IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 13, Issue 9 Ver. I (Sep. 2014), PP 20-26
www.iosrjournals.org

Evaluation and comparison of shear bond strength of new and rebonded orthodontic brackets having various mesh base designs: An in vitro study

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Abstract: *Introduction - To evaluate and compare the shear bond strength of orthodontic brackets with different mesh base design viz. single mesh base,double mesh base , Microlock base & Dynalock base and to assess shear bond strength after rebonding using sand blasting & acid bath method.The surface characteristics of new and rebonded bracket bases were compared using scanning electron microscopy (SEM). Sample comprised of 40 extracted human mandibular premolars. Sample was divided in to four groups and brackets with different mesh base designs were bonded. (n=10 for each mesh base design). SEM was used to compare the surface characteristics of the new & rebonded bracket bases for all the four groups Multiple comparison Scheffe test wasused to compare the shear bond strength of new brackets in all 4 groups revealed that mean shear bond strength for single mesh base(Gr I) , double mesh base (Gr II)& Microlock base (Gr III)were not statistically significant with P-value (P>0.05),whereas Dynalock(Gr IV) showed significant difference (P< 0.05).Shear bond strength ranking from highest to lowest was highest in single mesh base, double mesh base, microlock base & lowest with Dynalock base brackets Sand blasting showed more shear bond strength than acid bath method.*

Key words: *Single mesh, Double mesh, Microlock, Dynalock, Sand blasting, Acid bath, Shear bond strength.*

I. Introduction

To enhance the retention of the adhesive to the metal bases of the orthodontic brackets, various chemical and mechanical methods have been suggested like milling the undercuts in the bracket bases, welding different diameter mesh wires to the bases, brazing of bracket bases, chemical etching or sintering with porous metal powder on the bases & perforation in the bracket bases with small spherical photo etched undercuts. Recent advancements being laser structured bracket bases, metal plasma coated bases & fusing metallic or ceramic particles to the bases.

Smith & Reynolds[1]evaluated the performance of fine mesh, coarse mesh, undercut bracket base and found that the fine mesh base had a higher tensile bond strength than the coarse mesh and both were better than the undercut bases. Reynolds & Von fraunhofer[2] suggested use of a coarse mesh with a diameter of not less than 150 µm for better bond strength. Studies on single mesh & double mesh bases showed different shear bond strength and were dependent on resin penetration. Bishara et al[3] evaluated the bond strength of two orthodontic metallic brackets with a single mesh and a double bracket mesh design and found out that both bracket types had similar bracket failure modes and were not significantly different from each other. Buncha Samruajbenjaku et al[4] compared the shear bond strength of ceramic brackets with different base design and were bonded to glazed feldspathic porcelains. It was revealed that beads base design had the greatest shear bond strength and was significantly different from the large round pits base, irregular base, and metal mesh base. Wei Nan Wang et al[5] evaluated 6 types of bracket mesh design on the bond strength and suggested that circular concave bracket base, produced greater bond strength than did the mesh-based brackets

Also the precise and complex design of present day brackets has led to significant increase in the cost. Various methods of recycling of used brackets have been suggested as an alternative to the “disposable” bracket practices of past, as the cost is significantly less than the price of the new brackets, the economic saving could be as high as 90 % due to the fact that a single bracket can be reused upto five times [6].

The disadvantages of the recycling may include reduction in bracket quality, loss of identification marks, lack of sterility, increased risk of cross infection, some degree of metal loss and reduction in the diameter of the mesh strands resulting in low bond strength.

The literature provides conflicting results regarding the effects of using different retentive bracket base designs & the effects of recycling on shear bond strength. Hence the present study was carried out with the objective to determine what type of bracket base design yields the highest bond strength & to assess the effects of two different chair side recycling techniques (sand blasting & acid bath) on the shear bond strength of these brackets.

