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ORIGINAL RESEARCH

Effect of Thermal Recycling of Metal Brackets on Shear and Tensile Bond Strength

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ABSTRACT

Aim: The study was undertaken to measure the changes within the mesh pad associated with reconditioning process, measure the bond strength of new and reconditioned orthodontic brackets and correlate the changes in mesh strand diameter with changes in bond strength.

Material and methods: 120 clinically normal premolar teeth extracted for orthodontic reasons, were divided equally for bonding with new and recycled brackets using a no-mix type of adhesive. The mesh strand diameters of new and reconditioned brackets were evaluated with a binocular light microscope. Recycling of brackets was done using Esmadent® bracket and band reconditioner.

Results: The mesh strand diameter, tensile and shear bond strength of new and reconditioned brackets were evaluated statistically and the latter was found to show a significant reduction ($p < 0.0001$). However, the bond strength values of the reconditioned brackets were found to be well above the clinically required minimum.

Conclusion: Reduction in mesh strand diameter, as a result of reconditioning process, does not correlate with the change in bond strength between initial and recycled bondings.

Clinical significance: The bond strength of reconditioned brackets is adequate enough to resist the magnitude of forces generated in the mouth, throughout the duration of orthodontic treatment for successful treatment results.

Keywords: Premolar teeth, Brackets, Bonding adhesive, Recycling unit.

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INTRODUCTION

The evolution of the concept of directly bonding orthodontic brackets to the tooth surface by means of an adhesive material has been a monumental step in the progress of orthodontics. As the manufacturers of brackets are becoming increasingly precise about the quality and design of the brackets, to improve the quality of treatment results, the cost of the brackets also tends to increase. The orthodontists are also faced with a decision of what to do with the used brackets indicating an alternative to the 'disposable' bracket practices. Currently, there is an increased interest in the recycling of metallic direct bonding orthodontic brackets. Several new companies like Esmadent, Orthobond and Orthocycle continue to enter the market with various reconditioning procedures that would be beneficial in minimizing the cost and waste to the orthodontists and ultimately to the patient. It is possible that the various recycling procedure followed may affect the bond strength of brackets by an alternative in their physical, chemical or dimensional configurations.[1-7]

AIMS

The aims of this study are as follows:

1. To evaluate the effect of commercial thermal recycling procedure on the bond strength of direct bonding orthodontic bracket.
2. To correlate the changes in mesh strand diameter with changes in bond strength.

MATERIALS AND METHODS

This study was carried out in the Department of Orthodontics, College of Dental Surgery, Mangalore. The material testing procedures were carried out at Hindustan Cables Limited and Regional Forensic Science Laboratory, Hyderabad.

Materials

1. *Premolar Teeth:* The sample consisted of 120 freshly extracted human premolar teeth which were extracted for orthodontic purpose. Care was taken to select only intact, noncarious, unrestored teeth which were not hypoplastic and with no development defects.

2. *Brackets:* The brackets selected in this study were No. 256-650 series TP Orthodontics Begg Brackets, having a curved base and minimesh type. The new brackets and heat-treated recycled brackets are used in the study (Figs 2A and B).
3. *Bonding Adhesive:* Bonding material used in this study was Rely-a-Bond (no-mix system) by Reliance Orthodontic Products.
4. *Recycling unit:* An Esmadent (Esma Chemicals, Inc) bracket and band reconditioner was used to recondition the brackets (Fig. 3).

