

Research Article

Comparison of slot tolerance with manufacturing measurements of different stainless steel self-ligating brackets

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Abstract: Background: Bracket slot dimensions is of great interest to orthodontists as it plays a major role in torque expression by affecting the wire/ slot play. This study was designed to measure slot tolerance (dimensions) and convergence angles of different stainless steel self-ligating brackets and to compare between the chosen brands. Materials and methods: Eighty upper first premolar brackets of four different brands {Damon Q (Ormco corporation, Brea, California, USA), DTC (Medical apparatus Cor., Hangzhou, China), IOS (Pactive self-ligating bracket, IOS, Stafford, USA), Lotus Plus interactive bracket (Orthotechnology Inc., southern Ct, West Columbia, USA)} of stainless steel self-ligating brackets with claimed slot dimensions of 0.559 mm (0.022") in height, 0.711mm (0.028") in depth and with zero taper angle were used (twenty brackets of each brand). Brackets were mounted in a purposely planned way to ensure the parallelism of the slot's walls and assessed using an inverted fluorescent optic microscope. The slot dimensions measurements were done using an AutoCAD software version 2020. One sample t-test was done to compare between brands and nominal values and One-way ANOVA with Tukey tests were done to compare between brands. Results: Actual slot dimensions were different significantly from the manufacturing measurements; the DTC bracket had the largest slot height and depth compared with manufacturing values (0.571mm, 0.741mm respectively), while the Lotus Plus bracket had significantly the lowest slot height and depth (0.549mm, 0.504mm respectively). Furthermore, DTC and IOS brackets have convergent slot walls, whereas Lotus Plus and Damon Q brackets exhibited divergent slot walls where Damon Q showed significantly the highest mean value (2.81°). Conclusion: Apart from IOS brackets, the slot tolerances of the other brands did not comply with the manufacturer's specifications. Moreover, DTC and IOS showed a convergence slot angle, while Damon Q and Lotus Plus brackets showed a divergent one.

Keywords: Self-ligating brackets, slot tolerance, stainless steel

Introduction

Orthodontic treatment procedures require applying continuous force on teeth to reposition them, which causes various cellular–molecular changes that lead to biological movement into a new position ⁽¹⁾. Orthodontic bracket slot dimensions are included in all production processes, albeit manufacturers rarely specify them. However, different imperfections might result from various machining processes; for instance, rounded corners are more common with injection molding than with fine grinding and milling. Slot tolerance (dimensions) plays a major role in torque expression. In light of this, several studies have reported the torque expression in various contexts, including slot size ⁽²⁾, Ligating system (self-ligating brackets and traditional brackets) ⁽³⁾, archwire alloys, and the cross-sectional dimension of the archwires ⁽⁴⁾, bracket fabrication materials ⁽⁵⁾. Previous research discovered differences between the measured sizes of the bracket's slot and the supposedly claimed sizes ⁽⁶⁻¹¹⁾, with some brands being oversized up to 27% ⁽¹²⁾, moreover, molar tubes exhibited different dimensions than the manufacturer ones which may affect torque expression ⁽¹³⁾. This was true for 0.018" and 0.022" slots, as both brackets were used by orthodontists

⁽¹⁴⁾. Self-ligating brackets had been developed with an attempt to reduce the frictional resistance and pain during orthodontic treatment ⁽¹⁵⁾. The precision of self-ligating brackets and the effectiveness of orthodontic treatment have been the subject of many studies ^(16, 17, 18, 19). However, the newly innovated bracket systems, such as the pactive system, proposed to have a dual action of the passive bracket and active systems and optimize the orthodontic results ⁽²⁰⁾. The purpose of this study was to evaluate the accuracy of different commercial brands of self-ligating brackets regarding bracket slot's height, depth and walls parallelism.