II. Methods

The study was carried out in the department of orthodontics & Dentofacial Orthopedics, Sharad Pawar Dental College and Hospital, DMIMS, Wardha, India.

The sample comprised of 40 healthy mandibular premolars extracted for orthodontic purposes and forty 0.022" slot preadjusted edgewise mandibular premolar brackets ,10 each for single mesh base (Gemini-3M) ,double mesh base (supermesh- GAC) , Microlock base(GAC) & Dynalock base (3M) . Sample teeth were collected and stored in distilled water to prevent them from becoming brittle. The surfaces to be bonded were cleaned, rinsed, and thoroughly air dried. Etchant (3M Scotchbond) was applied to the tooth for 15 seconds, rinsed for 15seconds, and dried for 2 seconds. A thin coat of primer (3M Transbond XT light cured adhesive primer) was applied on the etched surfaces. The transbond XT adhesive was placed on each bracket base and the bracket was properly positioned on the tooth surface. Excess adhesive was removed with sharp scaler. The bracket was then light cured interproximally for 10 seconds.

The samples were divided into four groups with 10 premolars in each group and were mounted in color-coded acrylic blocks to permit subsequent identifications.

- Gr I-Single meshbase brackets(3M)
- Gr II-double mesh base brackets(GAC international)
- Gr III-microlock base brackets (GAC international)
- Gr IV-dynalock base brackets (3M)

2.1Shear bond strength testing

Instron machine (universal testing machineno.4467 H, ENGLAND) was used to test shear bond strength. It was carried out at Department of Metallurgy,VNIT engineering college ,Nagpur. The specimen mounted in its acrylic block was secured to the lower grip of the machine (fixed head). To maintain a consistent debonding force, a custom made blade was fixed in the upper grip (movable head) connected to the load cell. The blade was positioned in such a way that it touched the bracket

A crosshead speed of 1mm/min was used. The computer recorded the force to debondthe brackets in Newtons. The bond strength was calculated in MPa using the formula,

Bond strength in MPa= force in Newtons/ surface area of brackets in mm^2.

2.2 Adhesive remnant index

After debonding,the enamel surface was examined under stereomicroscope at 32X magnification to determine how much residual adhesive remained on the tooth according to the scale given by Artum & Bergland (1984) and scores were recorded for each sample. After scoring the adhesive remnant index, each sample was again stored in distilled water. Fig (1)

2.3 Rebonding methods

2.3.1 Sandblasting method

Half of the debonded brackets from each group were recycled with sand blasting with a portable unit (Due sand, Gin dentair,modelno. 0373) using 50 µm aluminium oxide abrasive powder at a distance of 5 mm from the bracket base. Each bracket was sandblasted for 20-40 seconds under 80 psi pressure & were denoted as Gr I A ,Gr II A, Gr III A& Gr IVArespectively.

2.3.2 Acid bath method

Half of the debonded brackets from each group were recycled with acid bath technique and were denoted as Gr I B, Gr II B, Gr III B & Gr IV B respectively. After adhesive has been burned, bracket bases were submerged in a solution of 32 % hydrochloric acid & 55% nitric acid, mixed in a proportion of 1:4 ratio for 5 – 15 seconds. This process rapidly removed any adhesive residual from the bracket bases. After acid bath these brackets were thoroughly rinsed under running water for 30 seconds & were air dried[7].

After the brackets were reconditioned, each was bonded to the enamel surfaces that had been prepared for rebonding, using same method as for new brackets. The teeth were stored in distilled water for 72 hours before the brackets were debonded as described previously. Shear bond strengths were again recorded for each sub group.