Fig. 1A: New orthodontic brackets used in the study

Fig. 1B: Debonded brackets with adhesive

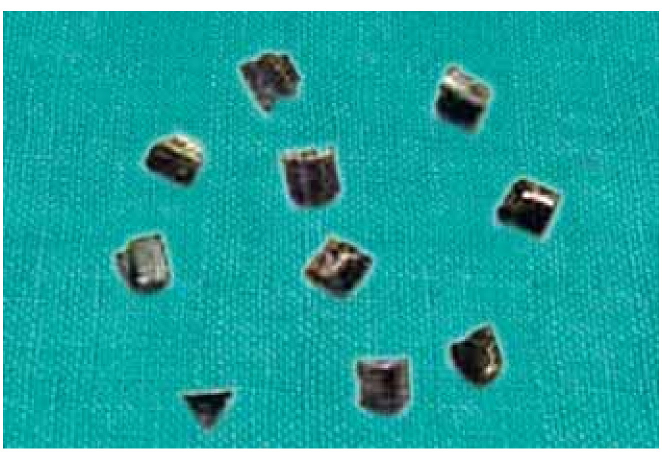


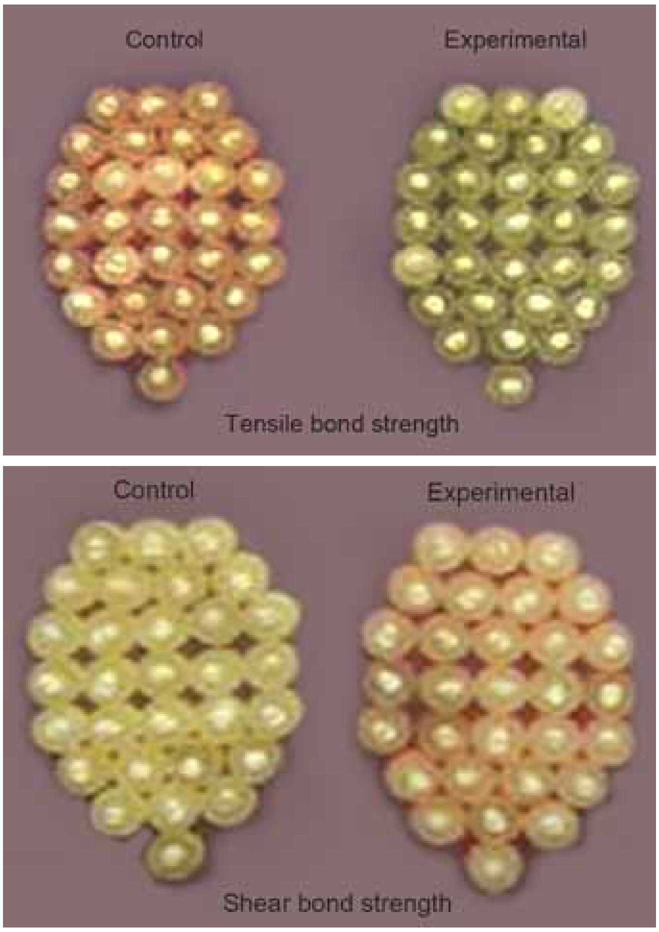
Fig. 2A: Brackets after heat treatment

Methods

Each bracket was cleaned of soft tissue debris and a retentive hole was placed on the middle of the root portion with the help of a diamond point bur with an air rotor handpiece perpendicular to the long axis of the tooth for better retention into acrylic. A total of 120 premolar teeth were divided into two groups comprising of 60 in control group and 60 in experimental group. Each group of 60 teeth was further divided into two subgroups of 30 each. For tensile and shear strengths evaluation, the samples were color coded based on chart (Fig. 4). All the teeth were mounted vertically on a cylindrical block of clear methyl methacrylate resin so that the buccal surface of the premolar was perpendicular to the horizontal surface of the acrylic block or parallel to the long axis of the block. The teeth along with the acrylic blocks were stored on 0.9 N saline until bonding.

Fig. 2B: Brackets after recycling

Fig. 3: Recycling unit "Big Jane". Esmadent bracket and band reconditioner



	Control group	*Experimental group*
Tensile bond strength	Pink	Green
Shear bond strength	Yellow	Orange

