A comparative study on effect of different methods of recycling orthodontic brackets on shear bond strength

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Abstract

Background: Recycling the old or debonded bracket is one possible alternative to the replacement with new bracket. The aim of this study was to evaluate and compare the effect of different methods of recycling stainless steel orthodontic brackets on shear bond strength.

Methods: One hundred twenty human premolars extracted for orthodontic purpose were randomly divided into four groups. Standard MBT (0.022”) brackets, (Leone co., Sesto, Florentine, Florence, Italy) were bonded on buccal surface of all samples with light cured adhesive primer Orthosol (Enlight, Ormco corp., USA) using LED curing unit for 10 seconds. Group I was assigned as control and the brackets of Group II, Group III and Group IV were subjected to recycling by flaming (Gas microtorch: RS Pro, Nozzle, MT 790) ,flaming with sandblasting (Bio-Art sandblaster; Rua Teotônio Vilela, Brazil) and flaming with ultrasonic cleaning (Ultrasonic cleaning unit ,Confident dental equipments Ltd, India) respectively. The recycled brackets were rebonded and final debonding of all brackets was done with universal testing machine (AG-IC/100 KN, Shimadzu, Japan) at a crosshead speed of 0.5mm/min and shear bond strength (MPa) was determined. The adhesive remnant index was evaluated by stereomicroscope at 10X magnification (Olympus corp., Japan).

Results: The highest shear bond strength was obtained with Group I (10.35 ± 0.46 MPa), followed by Group III (9.36 ± 0.55 MPa), Group IV (5.97 ± 0.66 MPa) and the least value was obtained with Group II (4.30 ± 0.55 Mpa). Significant differences among the groups were detected by analysis of variance. Tukey post hoc multiple comparison test showed that the shear bond strength of each group was significantly different from one another ($p < 0.001$). The Chi-square showed statistically significant differences in the adhesive remnant index of the 4 groups ($p < 0.001$).

Conclusions: Shear bond strength of new brackets was significantly higher than that of the recycled brackets. Among recycled brackets, flaming with sandblasting provided adequate shear bond strength, flaming with ultrasonic cleaning provided borderline value for clinical use while flaming alone led to significantly lower value.

Background

Bonding of brackets on tooth surface is a principal requirement in contemporary fixed orthodontic treatment. With the introduction of enamel etching by Buonocore [1] and direct bonding system by Newman [2], bonding of brackets became relatively more convenient. Nowadays preadjusted brackets are more popular which bear inbuilt features to compensate for first, second and third order bends. These inventories increase the cost of the brackets. So replacing the debonded or old brackets with a new one makes the orthodontic treatment more expensive. One possible alternative to the replacement with new bracket is to recycle the old or debonded bracket and rebond on tooth surface. The major advantage of recycling is the economic saving, which could be as high as 90 percent, due to the fact that a single bracket can be reused up to five times [3]. Commonly used recycling methods include roughening of debonded attachment with greenstone, direct flaming, sandblasting, use of chemical solvents, ultrasonic cleaning etc.

Clinically acceptable shear bond strengths have been reported in the literature to be between 5.9 and 7.8 MPa [4, 5]. Whereas enamel damage has been reported during debonding in cases where tensile bond strength was above 14.5 MPa [6]. So the bond strength of attachments must be sufficient to withstand functional forces but at a level to allow bracket debonding without causing damage to the enamel. Brackets should not be adversely affected after recycling with different methods. Previous studies have reported that recycling with flaming results in shear bond strength below the recommended range of clinical need [7–10], while recycling with sandblasting gives clinically acceptable shear bond strength.[8, 10–15] SBS of brackets recycled by flaming with sandblasting was reported much less in a study by Gupta et al (2.05 MPa) [12] and large value (26.94 MPa) was reported in a study by Bansal et al. [13]. However, limited studies are available in literature about the effects of recycling orthodontic brackets with ultrasonic cleaning on shear bond strength. Quick et al. [7] and Kumar et al. [16] reported shear bond strength of brackets recycled with ultrasonic cleaning less than the recommended bond strength (less than 6 MPa), while Chetan et al. [8] reported this within the recommended range. So, this study aimed to evaluate and compare the effect of different methods of recycling stainless steel orthodontic brackets on shear bond strength while rebonding. Working null hypothesis was set as; there is no difference in shear bond strength of stainless steel orthodontic brackets recycled with different methods.