A scanning electron microscope (SEM)(JEOL JSM-6380 A Japan) was used to compare the surface characteristics of the new and rebonded bracket bases. It was carried out at Department of Metallurgy,VNIT engineering college ,Nagpur. Each specimen was prepared for SEM by sputtering with gold palladium in a Polaron E5 100 sputter-coating unit. The bases of the brackets were then examined under an SEM Fig (2). One way analysis of variance (ANNOVA) was carried out to compare the shear bond strength between and within four groups and Multiple comparison Scheffe test was carried out to compare the samples as well as student t test

III. Results: (Fig 2)

Table 1 shows the values of shear bond strength of all four groups &subgroups.
Table 2, multiple comparison Scheffe test showed that values of Gr I, II & III were not significantly different from each other but showed a significant difference with Gr IV. Descriptive analysis showed decreased mean values for Gr IV.

Adhesive Remnant Index scores for all subgroups A & B showed no significant relations with each other. Most of the bond failure occurs between bracket bases and adhesive leaving adhesive on the tooth surface.

3.1 SEM observations (Fig 3)

Examination of the bases with scanning electron microscopeat 25X & 100X magnification revealed that the new brackets had a smooth base with clear retentive areas (A). After rebonding showed variations of surface characteristics between the subgroups.

The sandblasted bracket bases were dull and rough, with intact mesh base structure and retentive areas were well defined with noadhesive in the retentive areas (B). The acid bath treated brackets showed that some of the retentive areas were filled with adhesive(C).

IV. Discussion

There appears to be great variety of surface morphologic differences among the various brackets that are commercially available. The aim of changing the mesh base design is to increase the ultimate bond strength of the brackets. Various procedures of manufacturing different bases are welding and brazing of mesh to the brackets, casting, injection molding & milling of the brackets.

Precise and more complex manufacturing of these brackets increases the ultimate cost of the brackets thereby increasing the need for recycling for the purpose of reusing them. The main goal of rebonding process is to completely remove the bonding material from the bracket base without damaging or weakening the delicate mesh or distorting the dimension of the bracket slot.

One way analysis of variance (ANNOVA) was carried out to compare the shear bond strength between and within four groups. The between group variability (10.90) was greater than the within group variability (1.14). f-test reveals that the difference is significant with f value-9.53 ($p=0.00<0.05$).

The mean shear bond strength for Gr I -7.08 Mpa, Gr II-7.01 Mpa, Gr III-6.43 Mpa & Gr IV -4.83 Mpa suggest that Gr I ,II and III were not statistically different from each other ($p>0.05$),whereas Gr IV showed significant difference ($p<0.05$)

The mean values of shear bond strength for Gr I A-7.02Mpa,Gr II A-6.90Mpa,Gr III A-6.04Mpa and Gr IVA-4.38Mpa suggest that Gr IV A was statistically significant with pvalue-(p,0.05). Descriptive statistics showed lowest values for Gr IV A in all subgroups.

The mean values of shear bond strength for Gr I B-6.63 Mpa, Gr II B-6.49 Mpa, Gr III B-5.99 Mpa and Gr IV B-4.58 Mpa showed the similar inferences as subgroup A.

Student's t-test revealed no significant difference between group, subgroup A& subgroup B in all four bracket base designs .Though the difference was not statistically significant, the mean values showed slight difference with highest bond strength for new brackets than subgroup A & lowest for subgroup B.

Overall study showed that the shear bond strength ranking from highest to lowest was highest in single mesh brackets, double mesh brackets, microlock base brackets & lowest with Dynalock base brackets.Brackets recycled with sandblasting method were more or less similar to the new brackets, whereas brackets recycled with acid bath method showed decreased shear bond strength.

The adhesive remnant index comparisons indicated that all four types of bracket base designs in all three categories (Group, subgroup A & subgroup B)had similar bracket failure modes and were not significantly different from each other. Bond failure was adhesive type for all the groups and subgroups.

SEM examination showed that double mesh bracket retained adhesive material deep in the mesh design in some areas. Single mesh design brackets had very less amount of adhesive remained in the mesh design. Microlock & Dynalock showed no retained adhesive material in its base.