Fig.4: Control and experimental groups used in the study

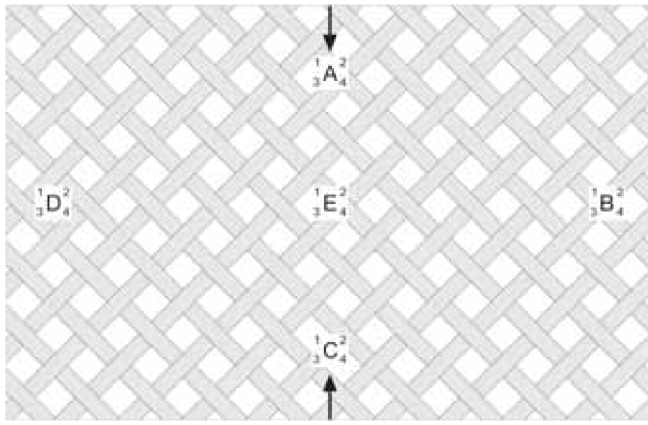


Fig. 5: Schematic map of a mesh pad. Four test sites (A,B,C,D) are located in relation to the periphery of the pad. The fifth test site (E) is located at the center of the bracket. Numbers designate the location of 20 test strands of the wire

Fig. 6: No-mix adhesive used for bonding

Method for measuring the Mesh Strand Diameter

The mesh pads of the brackets were evaluated with a binocular light microscope to which was added a filer micrometer eyepiece. This eyepiece was calibrated with a 10 micron interval grid micrometer. All the brackets bases were examined keeping in mind the opening of the slot on facial surface facing toward the examiner. A schematic map of the mesh pad was drawn. Five test sites were selected. A test site was defined as a closed aperture bounded by four wire strands not involved with bracket weld. A number was assigned to each of the twenty potential test strands thus designated (Fig. 5). By consulting a table of random numbers, three test strands on each brackets pad were selected for measurement. Strand diameter was measured.

Bonding Procedure

The bonding procedure was standardized according to Rely-a-Bond specifications by Reliance orthodontic products (Fig. 6).

A stainless steel ligature wire of 0.036" in diameter was passed through the bracket slot, and was twisted to form a single wire, to facilitate strength testing. The specimens were then stored in normal saline of 0.9 N until bond strength was evaluated.

Method of Mounting and Measuring Strength

After 48 hours, the specimens were tested using Instron Universal Testing Machine. The specimen was attached to the fixed crosshead (Fig. 7). The free end of the wire was attached to the movable crosshead. A crosshead speed of 5mm/minute was selected. Load was applied till the point of fracture that is till the bracket detached from the tooth surface. The electronic reader monitored the peak force that was required to bond the bracket in kilograms. The breaking load was converted into bond strengths using following formula:

Bond strength in MPa =

$$\frac{\text{Breaking load in kilograms} \times 9.8}{\text{Surface area of bonding base (mm}^2\text{)}}$$

The surface area of the bracket base was measured using Tool maker's microscope. It was found to be 9 mm^2.

- *Thermal recycling procedure:* After testing for shear and tensile bond strengths, the detached brackets were subjected to heating process using the furnace of the Esmadent bracket and band reconditioner
- *Measuring the mesh strand diameter for recycled brackets*: The procedure was repeated for recycled brackets as described for new brackets
- *Bonding procedure for recycled brackets*: The recycled brackets were bonded to the experimental group of specimens as described for new brackets
- *Mounting and strengths testing for recycled brackets:* After 48 hours, the specimens were tested using Instron Universal Testing Machine. The bond strengths were evaluated using same procedure used for testing new brackets.

Fig. 7: Acrylic blocks are placed in between the grips of Instron machine for measuring the tensile and shear bond strengths

