It was concluded that the enamel changes were similar across all groups. Transbond Self Etching Primer and Non Rinse Conditioner produced bonds that were similar to acid etching. When acid etching is used, it is possible to avoid etching for a second bond but not for following bonds.

In 2009, Endo T et al[25]conducted a study to evaluate Shear Bond Strength of brackets rebonded with a fluoride-releasing and recharging adhesive system. Transbond XT and Transbond Plus had significantly higher mean Shear Bond Strengths than did Beauty Ortho Bond at each debonding. No significant differences in mean Bond Strength were observed between the three debondings in each adhesive system. Bond failure at the enamel/adhesive interface occurred more frequently in Beauty Ortho Bond than in Transbond XT or Transbond Plus

In 2011, Ruger D et al[26]carried out a study on Shear Bond Strength after multiple bracket bonding with or without repeated etching. The purpose of the study was to measure the in vitro Shear Bond Strength of metal brackets after multiple bonding and debonding with and without repeated etching. It was concluded that after bracket loss and levelling of composite remnants, the Shear Bond Strength is sufficient for application of Orthodontic forces. Repeated etching may involve a higher risk of enamel tear-outs during debonding.

In 2012, Ahrari F et al[27]carried out a study on early versus delayed rebonding of Orthodontic brackets. The aim of this study was to evaluate the Shear Bond Strength of brackets following early and delayed rebonding, and after employing different methods of composite removal. It was concluded that late rebonding of brackets had no effect on the Shear Bond Strength ($p>0.05$). Postponing rebonding to the next visit does not improve the Shear Bond Strength significantly. He recommended to use a tungsten carbide bur or a green rubber wheel, and not a round bur for removing adhesive remnants following debonding of Orthodontic brackets.

In 2013, Faisal et al[9] conducted a study to evaluate the impact of recycling and repeated recycling on Shear Bond Strength of stainless steel Orthodontic brackets. It was concluded that sandblasted recycled Orthodontic brackets can be used as an alternative to new brackets.

In 2013, Aksu et al[11] carried out a study to evaluate the influence of two different bracket base cleaning procedures on Shear Bond Strength reliability.. Bond Strength of rebonded brackets after sandblasting was not significantly different from that of new brackets while the Bond Strength of rebonded brackets after carbide bur cleaning group significantly decreased.

In 2013, Oshagh M et al[28]conducted a study on comparison of the Shear Bond Strength of Orthodontic brackets in bonding and rebonding. The purpose of this study was to compare the Bond Strength of Orthodontic brackets using laser versus acid etching. It was concluded that Primary preparation with acid has a higher Bond Strength value than does CO_2 laser. Less adhesive residue remained on enamel after tooth preparation with laser following debonding. Secondary preparation of the enamel using laser has higher Bond Strength value than primary preparation with laser, which can rationalize use of laser in rebonding of brackets.

In 2013, Chacko PK et al[29]conducted a study on recycling stainless steel Orthodontic brackets with Er:YAG laser. It was found that ER: YAG laser (2940 nm) was found to be the most efficient method for recycling, followed by the sandblasting, thermal, and the tungsten carbide methods.

In 2013, Al Maaitah et al[30] conducted a study to evaluate the effect of different bracket base cleaning method on Shear Bond Strength of rebonded brackets. It was concluded that In-office methods; slow speed Carbide Bur and UltasonicScaler are effective, quick and cheap methods for bracket base cleaning for rebonding.

In 2014, Yassaei et al[31]carried out a study compare the Shear Rebond Strength (SRS) of brackets recycled with different resin removal methods by means of Er:YAG laser, sandblasting, direct flame, and CO_2 laser, respectively. It was concluded that Microroughening of the base of sandblasted bracket was observed in the Scanning Electron Microscope image. Resin removal with direct flame and CO_2 laser irradiation was incomplete. Er:YAG laser recycling of brackets is an efficient in-office method of reconditioning which caused minimum damage to the bracket base.