The results in the present study showed favourable bond strength ranked from single mesh brackets , double mesh brackets, microlock base brackets (photo etched bases) and lastly dynalock base brackets (machine integral bases).

The present study supports a previous study[8] in which foil mesh, photoetched and machine integral bracket base combination were compared. They reported that the integral bases were not as retentive as either of the other two when Right–on adhesive was employed and the bond strength of the bases varied with the adhesive used. The present study also shows same kind of results in which dynalock bases gave lower values of shear bond strength than microlock and mesh base brackets.

The findings of the present studyis comparable withthe study by Regan D et al [9] in which they proposed that machine integral bases show lower values of bond strength . Machined dynalock bases have smooth surfaces that would appear to play no part in the retentive process with only undercut channels alone being responsible for the retention.

The present study also supports the study conducted by Smith N.R, Reynolds I R[1], they evaluated the difference in mean tensile bond strength between three groups of orthodontic bracket bases; coarse mesh, fine mesh and undercut bases. The fine mesh base showed significantly higher tensile bond strength compared with coarse bases. Both mesh bases and coarse bases performed better than undercut bases.

The findings of Samir Bishara, Manal Soliman[3] are comparable with present study findings that single and double mesh brackets have comparable shear bond strength and bracket failure modes. There was no statistical difference occurred between bond strength values of single mesh base and double mesh brackets.

Regan et al [9] compared the initial bond strength and rebonded strength of metal brackets. Rebonding was carried out by using new or used and recycled brackets. They found out that initial bond strength of fresh brackets i.e. Microlock brackets, Edgeway brackets and dynalock brackets were significantly greater that the rebonded brackets. The present study also shows same kind of result that there was decrease in bond strength when compared to initial bond strength but was not statistically significant.

Stenyo, Wonderley, Travares et al [10]found out there was no statistically significant difference between the new brackets,brackets recycled by aluminium oxide blasting and new brackets attached to previously bonded teeth. Our study also support the above study as the mean shear bond strength of new brackets and sandblasting was not significantly different.

Present study showed that the bracket base –adhesive cement interface is the weakest point in orthodontic bonding. Most studies demonstrate that the bond failure in enamel bonded brackets occurs at the resin mesh interface because of stress concentrations and defects in the resin film. The bond strength of bases may also be reduced by corrosion following leakage at the resin interface.[11]

SEM observation by Maijer and Smith[12] showed the existence of spaces at the wire resin interface indicates that there is little actual adhesion between the resin and the stainless steel. These spaces arise from the polymerization shrinkage and subsequently contribute to interfacial leakage as well as poorer bonding.

The findings of the present study was not similar to the study by Simoka and Powers[13]that the bond strength of dynalock brackets was greater than that of brackets with mini mesh bases when bonded without acid etching of the base using a no mix highly filled adhesive.

The findings of Leas T.J Honduram S[14]are not comparable with the present study. They studied the effect of two recycling techniques on the shear bond strength of debonded orthodontic appliances when compared with their original bond strengths. The recycling methods include flame and sandblasting or only sandblasting. On comparing original and rebond bond strength, the rebond strength was higher than the initial bond strength whereas in our present study the bond strength after recycling method was less compared to the initial bond strength

V. Conclusions

1) Single mesh and double mesh bracket bases showed greater bond strength than photo etched microlock base brackets with Dynalock brackets having lowest bond strength amongst the four groups.

2) Recycled brackets with sand blasting method had more shear bond strength as compared to acid bath method. Both techniques of recycling showed greater shear bond strength of foil mesh base brackets i.e. single mesh and double mesh bracket bases than photo etched microlock base brackets and both these mesh base and microlock base brackets showed significantly greater bond strength compared to an undercut base brackets i.e. Dynalock brackets.
3) Amongst the brackets with mesh type bases the larger the mesh spacing, greater was the bond system i.e. single mesh bracket bases had slightly more bond strength as compared to double mesh brackets. The reason being the complex intervention of the double mesh used, this complex structure and increased depth makes it difficult for the adhesive to reach into full depth leading to decrease bond strength.
4) Most of the sites of bond failure were adhesive in nature i.e., between bracket base and resin.