Methods:

The study was an in vitro experimental study conducted at Orthodontics & Dentofacial Orthopedics Unit, Department of Dentistry, Tribhuvan University Teaching Hospital, Maharajgunj Medical Campus, Maharajgunj, Kathmandu, Nepal in co-ordination with Nepal Bureau of Standards and Metrology, Balaju and Nepal Agricultural Research Council (NARC), Khumaltar. Ethical clearance was obtained from Institutional Review Board. One hundred twenty human premolars extracted for orthodontic treatment purpose were used in this study and non-probability convenience sampling technique was applied. Inclusion criteria were; human premolars with extraction time less than 4 months, intact buccal surface and stored in distilled water, while the exclusion criteria were; those with developmental defects, cracks caused by the extraction forceps, dental caries and the teeth subjected to any pretreatment chemical agent.

Custom fabricated mould was used to make acrylic block (Rapid repair, Dentsply India Pvt. Ltd.) and the teeth thus collected were mounted on an acrylic block such that the roots were completely embedded into the acrylic up to the cemento-enamel junction leaving the crown exposed. The labial surfaces of the teeth were kept perpendicular to the bottom surface of the mould [17]. Each sample was assigned number 1 to 120 and randomly divided into 4 groups (Fig. 1):

Group I : Control (new brackets, assigned with “C”)

Group II : Flaming group (assigned with “F”)

Group III : Flaming with sandblasting group (assigned with “S”)

Group IV : Flaming with ultrasonic cleaning group (assigned with “U”)

Before bonding, the buccal surfaces of the teeth were cleaned with fine pumice powder in water using a cup [7, 8, 10]. The buccal surface of each tooth was etched for 30 seconds with 37% phosphoric acid gel [18–20]. Each tooth was then rinsed with a distilled water spray for 5 seconds and dried with oil free air till the etched tooth will appear chalky white.[13, 16, 17, 21] A thin coat of light cured adhesive primer Orthosol (Enlight, Ormco corp. USA) was applied to acid-etched enamel. Enlight light cure adhesive resin was applied on the 0.022” slot MBT stainless steel double mesh premolar bracket base (Standard, Leone co, Sesto, Florentine, Florence, Italy) having a surface area of 11.6 mm^2, which was then placed on the teeth with a reverse tweezers near the centre of the buccal surfaces. Light curing was done with Rainbow LED curing light for 10 seconds [13]. The light intensity measured with radiometer (CM300-2000, APOZA, Taiwan) was 830 mW/cm^2. Group II, Group III and Group IV brackets were subjected to recycling and Group I brackets were stored in distilled water until final debonding with universal testing machine to measure shear bond strength.

Debonding of brackets in Group II, Group III and Group IV was done using peeling type of force before recycling as recommended by Zachrisson and Büyükyılmaz [22]. Recycling of brackets in Group II were done using flaming with reducing zone of the flame of the Gas microtorch (RS Pro, Nozzle, MT 790) for 5 seconds then quenched in water at room temperature and dried in an air stream (Fig. 2). Group III brackets were subjected to flaming for 5 seconds, quenched in water at room temperature and dried in an air steam as described above followed by sandblasting with 50 μm aluminium oxide abrasive powders using Bio-Art sandblaster (Rua Teotônio Vilela, Brazil). The distance between the bracket base and the handpiece head was fixed at 10 mm [8]. Each bracket was sandblasted for 25 seconds under 5 bar (72.5 psi) line pressure [8] (Fig. 3). In Group IV brackets, flaming was done using the same protocol followed by ultrasonic cleaning using ultrasonic cleaning solution from Gemoro ultrasonic parts cleaner solution solvent fluid, USA in an ultrasonic cleaning unit (Confident dental equipments Ltd, India) for 10 minutes [8] (Fig. 4).