RESULTS

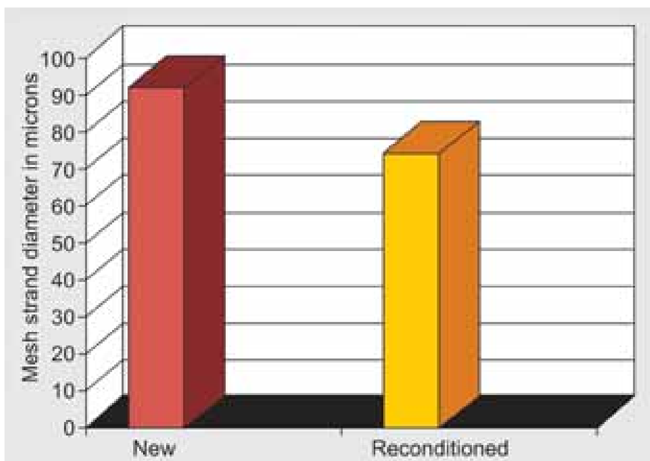
Evaluation of Mesh Strand Diameter

A total of 60 new brackets were evaluated for the mesh strand diameter. Thirty each for tensile and shear bond strength group and the same were evaluated after reconditioning. (Tables 1 and 2, Graphs 1 and 2). The mean and standard deviations for both new and reconditioned brackets were calculated separately for shear and tensile bond strength groups.

The values were subjected to statistical analysis to find whether difference in strand diameter were statistically significant. 'Z' test was used to calculate z-value and to find the probability (p-value) (Table 3).

Table 1: Mesh strand diameter of new and recycled brackets for the shear bond strength group

	Shear group					
	Mesh strand diameter (in microns)					
	New brackets			*Reconditioned brackets*		
1	80	80	80	60	70	60
2	80	90	100	70	70	100
3	90	100	90	80	100	90
4	80	90	90	80	60	80
5	100	90	90	100	90	90
6	90	80	100	70	60	80
7	90	80	80	80	60	80
8	80	90	80	70	80	70
9	90	100	100	80	60	70
10	90	90	90	80	80	90
11	90	90	80	90	80	90
12	90	90	100	90	80	70
13	90	80	90	90	50	90
14	90	100	80	80	70	60
15	90	90	90	60	70	60
16	110	100	90	60	70	80
17	100	80	90	90	80	80
18	100	80	80	80	80	80
19	90	80	80	70	80	60
20	100	90	80	50	80	80
21	100	90	80	90	70	60
22	100	100	90	70	70	80
23	100	90	100	70	80	80
24	90	90	100	60	60	80
25	100	90	100	90	90	100
26	90	90	90	80	80	60
27	90	90	90	70	70	60
28	90	90	90	80	70	90
29	90	90	100	90	80	70
30	90	90	80	80	70	80



Graph 1: Bar diagram comparing mesh strand diameter of new and reconditioned brackets (shear group)

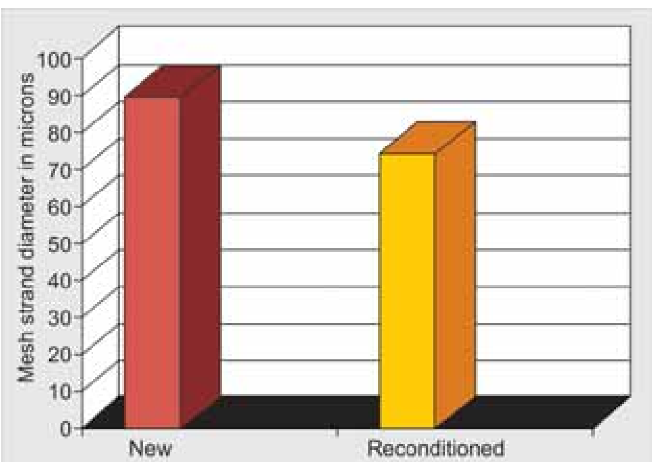
Evaluation of Bond Strength

One hundred and twenty specimens were equally divided into 60 control and 60 experimental groups. Thirty specimens from each group were evaluated for tensile and shear strength (Tables 4 and 5).

The mean and standard deviations for both control and experimental groups, for tensile and shear strengths were

Table 2: Mesh strand diameter of new and recycled brackets for the tensile bond strength group