Materials and Methods

The study was approved by the Research Ethics Committee of the College of Dentistry/ University of Baghdad (Ref no.609 in 2022). The sample size was determined by using G power 3.1.9.7 with power of study 80%, alpha= 0.05 with sample size estimated to be eighty brackets of four brands; so that eighty upper first premolar stainless steel self-ligating brackets of 0.022×0.028 inch slot size of four brands were used. These included two brands of passive self-ligating brackets; Damon Q (Ormco corporation, Brea, California, USA) and DTC self-ligating brackets (Medical apparatus Cor., Hangzhou, China), and others of Pactive self-ligating brackets; IOS (IOS, Stafford, USA) and interactive Lotus plus (Orthotechnology Inc., southern Ct, West Columbia, USA). Twenty brackets of each brand were used. Each bracket was mounted on its distal surface. The mesial surface of the bracket was assessed using an optic microscope (inverted florescent optic microscope, Leica, Germany) with a magnification of 10x in the Department of Oral Pathology at the College of Dentistry/ University of Baghdad. To ensure precision, the bracket aligned on the glass slides on the microscope table so that the image was absolutely vertical on the bracket's slot without shadow of the slot wall interference. Furthermore, a piece of ruler placed adjacent to the bracket to help assessing the magnification scale during measurements. The bracket images were stored on a computer connected to the microscope. The slot height, depth in mm and the taper angle from the slot's base between slot's walls were measured using AutoCAD software (version 2020) as shown in Figure 1.

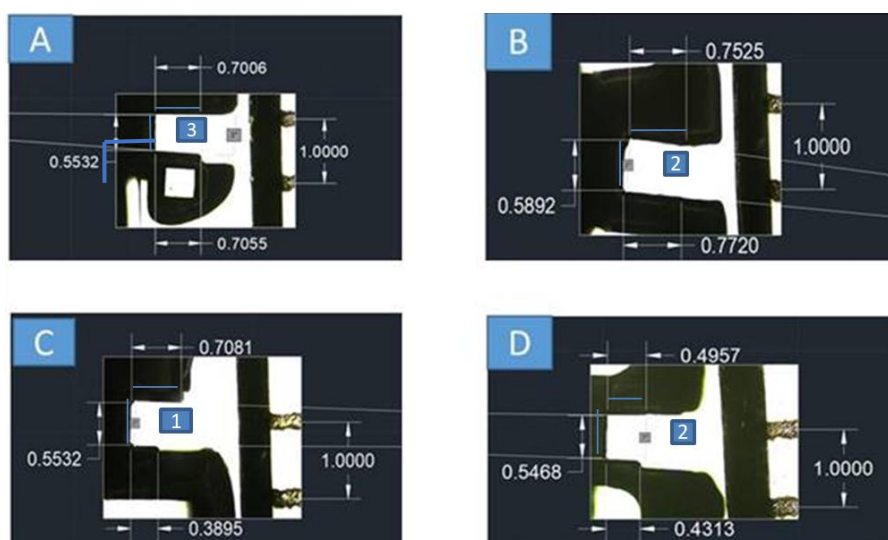


Figure 1: Measurement of slot height and depth of self-ligating brackets using AutoCAD software. A, Damon Q bracket, B, DTC bracket, C, IOS bracket and D, Lotus Plus bracket.

Slot depth was measured from the slot base to the point of intersect of the slot and the bracket gate, whereas the slot height was measured by the line of distance between gingival and occlusal walls of the slot. Statistical Analysis was done using statistical software for social sciences (SPSS, Version 26). Since the data were normally distributed as determined by the Shapiro-Wilks test (data not supplied), the slot

dimensions of the four different brands were compared to their manufacturer values using one sample t-test and one-way ANOVA followed by Tukey tests were used to compare between the brands.

Results

Regarding the slot’s depth; apart from Damon Q brackets, all other brackets showed significant differences with the manufacturing value. Regarding the slot’s height; the Damon Q and Lotus Plus brackets had significantly lower than the manufacturing value while DTC bracket has significantly a higher one. Regarding taper angle; all brands had significant differences with the manufacturing value as seen in Table 1 of descriptive statistics and one sample t-test.