Composite was removed from tooth surface with sixteen fluted tungsten carbide bur in unidirectional movement [23] with water cooling system until there was no visible adhesive remaining on tooth surface [22]. All recycled brackets were bonded to teeth using standard bonding procedure as described above. All samples were stored in distilled water until final debonding was done. Final debonding was done immediately after 24 hours of bonding to standardize shear bond strength in a universal testing machine (AG-IC/100 KN, Shimadzu, Japan) (Fig. 5) available at the Nepal Bureau of Standards and Metrology, Balaju at a crosshead speed of 0.5 mm/min[17]. The force required to dislodge the brackets was measured in Newton, and the shear bond strength (MPa) was calculated by dividing the force values with the bracket base area of 11.6 mm^2

$$\text{SBS (MPa)} = \frac{\text{Peak load at failure (N)}}{\text{Specimen surface area (mm}^2\text{)}}$$

After bond strength testing, all specimens were collected and visually examined with a stereomicroscope (Olympus SZX12, Olympus corp., Japan) at 10X magnification to assess the adhesive remnant index [17, 24] available at Nepal Agricultural Research Council (NARC), Khumaltar. The adhesive remnant index was used to evaluate the amount of resin remaining on the tooth after debonding. At the beginning of the experiment, assessment of intraobserver reliability was done for which the entire procedure was performed by single person and the observation of shear bond strength and ARI scoring was also done by the same observer. Twenty percentage of samples from each group were randomly selected, altogether comprising 24 in number (6 in each group), and subjected to respective method of recycling. Shear bond strength was recorded using universal testing machine (T_1). Same procedure was repeated after 2 weeks of first observation and shear bond strength was recorded (T_2). The data were processed and analysed using the Statistical Package for the Social Sciences software version 21.0 (SPSS Inc. Chicago, Illinois, USA).

Results:

The intraclass correlation coefficient (ICC) of shear bond strength of brackets selected for reliability test and subjected to respective methods of recycling at T_1 and $T_{2,}$ which showed good intra-personal reliability of shear bond strength between two measurements. Findings of Kolmogorov-Smirnov test and Shapiro Wilk test used for test of normality showed that the data were normally distributed in all four groups. The mean and standard deviation of shear bond strength obtained from four groups are shown in Table 1. The highest SBS was obtained with the control group (10.35 ± 0.46 MPa), which was followed by Flaming with sandblasting group (9.36 ± 0.55 MPa), Flaming with ultrasonic cleaning group (5.97 ± 0.66 MPa) and the least SBS was obtained with the Flaming only group (4.30 ± 0.55 Mpa). The graphical representation of mean shear strength value by Box plot diagram is shown in Fig. 6. ANOVA test was used to compare the mean values of shear bond strength obtained in each group (Table 2). The test showed that the difference in the mean values of shear bond strength was statistically significant ($p < 0.001$). Tukey post hoc multiple comparison test was used for intergroup comparisons. All statistical analysis was conducted at a significance level of 0.05. The test showed that the shear bond strength of each group was significantly different from one another. p-value less than 0.05 in both ANOVA test and Tukey Post Hoc test led to rejection of Null hypothesis and acceptance of Alternate hypothesis. So there is difference in shear bond strength of stainless steel orthodontic brackets recycled with different methods. Adhesive remnant index scores (by Artun and Bergland [25]) based on the amount of resin left on the tooth after debonding of the four groups are shown in Table 3. The graphical representation of the adhesive remnant index score is shown in Fig. 7. The Chi-square test was used to compare the ARI values

(Table: 4) found for each group and that detected statistically significant difference in the adhesive remnant index scores of the 4 groups ($p < 0.001$). i.e. the method of recycling influenced the ARI. Group I and Group III showed predominant score 0 and 1, Group II showed predominant score 2 and 3 while the Group IV showed predominant score 1 and 2.

Table 1
Shear bond strength mean values (in MPa) of different groups

Group	N	Mean	Std. Deviation
Group I (Control)	30	10.35	0.46
Group II (Flaming)	30	4.30	0.55
Group III (Flaming with sandblasting)	30	9.36	0.55
Group IV (Flaming with ultrasonic cleaning)	30	5.97	0.66

Table 2
Analysis of variance for comparisons of shear bond strength mean values in different groups

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	723.96	3	241.32	776.13	< 0.001
Within Groups	36.07	116	0.31		
Total	760.03	119			

Table 3
Adhesive remnant index (ARI) scores for different groups

Group	ARI				Total
	Score 0	Score 1	Score 2	Score 3	
Group I (Control)	8	21	1	0	30
Group II (Flaming)	0	0	10	20	30
Group III (Flaming with sandblasting)	4	25	1	0	30
Group IV (Flaming with ultrasonic cleaning)	1	11	14	4	30

Table 4
Chi-Square tests for comparisons of ARI values in different groups

	Value	Df	p value
Pearson Chi-Square	103.401[a]	9	< 0.001
Likelihood Ratio	119.940	9	< 0.001
Linear-by-Linear Association	1.833	1	0.176
N of Valid Cases	120		
a. 4 cells (25.0%) have expected count less than 5. The minimum expected count is 3.25.			