5) Scanning electron microscope results revealed that Sand blasted bracket were dull and rough with intact multistranded structure and well defined retentive areas in all the four groups of brackets bases. Whereas some retentive areas were filled with adhesive in acid bath method suggesting of incomplete removal of adhesive
   This study showed that both sand blasting and acid bath method are more viable easy and simple method for recycling brackets but the brackets recycled with sand blasting technique showed more bond strength as compared to acid bath technique.

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Figures

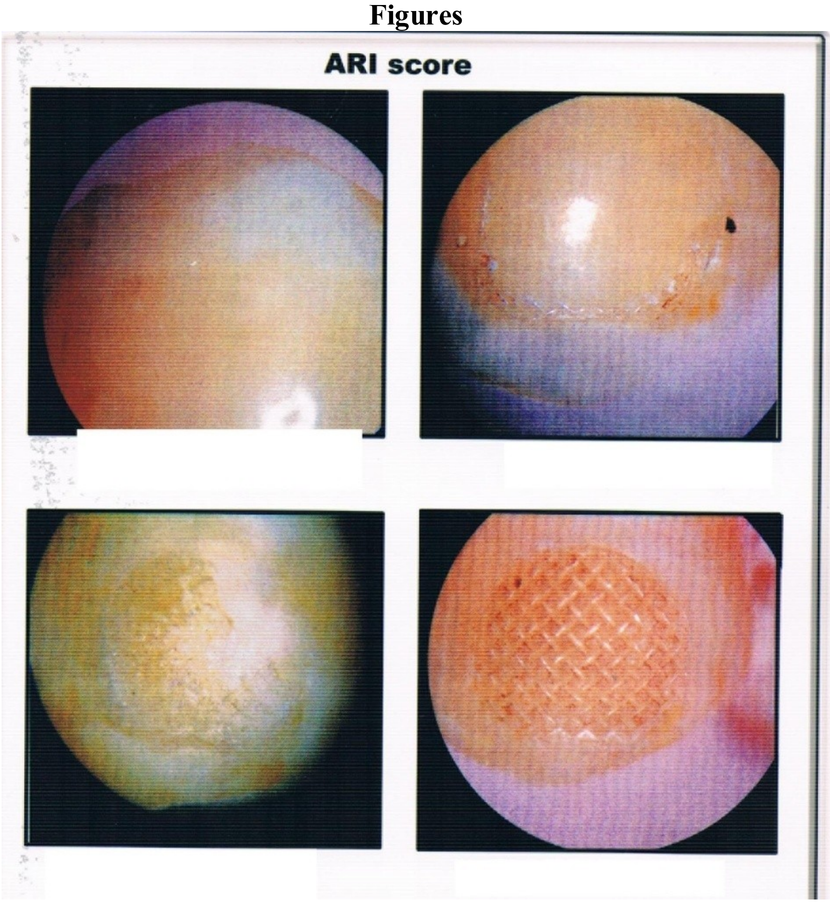

Fig 1 – adhesive remnant index

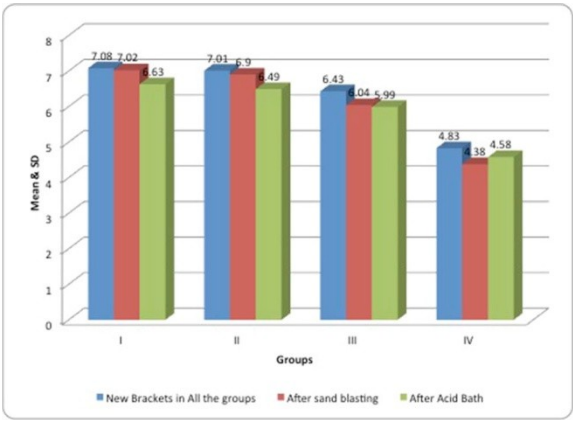

Fig 2- shear bond strength of the new brackets and after sand blasting and acid bath technique

