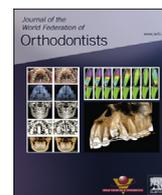




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Research Article

Evaluation and comparison of bracket slot dimensions in lingual bracket systems: An in vitro study



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ABSTRACT

Background: The aim of this study was to evaluate bracket slot width and slot depth and to compare and assess the variation between reported and actual slot dimensions of various commercially available lingual brackets.

Materials and Methods: The study comprised 60 new lingual upper right central incisor brackets from four different manufacturers. Brackets were segregated into four groups composed of 15 brackets: Group A, Ormco STb Lingual Brackets; Group B, Leone Lingual Brackets; Group C, Dentaurem Lingual Brackets; Group D, Dentos Org. Lingual Brackets. Each bracket was individually mounted on a slide using modeling clay. The bracket slot was oriented vertically on the slide so that the line of view of the confocal microscope was parallel to the slot axis. Slot dimensions were measured from the LEXT software of the confocal microscope.

Results: Slot dimensions were not as mentioned by manufacturers. Slots were either undersized or oversized.

Conclusions: Actual slot size and shape of commercially available brackets are larger or smaller from the actual prescribed value within a bracket series. Slot geometry and the standard of bracket finish varies between the brackets of different groups. Clinicians should be aware that there may be a three-dimensional loss of tooth positioning as a result of the inadvertent use of orthodontic brackets with oversized slots prolonging treatment duration and the need of additional wire bending to overcome the inadequacies of the brackets so as to achieve a good finishing.

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1. Introduction

An increased interest toward esthetic approaches for correction of malocclusion as well as for achieving functional excellence has been observed among patients seeking orthodontic care [1]. Today orthodontists are facing increasing demand by adults for lingual orthodontics as a treatment alternative due to its esthetic nature. During the early 1970s, Dr. Craven Kurz developed the first true lingual appliance due to increasing demands of orthodontic

treatment especially for adult patients concerned with esthetics. The appliance consisted of plastic brackets bonded to the lingual aspect of the anterior dentition and metal brackets bonded to the lingual aspect of the posterior dentition. Lingual orthodontics has been evolving ever since [2].

Manufacturing of a lingual appliance was undertaken by Ormco, wherein anterior brackets had a flat maxillary occlusal bite plane from canine to canine. The lower incisor and premolar bracket had a low profile and a half round bracket design. Improvements were made in subsequent generations of brackets. Hooks were attached to brackets and pronounced anterior inclined plane was incorporated. The current design of brackets has a rhomboidal bite plane that has caused an increase in the interbracket distance. The recent Scuzzo Takemoto light lingual bracket system has a small design for minimal impact on tongue position and speech, also reduced friction enhancing patient comfort and maximizing the interbracket distance.

Three-dimensional orthodontic tooth positioning occurs as a result of the interaction between orthodontic arch wires and pre-programmed brackets on the teeth. Biomechanics of lingual

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appliance are different, interbracket distance is reduced compared with labial procedures, thus requiring lighter force application for tooth movement when considering the labial aspect. Lingual bracket position is dictated by the morphology of the lingual surface anatomy of the tooth. Lingual bracket placement is closer to the center of resistance of the tooth than what is found with labial bracket position. The main slot of lingual brackets is the 0.018×0.018 -inch slot through which the main arch wire is engaged. Programmed features can be effective only if the bracket slot is accurate [3].

Oversized or undersized bracket slots lead to variation in friction, loss of torque, anchorage loss, and compromised sliding and adversely affects three-dimensional tooth positioning. A 10° inaccuracy in torque results in an average vertical deviation of 1.2 mm [4]. Many studies have been conducted to determine the accuracy of slot dimensions of labial brackets; however, very little is known about the slot dimensions of commercially available lingual brackets. Because the slot dimension is one of the vital factors in the expression of desired tip and torque, it is necessary to know whether the slot dimensions of these brackets are meeting standards prescribed by the manufacturers. The clinician will need to compensate for the inadequacies by using auxiliaries or applying bends in the wire. The errors in bracket slot dimensions clearly reduce the simplicity, effectiveness, and precision of treatment outcome by a preadjusted system, hence the purpose of this study was to evaluate slot dimensions of commercially available lingual brackets as prescribed by different manufacturers. This study was undertaken.

