A Study of Frictional Resistance in a Premolar Bracket when a Canine Tipping with Two Different Degrees

การศึกษาความต้านทานแรงเสียดทานแพร่เกิดฟันกรมน้อยเมื่อฟันเขี้ยวเอียงแตกกําลังกันสองมุม

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ABSTRACT

The objective of this study was to determine frictional resistance of a premolar bracket with various degrees of wire bending and different wire sizes, simulating canine tipping during canine retraction. Each of eight 0.016 x 0.016-inch and 0.016 x 0.022-inch stainless-steel (SS) wires was ligated to second premolar bracket on the experimental model. Frictional resistance (FS) of the both wire sizes were measured at 0° and 5° wire angle (four wires per group) using universal testing machine with 50 N load cell with pulled speed 10 mm/min for 2 mm at room temperature. According to the results, mean FS of 0.016 x 0.022-inch SS wire at 5° angle had a significantly higher value than mean FS at 0° angle (p-value < 0.034). Statistical difference was not found between the mean FS of 0.016 x 0.016-inch SS wire at 0° and 5° angle (p-value > 0.05). Moreover, wire size had no effect to frictional resistance in the both wire angles.

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อพิจารณาความต้านทานแรงเสียดทานแพร่เกิดฟันกรมน้อยที่ระดับการมองและขนาดลวดที่ต่างกัน ทักษะการเอียงฟันเขี้ยวขณะดึงฟันเขี้ยว โดยใช้ลวดเหล็กกล้าไร้สนิมขนาด 0.016 x 0.016 นิ้วและ 0.016 x 0.022 นิ้ว อย่างละ 8 เส้น ยึดกับแพร่เกิดฟันกรมน้อยที่สองแบบจำลอง วัดความต้านทานแรงเสียดทานของลวดตึงที่ช่องฟันที่มุม 0° และ 5° องศาและ 4 เส้นตัวเครื่องทดสอบแรงสักด่วน 50 นิวตัน ที่อุณหภูมิห้อง พบว่า ค่าเฉลี่ยแรงต้านการเสียดทานของลวดขนาด 0.016 x 0.022 นิ้วที่มุม 5° องศามากกว่าที่มุม 0° องศาอย่างมีนัยสําคัญทางสถิติ (p-value < 0.034) ไม่พบความแตกต่างกันทางสถิติของค่าเฉลี่ยแรงต้านการเสียดทานของลวดขนาด 0.016 x 0.016 นิ้วที่มุม 0° และ 5° องศา (p-value > 0.05) และขนาดลวดตัวเครื่องทดสอบไม่ได้ต่อความต้านทานแรงเสียดทานทั้งสองมุม

Keywords: Canine tipping, Frictional resistance, Wire angle

คําสําคัญ: การเอียงฟันเขี้ยว, ความต้านทานแรงเสียดทาน, มุมแหวก

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Introduction

To close spaces, orthodontic movement could be succeeded with two types of mechanics. The first type was loop mechanics, developed by Burstone, which utilized closing loops for anterior retraction or posterior protraction. Tooth movement occurred via activation of the wire loop. The second type was sliding mechanics, involved either sliding brackets along an archwire or the archwire was moved through brackets and tubes. A problem of sliding mechanics with space closure in orthodontic treatment was frictional resistance, which was a significant factor during tooth movement (Sadowsky and Rossouw, 2003; Kusy and Whitley, 1999a).

The loss of orthodontic force through frictional resistance generation ranged from 12% to 60% and that anchorage loss could result in orthodontic extraction cases (Kusy and Whitley, 1999a). Nanda and Tosun (2010) suggested that friction had importantly impacted on the efficiency of orthodontic mechanics because approximately 40% - 50% of the tooth movement force was lost due to friction. The nature of friction in orthodontics was multifactorial, derived from both multitudes of mechanical and biological factors. Numerous variables had been assessed using a variety of model systems with nearly equally varying results. Angulation between bracket and wire (Kusy and Whitley, 1999b; Ogata et al., 1996; Ho and West, 1991; Lee and Hwang, 2015) and archwire size (Lee and Hwang, 2015; Ireland et al., 1991) were other factors that related to frictional resistance.

