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Research Article

EVALUATION OF SURFACE TOPOGRAPHY OF AS RECEIVED AND RETRIEVED ORTHODONTIC BRACKETS- A 3D PROFILOMETRIC STUDY

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A B S T R A C T

An important component of orthodontic appliance is the orthodontic bracket. When sliding mechanics are applied, it is either the bracket or the arch wire that slides through the bracket slot. Whenever two different surfaces meet, the resultant effect was friction and overcoming this friction is crucial for a successful treatment outcome.
Aim & Objective: The aim and objective of the present study was to analyse the surface roughness of stainless-steel brackets, as received from the manufacturer and from the oral cavity of patients post orthodontic treatment with bicuspid extraction.
Material and Methods: Surface roughness was qualitatively analyzed of retrieved and as received orthodontic brackets at the slot and floor, using a three-dimensional non-contact surface profilometer.
Results: The surface roughness of the retrieved brackets was greater when compared to the as received brackets. This indicates that there were differences in the surface roughness across the as received and retrieved brackets.
Conclusion: Orthodontic treatment brought about a significant increase in the surface roughness and COF of brackets. However, there was no significant difference in the surface roughness at the mesial and distal slots of as received and retrieved brackets.

INTRODUCTION

Friction is a parameter that must be overcome, when translatory orthodontic tooth movement is desired. To better control the desired movement of each tooth by applied forces, the frictional contribution of each component of the system, namely, the bracket, the wire and the environment must be taken into consideration. Minimizing the frictional force that contradicts the initiation and maintenance of tooth movement will provide a more efficient and reproducible mechanical system.

In orthodontic treatment, resistance to sliding (RS) between brackets and archwires greatly influences the force transmitted to the teeth due to application of sliding mechanics, which is widely used to close the extraction space, and they may decrease the orthodontic force by fifty percent. The coefficient of friction of the bracket and archwire material is an important factor in resistance to sliding, which may depend on the roughness, texture and hardness of the contacting material surfaces. Therefore, studies of bracket surface roughness and COF are of great clinical interest with regard to RS. There is a renewed focus on retrieval analyses of orthodontic materials because the morphological, structural, compositional characteristics and mechanical properties of the materials may be altered after exposure to the oral environment. During orthodontic treatment, the materials may not perform up to the manufacturer's specifications with increasing time in the oral cavity. The adsorption and calcification of biofilm, could increase the porosity and roughness of brackets and archwires, and could lead to inaccurate torque expression and variation in friction between them. It is important for clinicians to understand changes in the materials and evaluate their clinical behaviour, and to modify the treatment process accordingly.

Most studies using AFM in the field of orthodontics were concentrated on surface roughness (Alcock *et al*., 2009; Bourauel *et al*., 1998; Huang, 2007; Widu *et al*., 1999). Some studies focussed on wings (Lin *et al*., 2006) and the slots (Lee *et al*., 2010) of brackets. Choi *et al*. (2010) focused on reports of changes in the surface roughness of bracket slots from post orthodontic treatment of a bicuspid extraction case using non-contact surface profilometer. However, to the best of our knowledge, there are no reports on comparison of surface changes between as received and retrieved orthodontic brackets in bicuspid extraction cases, using non-contact surface profilometer.

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Hence, the present in vitro study was conducted to evaluate the surface roughness in three dimensions of as received and retrieved stainless steel bracket slots in bicuspid extraction cases which can help to determine the clinical performance of the bracket, the accuracy of bracket slot dimensions and roughness of the bracket slot resulting from intraoral exposure.

MATERIAL AND METHODS

The study was designed to evaluate surface topography of as received and retrieved orthodontic brackets using three-dimensional non-contact surface profilometer. (Available at IIT Chennai, India). A total of forty pre-adjusted conventional maxillary right second premolar and canine stainless-steel brackets with MBT prescription in as-received and retrieved condition respectively were taken with 0.022 in. (0.56 mm) slot.