Discussion:

The goal of reconditioning of orthodontic brackets is to remove the adhesive from the bracket completely without damaging or weakening the delicate base or distorting the dimensions of the bracket slot. The present study compared the shear bond strength of rebonded brackets that were reconditioned by three office reconditioning methods. Research evaluating the effect of the storage media on bond strength have found that distilled water storage did not adversely affect the bond strength of the teeth stored for up to 6 months [26, 27]. Zachrisson and Büyükyılmaz recommended using peeling type forces, which allow for a recycling process without deformation of bracket during the removal[22]. Debonding with peeling force is easily performed by eliminating the peripheral stresses with low force (Oilo) [28]. So, peeling type of force was used for debonding in this study. Buchman [29] stated that when the stainless steel bracket is subjected to high temperature, chromium carbide precipitate is formed leading to general weakening of the structure. Accordingly flaming for 5 seconds was used by Bansal et al. [13], Bahnasi et al. [10], Chetan et al. [8]. So, in this study, flaming was done for 5 seconds then quenched in water at room temperature and dried in an air stream.

In this study the mean shear bond strength of the new brackets was 10.35 ± 0.46 MPa. Flaming with sandblasting showed the highest mean shear bond strength of 9.36 ± 0.55 MPa among the reconditioned methods tested followed by flaming with ultrasonic cleaning i.e. 5.97 ± 0.66 MPa, and direct flaming i.e. 4.30 ± 0.55 MPa. This finding is consistent with the study by Chetan et al. [8]. This might be due to obstruction of the mechanical retentive areas with char in flamed brackets, which is partially removed in ultrasonic cleaning and greatly removed in sandblasting. Reynolds gave 5.9 MPa to 7.8 MPa as the optimal range for bond strength required clinically [4]. The results of the present study indicates that the bond strengths of brackets reconditioned by flaming with ultrasonic cleaning and flaming with sandblasting fall under optimal range for bond strength required clinically. In this study, mean shear bond strength of brackets recycled by flaming with ultrasonic cleaning is 5.97 ± 0.66 MPa, which fall in the lower limit of recommended optimal range for bond strength required clinically. Though this finding agrees with that of Chetan et al. [8], it differs from the result of Quick et al. in [7] (4.24 ± 2.54 MPa) and

Kumar et al. [16] (5.56 ± 0.92 Mpa). The results of this study agrees with Regan et al. [9], they compared the initial bond strength and rebond strength of metal brackets and found that, the initial bond strength were significantly greater than that of rebond strength of flamed brackets.

Quick et al. [7] reported in their study that, flamed, ultrasonically cleaned brackets had significantly lower bond strength than new brackets and indicated that ultrasonically cleaning for 5 minutes was insufficient to dislodge the residue. In a study by Chetan et al. [8] timing for ultrasonic cleaning was increased to 10 minutes. The results of the bond strength tests of that study showed that flamed, ultrasonically cleaned brackets had slightly higher bond strength (6 MPa). In this study, ultrasonic cleaning of flamed brackets was also done for 10 minutes and mean shear bond strength (5.97 Mpa) was reported similar to that in the study by Chetan et al. This value though falls in the lower limit of recommended optimal range is still significantly lower bond strength than new brackets. This indicates that, either flaming for 5 seconds was insufficient to combust all the composite, or that ultrasonic cleaning for 10 minutes was insufficient to dislodge the residue. Based on the study by Kumar et al. [16], flaming followed by ultrasonic cleaning, electropolishing and silane coupling agent agent application could be a viable option of recycling brackets to achieve adequate shear bond strength. Quick et al. [7] found that the shear bond strength of flamed followed by sandblasted brackets is not statistically different from that of new brackets. Bansal et al. [13] investigated six different reconditioning methods of brackets and found the lowest shear bond strength in flaming group. However, the values of that study didn’t correlate with that of other studies reported in the literature. The authors stated, this difference could be attributed to type of bracket, adhesive used and variations in standardization procedures. Shetty et al. [14] reported in a study that the shear bond strength of brackets recycled by sandblasting with 50 μm aluminum oxide produced a bond strength value of 9.11 ± 4 MPa which is slightly less than the bond strength of present study. This might be due to difference in pressure used in sandblasting and crosshead speed. Present study used 5 bar (72.5 psi) pressure and crosshead speed was set at 0.5 mm/min, while Shetty et al. used 2.5 bar pressure and crosshead speed was set at 1 mm/min.