Increasing second order angulation between the bracket and the archwire increased the frictional resistance to sliding movement (Kusy and Whitley, 1999b; Ogata et al., 1996; Ho and West, 1991; Lee and Hwang, 2015). This was attributable to binding rather than classical friction (Kusy and Whitley, 1999b). Sliding mechanics could come to a halt because of mechanical notching of the archwire from contact with the edge of the bracket slot in the latter stages of binding (Kusy and Whitley, 1997). The relationship between frictional resistance and second order angulation might not be linear and become more important as the angulation increased (Kusy and Whitley, 1999a). Min Lee et al. (2015) report that with regard to frictional resistance according to the bracket-archwire angle, the rate of an increase in frictional resistance was greater as the angle increased from 5°-10° than when the angle increased from 0°-5°.

Excessive frictional resistance was undesirable in orthodontic treatment, causing uncontrolled tooth movement. Using the orthodontic appliance with understanding frictional resistance was considerable. This knowledge could help us to improve our use of an appliance system, determine in part the efficiency of tooth movement and anchorage control, and eliminate undesirable side effects.

Until now, numerous studies were determined frictional resistance in a canine bracket with various variables. A few number of orthodontic resistance researches reported resistance in the buccal segment. The report by Ireland AJ (1991), investigated friction of steel and ceramic bracket, using stainless steel and NiTi wire in buccal segment attachments with sliding mechanics and Taylor NG (1996),
assessed frictional resistance by sliding different sizes of the wire through brackets and tubes in the buccal segment.

Objectives of the study

The aims of this experiment were to determine the frictional resistance in a premolar bracket when a wire was bent with two different degrees, which simulated clinical situation of canine tipping after retraction, and compare frictional resistances in a premolar bracket when the different sizes of wires are used.

Methodology

The experimental model (Figure 1) which represented upper left buccal segment, was used to measure frictional resistance of a second premolar bracket. This model was designed by our researchers. The model contained 2 rollers; the adjustable and the fixed rollers, which were represented the mesial and the distal wings of a canine bracket respectively. The adjustable roller could give the wire angle. The distance between the fixed roller (center) and the premolar bracket (center) was set at 14 mm.

Two stainless steel (SS) wire sizes, 0.016 x 0.016-inch and 0.016 x 0.022-inch, (ORMCO, Glendora, CA) were pulled through an upper left standard SS brackets with slot 0.018 x 0.025-inch for a premolar (ORMCO, Glendora, CA). A premolar bracket was aligned with a 0.018 x 0.025-inch stainless steel wire and guided bracket-tube on an acrylic template and fixed with light-cured adhesive (Transbond®XT, 3M Unitek, Monrovia, CA). The sample size was calculated from the equation for testing mean of two independent populations. From the previous study (Tselepis et al., 1994), the sample size in each independent group was four per group. The tested wire would be cut into 60 mm length in order to
have the same stiffness among groups and tied to bracket by elastomeric ligation. This experimental model was gripped with the universal testing machine (SHIMADZU, AG-10TA Autograph, Kyoto, Japan) for resistant test. The test was performed with 10 mm/min for 2 mm with 50 N load cell at room temperature. Frictional forces of two wire sizes were recorded in gram-force at 0° and 5° of wire angle. To avoid abrasion or wear after testing, each bracket-wire combination was tested only once. Frictional resistance, measured in the experiment, would be subtracted with mean frictional resistance of the rollers to obtain the real frictional resistance in a premolar bracket before analysis.

**Statistical analysis**

Mean and standard deviation of the frictional resistance for each group of wire sizes and angulations were analyzed with SPSS statistic software version 22 (IBM Inc., Chicago, IL). Normality of the data was evaluated with Kolmogorov-Smirnov test. Statistical differences in each value were assessed by using the independent t-test (level of significance, \( p < 0.05 \)).

