An Evaluation of Slot Size in Orthodontic Brackets—Are Standards as Expected?

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Abstract: The slots of five upper left central incisor brackets from 11 commercially available bracket systems (3M Unitek, Monrovia, Calif: Twin Torque Roth, Clarity MBT, and Victory Series MBT; Dentarum, Pforzheim, Germany: Discovery Roth (0.56 mm) and Elegance Plastic Roth; Forestadent, Pforzheim, Germany: Mini Mono MBT; TP LaPorte, Indiana: Nu-Edge Roth and Mxi Advant-Edge Roth; Ormco Corp., Orange, Calif: Damon II SL Roth; Ortho Organizers, San Marcos, Calif: Elite Mini Opti-MIM Roth and Elite Mini Opti-MIM MBT) were measured in the 0.022-inch (0.5588 mm) dimension. Measurements were taken after operator calibration, and a digital readout was produced. Results indicate that all bracket slots are oversized. Three bracket systems slots (Twin Torque, Clarity, and Mini Mono) were within 5% (±1.08, 1.655, 1.75) of their stated dimensions with essentially parallel slot walls. The Elegance Plastic slot was parallel sided but oversized by 12% (±1.15). The geometry of bracket slots was also variable. The Victory Series slot was slightly divergent with the top oversized by 6% (±1.035). The Nu-Edge slot was divergent and slot top oversized by 14% (±1.32). The Mxi Advant-Edge, Damon II SL, Elite Mini Opti-MIM Roth, and MBT were all convergent, and the base of the Damon slot was oversized by 17% (±1.79). The Discovery bracket was convergent, and the slot base was oversized by 24% (±1.255), which was the largest recorded variance. This bracket also had a 7% difference between the widths of the slot top and the base. Inaccurate machining of bracket slot dimensions and the use of undersized archwires may directly and adversely affect three-dimensional tooth positioning. (Angle Orthod 2004;74:450–453.)

Key Words: Machining accuracy; Bracket slot tolerance; Slot geometry

INTRODUCTION

The early pioneers of orthodontics devised appliances that have evolved into what is now known as the preadjusted edgewise appliance. These pioneers included Angle, Kingsley, and Farrar, and in the final quarter of the 19th century, they developed the use of wires constructed from alloys of gold, platinum, and silver. They described the wire dimensions using what was then the recently introduced American Standard Wire Gauge. This gave rise to the thousandths-of-an-inch scale, which is familiar to orthodontists worldwide but is perhaps somewhat confusing to those from a metric background.

The on-going appliance evolution resulted in two orthodontic bracket slot sizes that a clinician may choose to use when correcting a patient’s malocclusion today. These two dimensions, 0.018 inch (0.4572 mm) and 0.022 inch, are separated by four thousandths of an inch, a somewhat unusual description in a metric modern world, where the scientific community measures in millimeters and micrometers. The 0.022-inch slot was the first to be introduced, and this suited the gold wires that were used either singly or in a twinned configuration.

In the 1930s, a chromium steel alloy, stainless steel, was introduced into orthodontics. This wire was almost twice as resilient as its precious metal predecessors and was also less costly. As a result, stainless steel was adopted by many, but a conscientious group of clinicians was troubled by the increased forces steel wires in the 0.022-inch slot applied to the oral tissues. As a result, “light-wire” techniques were developed. The Begg technique, for example, used a ribbon arch 0.020-inch bracket slot with 0.016-inch stainless steel
archwires, and this downward trend in slot dimensions settled at 0.018 by 0.022 inches.

Many modern orthodontic wires are manufactured from highly sophisticated nickel titanium alloys, and as a result, we are able to preprogram our wire, even larger-dimension wires, with exquisitely finely tuned mechanical properties. The slot dimension dichotomy has yet to be resolved because modern wires are probably equally effective in both the 0.022 and the 0.018-inch slots. As a result, several authors\textsuperscript{1,2} have called for construction of a new breed of orthodontic brackets in metric dimensions.

Researchers have evaluated the dimensions and the accuracy with which medical devices are constructed. In the dental implant field, Ma et al\textsuperscript{3} have shown that the machining tolerances between the many components that make up the implant can range from 22 to 100 microns ($\mu m$), and Dellow et al\textsuperscript{4} have stated that poorly fitting components may separate as a result of screw loosening or fracture. Poor fit may also increase plaque retention, and all these complications increase the risk of implant failure.

Holmes et al\textsuperscript{5} showed that the marginal fit of electro-formed crowns was superior compared with those constructed by the lost-wax technique with interface gaps of 36 and 64 $\mu m$, respectively. Karlsson\textsuperscript{6} stated that most authors agreed that with regard to longevity, a marginal gap of 100 $\mu m$ is clinically acceptable.