Surface Roughness Measurement From the sample of forty pre-adjusted conventional maxillary right second premolar and canine stainless-steel brackets in as-received and retrieved condition respectively were randomly selected for testing. Each group was evaluated for the Sa of the bracket slot floor with the help of a 3D non-contact optical surface profilometer machine. Each sample was placed on the flat surface of the profilometer machine with the help of a tweezer, under a beam of the white light interferometer which is usually made up of the He-Ne (633 nm). Before placing the sample on the flat surface of profilometer, brackets were wiped with a cloth to remove any surface impurities. Also, the measurement of the mesial slot was done first and then the distal slot for all the samples to maintain a standardized protocol.

Scanning Speed: The 10X option was selected, as the scanning speed of the sample is inversely proportional to the detailing of the fringes of the bracket slot and floor.

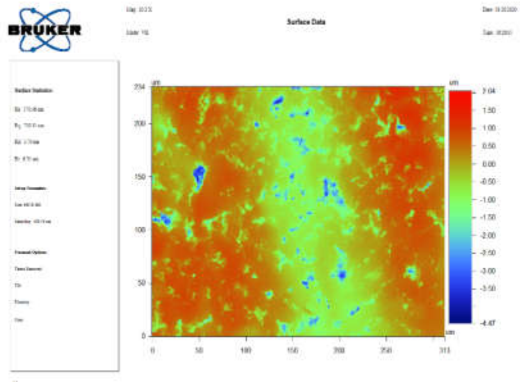
Measurement Setting: The 3D surface texture parameters and height parameters (ISO 25178) are the following

1. Sp-Maximum peak height
2. Sv-Maximum pit height
3. Sz-Maximum height
4. Sq-Root mean square height
5. Ssk-Skewness
6. Sku-Kurtosis
7. Sa-Arithmetic mean height

From these 3D parameters, we were interested in the Sa value which was an average of the surface heights giving us the average surface roughness of the bracket slot floor in three dimensions. A template was made in which, once the slot surface is scanned, a raw surface view of the slot was received. The raw surface view which was obtained requires a levelling to be done, so that the whole surface is levelled in one form, we took help of the Bruker software. Once this was achieved and the threshold was applied, the software eliminates the highest peak and the deepest valley of the slot floor surface, giving the readings which were less biased by the highest peaks and the deepest valleys. Likewise, all the forty samples of stainless-steel bracket measurements were completed. Eighty readings of the Sa value were obtained which were represented in Table 3.

Method of Statistical Analysis: All the data collected had a normal distribution, hence parametric tests such as Student t test was applied.

Surface Roughness Results: Figure 1 shows the mean Sa values across the two groups, the surface roughness for the retrieved brackets was highest compared to as received brackets. This indicates that there were differences in the surface roughness across the as received and retrieved brackets.



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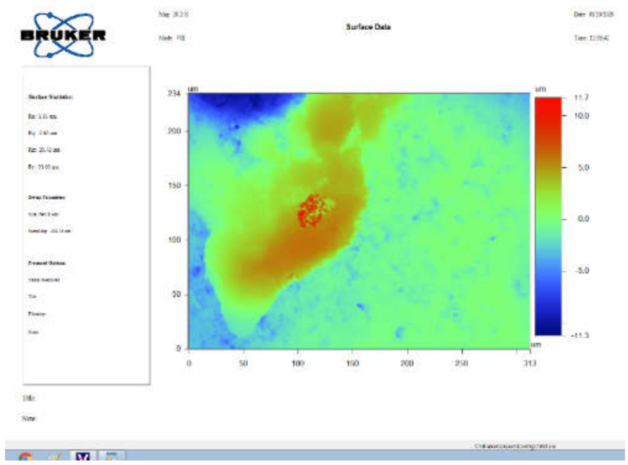

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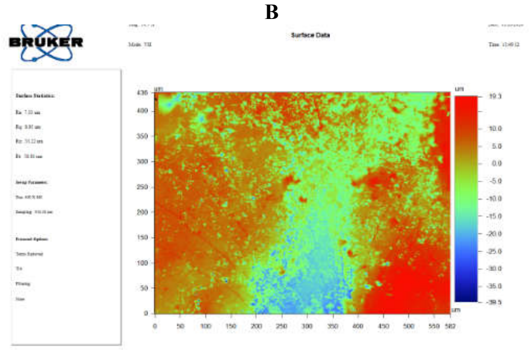