Table 1: Descriptive statistics and one sample t-test comparison of bracket’s slot height, slot depth and taper angle difference (in mm) between the manufacturer’s and actual values.

Brackets	Depth (mm)*	SD	Sig. t (p-value)	Height (mm)*	SD	Sig. t (p-value)	Taper angle	SD	Sig. t (p-value)
Damon Q	0.728	0.027	1.989 (0.078)	0.548	0.009	-3.575 (0.006)	2.81	0.78	11.225 (0.000)
DTC	0.741	0.017	5.549 (0.000)	0.571	0.013	2.928 (0.017)	-1.53	0.70	6.708 (0.000)
IOS	0.725	0.015	2.926 (0.017)	0.559	0.014	0.203 (0.843)	-2.03	1.05	6.000 (0.000)
Lotus Plus	0.504	0.002	-358.2(0.000)	0.549	0.007	-3.892(0.004)	1.59	0.51	9.798 (0.000)

* 0.028"=0.711 mm, 0.022"=0.559mm

Table 2 shows the mean difference (manufacturer value- actual value) of bracket’s slot depth of four different self-ligating brackets All brackets showed higher slot depth compared to that proposed by the manufacturers apart from Lotus Plus, which showed a significantly lower value ($p=0.000$, 0.504mm). Furthermore, the DTC bracket had the highest mean value (0.741mm) followed by Damon Q bracket (0.728mm) and IOS bracket (0.725mm).

Table 2: Comparison of bracket’s slot depth difference (in mm) between the manufacturer and actual values using ANOVA and Tukey tests.

Brackets	Mean Difference (mm)	SD	ANOVA Test		Brackets I	Brackets J	Tukey Test	
			F	P value			Mean Difference (I-J)	P value
Damon Q	-0.017	0.027	407.038	<0.001	Damon Q	DTC	-0.013	0.381
						IOS	0.002	0.986
						Lotus Plus	0.225	<0.001
DTC	-0.03	.0172	407.038	<0.001	DTC	IOS	0.015	0.220
IOS	-0.014	0.015			Lotus Plus	0.238	<0.001	
					Lotus Plus	0.222	<0.001	
Lotus Plus	0.21	0.002	407.038	<0.001	IOS	Lotus Plus	0.222	<0.001

Table 3 shows the mean difference (manufacturer value- actual value) of bracket’s slot heights of four different self-ligating brackets. The DTC showed the highest value among the tested brackets (0.571mm),

whereas, IOS exhibited a similar slot height compared to the nominal values (0.559mm). Both Damon Q and Lotus Plus brackets were smaller than the nominal slot's height (0.548mm, 0.549mm respectively).

Table 3: Comparison of bracket's slot height difference (in mm) between the manufacturer and actual values using ANOVA and Tukey tests.

Brackets	Mean Difference (mm)*	SD	ANOVA Test		Brackets I	Brackets J	Tukey Test	
			F	P value			Mean Difference (I-J)	P value
Damon Q	0.011	0.009	8.487	<0.001	Damon Q	DTC	0.024	<0.001
DTC	-0.013	0.013			Damon Q	IOS	-0.011	0.131
					Damon Q	Lotus Plus	-0.001	0.993
IOS	0	0.014			DTC	IOS	-0.013	0.143
Lotus Plus	0.01	0.007	DTC	Lotus Plus	0.022	<0.001		
			IOS	Lotus Plus	-0.010	0.218		

Regarding the taper angle, the results showed that IOS and DTC bracket exhibited a convergent taper slot walls (-1.53°, -2.03° respectively), whereas the Damon Q and Lotus Plus exhibited a divergent taper angle (2.81°, 1.59° respectively). However, Damon Q brackets has significantly the highest slot taper angle compared to the other groups (p= 0.001 and 0.004 for DTC and Lotus Plus brackets respectively) (Table 4).

