Effect of Various Mesh Designs on Shear Bond Strength of New and Recycled Brackets –A Comparative, Invitro Study

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Abstract

Introduction: Various chemical and mechanical methods are used to enhance the retention of adhesive to the metal bases of the brackets.Inspite of several efforts,bracket failure is one of the commonest problems faced during treatment.Debonded brackets are generally recycled and reused.This study was designed to compare the shear bond strength(SBS)of five commonly available mesh designs and to determine which mesh design offers least reduction of SBS following recycling.

Method: Sample consisted of 5 types of brackets with different mesh designs, bonded to 70 extracted human premolars.The SBS was checked using Instron universal testing machine.The brackets were recycled using sandblasting procedure and were rebonded on the sample teeth.Bond strength testing was again carried out using the same procedure.

Results: Mean SBS of Discovery smart bracket with laser structured base was highest followed by 3M Unitek brackets.The brackets by American Orthodontics had lowest bond strength.After recycling with sandblasting procedure,an insignificant reduction in SBS was noticed in all five groups.

Conclusion: Laser structured base design was superior to other bracket base designs.All five bracket types had optimal bond strength required for successful bonding both before and after recycling (>7.8 MPa).

***Key words –** Shear bond strength, recycled brackets*

Introduction

Good bond strength and retention of orthodontic brackets to the tooth surface is critical for a favorable outcome of orthodontic treatment.An orthodontic bracket must be able to resist a force of 6-8 MPa for clinical success.[1]

Various chemical and mechanical methods such as milling undercuts in the bracket bases, welding different diameter mesh wires to the bases, brazing, chemical etching or sintering with porous metal powder & perforating the bracket bases are used to enhance the retention of the adhesive to the metal bases of the brackets.Recent advancements include laser structured bracket bases and metal plasma coated bases to further improve retention.Inspite of several efforts to prevent bracket failure,it is one of the commonest problems clinicians face during treatment.This is usually the result either of the patient's accidentally applying inappropriate forces to the bracket or of a poor bonding technique. Debonded brackets are generally recycled and reused in the orthodontic office as the advantages are both economic and environmental.[6]There are various methods to recycle brackets such as direct flaming[2], Buchman method[3],sandblasting[4],green stone,and tungsten carbide bur[5].

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Previous studies have reported that recycling of brackets can lead to reduction in bracket quality,loss of identification marks,lack of sterility,increased risk of cross infection and lower bond strength.[6,7]

Since there are varieties of bracket bases that are available to the orthodontists, there have been various studies evaluating the success and advantage of one bracket base to another.

Several studies have compared the SBS of orthodontic brackets with different base surface areas and base designs. However,a literature search revealed that a comparison of SBS of different mesh designs after recycling,has not been previously studied.

Therefore,the present study was undertaken to determine which among the various commonly available mesh designs offer least reduction in bond strength following recycling.

Methodology

A total of 70 extracted human premolars were collected and stored in distilled water.

Inclusion criteria:Intact premolars extracted for orthodontic purpose.

Exclusion criteria-

Teeth with history of any pre-treatment with chemical agents like hydrogen peroxide restorations,cracks due to the extraction forceps and caries.

The teeth were cleansed and polished with pumice and rubber prophylactic cups for 10 seconds and washed with water.Transbond XT adhesive system(3M Unitek,Calif)was used to bond all brackets to teeth.

Teeth were then embedded in cold cure acrylic blocks which were fitted into the jig of the universal testing machine(Instron-3366, load capacity 7kN, Instron Corp, UK)to determine the SBS(fig 1).