- To evaluate bracket slot width
- To evaluate slot depth
- To compare and assess the variation between reported and actual slot dimensions of various commercially available brackets

2. Materials and methods

The material for this study consisted of 60 new lingual upper right central incisor brackets from four different manufacturers: 15 Ormco STb Lingual Brackets (Ormco Corporation, Glendora, CA), 15 Leone Lingual Brackets (Leone, Sesto Fiorentino, Italy), 15 Dentaurem Lingual Brackets (Dentaurem, Inspringen, Germany), and 15 Dentos Org. Lingual Brackets (Dentos India Pvt Ltd, Mahatrasht, India).

To avoid any operator bias, the operator measuring the slot dimension was unaware of which bracket belongs to which manufacturer. Each bracket was individually mounted on a slide using modeling clay; the bracket slot was oriented on the slide of the confocal microscope, so that the line of view of the measuring microscope was parallel to the slot axis after being placed on the microscope table and adjusted until a sharp, well-focused image was viewed.

For each sample, one laser image was captured to measure the slot top, slot base, and walls of the slot. Another light microscopic image was also captured to assess the surface characteristics of the bracket. The dimensions of the slot were evaluated from the laser image using inbuilt measuring software (LEXT, Thorlabs imaging systems, Sterling, VA). All dimensions were measured for the four bracket groups and values were recorded (Fig. 1). Data were tabulated and subjected to statistical analysis using one-way analysis of variance and Tukey's post hoc.

3. Results

Evaluation of slot dimensions of 0.018×0.018 -inch lingual brackets provided by four different manufacturers was carried out. The brackets were examined under confocal microscope and

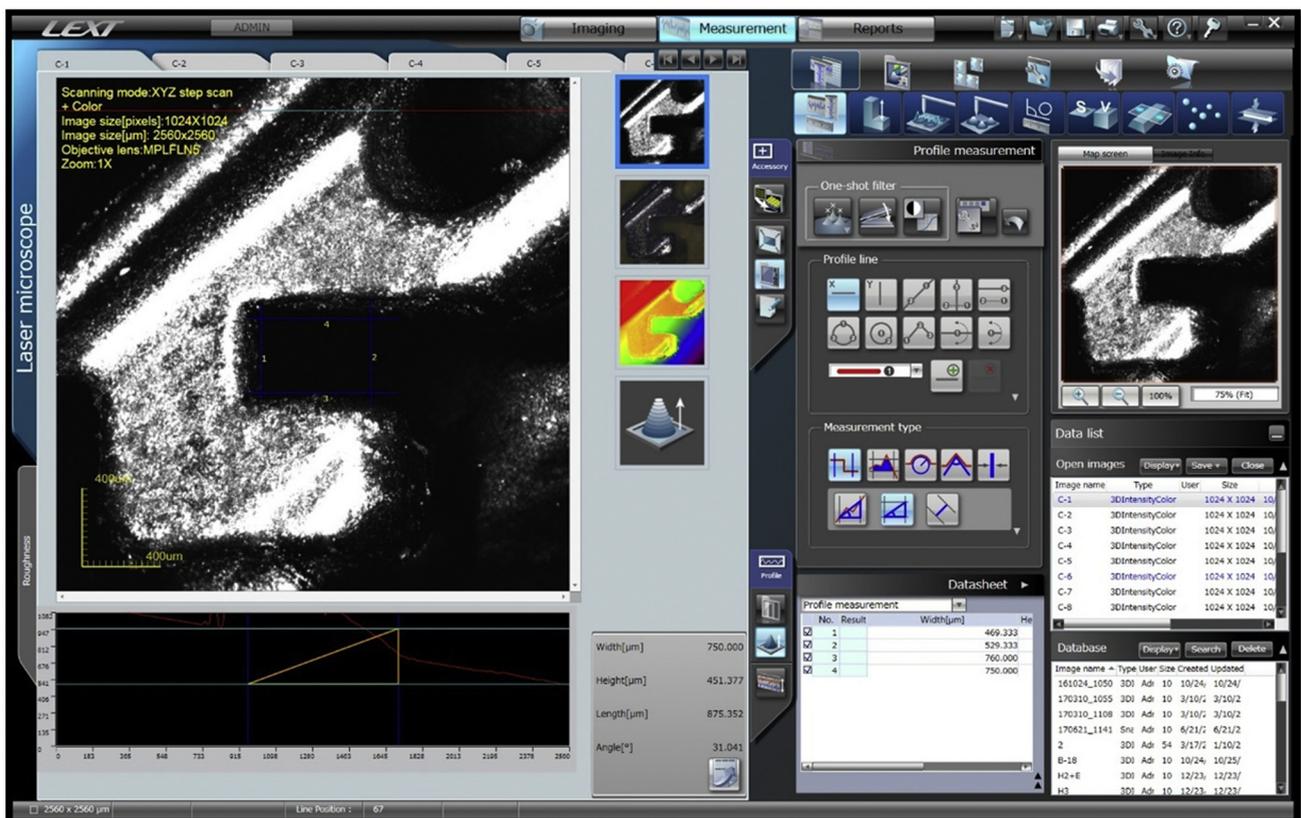


Fig. 1. Laser image generated by Confocal microscope.