Table 4: Descriptive statistics of slot's taper angle of brackets with ANOVA and Tukey tests.

Brackets	Mean	SD	ANOVA Test		Brackets I	Brackets J	Tukey Test	
			F	P value			Mean Difference	P value
Damon Q	2.81°	0.78	20.84	<0.001	Damon Q	DTC	1.3	0.001
DTC	-1.53°	0.7			Damon Q	IOS	0.8	0.126
					Damon Q	Lotus Plus	1.2	0.004
IOS	-2.03°	1.05			DTC	IOS	-0.5	0.499
Lotus Plus	1.59°	0.51	DTC	Lotus Plus	-0.1	0.013		
			IOS	Lotus Plus	-0.4	0.022		

Discussion

Self-ligating brackets are ligature-less bracket systems that have a mechanical device built into the bracket to close off the edgewise slot. It was claimed that self-ligating brackets have advantages over the conventional ones, being more comfortable, easier to clean and better tooth control (21). In clinical practice, three-dimensional control of the tooth is a prime objective to keep the integrity of the dento alveolar region and obtain optimum results (15). To achieve that, orthodontists should be aware of bracket/ wire systems and the possible compensatory root torque needed to meet the proposed treatment objectives. This may be especially obvious in cases where incisor inclination correction was intended (22).

In this study, Upper premolar brackets were used to standardize the bracket settling and to avoid the possible alignment and/or measurement issues, due to the variability of torque values, especially in incisors brackets. In the current study, it was found that there were differences between the manufacturing (nominal) slot's dimensions of brackets and the actual slot dimensions. Regarding the slot's height, DTC bracket showed significantly the highest value compared to the nominal slot's height and the other brands,

whereas the Damon Q bracket and Lotus Plus bracket exhibited smaller values compared to the manufacturer's ones. This could be due to differences in the bracket's design and manufacturing process⁽¹⁶⁾. It was reported that Damon Q brackets have slot height smaller than the manufacturer's value⁽²²⁾, which comes in accordance with the current study. However, other researchers^(17,18) reported an oversized slot height. This could be due to differences in the setting of the study and the assessment equipment i.e., the use of different microscopes, cameras and soft wares and differences in the tested brackets i.e., upper central incisor rather than upper premolar teeth in the current study, in addition to differences in manufacturing methods of the brackets. It was proposed that when the slot height value is low, there is a propensity to improve the contact between the bracket and archwire, which would reduce the contact angle and the binding effect and, hence, increase the torque expression^(16,23). However, this may enhance pain which may intensify during the first few months of the treatment⁽²⁴⁾. Regarding the slot depth, brackets appear to express higher actual value compared to the nominal slot's depth. This is especially true for the DTC bracket, which had significantly the highest value. On the other hand, Lotus Plus brackets showed significantly smaller slot depth compared to the nominal value and other brands. This could be attributed to the design of the bracket, its interactive clip mechanism and the manufacturing process as different imperfections might result from various machining processes; for instance, rounded corners are more common with injection molding than with fine grinding and milling. The result of the current study come in accordance with that reported by many researchers^(12, 16, 17, 19, 25), who suggested imperfections in the manufacturing process of brackets and possible variations in prescription, confirming that these appliances may lack a high degree of precision.

Moreover, the data showed that the slot's walls are not parallel, and there was an angle detected between the occlusal and gingival walls of the slot. Both the IOS and DTC brackets exhibited convergent taper slot walls, whereas the Damon Q and Lotus Plus exhibited divergent taper angles. This comes in agreement with many studies^(16, 22, 18, 26) who found that brackets from different brands had either divergent or convergent slots. This required that clinicians should not fully rely on the brands only, and some wire bending may be required during the final stages of the orthodontic therapy⁽²⁷⁾; this is especially true when considering the recent advancement in digital orthodontics where compensating angles should be considered during AI based treatment planning⁽²⁸⁾.