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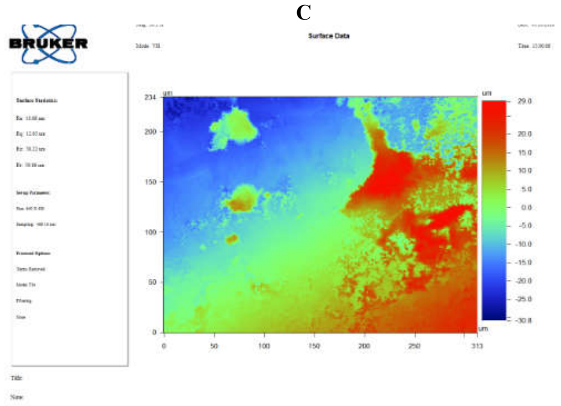

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Table 1 mean, standard deviation, t value for mesial and distal slots of maxillary right canine and maxillary right 2nd premolar as received and retrieved bracket

Brackets	Group (Slot)	N	Mean	Standard deviation	t-value	p-value
Canine as received	Mesial	10	0.53	0.26	0.360	0.723
	Distal	10	0.57	0.28		
Canine Retrieved	Mesial	10	4.75	2.57	0.379	0.709
	Distal	10	5.18	2.50		
Premolar as received	Mesial	10	0.58	0.15	1.398	0.179
	Distal	10	0.48	0.18		
Premolar retrieved	Mesial	10	5.63	2.99	0.344	0.735
	Distal	10	5.10	3.81		

p value <0.05* statistically significant, p value >0.05 not significant

Table 1 shows the results of mean, standard deviation, t value for mesial and distal slots of right upper canine and right upper 2nd premolar as received and retrieved bracket was 0.360, 0.379, 1.398, 0.344 respectively. All of these values result in p value > 0.05 which shows there was no statistically significant difference.

Table 2 mean, standard deviation, t value of maxillary right canine and maxillary right 2nd premolar bracket in retrieved condition

Brackets	**Group**	**N**	**Mean**	**Standard deviation**	**t-value**	**p-value**
Canine mesial slot	As received	10	0.53	0.26	5.174	0.000
	Retrieved	10	4.75	2.57		
Canine distal slot	As received	10	0.57	0.28	5.805	0.000
	Retrieved	10	5.18	2.50		
Premolar mesial slot	As received	10	0.58	0.15	5.330	0.000
	Retrieved	10	5.63	2.99		
Premolar distal slot	As received	10	0.48	0.18	3.833	0.001
	Retrieved	10	5.10	3.81		

p value <0.05* statistically significant, p value >0.05 not significant

Table 2 shows the results of mean, standard deviation, t value of right upper canine and right upper 2nd premolar bracket in retrieved condition was 5.174, 5.805, 5.330, 3.883 respectively. All of these values result in p value < 0.05 which shows a statistically significant difference between canine and right 2nd premolar brackets in both as received and retrieved conditions.

Table 3 Average surface roughness readings of as received and retrieved maxillary canine and premolar brackets

Sl.no	**Canine as received (S_a)**		**Canine retrieved (S_a)**		**Premolar as received (S_a)**		**Premolar retrieved (Sa)**	
	Mesial slot	**Distal slot**	**Mesial slot**	**Distal slot**	**Mesial slot**	**Distal slot**	**Mesial slot**	**Distal slot**
1.	0.10	0.10	5.42	6.69	0.57	0.47	6.19	4.53
2.	0.50	0.70	1.84	2.43	0.79	0.10	2.49	2.24
3.	0.41	0.42	9.03	4.35	0.74	0.42	5.47	1.39
4.	0.1	0.90	3.21	2.48	0.48	0.49	5.26	9.35
5.	0.82	0.71	7.63	5.10	0.30	0.36	2.54	1.48
6.	0.62	0.76	7.33	7.68	0.47	0.45	10.60	9.45
7.	0.80	0.66	5.00	6.53	0.64	0.56	2.70	1.45
8.	0.64	0.58	3.82	9.49	0.51	0.73	5.24	9.38
9.	0.58	0.10	1.87	5.29	0.67	0.72	4.97	9.42
10.	0.70	0.76	2.37	1.77	0.63	0.48	10.80	2.30