Conclusion:

Based on the analysis of the data obtained in this study, it is concluded that:

- Shear bond strength of new brackets was significantly higher than that of the recycled brackets.
- Flaming with sandblasting as a method of recycling brackets provided adequate shear bond strength for clinical use. Hence, sandblasting should be considered as viable, time saving and convenient method of chairside recycling.
- Recycling brackets using flaming with ultrasonic cleaning provided shear bond strength falling in the lower limit of optimum recommended range by Reynolds.
- Flaming alone led to significantly lower shear bond strength than recommended range and can be eliminated as a chairside recycling method.

Abbreviations

ANOVA: Analysis of Variance; ARI:Adhesive Remnant Index; Df:Degree of Freedom; ICC:Intraclass Correlation Coefficient; MPa:Mega Pascal; SBS:Shear Bond Strength

Declarations

Ethics approval and consent to participate

Ethics approval for the study was obtained from Institutional Review Board of Tribhuvan University Teaching Hospital, Institute of Medicine, Kathmandu, Nepal with Ref no: 1(6-11-E) [2] 074/075. Written consent was obtained from all participants to use their extracted teeth in this study.

Consent for publication

Not applicable

Availability of data and materials

The full dataset supporting the conclusion of this article can be obtained upon request to the corresponding author at purna087@gmail.com

Competing interests

The authors declare that they have no competing interests.

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Not applicable

Author’s contribiution

PPK conceptualized the study and contributed to study design, data collection, analysis and interpretation. BKS, RY and SPG helped in data collection, analysis and interpretation. All authors have read and approved the manuscript.

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Disclosure

This study was conducted as a thesis under the guidance of Professor Dr. BK Shrestha