	Tensile group					
	Mesh strand diameter (in microns)					
	New brackets			*Reconditioned brackets*		
1	90	90	100	90	80	90
2	90	90	100	90	90	90
3	90	90	80	90	90	80
4	100	80	100	90	80	90
5	90	90	90	90	90	80
6	100	100	90	100	80	70
7	80	80	90	80	60	80
8	100	90	90	60	60	60
9	100	90	90	70	60	60
10	90	90	90	70	60	70
11	100	90	100	80	90	90
12	90	100	100	90	80	90
13	90	80	90	90	80	90
14	90	80	90	90	80	90
15	90	90	100	80	90	80
16	100	90	90	90	90	90
17	80	90	90	90	80	90
18	90	100	100	90	90	60
19	100	90	100	70	60	70
20	80	80	80	60	80	80
21	90	90	80	60	60	80
22	90	90	100	70	80	60
23	90	90	100	70	70	60
24	80	90	90	60	60	70
25	100	90	80	60	70	60
26	90	100	90	70	60	80
27	100	100	100	80	70	60
28	90	100	100	60	70	70
29	90	100	90	60	80	60
30	90	100	90	60	70	70



Graph 2: Bar diagram comparing mesh strand diameter of new and reconditioned brackets (tensile group)

Table 3: Statistical analysis of mesh diameter for control and experimental groups

	Shear group		*Tensile group*	
	New	*Recycled*	*New*	*Recycled*
Mean	91.99	74.11	90.33	74.65
Standard deviation	4.99	10.89	4.90	8.18
z-value	8.33		8.99	
p-value	< 0.0001*		< 0.0001*	

*p-values — very highly significant

Table 4: Breaking load and shear bond strength for control and experimental groups

	Control group		*Experimental group*	
	Breaking load (kg)	*Strength (kg/mm²)*	*Breaking load (kg)*	*Strength (kg/mm²)*
1	12.07	1.34	10.25	1.13
2	11.02	1.22	11.54	1.28
3	14.02	1.55	12.08	1.34
4	13.33	1.48	12.01	1.33
5	12.87	1.43	9.28	1.03
6	11.24	1.24	9.05	1.00
7	12.38	1.37	12.08	1.34
8	15.09	1.67	14.01	1.55
9	15.2	1.68	10.28	1.14
10	14.28	1.58	11.02	1.22
11	15.09	1.67	12.01	1.33
12	15.03	1.67	10.89	1.21
13	14.08	1.56	11.89	1.32
14	11.03	1.22	12.03	1.33
15	15.04	1.67	11.04	1.22
16	11.28	1.28	12.05	1.33
17	16.02	1.78	12.11	1.34
18	11.29	1.25	9.84	1.09
19	15.23	1.69	9.88	1.09
20	11.2	1.24	10.02	1.11
21	15.1	1.67	11.5	1.27
22	16.03	1.78	11.54	1.28
23	16.01	1.78	10.8	1.2
24	15.03	1.67	10.25	1.13
25	14.8	1.64	11.28	1.25
26	13.09	1.45	11.54	1.28
27	12.9	1.43	10.38	1.15
28	13.93	1.54	10.8	1.2
29	14.88	1.65	11.24	1.24
30	15.08	1.67	12.09	1.34

Table 5: The breaking load and tensile bond strength for control and experimental groups

	Control group		*Experimental group*	
	Breaking load (kg)	*Strength (kg/mm²)*	*Breaking load (kg)*	*Strength (kg/mm²)*
1	11.56	1.28	11.04	1.22
2	12.02	1.33	12.02	1.33
3	13.08	1.45	11.03	1.22
4	13.02	1.42	12.04	1.33
5	11.92	1.32	9.8	1.08
6	11.08	1.23	9.08	1.00
7	12.01	1.33	9.10	1.01
8	12.82	1.42	9.23	1.02
9	13.01	1.44	10.23	1.13
10	12.02	1.33	10.43	1.15
11	13.04	1.44	12.01	1.33
12	13.28	1.47	11.2	1.24
13	13.92	1.54	10.08	1.12
14	12.92	1.43	11.05	1.22
15	11.28	1.25	11.03	1.22
16	11.58	1.28	10.28	1.14
17	12.02	1.33	10.05	1.11
18	13.01	1.44	10.05	1.16
19	12.22	1.35	10.25	1.13
20	12.92	1.43	11.43	1.27
21	11.98	1.33	12.23	1.35
22	9.92	1.1	11.58	1.28
23	10.03	1.11	10.9	1.21
24	10.38	1.15	11.35	1.26

Contd.