III. Materials And Methods

This in-vitro study was conducted at The Department of Orthodontics and DentofacialOrthopaedics, Government Dental College and Hospital, Ahmedabad and Ahmedabad Textile Industry's Research Association (ATIRA), Ahmedabad, India.30 test specimens were prepared from extracted maxillary and mandibular premolar teeth, which were subjected to repeat bonding (2 repetitions) and Shear Bond Strength was measured for each of them. Thus, 90 samples were tested for Shear Bond Strength using Instron Universal Testing Machine – 5982. The premolar teeth used as specimen were previously extracted for Orthodontic purposes. Following extraction, the teeth were stored in 10% formaldehyde solution at room temperature.

Inclusion criteria for tooth specimens were as follows:

- Intact labial enamel surface
- Specimen correctly stored following extraction

Exclusion criteria were:

- Caries
- Restorations in the tooth
- Gross enamel hypoplasia
- Enamel defects
- Cracking of labial enamel surface
- Specimen stored incorrectly following extraction

All teeth were examined under normal surgery light conditions to assess suitability for inclusion.

Tooth Preparation:

The teeth were then inserted into plastic tubes containing dental stone so that the buccal surface of the tooth was perpendicular to the bottom of the tube.

Enamel Surface Preparation:

Labial enamel surfaces of premolar teeth were polished with fluoride free pumice slurry using a rubber cup attached to a slow handpiece for 10 seconds. It was rinsed with air / water spray for 15 seconds and dried with a stream of oil-free compressed air for 10 seconds.30 test specimens were thus prepared and bonded with “Transbond XT (3M Unitek, Monrovia, California)” 30 uncoated premolar metallic brackets of 3M Unitek, Gemini were used. The base surface area of each bracket was 9.79 mm2 as given by manufacturer.

Bracket Placement:

Brackets were bonded in all groups to the labial surface at the intersection of the long axis of the clinical crown (LACC) and the midpoint of long axis of clinical crown (LA point)[32]. These bonded brackets were subjected to debonding-rebonding-debonding-rebonding and debonding, thus forming the following groups.

Group 1, 2 and 3 – Phosphoric acid etch, Primer, “Transbond XT (3M Unitek, Monrovia, California) composite”, Uncoated metallic brackets 3M Unitek, Gemini with curing time of 20 seconds.

30 teeth were etched with 37% Phosphoric acid for 30 seconds. The etched surface was then washed with water for 15 seconds and dried with oil-free compressed air until the surface of the etched enamel had a frosty appearance.

Transbond XT (3M Unitek, Monrovia, California) primer was applied to the etched surface of the tooth lightly blown with a stream of oil-free compressed air to ensure that a thin layer of primer remained before light curing for 10 seconds.An upper premolar metallic bracket was then coated with Transbond XT (3M Unitek, Monrovia, California) composite applied directly to the etched and primed tooth surface and seated. Excess adhesive was cleared from around the bracket periphery and the bonding material polymerized by exposure to light intensity of 500 mW/cm2 and wavelength 470 – 480 nm for 20 seconds.

Bond Strength Testing

Each plastic cylinder with its embedded specimen was assembled in the customized jig in the lower cross head of the Instron Universal Testing Machine – 5982. The plastic cylinder could be adjusted in both a rotational and in-out direction, enabling shear forces to be directed at right angles to the long axis of the bracket body. Specimens were mounted purposely to direct the applied force gingivo-occlusally and parallel to the labial tooth surface.

A shear-peel force was applied through a looped stainless steel wire (0.016” x 0.016”, 5 mm wide, 68 mm long) engaged between the fixed upper crosshead and the gingival tie-wings of the bracket. Wire of this dimension fills the entire width between the bracket base and tip of the gingival tie-wing and ensures that the point of application is at the same distance from the bracket / resin interface in all cases, helping to make the method of testing more reproducible.

During testing, the Instron Universal Testing Machine – 5982 had a 2 KN load cell and cross-head speed of 0.5mm / min.

