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To Assess the Dimensional Accuracy of Slot Size in Passive Self-Ligating Brackets from Three Distinct Orthodontic Companies

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KEYWORDS
Dimensional accuracy, Slot size, Self-ligating brackets, Orthodontic companies

ABSTRACT:

Aim: To assess the dimensional accuracy of slot size in passive self-ligating brackets from three distinct orthodontic companies.

Material and method: A total of 120 self-ligating brackets for the upper right central incisor were obtained, with 40 brackets from each of three different manufacturers (American Orthodontics, Forestadent, Damon Q). These brackets had a slot size of 0.022 inches and were separated into three groups, with each group including 40 brackets. The brackets were positioned on an acrylic plate that functioned as a template. A perforation was created in the plate to affix the brackets. The perforation was then filled with modelling clay, allowing for half of the bracket to be placed while the other half remained visible for evaluation purposes. A stereomicroscope was used, connected to a computer equipped with a Charge Coupled Device camera to capture the photos. Following the insertion, the brackets were fine-tuned using a 0.016” x 0.022” stainless steel wire segment. The microscope's pictures were processed.

Results: The average slot width at the base of the brackets was determined to be: American orthodontics (0.025 inch), Demon Q (0.026 inch), and Forestadent (0.026 inch). Group 1 and group 2 had more variance in their mean value compared to group 3. Upon comparing the slot width at the base of the brackets across the three groups, it was found that there was no statistically significant difference between group 1 and group 3 ($P=0.15$). The comparison between group 1 and groups 2 and 3 showed a statistically significant difference ($p < 0.001$). The average slot widths at the top of the brackets were determined to be: 0.026 inch for American orthodontic, 0.027 inch for Demon Q, and 0.026 inch for Forestadent.

Conclusion: The analysis revealed a substantial disparity between the measured dimensions of the tested arch wires and the dimensions provided by the companies. There was significant disparity in the slot dimensions across various bracket systems. The walls of the slots deviated from the bracket bases. Forestadent offers the most optimal bracket slot size for precise dimensional accuracy.

Introduction

A bracket is an orthodontic attachment that is securely fastened to a tooth in order to connect with the arch wire. This definition was provided by Raymond C. Thurow. Brackets, which are passive components, transmit the applied force from active components like arch wire, springs, and elastomeric chains to the teeth. The insertion of arch wires into a preadjusted bracket is intended to provide multidimensional pressures for tooth movement. The pressures arise due to the close fit of the wire into the bracket slot. Any looseness or movement between these components will lead to an inadequate transfer of the bracket prescription to the tooth and its supporting tissues[1]. Standardisation is a crucial need for technological advancement. Currently, there are two different sizes of orthodontic bracket slots available for clinicians to choose from when treating a patient. The two dimensions, 0.018 inch and 0.022 inch, are spaced apart by a difference of 0.004 inch, which is an uncommon measurement in the metric system used

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by the scientific community, where measurements are often expressed in millimetres and micrometers[2]. Currently, orthodontists possess several options for rectifying dental abnormalities. Although standard orthodontic brackets are often used, there are several manufacturers that provide a wide range of options in terms of size, wings, slots, prescriptions, and ligation characteristics[3]. The use of inadequate wires and excessive brackets might have a detrimental impact on the ultimate three-dimensional alignment of the tooth. Thanks to advancements in orthodontic technology, orthodontists now have the option to choose between two different sizes of orthodontic bracket slots. Depending on the selected choice, they may be joined and paired in either 0.018-inch or 0.022-inch sizes{4,5}. In order to get the desired tip and torque in the brackets, it is essential to provide the precise dimensions of the bracket slots. Despite the longstanding assumption of the accuracy of bracket slot measurements, many examinations have shown discrepancies between the officially stated size of orthodontic brackets and their true dimensions. Kusy and Whitley[6] observed that orthodontists need accurate measurements in order to determine the optimal contact angle for binding. The contact angle between the arch wire and bracket is considered crucial for the successful treatment of patients, as it may lead to binding and sliding resistance. However, this issue can be somewhat mitigated by utilising slightly bigger slots and smaller arch wires. To get a visually acceptable result, it is necessary for the incisors to have the appropriate torque[7]. Several factors, such as the dimensions of the bracket slot and arch wire, influence the expression of torque. An arch wire that is appropriate for the bracket slot allows for total torque expression. However, a certain degree of flexibility is required to insert a full-size rectangular arch wire. Hence, the vertical dimension or height of the slot must exceed the height of the archwire. An inaccurate torque will result if there is a substantial disparity in size between the bracket slot and the arch wire. Various studies have investigated the influence of several elements on torsion play. These factors include the choice of bracket and arch wire material, irregularities in tooth shape, issues with bracket placement, and the technique of arch wire beveling[8-10].

