Noncompliance Unilateral Maxillary Molar Distalization: A Three-Dimensional Tooth Movement Analysis

Anestis Mavropoulos; Korkmaz Sayinsu; Ferdi Allaf; Stavros Kiliaridis; Moschos A. Papadopoulos; Ahmet Ozlem Keles

Abstract: The aim of this prospective study was the three-dimensional (3-D) analysis of tooth movements after unilateral upper molar distalization by means of a noncompliance intraoral appliance, the Keles slider. This appliance exerts a distalizing force of 150 g at approximately the level of the center of resistance of the upper first molar. Twelve patients (six girls and six boys with a mean age of 13.1 years) with a unilateral Class II molar relationship participated in the study. Dental casts were taken immediately before placement and after removal of the appliance. The casts were digitized using a 3-D surface laser scanner and superimposed on a predefined area of the palate. The average unilateral upper first molar distal movement was 3.1 mm (range: 2.4 to 5.3 mm). Anchorage loss was expressed by a 2.1 mm (range: 0.8 to 3.8 mm) proclination of the central incisors and a 6.1° mesial inclination of the ipsilateral first premolar (range: 1.7° to 12.3°). There was approximately 1 mm of midline deviation toward the contralateral side and a 1.6 mm (range: 0.8 to 2.3 mm) buccal displacement of the contralateral first premolar. A substantial variation was observed among patients. Noncompliance unilateral upper molar distalization was an efficient treatment approach. There was, however, a substantial anchorage loss. Case selection is strongly recommended because significant anterior crowding, ectopic canines, or spacing can lead to significant anchorage loss. (Angle Orthod 2006;76:382–387.)

Key Words: Class II malocclusion; Noncompliance treatment; Unilateral distalization; Three-dimensional cast superimposition; Keles slider

INTRODUCTION

For many years asymmetric headgear force application was used routinely for the unilateral distalization of maxillary molars. It has, however, been shown that such a force delivery system unavoidably contains a lateral component, which can result in a posterior crossbite. Another serious disadvantage of headgear treatment is the need of patient compliance, which is sometimes difficult or impossible to obtain. Over recent years, several noncompliance methods to move molars distally have gained popularity. A number of previous investigations evaluated the effectiveness of these treatment modalities on lateral cephalometric radiographs. They all reached the conclusion that the distal movement of the upper molars is accompanied by distal tipping and a considerable loss of anchorage with mesial displacement and tipping of the anterior anchorage unit. There are a few case reports but yet no conclusive evidence on the tooth movements that occur when the same appliances are used unilaterally after some modification.

It is extremely difficult to accurately evaluate unilateral tooth movements on cephalometric radiographs because both sides are projected simultaneously on the midsagittal plane. Recent advances in the application of three-dimensional (3-D) imaging for dental purposes have made possible a more accurate as-
TABLE 1. Detailed Information for All Patients Participating in This Study

<table>
<thead>
<tr>
<th>Patient</th>
<th>Pretreatment Age (y)</th>
<th>Treatment Duration (wk)</th>
<th>Presence of Upper Second Molars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.0</td>
<td>16.0</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>14.1</td>
<td>15.5</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>12.4</td>
<td>15.5</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>14.1</td>
<td>20.0</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>13.7</td>
<td>18.5</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>10.8</td>
<td>16.5</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>13.8</td>
<td>19.0</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>13.5</td>
<td>17.5</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>10.7</td>
<td>19.5</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>14.2</td>
<td>21.5</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>13.5</td>
<td>16.0</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>12.5</td>
<td>14.5</td>
<td>-</td>
</tr>
</tbody>
</table>

Assessment of tooth positional changes on dental casts. The reliability of generating 3-D dental images using surface laser scanners has been investigated, and it has been demonstrated that these devices have great research potential in orthodontics because of their ability to yield accurate and reproducible data. The assessment of differences between direct measurements made on dental casts and those made on computer reconstructed images generated by surface laser scanners showed that these devices are highly accurate for dental cast analysis.

The aim of this prospective study was the 3-D analysis of tooth movements after the noncompliance unilateral distalization of the maxillary molars by means of the Keles slider. By incorporating the whole contralateral side in the anchorage unit, unilateral distalization could theoretically be accomplished with less anchorage loss than with bilateral distalization.

MATERIALS AND METHODS

Subjects

Twelve patients (six girls and six boys with a mean age of 13.1 years) with unilateral Class II molar relationship were treated with this appliance during the first phase of their overall orthodontic treatment. In all but two cases, upper second molars had already erupted. Class I molar relationship was achieved on both sides in all cases during an average treatment period of 17.5 weeks (Table 1). Maxillary dental casts were taken immediately before placement and after removal of the appliance.

Intraoral appliance

The Keles slider (Patent no: US 6,626,665 B1) was modified for unilateral use. In summary, the appliance consisted of an active unit and an anchorage unit.