measured for slot width at base and top, and depth of slot walls, respectively. Depth from the slot point also was calculated.

Comparison of slot width at base showed that the mean width at slot base in Ormco STb was 0.0178 inch, in Leone lingual brackets was 0.0186 inch, in Dentaaurum lingual brackets was 0.0194 inch, and in the Dentos Org. Lingual Brackets was 0.1750 inch (Table 1).

Dimensions of Dentos brackets were significantly different from other brackets (Table 2).

Comparison of slot width at top showed a mean for Ormco STb of 0.0200 inch, Leone lingual brackets of 0.0200 inch, Dentaaurum lingual brackets of 0.0212 inch, and Dentos Org. Lingual Brackets showed a mean of 0.2166 inch (Table 3).

Dimensions of Dentos brackets were significantly different from other brackets (Table 4).

Comparison of slot depth at side 1 showed a mean of 0.0276 inch in Ormco STb, Leone lingual brackets of 0.0195 inch, Dentaaurum lingual brackets of 0.0259 inch, and Dentos Org. Lingual Brackets of 0.1612 inch (Table 5).

Dimensions of Dentos brackets were significantly different from other brackets, and also there was a statistically significant difference between Ormco STb and Leone lingual brackets (Table 6).

Comparison of slot depth at side 2 showed for Ormco STb a mean of 0.0078, Leone lingual brackets of 0.0195, Dentaaurum lingual brackets of 0.0253, and Dentos Org. Lingual Brackets of 0.1622 (Table 7).

All the bracket groups showed a statistically significant difference in dimensions (Table 8).

For comparison of depth from slot point, Ormco STb showed a mean of 0.0177, Leone lingual brackets of 0.0195, Dentaaurum lingual brackets of 0.0256, and Dentos Org. Lingual Brackets of 0.1617 (Table 9).

Statistically significant differences were found between Ormco STb and Dentaaurum brackets and dimensions of Dentos brackets were significantly different from other brackets (Table 10).

All the bracket slot dimensions were different. None of the brackets had similar slot dimensions when compared with brackets of the same manufacturers, as well as different manufacturers.

Table 1
Comparison of mean width at slot base among four study groups using analysis of variance

Comparison of mean slot dimensions of lingual brackets (in inches) between different groups using one-way analysis of variance								
Parameters	Groups	n	Mean	SD	Min	Max	F	P
Slot base width	Group A	15	0.0178	0.0009	0.016	0.019	666.706	<0.001*
	Group B	15	0.0186	0.0004	0.018	0.020		
	Group C	15	0.0194	0.0011	0.018	0.022		
	Group D	15	0.1750	0.0234	0.142	0.218		

Max, maximum; Min, minimum; SD, standard deviation.

* Statistically significant.

Table 2
Comparison of intergroup mean width at slot base among 04 study groups using Tukey's honestly significant difference post hoc analysis

Multiple comparison of mean difference of slot dimensions between different groups using Tukey's honestly significant difference post hoc analysis						
Groups	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Slot base width	1.00	0.98	<0.001*	1.00	<0.001*	<0.001*

* Statistically significant.

Table 3
Comparison of mean width at slot top among four study groups using analysis of variance

Comparison of mean slot dimensions of lingual brackets (in inches) between different groups using one-way analysis of variance								
Slot top width	Group A	15	0.0200	0.0006	0.019	0.021	2303.126	<0.001*
	Group B	15	0.0200	0.0003	0.020	0.021		
	Group C	15	0.0212	0.0006	0.020	0.022		
	Group D	15	0.2166	0.0158	0.189	0.238		

* Statistically significant.