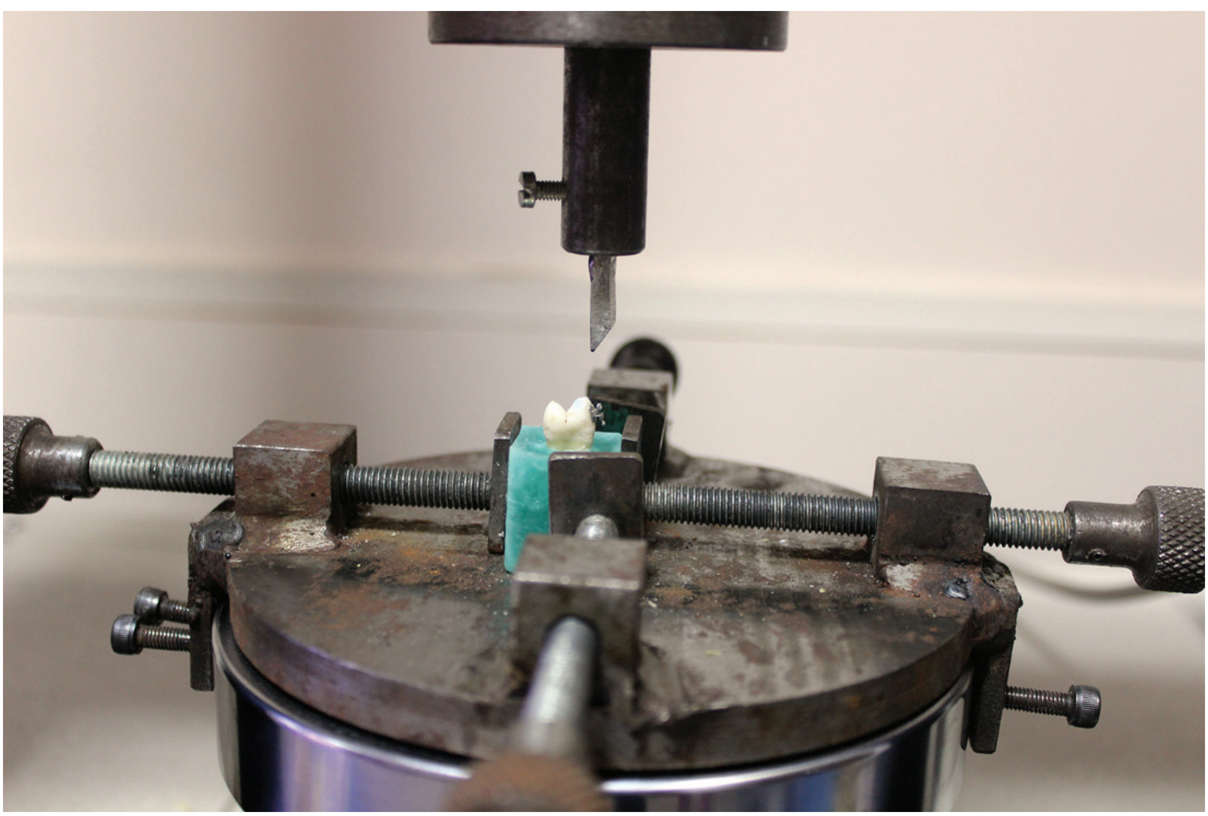

Fig 1:Instron universal testing machine

The sample blocks were coded in 5 different colours corresponding to five brackets used,

Group 1:American Orthodontics(AO),dual mechanical retention, 80 gauge mesh over a photo-chemically etched base(fig 2a)

Group 2:RMO(mini taurus contur-lok bases) laminate of stainless steel foil to an 80x80 mesh, oriented at 45^0 (fig 2b)

Group 3: Discovery smart (Dentaurum,Germany) laser structured base (fig 2c)

Group 4: Twin torque bracket(3M-Unitek,calif.) Dyna-Bond II mesh base(fig 2d)

Group 5: Mini diagonal Roth(Leone,Italy)(fig 2e)