Material and methods

A total of 120 self-ligating brackets for the upper right central incisor were obtained, with 40 brackets from each of three different manufacturers (American Orthodontics, Forestadent, Damon Q). These brackets had a slot size of 0.022 inches and were separated into three groups, with each group including 40 brackets. The brackets were positioned on an acrylic plate that functioned as a template. A perforation was created in the plate to affix the brackets. The perforation was then filled with modelling clay, allowing for half of the bracket to be placed while the other half remained visible for evaluation purposes. A stereomicroscope was used, connected to a computer equipped with a Charge Coupled Device camera to capture the photos. Following the insertion, the brackets were fine-tuned using a 0.016” x 0.022” stainless steel wire segment. This modification enables the bracket's proximal view to align parallel with the template base and perpendicular to the optic visor of the microscope. The microscope's pictures were processed using the Image analysis programme (MVIG 2005) by a laboratory technician, following the authors' instructions. Upon receiving the photographs, the image analysis system was used to designate lines on the bracket. Specifically, one line was marked on the base of the bracket while another line was drawn on the top. The linear measurement between these two lines was obtained to determine the slot size of the bracket. The same method was repeated for the remaining two groups.

Statistical Analysis

The statistical analysis was conducted using SPSS version 25.0. A statistical study was conducted to evaluate the torque values of three distinct firms. The purpose was to determine whether there was a significant difference between these values and to compare the mean of these slot size values with the standard values recommended by the manufacturer. The statistical methods used for the investigation were the One sample t test and the one way ANOVA test.

Results

The result indicates that the slot's width deviated from the manufacturer's stipulated norm, either exceeding or falling short. The width of the bracket slot at the top and

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the base was likewise unequal. The average slot width at the base of the brackets was determined to be: American orthodontics (0.025 inch), Demon Q (0.026 inch), and Forestadent (0.026 inch). Group 1 and group 2 had more variance in their mean value compared to group 3. Upon comparing the slot width at the base of the brackets across the three groups, it was found that there was no statistically significant difference between group 1 and group 3 (P=0.15). The comparison between group 1 and groups 2 and 3 showed a statistically significant difference ($p < 0.001$). The average slot widths at the top of the brackets were determined to be: 0.026 inch for American orthodontic, 0.027 inch for Demon Q, and 0.026 inch for Forestadent. The mean value of group 1 and group 2 exhibited more variability than group 3 in relation to the values asserted by the manufacturer. The mean values for all three groups were determined to be statistically significant at a significance level of P<0.05. When comparing the slot width at the base of the brackets between the two groups, the results indicated that there was no statistically significant difference between group 1 and group 2 (P=0.11). When comparing group 1 with group 2 and group 3, there was a statistically significant difference ($p < 0.001$) between group 2 and group 3. Upon comparing the slot width at the base and top of the brackets for three groups, it was seen that the slots at the top were much wider than the slots at the base. This was done using a typical slot size of 0.022 inch. The slot base exhibited divergence, with a larger slot size seen near the top of the slot. The mean results for all three groups were determined to be statistically significant (P<0.05).