Conclusion

In contrast to the manufacturer's claims, the actual slot dimensions were either oversized or undersized; additionally, the slot's walls lacked parallelism. The IOS showed a similar measurement regarding the slot height, whereas Lotus Plus showed a significantly shorter depth. Moreover, both DTC and IOS brackets showed a convergent slot angle, while Damon Q and Lotus Plus brackets have divergent slots.

Conflict of interest

The authors have no conflicts of interest to declare.

Author Contribution

NLA and DHA; study conception and design. NLA; data collection. NLA and DHA; methodology, statistical analysis and interpretation of result. NLA, DHA and AA; writing- review and editing. Supervision; DHA and AA. All authors reviewed the result and approved the final version of the manuscript to be published.

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مقارنة ابعاد الفتحة مع قياسات التصنيع لحواصر تقويمية ذاتية الربط المختلفة المصنوعة من الفولاذ المقاوم للصدأ نور لفته عفتان، ضياء حسين الكروش، عبد الله البرخيل

المستخلص:

الخلفية: أبعاد الحاصرة التقويمية ذات أهمية كبيرة لأطباء تقويم الأسنان لأنها تلعب دورًا رئيسيًا في التعبير عن عزم الدوران من خلال التأثير على حركة السلك / الفتحة. تم تصميم هذه الدراسة لقياس تحمل الفتحة (الأبعاد) وزوايا التقارب لمختلف الحواصر التقويمية ذاتية الربط المصنوعة من الفولاذ المقاوم للصدأ والمقارنة بين العلامات التجارية المختارة. المواد والطرق: تم استخدام ثمانين حاصرة تقويمية للضاحك العلوي الأول من أربع علامات تجارية مختلفة (IOS (Pactive self-ligating bracket ، China) ، Hangzhou ، DTC (Medical apparatus Cor. ، USA) ، California ، Brea ، {Damon Q (Ormco corporation من USA) ذاتية الربط المصنوعة من الفولاذ المقاوم للصدأ بأبعاد فتحة تبلغ 0.559 مم (بوصة) في الارتفاع، و 0.711 مم (0.028 بوصة) في العمق وزاوية فتحة صغيرة (تم استخدام عشرين حاصرة تقويمية من كل علامة تجارية). تم تركيب الحواصر التقويمية بطريقة مخططة لضمان التوازي بين جدران الفتحة وتم تقييمها باستخدام مجهر بصري فلوري مقلوب. تم إجراء قياسات أبعاد الفتحة باستخدام برنامج AutoCAD إصدار 2020. تم إجراء اختبار t لعينة واحدة للمقارنة بين العلامات التجارية والقيم الاسمية وتم إجراء تحليل التباين أحادي الاتجاه مع اختبارات Tukey للمقارنة بين العلامات التجارية. النتائج: كانت أبعاد الفتحة الفعلية مختلفة بشكل كبير عن قياسات التصنيع؛ كان للحاصرة التقويمية DTC أكبر ارتفاع وعمق للفتحة مقارنة بقيم التصنيع (0.571 مم ، 0.741 مم على التوالي) ، بينما كان للحاصرة التقويمية Lotus Plus أقل ارتفاع وعمق للفتحة (0.549 مم ، 0.504 مم على التوالي). علاوة على ذلك ، تحتوي الحواصر التقويمية DTC و IOS على جدران فتحة متقاربة ، بينما أظهرت الحواصر التقويمية Lotus Plus و Damon Q جدران فتحة متباعدة حيث أظهر Damon Q أعلى قيمة متوسطة (2.81 درجة). الاستنتاج: بصرف النظر عن حواصر IOS ، فإن أبعاد الفتحات للعلامات التجارية الأخرى لم تتوافق مع مواصفات الشركة المصنعة. علاوة على ذلك ، أظهرت حواصر DTC و IOS زاوية فتحة متقاربة، بينما أظهرت حواصر Lotus Plus و Damon Q زاوية متباعدة.