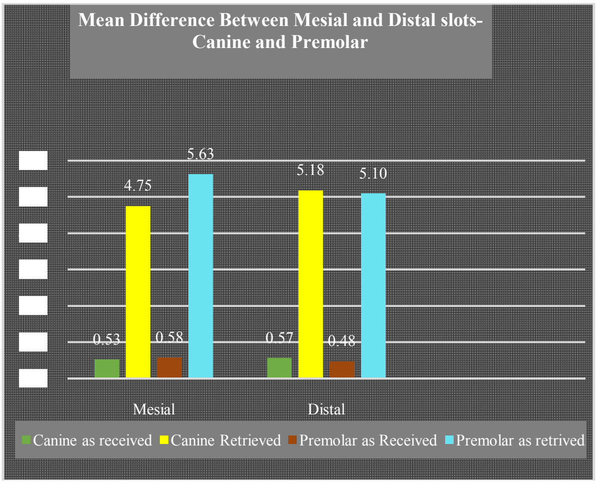

Fig 2 Graphical representation of mean difference between mesial and distal slots maxillary canine and premolar as received and retrieved brackets respectively.

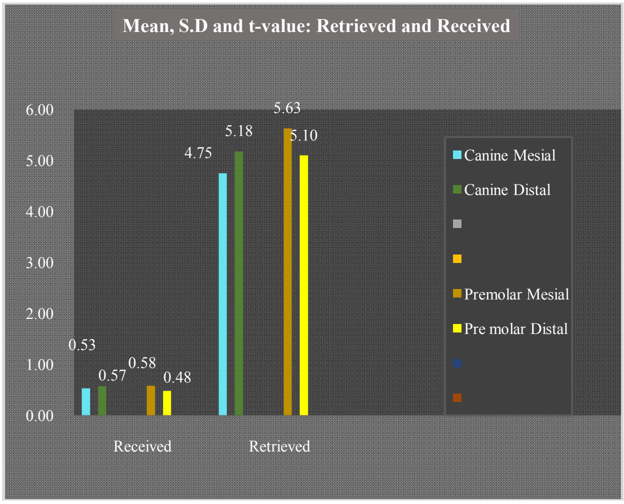

Fig 3 Graphical representation of mean difference maxillary canine and premolar as received and retrieved brackets

DISCUSSION

This study first examined the effects of orthodontic treatment with bicuspid extraction on the morphology and properties of clinically used SS orthodontic brackets using the microscopic techniques. We used the brackets taken from patients treated clinically with bicuspid extraction, thus, this study might be more clinically applicable. From the microscopic findings, it was obvious that the slot surfaces of brackets before orthodontic treatment were relatively smooth, whereas those after the orthodontic treatment showed severe scratches caused by the sliding movement of the archwires.

In this study, it was hypothesized that in the bicuspid extraction case, orthodontic treatment would alter the surface roughness. The findings confirmed the hypotheses.

A total of forty pre-adjusted conventional upper right second premolar and canine stainless-steel brackets with MBT prescription in as-received and retrieved condition respectively were taken with 0.022 in. (0.56 mm) slot because usually, the second premolar brackets experience classical sliding with the archwire while closing the space. In this study, canine brackets were selected because the tooth is in a unique position in the arch. The canine has the longest root and is located in the corner of the arch and during the space-closure stage, it experiences a “tip-upright-tip-upright” sequence of movements

(Drescher *et al*., 1989). To some extent, the canine brackets experience the most complex interaction with the archwires. The specimens were taken from orthodontic patients with the first premolar extraction, so these results may have more clinical significance. The ongoing appliance evolution resulted in two orthodontic bracket sizes that a clinician may choose, either 0.018 or 0.022" slot. The 0.022" slot size is larger when compared to 0.018" slot and facilitates easier wire insertion with less frictional binding during initial alignment and provides increased stiffness during retraction. Mclaughlin, Bennet and Trevisi recommended using 0.022" slot and most of the orthodontists prefer using this slot size, hence we preferred the same for our study.