Contd.

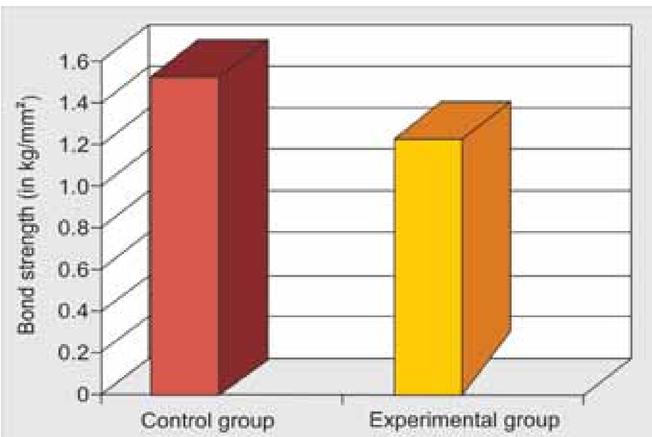
	Control group		*Experimental group*	
	Breaking load (kg)	*Strength (kg/mm²)*	*Breaking load (kg)*	*Strength (kg/mm²)*
25	12.34	1.37	12.05	1.33
26	12.82	1.42	10.6	1.17
27	13.02	1.44	11.54	1.28
28	12.99	1.44	12.85	1.42
29	12.02	1.33	9.9	1.1
30	11.92	1.32	9.34	1.03

calculated. The values were subjected to statistical analysis to find whether the differences in bond strength were statistically significant (Table 6) (Graphs 3 and 4).

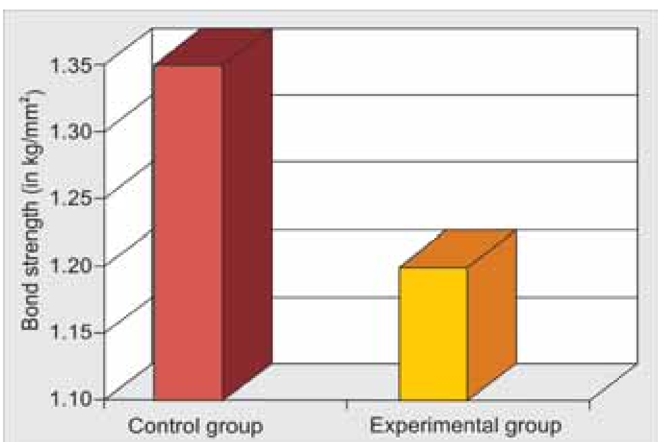
Table 6: Statistical analysis of bond strength for control and experimental groups

	Shear bond strength		*Tensile bond strength*	
	Control	*Experimental*	*Control*	*Experimental*
Mean	1.53	1.24	1.35	1.20
Standard deviation	0.19	0.12	0.11	0.11
z-value	7.29		5.52	
p-value	< 0.0001*		< 0.0001*	

*p-values—very highly significant



Graph 3: Bar diagram comparing shear bond strength of control and experimental groups



Graph 4: Bar diagram comparing tensile bond strength of control and experimental groups

An analysis of multiple linear regression was done to correlate the mesh strand diameter of new and recycled brackets to their shear bond strength and tensile bond strength separately.

DISCUSSION

The present study was undertaken to evaluate the effect of a commercial thermal reconditioning procedure on the tensile and shear bond strength of direct bonding TP Begg Brackets (No: 256-650 series) curved base, minimesh type.

The study indicates that the mean tensile bond strength for control and experimental groups were 1.36 and 1.20 kg/mm^2 and the mean shear bond strength were 1.53 and 1.24 kg/mm^2, respectively. It is evident from the above result that there is a significant reduction in bond strength for experimental groups when compared with control groups for both tensile and shear samples.

The bond strength of bracket is affected by the area of bonding base, mesh strand diameter and impurities on surface of the bracket's base. In the present study, the area of bonding base remained the same but showed a decrease in mesh strand diameter.