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Figures

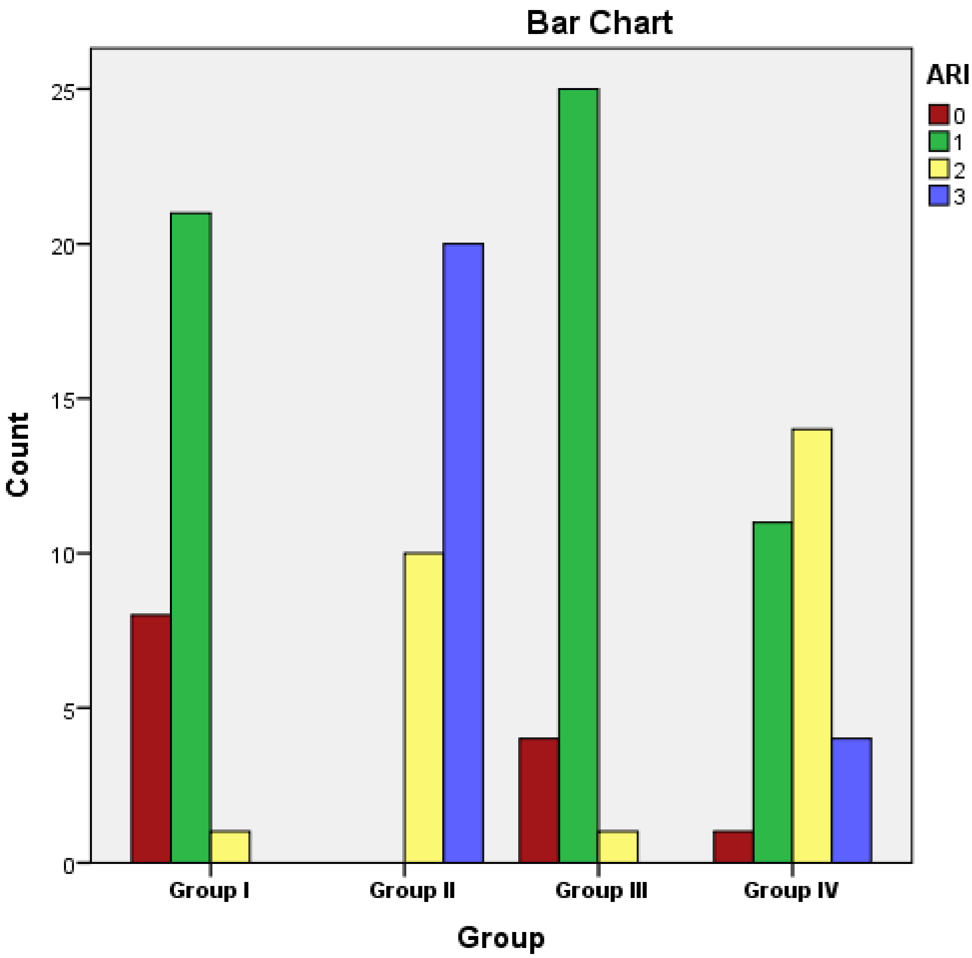

Figure 1

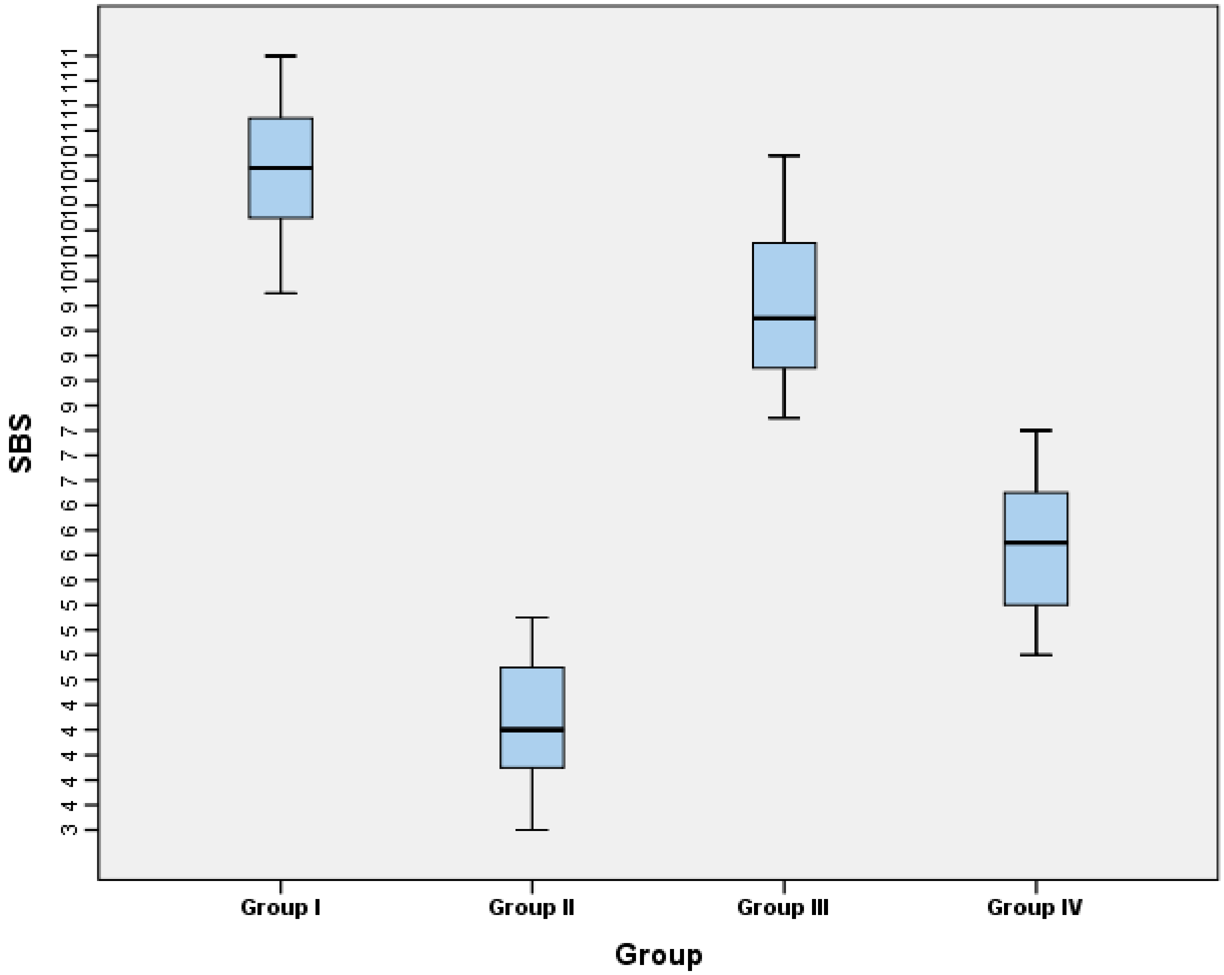

Figure 2

Bar chart for ARI of 4 different groups

Figure 3

Box plot for mean SBS of different groups

Figure 4