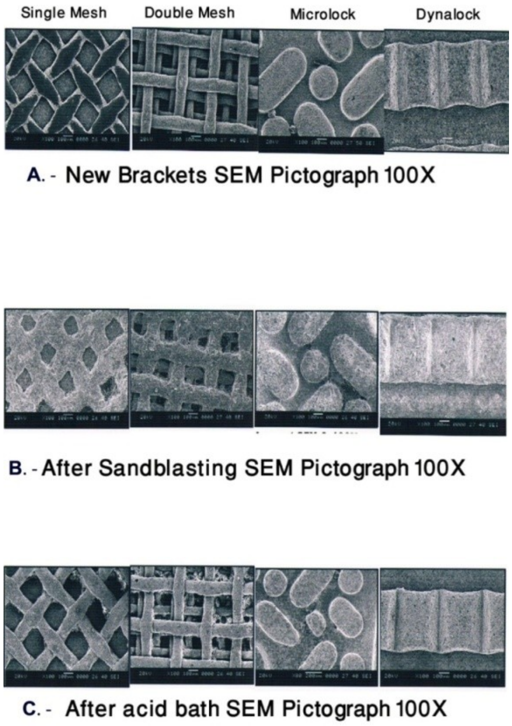

Fig 3- observation of bracket bases after scanning electron microscope (Single mesh Double mesh, Microlock, Dynalock

A. SEM 100x of new bracket bases.
B. SEM 100X bracket bases after sand blasting
C. SEM 100x brackets bases after acid bath

Table I

Shear bond strength values of all Groups & subgroups in Mpa.
(Gr I- Single mesh base brackets, , Gr II-Double mesh base brackets ,Gr III –Microlock base bracket, Gr IV- Dynalock base brackets, Sub group A-Sandblasted, Sub group B-Acid bath method)

Sample no.	Gr I	Gr I A	Gr II	Gr II A	Gr III	Gr III A	Gr IV	Gr IV A
1	7.43	7.49	5.60	6.38	9.24	6.59	5.53	4.53
2	7.31	7.82	7.25	7.03	8.88	4.99	4.71	4.37
3	7.23	5.69	6.31	5.82	5.89	5.51	3.99	3.81
4	6.67	7.23	9.16	8.02	4.99	7.06	4.61	5.20
5	7.82	6.89	6.70	7.25	7.82	6.09	5.23	4.03
		Gr I B		Gr II B		Gr III B		Gr IV B
6	6.96	6.55	5.52	5.11	4.31	6.21	4.62	5.23
7	7.52	6.76	7.61	6.88	6.24	6.82	4.93	4.92
8	6.23	7.23	6.55	6.31	5.78	6.82	5.58	3.90
9	7.31	6.49	7.93	7.45	6.27	5.13	4.62	5.03
10	6.37	6.12	7.50	6.70	4.91	5.01	4.56	4.27

Table II Multiple Comparison: Scheffe Test

Group		Mean Difference (I-J)	Std. Error	p- value	95% confidence interval	
(I)	(J)				Lower bound	Upper bound
I	II	0.07	0.47	0.99 NS,p>0.05	-1.33	1.47
	III	0.65	0.47	0.60 NS,p>0.05	-0.75	2.05
	IV	2.24	0.47	0.00 S, p<0.05	0.84	3.64
II	III	0.58	0.47	0.69 NS, p>0.05	-0.82	1.98
	IV	2.17	0.47	0.69 NS, p>0.05	0.77	3.57
III	II	-0.58	0.47	0.69 NS, p>0.05	-1.98	0.82
	IV	1.59	0.47	0.02 S, p<0.05	0.19	2.99