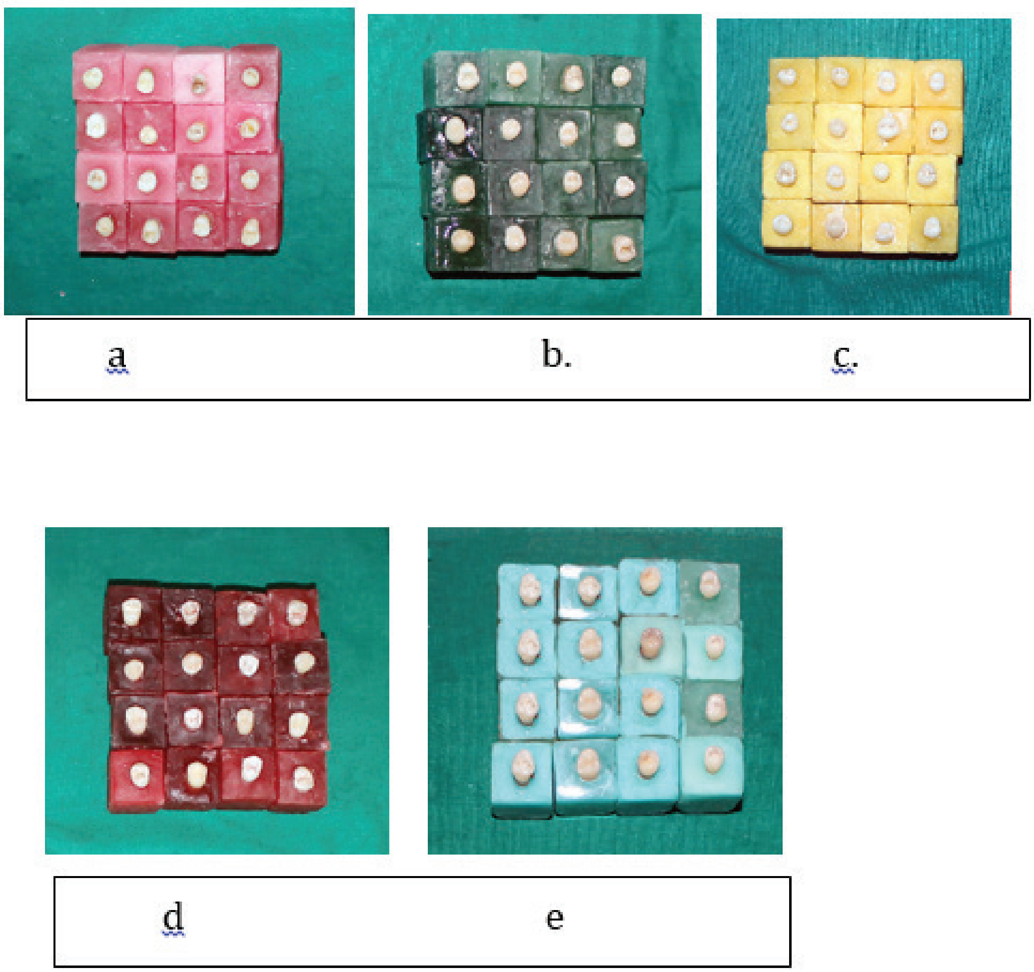

Fig 2: Teeth embedded in colour coded acrylic blocks

SBS testing was done using the universal testing machine-Instron.An occlusogingival load was applied to the brackets using SS metal blades producing shear force at the bracket base tooth interface,at a crosshead speed of 1mm/min until rupture of bracket occured.

After debonding the entire sample of brackets was subjected to sandblasting using 50micron alumina abrasive particles for 15 sec at a distance of 10mm. Brackets were rebonded to the tooth surface and bond strength testing was carried out on Instron machine.

Statistical Analysis

Descriptive statistics,including the mean,standard deviation were calculated for each group.ANOVA was used to determine whether significant differences existed in the overall SBS of the 5 groups.Posthoc tukey test was done to compare the five groups.Significance for these statistical tests was predetermined at $P < .001$.Student's paired *t*-test was used to compare the SBS before and after recycling ($P < .05$).

Results

The results of ANOVA test showed that there was a significant difference in the SBS of the five groups. The Discovery brackets with laser structured base had highest mean SBS of 22.44MPa followed by 3M Unitek with mean SBS of 19MPa.The brackets by AO had lowest SBS of 10.75Mpa.

Recycled brackets of all the five groups showed a reduction in bond strength when compared to the new brackets(Table I)

Post recycling ,bond strength of 3M Unitek was found to be the highest (18.46MPa),followed by Discovery smart brackets (17.414MPa).Leone brackets had lowest SBS of 9.89MPa.

Table II shows the results of Posthoc tukey test that was used to compare SBS of each group with the other 4 groups.

The comparison of 3M Unitek brackets with other groups show that SBS of these brackets was significantly higher than brackets by RMO,AO and Leone and were comparable to Discovery brackets.

Similarly when the brackets by RMO,AO and Leone were compared,difference between their SBS was insignificant but compared to the Discovery brackets their SBS was significantly lower.

Posthoc tukey test for recycled brackets also gave similar results with bond strength of 3M Unitek and Dentaurum being significantly higher compared to the other three.