Table 4
Comparison of intergroup mean width at slot top among four study groups using Tukey's honestly significant difference post hoc analysis

Multiple comparison of mean difference of slot dimensions between different groups using Tukey's honestly significant difference post hoc analysis						
Groups	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Slot top width	1.00	0.98	<0.001*	0.97	<0.001*	<0.001*

* Statistically significant.

Table 5
Comparison of mean slot depth width at side -1 among four study groups using analysis of variance

Comparison of mean slot dimensions of lingual brackets (in inches) between different groups using one-way analysis of variance								
Parameters	Groups	n	Mean	SD	Min	Max	F	P
Slot Depth-1	Group A	15	0.0276	0.0018	0.025	0.031	1380.48	<0.001*
	Group B	15	0.0195	0.0004	0.019	0.020		
	Group C	15	0.0259	0.0018	0.023	0.030		
	Group D	15	0.1612	0.0140	0.135	0.188		

Max, maximum; Min, minimum; SD, standard deviation.

* Statistically significant.

Table 6

Comparison of intergroup mean slot depth width at side 1 among four study groups using Tukey's honestly significant difference post hoc analysis

Multiple comparison of mean difference of slot dimensions between different groups using Tukey's honestly significant difference post hoc analysis						
Groups	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Slot depth 1	0.02*	0.92	<0.001*	0.08	<0.001*	<0.001*

* Statistically significant.

Table 7

Comparison of mean slot depth width at side -2 among four study groups using analysis of variance

Comparison of mean slot dimensions of lingual brackets (in inches) between different groups using one-way analysis of variance								
Parameters	Groups	n	Mean	SD	Min	Max	F	P
Slot depth 2	Group A	15	0.0078	0.0018	0.006	0.010	1890.342	<0.001*
	Group B	15	0.0195	0.0004	0.019	0.021		
	Group C	15	0.0253	0.0022	0.022	0.030		
	Group D	15	0.1622	0.0126	0.139	0.180		

Max, maximum; Min, minimum; SD, standard deviation.

* Statistically significant.

Table 8

Comparison of intergroup mean slot depth width at side 2 among four study groups using Tukey's honestly significant difference post hoc analysis

Multiple comparison of mean difference of slot dimensions between different groups using Tukey's honestly significant difference post hoc analysis						
Groups	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Slot depth 2	<0.001*	<0.001*	<0.001*	0.08	<0.001*	<0.001*

* Statistically significant.

Light microscope images showed Dentaurem and Dentos had better surface finishing, whereas surface irregularities were higher in Ormco and Leone lingual brackets (Fig. 2).

4. Discussion

Slot dimension is one of the vital factors in the expression of desired tip and torque. Kusy [5] stated that "If the slot size is more, then there will be excessive chair side time and increase in total treatment time. When slot dimensions are decreased, it results in friction binding of archwire and sliding may stop due to notching in archwires." Kusy and Whitley [6] stated that dimensions must be clearly specified by manufacturers so clinicians will benefit from accurate calculations. It is thus necessary to know whether the slot dimensions of these brackets are meeting standards prescribed by the manufacturers, without which the treatment outcomes would be compromised [7]. The results are in agreement with the study done by Kusy and Whitley [6], which showed that slot precision varied significantly between all the bracket systems that had been

evaluated. Orthodontic bracket slots are mostly larger than stated by manufacturers. Slot geometry and the standard of bracket finish also varied greatly between bracket groups, as seen in the study done by Doshi and Patil [7]. They state that frictional force between a wire and bracket is recognized as a detrimental factor that affects smooth movement of the teeth during sliding mechanics. Although it is impossible to make a bracket with no frictional resistance, it is necessary to eliminate or reduce the friction as much as possible to obtain optimal tooth movement. Studies by Kusy and Whitley [6] found that all the brackets were convergent, divergent, or parallel, but our study showed that brackets had convergent slots. Slot top was of a higher dimension than the slot base. The geometry is trapezoidal and not rectangular as expected. Cotrim Ferreira et al. [8] studied the cervico-occlusal dimensions of lingual incisor brackets. Results showed that the slot depth varied greatly. The convergence/divergence in the bracket slot walls further increased inaccuracy of brackets. This highlights the difficulty of standardization and quality control in the manufacturing process of orthodontic brackets. These discrepancies result in incomplete

Table 9

Comparison of mean slot depth from slot point among four study groups using analysis of variance

Comparison of mean slot dimensions of lingual brackets (in inches) between different groups using one-way analysis of variance								
Parameters	Groups	n	Mean	SD	Min	Max	F	P
Depth from slot point	Group A	15	0.0177	0.0017	0.016	0.020	1786.167	<0.001*
	Group B	15	0.0195	0.0003	0.019	0.020		
	Group C	15	0.0256	0.0019	0.022	0.030		
	Group D	15	0.1617	0.0127	0.138	0.184		

Max, maximum; Min, minimum; SD, standard deviation.