Table 1: The mean values of slot width at base of brackets

GROUP	MEAN	±SD	P-Value
American Orthodontic	0.025	0.002	0.001
Demon Q	0.026	0.003	0.001
Forest Adent	0.026	0.003	0.001

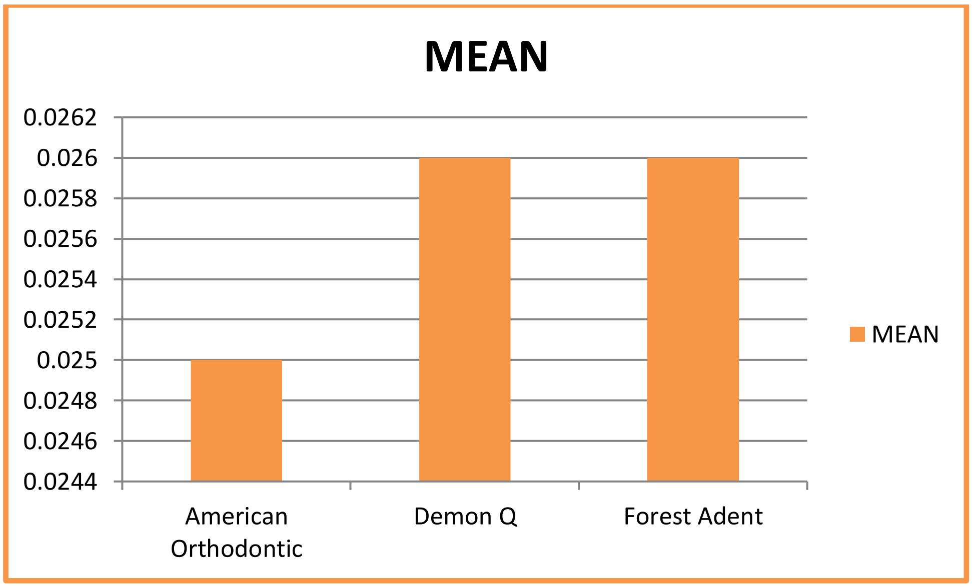

Figure 1: The mean values of slot width at base of brackets

Table 2: The mean values of slot width at top of brackets

GROUP	MEAN	±SD	P-Value

American Orthodontic	0.026	0.005	0.001
Demon Q	0.027	0.003	0.001
Forest Adent	0.026	0.003	0.001