It is impossible to apply a pure shear load to a bracket, due to an unavoidable inherent bending moment. The term ‘shear–peel’ is used in the literature to acknowledge this phenomenon. The Instron, is therefore more likely to create shear-peel forces that mimic the clinical situation although never truly represent it.Bluehill-3 software (Figure 10) electronically connected to the Instron Universal Testing Machine – 5982 recorded the results of the load applied at failure in Kg and Newton and this data was subsequently converted to MPa.

$$\text{MPa} = \frac{\text{Load (mass) (Kg)}}{\text{Bracket base area}} \times \text{gravitational acceleration constant (9.81)}$$

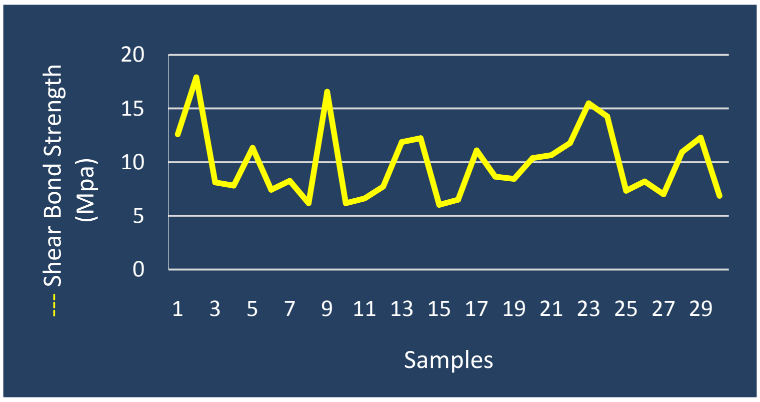
1 Kg = 9.81 N

1 MPa = N / mm2

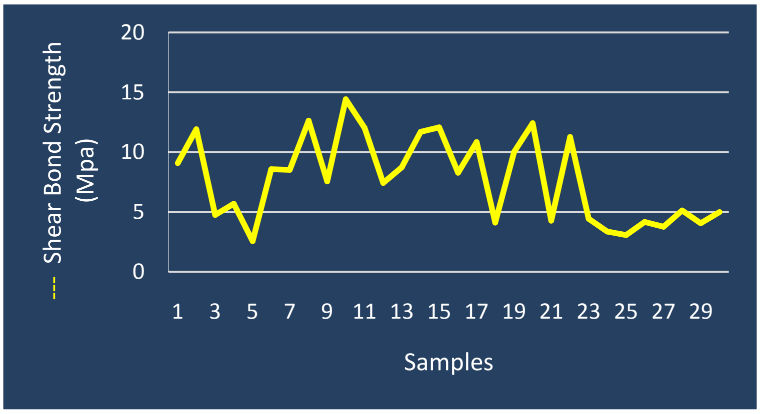
Rebonding Sequence

After each debonding, all visible residual adhesive was removed with a finishing tungsten carbide bur - Dentsply #7702 until the enamel surface regained its gloss and then cleaned with a water spray. The debonded brackets were sandblasted with 110 µmaluminium oxide powder (Delta Labs, Chennai, India) until no residual composite was seen on visual inspection and rebonded again. This rebonded tooth was placed in the Jig and Shear Bond Strength was measured after first debonding. Between debonding and rebonding, the teeth were placed in distilled water. This procedure was repeated again following the same regime of cleaning the tooth and measuring Shear Bond Strength after second debonding. Hence three different groups were obtained which were marked with different colours for easy identification and comparison.

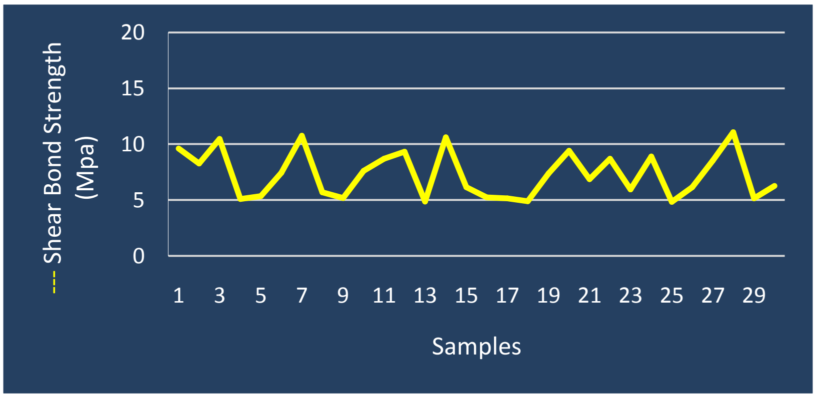
IV. Figures, Graphs And Tables



Graph 1 – 30 metallic brackets bonded with Transbond XT (3M Unitek, Monrovia, California) and cured for 20 seconds.