There has been considerable interest in the use of CAD/CAM to produce tailor-made chair-side ceramic dental restorations. Addi et al\textsuperscript{7} examined the accuracy of the internal fit of ceramic CAD/CAM inlays and inlays constructed by the lost-wax process using heat-pressed ceramics made in the laboratory. These workers showed a maximum interface gap of 965 $\mu m$, but with a mean of 177 $\mu m$, and no significant differences between the different systems when the inlays were placed in vitro.

In the orthodontic specialty, the placing of maximum-prescription archwires in a preadjusted bracket is designed to produce three-dimensional tooth-moving forces. These forces are created as a result of the intimate fit of wire into the bracket slot, and any “play” or “slop” between these components will result in incomplete transmission of the bracket prescription to the tooth and its supporting tissues. For example, when retracting a maxillary incisor to reduce an overjet, slop between the bracket and wire results in palatal tipping of the crown, with the root of the tooth concurrently moving labially.

Kusy and Whitley\textsuperscript{8} examined 24 brackets from eight manufacturers and found three bracket slots smaller and 20 others larger than the dimensions stated by their manufacturers. The largest 0.018-inch slot measured 16% larger than stated, and the largest 0.022-inch slot measured 8% larger than stated.

This study aims to investigate the precise slot size and geometry of 11 commercially available orthodontic brackets in the 0.022-inch dimension.

\section*{MATERIALS AND METHODS}

Five upper left central incisor brackets were selected at random from a total of 11 commercially available conventional, esthetic, and self-ligating orthodontic bracket systems. Brackets were measured on two occasions by two different operators across the top and across the base of the slot in the positions indicated by the red lines A and B in Figure 1. When a metal slot had been incorporated into a bracket base of a different material (Clarity and Elegance Plastic), only the metal slot insert was measured. Measurements were completed after calibration on a one-mm scale, using a single-axis Maxtascan 100 (Graticules, Tonbridge, Kent, UK) producing a digital readout.

The 11 bracket systems evaluated were manufactured by the following five companies to the following prescriptions (all bracket dimensions 0.022 inch unless stated otherwise):

1. 3M Unitek, Monrovia, Calif
   - Twin Torque Roth
   - Clarity MBT
   - Victory Series MBT
2. Dentarum, Pforzheim, Germany
   - Discovery Roth (0.022 $\times$ 0.030 inch/0.56 $\times$ 0.76 mm)
   - Elegance Plastic Roth
3. Forestadent, Pforzheim, Germany
   - Mini Mono MBT
4. TP LaPorte, Indiana
   - Nu-Edge Roth
   - Mxi Advant-Edge Roth
5. Ormco Corp. Orange, Calif
   - Damon II SL Roth
6. Ortho Organizers, San Marcos, Calif
   - Elite Mini Opti-MIM Roth
   - Elite Mini Opti-MIM MBT.

In this study, measurement of the brackets was slightly
TABLE 1. Bracket Slot Size, Geometry and Difference Between Slot Top and Base

<table>
<thead>
<tr>
<th>Bracket-Type Prescription</th>
<th>Mean % Slot Size, SD Mean</th>
<th>Slot Shape</th>
<th>Difference From Slot Top To Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin Torque Roth</td>
<td>4.69, 1.03</td>
<td>( \bigtriangledown )</td>
<td>0.36</td>
</tr>
<tr>
<td>Clarity MBT</td>
<td>2.54, 1.85</td>
<td>( \bigtriangledown )</td>
<td>0.27</td>
</tr>
<tr>
<td>Victory Series MBT</td>
<td>5.94, 1.41</td>
<td>( \bigtriangledown )</td>
<td>1.34</td>
</tr>
<tr>
<td>Discovery Roth (0.56 mm)</td>
<td>16.96, 1.46</td>
<td>( \bigstar )</td>
<td>-6.79</td>
</tr>
<tr>
<td>Elegance Plastic Roth</td>
<td>11.31, 1.05</td>
<td>( \bigstar )</td>
<td>-0.36</td>
</tr>
<tr>
<td>Mini Mono MBT</td>
<td>2.99, 1.76</td>
<td>( \bigstar )</td>
<td>0.71</td>
</tr>
<tr>
<td>Nu-Edge Roth</td>
<td>13.64, 1.58</td>
<td>( \bigstar )</td>
<td>4.03</td>
</tr>
<tr>
<td>Mxi Advant-Edge Roth</td>
<td>8.27, 1.63</td>
<td>( \bigstar )</td>
<td>-3.13</td>
</tr>
<tr>
<td>Damon II SL Roth</td>
<td>13.19, 1.59</td>
<td>( \bigstar )</td>
<td>-3.67</td>
</tr>
<tr>
<td>Elite Mini Opti-MIM Roth</td>
<td>9.43, 2.19</td>
<td>( \bigstar )</td>
<td>-2.77</td>
</tr>
<tr>
<td>Elite Mini Opti-MIM MBT</td>
<td>6.21, 1.84</td>
<td>( \bigstar )</td>
<td>-3.13</td>
</tr>
</tbody>
</table>

complicated by the fact that, to a varying degree, the brackets have rounded or beveled edges to their slots. This complicated the evaluation of the exact end point of the bracket slot, but the microscope’s measurement crosshairs simplified intersecting the edge bevel to produce an accurate and reproducible reading.