Paired t test showed that there was significant difference in SBS for Leone and Dentaurum before and after recycling.However for the other three groups,reduction in bond strength following recycling was not significant.(Table III)

TABLE I- ONE WAY ANOVA TEST TO EVALUATE THE SBS OF THE GROUPS ON BONDING, REBONDING AND THE DIFFERENCE

		N	Mean	Std. Deviation	F/ statistics	Mean square/df2	Ps value
SBS(N/m2)	3M UNITEK	14	19.057	2.9011	48.776	386.043	<0.001
	AO	14	10.75	2.127			
	LEONE	14	12.071	2.0934			
	DENTAURUM	14	22.443	3.8872			
	RMO	14	11.543	2.672			
	Total	70	15.173	5.4621			
SBS(N/m2) (Recycled brackets)	3M UNITEK	14	18.464	5.1244	22.684	29.44	<0.001
	AO	14	9.907	0.9499			
	LEONE	14	9.893	2.1073			
	DENTAURUM	14	17.414	3.4402			
	RMO	14	10.593	3.0786			
	Total	70	13.254	4.9991			

Cont... **TABLE I- ONE WAY ANOVA TEST TO EVALUATE THE SBS OF THE GROUPS ON BONDING, REBONDING AND THE DIFFERENCE**

Difference in the SBS	3M UNITEK	14	0.607	6.698	2.041	47.79	0.099
	AO	14	0.864	2.5485			
	LEONE	14	2.179	3.4235			
	DENTAURUM	14	5.043	5.4895			
	RMO	14	0.921	4.8866			
	Total	70	1.923	4.9831			

TABLE II- POSTHOC TUKEY TEST

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	P VALUE
SBS MPa (N/m2)	3M UNITEK	AO	8.3071*	<0.001
		LEONE	6.9857*	<0.001
		DENTAURUM	-3.3857*	0.018
		RMO	7.5143*	<0.001
	AO	LEONE	-1.3214	0.727
		DENTAURUM	-11.6929*	<0.001
		RMO	-0.7929	0.945
	LEONE	DENTAURUM	-10.3714*	<0.001
		RMO	0.5286	0.987
	RMO	DENTAURUM	-10.9000*	<0.001
SBS (N/m2) (Recycled brackets)	3M UNITEK	AO	8.5571*	<0.001
		LEONE	8.5714*	<0.001
		DENTAURUM	1.05	0.912
		RMO	7.8714*	<0.001
	AO	LEONE	0.0143	1
		DENTAURUM	-7.5071*	<0.001
		RMO	-0.6857	0.981
	LEONE	DENTAURUM	-7.5214*	<0.001
		RMO	-0.7	0.979
	RMO	DENTAURUM	-6.8214*	<0.001
DIFFERENCE IN THE SBS	3M UNITEK	AO	-0.2571	1
		LEONE	-1.5714	0.911
		DENTAURUM	-4.4357	0.122
		RMO	-0.3143	1
	AO	LEONE	-1.3143	0.951
		DENTAURUM	-4.1786	0.163
		RMO	-0.0571	1
	LEONE	DENTAURUM	-2.8643	0.524
		RMO	1.2571	0.959
	RMO	DENTAURUM	-4.1214	0.174

TABLE III- PAIRED T TEST TO COMPARE THE 5 GROUPS INDIVIDUALLY

Group		Mean	N	Std. Deviation	Paired Differences		P VALUE
					Mean Difference	Std. Deviation	
3M UNITEK	SBS BEFORE	19.057	14	2.9011	0.5929	6.7068	0.746
	SBS AFTER	18.464	14	5.1244			
AO	SBS BEFORE	10.75	14	2.127	0.8429	2.5437	0.237
	SBS AFTER	9.907	14	0.9499			
LEONE	SBS BEFORE	12.071	14	2.0934	2.1786	3.426	0.033
	SBS AFTER	9.893	14	2.1073			
DENTAURUM	SBS BEFORE	22.443	14	3.8872	5.0286	5.4878	0.004
	SBS AFTER	17.414	14	3.4402			
RMO	SBS BEFORE	11.543	14	2.672	0.95	4.8807	0.479
	SBS AFTER	10.593	14	3.0786			

Discussion

Bond failure during orthodontic treatment is frequent and undesirable.As a result,SBS of new and recycled brackets has been a subject of great interest in orthodontic research.Some studies have shown that recycling of bonded and rebonded orthodontic attachments adversely affects SBS.