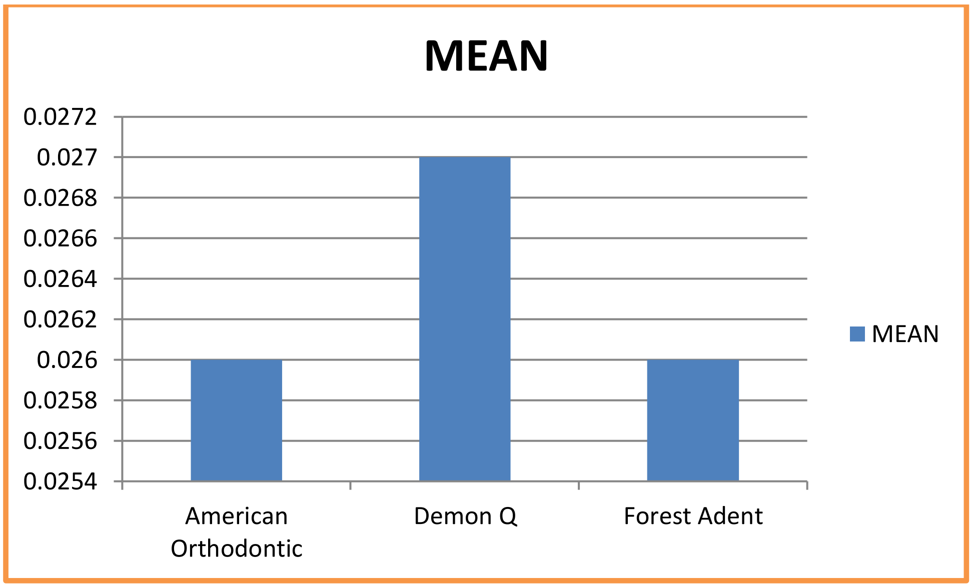

Figure 2: The mean values of slot width at top of brackets

Discussion

A self-ligating bracket is a mechanism that does not need ligatures and instead use a built-in mechanical device to close the edgewise slot. Secure engagement may be achieved via the use of either a metal labial face integrated into the structure or a clip mechanism that replaces the traditional stainless steel or elastomeric ligature ties. The slot must exhibit sufficient hardness, minimal roughness, uniform size and shape, and have consistent tip and torque characteristics in a predictable way. The manufacturing process of brackets permits a permissible range in their dimensions, which is defined by factors such as dimensional precision and consistent torque. The precision of the recommended torque value may be influenced by several production procedures for brackets, such as injection mould casting or milling. Moulding exposes the material to both expansion and shrinkage, whereas milling has the potential to introduce roughness. Ensuring consistent slot size is crucial for achieving effective wire engagement and predictable expression of the slots. The introduction of the preadjusted appliance marked a significant advancement in orthodontic mechanics. Nevertheless, preadjusted brackets that come with a set slot size might be affected by several variables, one of which is the level of accuracy in their manufacturing by the industry[11]. The actual slot size of the brackets must align with the notional values provided by the manufacturers. The larger slot may clinically alter the net effective torque, namely by increasing the play between the wire and the slot. If the slot is larger than necessary, even when the built-in torque is precise, the torque will not be effectively transmitted due to the increased gap between the wire and the slot. This scenario is especially unfavourable in instances of insufficiently tightened anterior structures and during the process of retracting [12,13]. Conversely, a slot that is too small leads to the wire being stuck, resulting in increased friction when sliding and eventually causing dental strain. Several writers specialising in orthodontic materials have designed mechanical devices to facilitate their study withsome usingcomputerised equipment such as graphic computation systems (CAD) or profile projectors, as well as electron scanning microscopes[14].

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Therefore, to determine the dimensions of the brackets' slots, the sterio microscope's accuracy was used in combination with image analysis software to estimate the slot size. The study findings align with earlier research on the slot widths of self-ligating brackets. Due to their small size, orthodontic brackets might be challenging for the operator to manage. Consequently, many templates were experimented with in order to manage the brackets, until one of them closely approximated the desired outcome. The brackets were first submerged in modelling wax, which allowed for fine adjustment but also caused the brackets to become hard. In addition, some brackets exhibited superior surface finishing on one side compared to the other. If these brackets were permanently affixed, it would restrict the ability to see both of their adjacent surfaces. Considering this, the technique of fixation selected was acrylic plates with holes filled with clay due to its suitable consistency and little sensitivity to heat stimuli. The brackets were put into this template in the profile and adjusted to ensure that the proximal surface is parallel to the template base. The three-dimensional alignment of teeth in orthodontic treatment is achieved by the interplay of orthodontic arch wires and pre-programmed brackets on teeth, all within a healthy supporting periodontium. This may be especially noticeable in situations when there is a need to rectify the inclination of the incisors, by adjusting the position of the upper incisors to compensate for any inaccuracies in their manufacturing dimensions[13]. The results of the current investigation are consistent with the study done by Bhalla et al[11]. The research included a comparison of five upper left central 0.022 inch self-ligating brackets from each of six distinct bracket series, which were chosen to represent four different manufacturers. According to their study, the brackets were found to be 5% to 15% bigger than the expected values, and the slot walls deviated from the base to the top of all the brackets. It was observed that brackets from the same manufacturer may exhibit variations in size.