Graph 2 – 30 metallic brackets rebonded with Transbond XT (3M Unitek, Monrovia, California) and cured for 20 seconds



Graph 3 – 30 metallic brackets rebonded again with Transbond XT (3M Unitek, Monrovia, California) and cured for 20 seconds

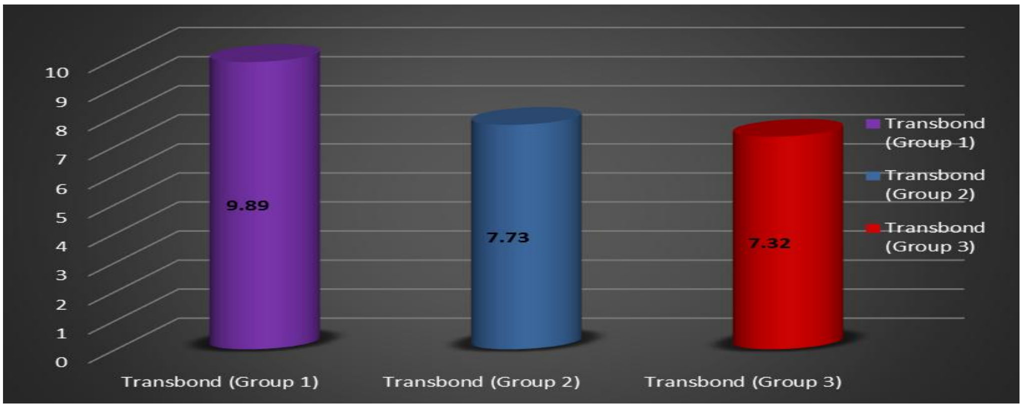
Table 1 showing the Mean (x), Standard Deviation, Median, Minimum, Maximumand Standard Error of Mean of Shear Bond Strength measurements using TRANSBOND XT.

Group	Parameters	N	Mean	Standard Deviation	Median	Minimum	Maximum	Standard Error
Group 1	Shear Bond Strength	30	9.89	3.25	8.55	6.03	17.90	0.59
Group 2	Shear Bond Strength (Repetition 1)	30	7.73	3.55	7.93	2.56	14.42	0.65
Group 3	Shear Bond Strength (Repetition 2)	30	7.32	2.06	7.12	4.84	11.08	0.38

Table 2 showing the Mean (x), Standard Deviation, Standard Error, Range, Mean Difference and P-Value of Shear Bond Strength measurements using TRANSBOND XT.

Groups	Transbond XT	Mean	N	Standard Deviation	Standard Error	Range	Mean Difference	p value
Group 1	Shear Bond Strength	9.89	30	3.251	0.593	11.870	-2.16	*0.025
Group 2	Shear Bond Strength *(Repetition 1)*	7.73	30	3.549	0.648	11.860		
Group 1	Shear Bond Strength	9.89	30	3.251	0.593	11.870	-2.57	***0.001
Group 3	Shear Bond Strength *(Repetition 2)*	7.32	30	2.060	0.376	6.240		
Group 2	Shear Bond Strength *(Repetition 1)*	7.73	30	3.549	0.648	11.860	-0.41	0.547
Group 3	Shear Bond Strength *(Repetition 2)*	7.32	30	2.060	0.376	6.240		

Graph 4Comparative analysis of Shear Bond Strength Within Transbond XT Group - (Group 1, 2 and 3).



V. Discussion

The purpose of this study was to evaluate the Shear Bond Strength of Orthodontic brackets bonded with Transbond XT (3M Unitek, Monrovia, California). Another objective was to evaluate and compare the Shear Bond Strength when these brackets are subjected to repeated bonding.

Graph 1 shows the Shear Bond Strength of each sample of 30 metallic brackets bonded with Transbond XT and cured for 20 seconds. It shows a mean Shear Bond Strength of 9.89 MPa ± 3.25. The Mean Shear Bond Strength obtained in our study was higher than that obtained by Bishara et al[8] 6.1 MPa ± 3.4 using Transbond XT. Similar results were obtained by Nemeth et al[33] who observed Mean Shear Bond Strength of 10.57 ± 2.83 when using Transbond XT.