* Statistically significant.

Table 10

Comparison of intergroup mean slot depth from slot point among four study groups using Tukey's honestly significant difference post hoc analysis

Multiple comparison of mean difference of slot dimensions between different groups using Tukey's honestly significant difference post hoc analysis						
Groups	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Depth_SP	0.87	0.007*	<0.001*	0.06	<0.001*	<0.001*

* Statistically significant.

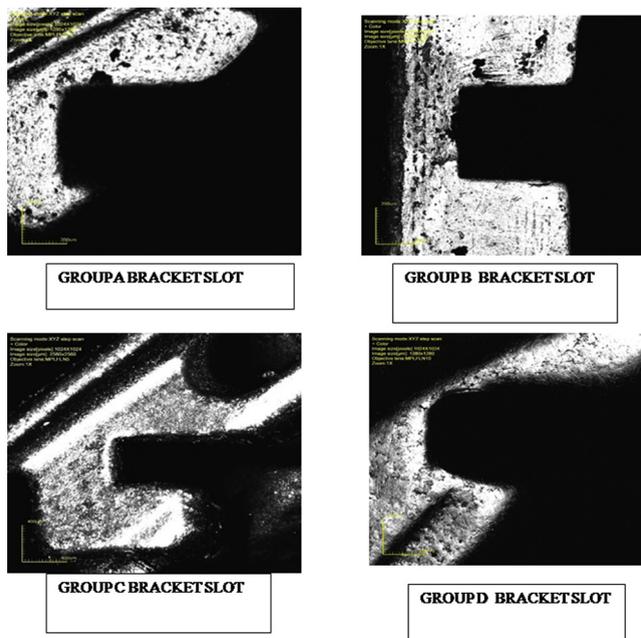


Fig. 2. Light microscopy image of bracket surfaces.

transmission of the bracket prescription to the tooth and its supporting tissues. Rajashekar et al. [9] compared bracket slot dimension of preadjusted edgewise appliances in which slot depth and width were measured using a confocal microscope. Results showed slots were oversized and undersized, concluding that slot dimensions are not accurate, which is in relation to results of the present study. Khan et al. [10] measured the bracket slot tolerance of maxillary canine brackets using metal leaf gauges, cross-checked by a digimatic micrometer. The results indicated that bracket slot heights are mostly oversized by the manufacturer, similar to the results of the present study.

Brown et al. [11] carried out studies on complete bracket series and found that 36% of slots were not large enough to insert a full-size wire. In our study, 85% of brackets were oversized and 15% were undersized in relation to the slot dimensions. Creekmore [12] mentioned that even finishing with a full-size wire in the slot, adjustments must be made to compensate for the play of the wire in the slot to get the teeth in the desired position. This statement might hold true for faulty manufacturing as well.

The main limitation of the present approach is the use of commercially available stock brackets. Fully customized lingual appliances based on patients specific malocclusion, such as In-cognito and WIN appliances, were not included in the present study. But the results of the study points towards more precision in manufacturing lingual appliances for expression of desired tip and torque values.

5. Conclusion

- The actual slot size and shape of a lingual orthodontic bracket are likely to be larger or smaller than the prescribed and advertised nominal value among the manufacturers and also within a bracket series.
- Slot geometry and the standard of bracket finish varied greatly among the bracket groups and brackets of the same group. Group D (Dentos org) showed statistically significant difference in the discrepancy of slot dimension. Group A (ORMCO), group B (Leone), and group C (Dentaurum) showed discrepancy, but it was not statistically significant.
- Bracket surface finishing standards showed considerable variation among all the different groups of brackets and, to a lesser extent, within bracket groups. Surface finishing was better in group C (Dentaurum) and group D (Dentos) brackets next to group A (ORMCO) and group B (Leone) brackets having surface irregularities as seen in light microscope images generated by the confocal microscope.
- The irregularities present in slot dimensions and the surface finish will not allow the achievement of predetermined treatment outcomes. To compensate for discrepancy in slot dimensions of the brackets, clinicians must carry out additional wire bending in finishing stages to counteract the effects of inaccurately manufactured brackets.

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