FIGURE 1. (A) Occlusal view of the intraoral noncompliance appliance used in this investigation for the distalization of the upper molars. (B) Diagrammatic representation of the point of force application (F, force; CR, center of resistance). (Figure 1A). The molar to be distalized was banded, and a tube (Dentaurum 607-301-00, Ispringen, Germany) was soldered parallel to the occlusal plane on the palatal side of the band at the level of the molar’s center of resistance (Figure 1B). A heavy Ni-Ti coil spring (Leone C1214, Firenze, Italy) was compressed by means of a screw (3M Unitek, Gurin lock, Monrovia, Calif) between this tube and the anchorage unit, which was a modified Nance button attached to bands on the first premolars and the contralateral molar.

This configuration resulted in the molar receiving an initial force of approximately 150 g with a force vector located very close to the level of its center of resistance. Patients were seen every month, and the screw was reactivated every 2 months with a special wrench (3M Unitek, Gurin lock wrench). After the removal of the appliance, the coil spring was removed, the screw positioned mesially to the tube, the wires connecting the Nance button to the premolars were cut off and their bands were removed. This way the same Nance appliance was used to stabilize the molars until after the retraction of the canines.

Three-dimensional cast superimposition and analysis

The method used for the 3-D analysis of tooth movements has been described previously and validated. In summary, all casts were digitized using a 3-D surface laser scanner (Laserscan 3-D Pro, Willy-tec GmbH, Gräfelfing, Germany) (Figure 2A). The ob-
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FIGURE 2. (A) The three-dimensional (3-D) laser scanner assembly. (B) An example of a cast occlusal surface as seen on screen after having been three-dimensionally scanned using this apparatus. The delineated area corresponds to the region where the 3-D superimposition was performed in this study. (From Mavropoulos et al 2005,23 with permission of Elsevier Health Sciences).

tained holograms were then transferred through a video acquisition system to a personal computer (Siemens Expert, Siemens AG, Munich, Germany), controlled by the SCAN-3-D software (Willytec GmbH). The pre- and posttreatment 3-D images were superimposed on a predefined area in the palate (Figure 2B). This area of superimposition included the anterior part of the palate comprising the palatal rugae and a zone in the palate along the midline raphe.

The result was a new hologram, the product of the fusion of the two initial holograms after their superimposition. To make the results clinically more relevant, tooth movements were measured along the axis where they actually took place, ie, the lateral arch segments. The vertical changes were measured by placing the cursor over the mesial fossa of the first premolar and over the central fossa of the first molar to register the differences in the z-axis.

Error of the method

The whole measurement procedure was repeated 2 to 4 weeks after the initial measurements. The error of both methods was calculated according to the formula: Se = \sqrt{\sum d^2/n}, where \Sigma d^2 is the sum of the squared differences between pairs of recordings and n is the number of duplicate measurements.24 It did not exceed 0.25 mm and 1.6° for the linear and angular measurements, respectively.

RESULTS

The software used to measure the data obtained from the 3-D cast digitization gave us the possibility to construct the mean tracing combining the data from the entire sample (Figure 3). The total and effective sagittal movements of the first molars, first premolars, canines, and incisors, as well as the vertical, lateral, tipping, and rotational changes are shown in Table 2. The distal movement of the first molars was a mean of 3.1 mm. Individual differences were significant with effective distal movement ranging from 2.4 to 5.3 mm. The distalization of the upper first molars was accompanied by minimum distal tipping (4.0°), buccal displacement (1.3 mm), intrusion (1.1 mm), and mesial rotation (5.1°).

Loss of anchorage was demonstrated on both the ipsilateral and the contralateral sides. The ipsilateral first premolar moved mesially 3.2 mm. This was accompanied by mesial tipping (6.1°), negligible palatal displacement (0.2 mm), extrusion (0.6 mm), and mesial rotation (4.5°). Individual variation was also evident with the mesial movement ranging from 2.4 to 5.3 mm. The ipsilateral canine, as part of the anterior anchorage unit, was also affected. It moved a mean of 3.5 mm mesially and 0.6 mm buccally. The central incisors were proclined a mean of 1.7 mm (range 0.8 to 3.5 mm). It is interesting to note that the upper dental midline moved toward the contralateral side by 1.2 mm on average.

The contralateral side did not remain unaffected. The contralateral canine moved buccally (1.3 mm), whereas the first premolar moved slightly distally (0.4 mm), buccally (1.6 mm), and rotated distally (3.3°). The contralateral first molar was not affected apart from a slight distal rotation of 1.0° on average. It appeared that the whole anterior anchorage unit was rotated toward the contralateral side with the contralateral first molar as the center of rotation.