The test instrument used to measure surface roughness in this study was a non-contact profilometer (BRUKER SOFTWARE). This instrument is faster and non-destructive when compared with a stylus profilometer, and provides a larger field, needs no sample preparation, in comparison with AFM. The system has repeatability (precision mode) of 0.1 nm and a field of view of 8 × 10 mm (at 0.78X) to 0.084 × 0.063 mm (at 100X). There are few reports on the use of a white-light interferometry technique to determine the surface roughness of bracket slots. (Lee *et al*., 2010) and (Choi *et al*., 2011) analyzed the surface roughness of bracket slots by AFM. However, the images scanned were only approximately 30 × 30 and 32 × 32 μm^2 respectively, and before scanning, the bracket wings had to be ground with a high-speed hand drill and a chamfer bur to expose the slot surface. The observed range in this study was 640 × 480 μm^2. The area was larger, and so our data may reflect the overall characteristics of the bracket slot better. The bracket wings needed no grinding, ensuring that the slots would not be damaged.

As the results in Tables I and II indicate, the readings of average surface roughness (Sa) exhibited similar tendencies in both as received and retrieved groups. This indicated that the selected parameters were comprehensive and reasonable. The results are consistent with the findings of (Regis *et al*., 2011), (Choi *et al*., 2011), (Liu *et al*., 2013), (Lee *et al*., 2010) that metallic brackets underwent significant degradation during orthodontic treatment, with an increase in surface roughness.

The surface roughness of dental materials affects the corrosion behaviour and biocompatibility of the material (Kappert *et al*., 1988), and may influence the aesthetics of the appliance and sliding mechanics caused by frictional forces (Bourauel *et al*., 1998). Many studies reported that the frictional force is proportional to the surface roughness of archwire and bracket surfaces. However, most studies (Eliades *et al*., 2005) (Marques *et al*., 2010) focused on the mechanical properties of the intact archwires, and not on the changes resulting from intraoral exposure. In clinical conditions, the brackets should have proper hardness and strength to apply an adequate force from the archwire to the teeth. In addition, they should have a smooth slot to reduce the frictional resistance. Two main factors were responsible for the changes in the surface roughness of brackets, i.e; corrosion from saliva, mouth washing solutions, or galvanic corrosion between two materials, and friction by the sliding movement of the archwire over the bracket slots. These factors were evaluated from the changes in the mechanical properties and the morphology of each bracket before and after the orthodontic treatment. Thus, retrieval analysis reveals the value of evaluation of the functional and effective alterations of the dental materials (Eliades and Bourauel., 2005).

There is little information on the increase in debris or changes in the surface roughness of the brackets before and after clinical use. Therefore, the brackets taken from patients treated clinically with bicuspid extraction were used in this study. The results are consistent with those reported previously which stated that orthodontic treatment might result in an increase in the surface roughness of SS brackets (Lee *et al*., 2010). However, their results were performed in vitro in the laboratory, whereas the present study examined the changes resulting from intraoral exposure, which is more clinically applicable.

Most specimens in retrieval analyses of orthodontic brackets were mixed, comprising incisor, canine, and premolar devices (Eliades *et al*., 2003; Eliades *et al*., 2005 Lindel *et al*., 2011; Regis *et al*., 2011). Few studies have focused on brackets from only one tooth position, except (Pandis *et al*., 2007 and Gkantidis *et al*., 2012) who focused on incisor brackets, and (Choi *et al*., 2011)[3], who investigated the second premolar brackets. In the first premolar extraction case, the force transmitted to the incisor brackets is vertical, and the incisors are retracted in the sagittal direction. The surface roughness of the bracket slots increased significantly after orthodontic treatment (Table 2). The amplitude parameters were selected because the amplitude property is one of the most important surface morphology characteristics. Historically, Sa (Ra in two dimensions) is one of the parameters used most commonly to quantify surface texture; it quantifies the "absolute" magnitude of the surface heights so, in this study we undertook Sa.

CONCLUSION

Brackets used in the study were maxillary second premolar and maxillary canine brackets manufactured by ORMCO, in both as received and retrieved conditions. Orthodontic treatment resulted in a significant increase in the surface roughness and COF of brackets. However, there was no significant difference in the surface roughness at the mesial and distal slots of as received and retrieved brackets.

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