Close view of crosshead of universal testing machine with sample in situ

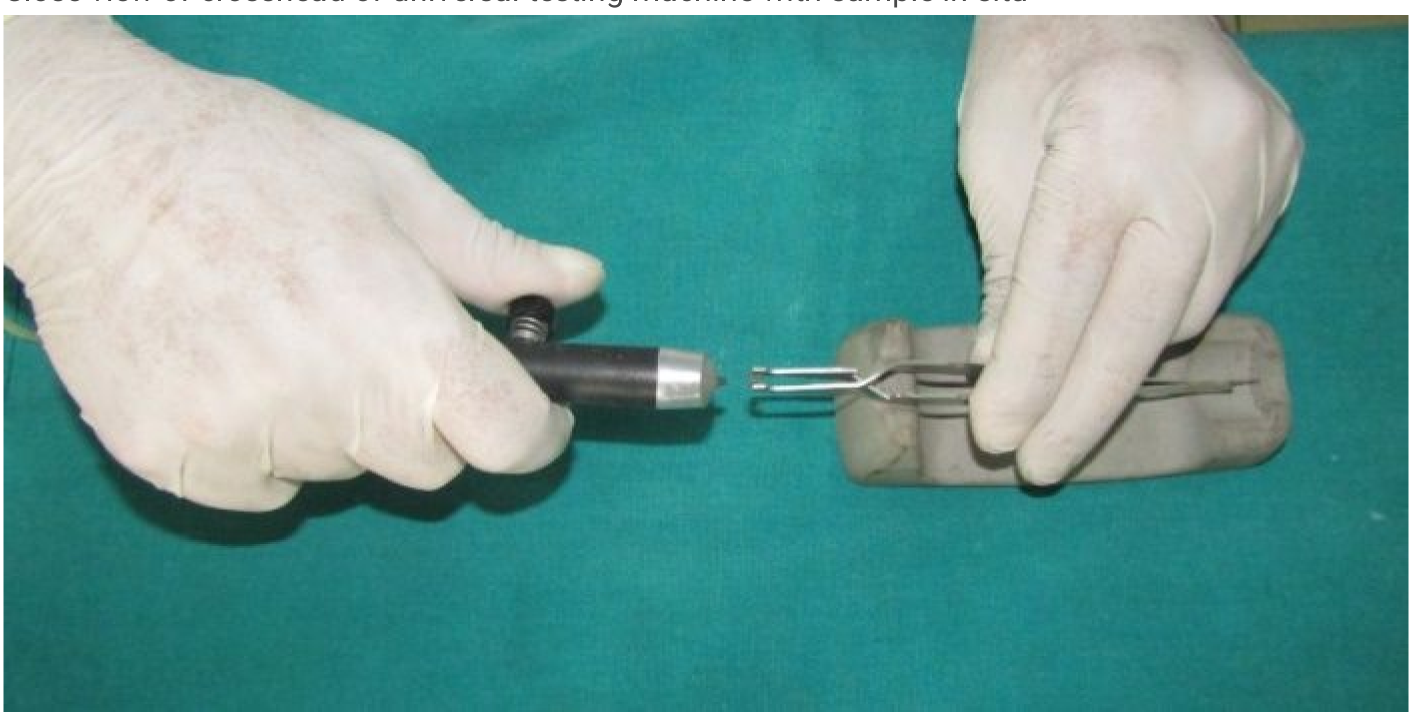

Figure 5

Ultrasonic cleaning of brackets

Figure 6

Flaming of brackets

Figure 7

Four different groups of samples

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