**Results**

**Table 1** Comparison of mean and standard deviation of frictional resistance (grams) of two wire sizes and wire angles

<table>
<thead>
<tr>
<th>Angulations</th>
<th>Wire sizes</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.016” x 0.016” SS</td>
<td>0.016” x 0.022” SS</td>
</tr>
<tr>
<td>0°</td>
<td>140.14±10.70</td>
<td>142.38±4.10</td>
</tr>
<tr>
<td>5°</td>
<td>150.96±5.48</td>
<td>151.54±5.28</td>
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</tbody>
</table>

Statistically significant \( p < 0.05 \)
The mean frictional resistance and standard deviation for each group of two wire sizes and angulations were showed in Table 1 and Figure 2. The 0.016 x 0.016-inch SS wire showed no significant difference in frictional resistance between 0° and 5° angle. However, the 0.016 x 0.022-inch SS wire created significantly greater frictional resistance at 5° angle than 0° angle ($p$-value < 0.034). Moreover, no statistically significant difference of frictional resistance was found between two wire sizes in the both angles.

Discussion

This experiment simulated the main archwire bending caused by the tipping of the canine bracket during canine retraction with sliding mechanics and the frictional resistance of premolar bracket was recorded. In our study, the larger wire size provided non-significantly greater frictional resistance than the smaller wire size. This finding was inconsistent with previous studies (Frank and Nikolai, 1980; Nanda, 1997; Tselepis et al., 1994; Kapila et al., 1990; Thorstenson and Kusy, 2002) that the larger size associated with greater frictional resistance than the smaller size. The wire with higher stiffness would produce higher normal force between bracket edge and wire. Therefore, increasing in the stiffness of the larger wire size resulted in the growth of frictional resistance (Smith et al., 2003). The elastomeric ligature with greater stretching on the larger wire was another contributing factor. The greater force on the wire was produced and caused the frictional resistance increases (Smith et al., 2003). However, the results of this present study was similar to the results from the previous study by Willems et al. (2001), which reported in the passive configuration that the larger wire produced non-significantly greater frictional resistance in the 0.018-inch bracket slot. Drescher et al. (1989) suggested that frictional forces were influenced by the vertical dimension of the wire. The 0.016 x 0.016-inch and 0.016 x 0.022-inch...
wire sizes, which were used in the present study, had the same vertical dimension. This might be a contributing factor.

Several studies confirmed that the increased in wire-bracket angulation could generate greater frictional resistance (Frank and Nikolai, 1980; Tselepis et al., 1994; Bednar et al., 1991). Tselepis et al. (1994) reported that at 10° bracket-wire angulation under both wet and dry conditions produced significantly greater frictional resistance than 0° for almost all bracket-wire combinations. Liewsaitong P. and Techalertpaisarn P. (2019) investigated frictional resistance of posterior segment with different degrees of molar tube tipping. They found that an increase in tube/wire angulation created higher frictional resistance of posterior segment. This present study showed that frictional resistance of premolar bracket increased when the wire angulation increased. The different value was statistically significant in the larger wire size group. This might be explained by the clearance between wire and bracket. The wire-bracket slot play of 0.016 x 0.016-inch wire in 0.018-inch slot was greater than 0.016 x 0.022-inch wire in 0.018-inch slot (Johnson, 2013). Therefore, the real wire-bracket angle of 0.016 x 0.022-inch wire was greater than 0.016 x 0.016-inch wire, resulting in greater frictional resistance when wire angle was increased.

These findings suggested that canine angulation could affect the frictional force of a premolar bracket. Therefore, to obtain the optimal force and effective tooth movement during canine retraction, the degrees of canine angulation and created frictional resistance in buccal segment should be considered.

Conclusions
Frictional resistance of buccal segment was influenced by canine angulation with 0.016 x 0.022-inch SS in 0.018 x 0.025-inch SS bracket slot. The slight difference in wire size did not affect the frictional resistance with the small bracket-wire angulation.

References