In our investigation, we observed that the slot width at the base of brackets differed among different types. Specifically, the American orthodontic brackets had a slot width that was 10% smaller than the standard size, while the Demon Q brackets had a slot width that was 12.5% smaller. Additionally, the Forest adent brackets had a slot width that was 10% smaller than the standard size. The slot widths at the top of the brackets were determined to be 15% for American orthodontic, 15% for Demon Q, and 12.5% for Forestadent, when compared to the conventional slot size of 0.022". Our analysis has shown that Forest Dent provides the most precise bracket slot size in terms of exact dimensions. In their work, Paul Brown et al[12] assessed the dimensions of slots in 10 bracket series that represented five full sets of brackets. Each bracket series was photographed and measured. According to their analysis, the real dimensions and form of an orthodontic bracket are expected to deviate from the marketed standard size, with variations that may be both bigger and smaller within a set of brackets. When using standard wire diameters and a direct wire technique, it is evident that many brackets advertised as preadjusted lack the ability to generate rotational tooth movement without the need for further wire manipulation. In our analysis, we observed variations in slot size among various manufacturers. The results indicate that, among the three groups, the forest adent bracket slot scan closely resembles the manufacturer's promise. Corresponding results were discovered by Cash et al[13]. The slots of five top left central 0.022-inch brackets were measured from 11 bracket series, which represented six distinct manufacturers. According to their analysis, all bracket systems were found to be larger than necessary, with a variation ranging from 5% to 24%. There were four systems with slot walls that were parallel to each other, five systems where the slot walls converged from the base to the top, and two systems where the slot walls diverged. In addition, Pal et al conducted an assessment of the slot size of several brackets and discovered that the slot size of the ortho organiser bracket (0.018″ slot) closely matched the standard size, whereas the other brackets were larger than the standard size[14]. It was discovered that the speed brackets were somewhat smaller than expected at the base, measuring 0.556mm (0.0219 inches), and had noticeable rounding and big fillets. Additionally, the base of the brackets converged slightly with the wall. The sample also exhibited bases-to-wall difficulties. According to Major et al.[15] the GAC In-Ovation had a base measurement of 0.564mm (0.0222 inches) and was described as most nearly resembling a trapezoidal form. Additionally, it was said that the base of Damon Q measured 0.572 mm (0.0225 inches), which had the

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greatest manufacturing accuracy among the three examined and had almost 90-degree corners. Although there are instances of Damon Q brackets in the present sample with 90-degree corners, the vast majority exhibit prominent rounded internal line angles.

The research conducted by Kusy and Whitley[6] assessed three brackets (without specifying the tooth) from a total of 24 distinct bracket series obtained from eight different firms. Their sample included brackets fabricated from four distinct materials and encompassed three varying slot sizes: 0.018, 0.0185, and 0.022 inches. According to their study, 15% of the brackets were smaller than first stated, and the slot diameters surpassed the expected value by up to 16% and 8% for the 0.018-inch and 0.022-inch slots, respectively. Ultimately, they emphasised the need of the practitioner having precise knowledge of the bracket's exact dimensions to prevent any compromise in treatment mechanics. The investigation done by Siatkowski et al[16] shown a decrease in anterior torque control as a result of differences in bracket slot and arch wire size. Placing little rectangular wires into large bracket slots attached to the incisors may have a significant effect. If the difference between a 0.022" slot bracket and the maximum error measured is 0.0235", then a 0.018" × 0.025" arch wire will have 5° of wire bracket play, which exceeds the conventional expectations. A 0.0215" × 0.028" arch wire, designed to fit into a 0.022" slot, will result in 5° or greater movement between the wire and brackets when moving the back teeth forward. This occurs because the mechanics of the treatment rely on forces applied to the brackets on the front teeth using rectangular arch wires. The mentioned errors in slot size can cause the front teeth to tilt towards the tongue. Fischer-brandies et al[17] used computer assisted light microscopy to test five arch wires and brackets that are available in the market. They found that, on average, the brackets were 0.8% bigger than the dimensions provided by the makers. Additionally, the arch wires had substantially lower cross sections.

Conclusion

Our analysis revealed a substantial disparity between the measured dimensions of the tested arch wires and the dimensions provided by the companies. There was significant disparity in the slot dimensions across various bracket systems. The walls of the slots deviated from the bracket bases. Forestadent offers the most optimal bracket slot size for precise dimensional accuracy.

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