Levels of reflection from the laboratory lights (Schott Glas, Mainz, Germany) varied as a result of the different bracket materials used and the level to which they were finished. Some brackets were of a dull matt appearance, and some were very glossy. Light reflection from the bracket slot edges complicated measurement on occasion because the margin of the bracket slot was not always clear. This problem was overcome by adjusting the light intensity until a clear, unreflective image was achieved.

RESULTS

A comparison of both operators’ calibrations on the one-mm scale indicated a mean measurement error of +0.0108 mm (SD 0.008) or 0.79% between the two operators. Paired Student t-testing of all bracket measurements illustrated no statistically significant difference (\( P > .05 \)) with correlation coefficients of 0.88 and 0.91, and, as a result, the second operator’s measurements were discarded. The percentage difference from the manufacturer’s stated dimensions of the upper and lower part of the bracket slot in the 0.022-inch dimension (unless stated) is illustrated in Table 1. This table also pictorially indicates the bracket slot wall geometry as being parallel \( \bigstar \), divergent \( \bigtriangledown \), or convergent \( \bigstar \).

All bracket slots examined were oversized. Only the Twin Torque, Clarity, and Mini Mono were within 5% of their stated dimensions with essentially parallel slot walls. The Elegance Plastic slot was parallel sided but oversize by 12%. The Victory Series slot was very slightly divergent and oversized by 6%. The Nu-Edge slot was also divergent and oversized by 14%. The Mxi Advant-Edge, Damon II SL, Elite Mini Opti-MIM Roth, and MBT were all convergent, and the base of the Damon slot was oversized by 17%. The Discovery bracket was also convergent, and the slot base was oversized by 24%, the largest recorded variance. This bracket also had a 7% difference between the widths of the top and the base of the slot.

There was considerable variation in the finishing standards between all the different groups of brackets and, to a lesser extent, within bracket groups. Some bracket slots, notably the cast ceramic Mxi Advant-Edge, had a convergent or “undercut” slot (Figure 2), whereas others, such as the Damon II SL, were divergent. The junction of the slot wall to slot base was also considerably rounded in the Mxi Advant-Edge, where one may expect a 90° angle. There was evidence of poor finish, with blebs of metal extending into the bracket slot from the inferior aspect of the bracket in the Mini Opti-MIM series (Figure 3).

DISCUSSION

Three-dimensional orthodontic tooth positioning occurs as a result of the interaction between orthodontic archwires and preprogramed brackets on teeth within a healthy supporting periodontium. In a medical environment striving for excellence in both patient care and treatment outcomes, it is disappointing to find that, in some cases, the tools of an orthodontist’s trade may be inaccurately manufactured.

The effects of oversized brackets on anterior torque loss
was illustrated by Siatkowski,9 who noted that maxillary and mandibular incisors may suffer unexpected loss of torque when protracting the buccal segments during space closure with the preadjusted Edgewise appliance. These anterior teeth may suffer a loss of torque of 5–10°, and this equates to 1.9 mm of lingual retrusion of incisal edges during space-closing protraction.

The loss of anterior torque may be further compounded when brackets deform,10,11 when using smaller-dimension rectangular wires, or when inadvertently using undersized maximum-prescription archwires or wires with an excessive edge bevel.12–14 Siatkowski9 also stated that European orthodontic bracket manufacturers use metric tooling, and, as a result of the difference between this and American tooling based on the imperial system, the 0.022-inch slots in European-made brackets are automatically oversized by 4.22% even before any manufacturing variability is encountered.

Orthodontic clinicians should be aware that the preadjusted bracket and wire systems widely used in clinical practice may not produce the three-dimensional control required to produce an acceptable result. This may be particularly evident in cases that require incisor inclination correction, and the clinician should be aware that additional root torque may have to be added to the upper incisors to overcome inaccurate manufacturing dimensions. This clearly reduces the simplicity and effectiveness of a straightwire, preadjusted system and may encourage a clinician to favor the use of zero-base edgewise style treatments.

A clinician, unhappy with a bracket and wire system that consistently produces over retraction of the incisors, may attempt to circumvent this problem by using a preprogramed bracket system with increased incisor torque values. This may be a way around the problem, but it would seem logical that bracket systems will only reproducibly produce their prescription when slots and wires are as intimately fitting as is clinically practical and possible to guarantee by the manufacturers.

CONCLUSIONS

The results of this study indicate that orthodontic bracket slots are all larger than stated by the manufacturers. Slot geometry and the standard of bracket finish varied greatly between the bracket 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.

REFERENCES