Graph 2 shows the Shear Bond Strength of each sample of 30 metallic brackets which after debonding, cleaning, and preparing were rebonded with Transbond XT and cured for 20 seconds. It shows a Mean Shear Bond Strength of 7.73 MPa ± 3.55. This is in accordance with the study by Endo T et al[25] who observed that the initial Mean Shear Bond Strength of 12.34 MPa ± 2.58 decreased to 11.90 MPa ± 2.77 on second debonding using Transbond XT. In a study by Bishara et al[34] it was observed that the Mean Shear Bond strength decreased from Initial Mean Shear Bond Strength of 6.1 MPa ± 3.4 to 4.1 MPa ± 2.3 on rebonding using Transbond XT.

Graph 3 shows the Shear Bond Strength of each sample of 30 metallic brackets rebonded again with Transbond XT and cured for 20 seconds showing a mean Shear Bond Strength of 7.32 MPa ± 2.06. Similar results are observed in a study by Endo T et al[25] who observed that the Initial Mean Shear Bond Strength reduced to 11.16 MPa ± 2.27 on third debonding using Transbond XT. Bishara et al[34] recorded similar findings where Shear Bond Strength gradually decreased from initial bonding to first and then to second rebonding to 4.0 MPa ± 3.3.

Table 1 shows various statistical analysis of Shear Bond Strength measurements of brackets bonded and rebonded using Transbond XT adhesive. This table shows that the initial Shear Bond Strength values achieved by Transbond XT to be 9.89 MPa ± 3.25 which is higher than the clinically accepted level of Bond Strength as mentioned by Reynolds et al[18]. The Mean Shear Bond Strength values for Group 2 i.e. repetition 1 is 7.73 MPa ± 3.55 and Group 3 i.e. repetition 2 is 7.32 MPa ± 2.06 which are both lower than initial Bond Strength. These values are higher than that suggested by Reynolds[18] who reported successful clinical bonding with adhesives that provide in vitro Bond Strength of approximately 4.9 MPa. These findings are in accordance with study carried out by Ana Nicolas et al[24] who found the Mean Shear Bond Strength (MPa) of the group cured with Transbond XT to be 10.50 MPa ± 3.73 on first debonding sequence; 10.13 MPa ± 3.61 on second debonding sequence and 9.42 ± 2.75 on third debonding sequence.

Table 2 shows the paired sample t-test showing significance of variation in Shear Bond Strength measured within the group for the Transbond XT Group i.e. Group 1, 2 and 3. This table shows that the difference between the Initial Mean Shear Bond Strength of Group 1 (9.89 MPa ± 3.25) was statistically significant ($p = 0.025$) when compared with the Mean Shear Bond Strength values of the rebonded brackets, Group 2 (7.73 MPa ± 3.54). Whereas this difference was statistically highly significant ($p = 0.001$) when Group 1(9.89 MPa ± 3.25) was compared with Group 3 (7.32 MPa ± 2.06).

Graph 4 shows comparative analysis of Shear Bond Strength within Transbond XT group (Group1, 2 and 3) indicating statistically significant difference between Group 1 and the other two groups. This finding is in accordance with study carried out by Ana Nicolas et al[24] who found the Mean Shear Bond Strength (MPa) of the brackets cured with Transbond XT decreased from the first bonding (10.50 MPa ± 3.73) to second rebonding (10.13 MPa ± 3.61) and still decreased further when the bracket was bonded the third time (9.42 MPa ± 2.75). Shear Bond Strength measured at the third sequence were significantly less ($P < 0.017$) than at the first and second sequence. In contrast to these studies, Leas T.J. and S. Hondrum[22], in their research on comparing the original and rebonded Bond Strengths showed that the rebonded Orthodontic appliances had higher mean Shear Bond Strengths than when they were originally bonded.

VI. Conclusion

Transbond XT has higher Shear Bond Strength at initial bonding than first and second debonding-rebondingbut showed Shear Bond Strength to be adequate for most Orthodontic needs even after debonding rebonding procedures.Rebonded teeth have significantly lower Shear Bond Strength. Hence, Orthodontist should judiciously use the bonding material depending on the clinical situations.Further studies with Scanning Electron Microscope (SEM) to validate the presence of resin tags as a reason to decreased Shear Bond Strength are required.

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