The possibility of direct loss of material from bracket surface during recycling and electropolishing procedure could reduce the size and effectiveness of the retentive elements of the base, thereby affecting the bond strength of the bracket. This can be attributed as the major cause for the reduction of the bond strength.

The present study showed that reconditioned brackets have weaker bond strength than the new brackets, which cannot be explained on the basis of reduction on mesh diameter alone as shown in charts 1 and 2. Some of the reconditioned brackets showed higher bond strength than the new brackets even though there is a decrease in mesh strand diameter, but majority of the reconditioned brackets showed lower bond strength, which could be attributed to the residues remaining of the strands, especially the central strands because of differential current density during electropolishing. The other factors that may affect the bond strength of the reconditioned brackets are the method of bonding and the recycling process employed. Clinical debonding generally involves uneven shear force applied with pliers or a scalar. Mesh distortion caused by their instruments may greatly affect bond strength of the reconditioned bracket.

The use of heat is a critical factor in recycling, as it influences not only the bond strength but also the microstructure of the brackets. The normal microstructure of the brackets is homogeneous and nongranular. If temperature is maintained above 400 °C a chromium carbide precipitate is formed and, as a result, a partial disintegration of alloy occurs leading to general weakening of the bracket.

The reduction ion tensile bond strength of experimental group of this study seems to confirm the findings of various earlier studies.[8-11] The value of the findings in this study does not correlate with them, which could be attributed to different adhesive of the bracket that has been used in their study. The above-mentioned correlations of this study appear to have a particular relevance in the view of the earlier studies, which have demonstrated that recycled brackets may be inferior in bond strength when compared with new brackets. However, when choosing to reuse a reconditioned bracket for orthodontic treatment, the clinician must accept the fact that there will be a reduction in the bond strength, when compared with new brackets. But, if the loss in strength when compared with the initial strength is still above the clinically required minimum, then reusing of their conditioned brackets can be considered. The decision to reuse a bracket ultimately depends on what magnitude of forces are generated in the mouth throughout the duration of orthodontic treatment. The incisal biting forces are said to be in the range of 14 to 17 kg,[12] while the maximum occlusal forces are in the range of 31 to 35 kg.[13] According to Reynolds (1975),[14] the average biting force is about 70 kg/cm^2 and the average force transmitted to the bracket during mastication is about 4.5 to 12 kg per cm^2. The maximum orthodontic force (headgear) is quoted to be 1.5 kg/mm^2. This translates into need of not more than 80 kg/mm^2 of bond strength. If we consider the bond strength values of reconditioned brackets above this 80 kg/mm^2, as being necessary to withstand the forces generated in the mouth to be clinically adequate, then the possibility of reusing the brackets, successfully, is more. The orthodontic forces are said to never exceed 450 gm per tooth.[1,3,5,6,8,9,15,16] Maijersmith (1979)[17] indicated that bond strength of 10 kg is adequate for orthodontic appliance. Hence, if we correlate the tensile and shear strength values (1.26 and 1.50 kg/mm^2, respectively) of the recycled brackets of this study with the above-mentioned contemporary orthodontic force prescription, then, the use of this single resin charring procedure followed by single electron polishing procedure, without compromising on the retention or mechanical precision of Begg mechanism will be adequate enough to resist the forces exerted during the entire orthodontic treatment procedures for a successful orthodontic treatment. However, the validity and the clinical success of multiple reconditioning on the bond strength of the Begg bracket is yet to be investigated.

CONCLUSIONS

On the basis of this study, it can be concluded that:

1. Mesh strand diameter decreases in mesh-backed brackets as a result of the reconditioning process outlined
2. Tensile and shear bond strength of new direct bonding brackets are greater than the same after reconditioning
3. Reduction in mesh strand diameter, as a result of reconditioning process, does not correlate with the change in bond strength between initial and recycled bondings.

It may also be concluded that the bond strength of reconditioned brackets will be adequate enough to resist the magnitude of forces generated in the mouth, throughout the duration of orthodontic treatment for successful treatment results.

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