Early metal bases were perforated with 12 to 16 holes or fabricated with lipped-edges,to create undercuts for the adhesive to flow into.[21] Significantly improved bond strengths were seen when perforated or lipped-edge bases were replaced with stainless steel mesh pads,due to exponentially increased areas for the adhesive to flow into and lock-in the bracket base-cement interface.[10,21,22] Reynolds and Von Fraunhofer found mesh bases to be 2.8 times as retentive as perforated bases.[18] Mesh pads were made by laminating stainless steel wires of differing diameters and configurations to stainless steel foil.The potential exists for numerous variations in mesh size,mesh number/gauge and aperture size.These variables can significantly change bond strengths especially when coupled with the many different available adhesives filler particle sizes.[23] In the present study five commonly used types of bracket base designs were studied.The base surface area of the brackets was determined using a vernier caliper and it ranged from 9-11 mm^2.Only one type of adhesive i.e.Transbond XT was used to ensure that any variations in SBS were clearly attributable to variations in bracket base design.

The SBS was highest for Discovery Smart brackets with laser structured base(22.44MPa). Olivier Sorel introduced this base design in 2002.[30] The smooth surface of injection molded single piece bracket base is treated by a powerful Nd: YAG laser,melting and evaporating the metal and burning hole-shaped retentions.This base design offers a combination of macro and micro retention ensuring superior bond strength.

The brackets by 3M Unitek ranked second in SBS. These brackets have an 80 gauge mesh bonding pad that matches the curvature of the tooth for maximum contact and strong bond strength.Mesh based brackets with larger mesh spaces provide a greater SBS than those with smaller mesh apertures.[23] Matasa claimed that the mesh number and the wire diameter of the mesh are the most important influencing factors.[23]

RMO brackets ranked third with the SBS of 11.54 MPa.These brackets had a bonding base made of a laminate of stainless steel foil to an 80x80 mesh which is oriented at 45 degree.

The brackets by Leone had mean SBS of 12.07 MPa and ranked fourth among the tested groups.We found that the bond strength of these brackets was inferior when compared to the mesh type base design. Similar to our findings,some studies have reported higher bond strengths with mesh bases than integral undercut bases.[8,18,24] Lopez et al[25] found mesh brackets vs. integral bases debonded at 21.5MPa ± 3.5 and 13.83MPa ± 2.78, respectively. Willems et al[26] found mesh brackets vs. integral bases debonded at 13.0MPa ± 2.1 and 3.9MPa ± 0.8, respectively.

Few studies found integral undercut bases to have higher bond strengths.[11,14,15] Sharma-Sayal et al[14] found integral undercut bases vs. mesh brackets debonded at 9.73MPa ±1.64 and 8.05MPa ± 2.75,respectively. Wang et al[16] found integral undercut bases vs. mesh brackets debonded at 9.32MPa ± 1.77 and 8.04MPa ± 2.46, respectively.

The brackets by AO,with a 80 gauge mesh over a photochemically etched base were found to have the least SBS.This can be attributed to poor penetration of resin which results in air inclusion inhibiting polymerization of uncured resin.[27]

Similar to this study,Tavarez also noticed that brackets recycled by aluminum oxide blasting had similar SBS when compared with new ones,and the bond strength values obtained after 90-μm particle aluminum oxide blasting were consistently higher than those obtained by an industrial process or by silicon carbide stone grinding.[17]

Bishara showed that rebonded teeth have significantly lower SBS due to residual adhesive on the enamel surface.[30] Therefore,the current findings suggest that this problem could be compensated by mechanical retention created by recycling procedures.

The mean SBS of the groups ranged from 10.75-22.44 MPa before recycling and 9.89-18.46 MPa after recycling.Reynolds suggested 5.9 to 7.8 MPa as the optimal bond strength required for bonding of brackets to enamel.[9] The results of our study show that all the bracket types had optimal bond strength required for successful bonding both before and after recycling.

Conclusions

On the basis of the results of the study the following conclusions were drawn-

1. Laser structured bracket base design(Discovery brackets) was found to be superior to other bracket base designs with the highest mean SBS.
2. Reconditioning of brackets by sandblasting led to a statistically insignificant decrease in SBS of all five groups.
3. SBS of brackets with DynaBond II mesh base(3M Unitek)showed least reduction following recycling.
4. All the five bracket types had optimal bond strength required for successful bonding both before and after recycling(>7.8 MPa).

Conflict of Interest: None

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Ethical Clearance:This research work was approved by Institutional Ethics committee,Manipal College of Dental Sciences,Mangalore,India.

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