DISCUSSION

The intraoral appliance used in this study was successfully used for the unilateral distalization of maxillary first molars into a Class I molar relationship in all cases. In all but two cases, the second molars had
Unilateral upper molar distalization is a treatment technique that involves the distal movement of one or more upper molars to create space for orthodontic or orthopedic treatment. The article discusses the effects of unilateral molar distalization on anchorage units and the presence of second molars.

**TABLE 2. Evaluation of Movement of All Teeth Under Investigation After the Use of the Noncompliance Molar-distalizing Intraoral Appliance.**

<table>
<thead>
<tr>
<th>Active unit</th>
<th>Total Movement</th>
<th>Effective (Mesiodistal) Movement</th>
<th>Mesiodistal Tipping</th>
<th>Vertical Movement</th>
<th>Lateral Movement</th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>First molar</td>
<td>3.7 ± 1.0 mm</td>
<td>−3.1 ± 0.9 mm</td>
<td>−4.0 ± 3.4°</td>
<td>−1.1 ± 0.9 mm</td>
<td>+1.3 ± 1.6 mm</td>
<td>+5.1 ± 4.7°</td>
</tr>
<tr>
<td>Anchorage unit (ipsilateral side)</td>
<td>(2.5 to 5.6)</td>
<td>(−2.4 to −5.3)</td>
<td>(−9.9 to −0.4)</td>
<td>(−2.3 to +0.5)</td>
<td>(−1.7 to +3.1)</td>
<td>(+0.1 to +12.4)</td>
</tr>
</tbody>
</table>

| First premolar | 3.4 ± 1.2 mm   | +3.2 ± 1.1 mm                   | +6.1 ± 4.2°         | +0.6 ± 0.8 mm    | −0.2 ± 1.3 mm    | +4.5 ± 4.7° |
| Canine        | 3.7 ± 1.3 mm   | −3.5 ± 1.1 mm                   | —                   | —                | —                | —         |
| Midline       | 2.1 ± 1.1 mm   | +1.7 ± 0.8 mm                   | —                   | —                | —                | —         |

<table>
<thead>
<tr>
<th>Anchorage unit (contralateral side)</th>
<th>Total Movement</th>
<th>Effective (Mesiodistal) Movement</th>
<th>Mesiodistal Tipping</th>
<th>Vertical Movement</th>
<th>Lateral Movement</th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine</td>
<td>1.5 ± 0.6 mm</td>
<td>−0.1 ± 0.7 mm</td>
<td>—</td>
<td>—</td>
<td>+1.3 ± 0.6 mm</td>
<td>—</td>
</tr>
<tr>
<td>First premolar</td>
<td>1.6 ± 0.8 mm</td>
<td>−0.4 ± 0.5 mm</td>
<td>+0.5 ± 1.9°</td>
<td>+0.5 ± 0.6 mm</td>
<td>+1.6 ± 0.6 mm</td>
<td>−3.3 ± 7.6°</td>
</tr>
<tr>
<td>First molar</td>
<td>0.2 ± 0.1 mm</td>
<td>0.0 ± 0.1 mm</td>
<td>+0.1 ± 0.6°</td>
<td>0.0 ± 0.3 mm</td>
<td>+0.1 ± 0.1 mm</td>
<td>−1.0 ± 1.2°</td>
</tr>
</tbody>
</table>

| Values are Given as Mean ± SD (Range in parentheses)* |

| First molar | 0.2 to 0.3 mm | 0.0 to 0.1 mm | +0.1 to 0.6° | 0.0 to 0.3 mm | +0.1 to 0.1 mm | −1.0 ± 1.2° |
| Anchor unit (contralateral side) | Canine | First premolar | First molar | | |

* +/− signs: + for mesial, buccal, or intrusive, − for distal, palatal, or intrusive movement; R, right; L, left; * Toward the contralateral side.

Additional information includes the importance of second molars and their effects on anchorage loss. The presence of second molars can increase anchorage loss and less tipping of the molar than bilateral distalization seems to be associated with less anchorage loss and less tipping of the molar than bilateral distalization. This may be due to the size of the anchorage unit and the point of force application (at approximately the level of the molar’s center of resistance) in the case of the appliance we used for the unilateral molar distalization. The differences are not very large, but in this unilateral study, the contralateral first molars were also part of the anchorage unit.
unilateral molar distalization with the Keles slider.\textsuperscript{32} The present investigation revealed more anchorage loss in comparison with that previous study, which used lateral cephalometric radiographs. This could be related not only to the different measurement approach but also to the differences in the anchorage unit size and design. In that previous study, the anchorage unit consisted of a Nance appliance, which covered the anterior part of the palate and the cingulum of the anterior teeth (anterior bite plane). An increased surface area in contact with the palatal mucosa and the anterior teeth might explain less anchorage loss.

Individual variation was an important finding of this investigation. The absence of contact points of the anchoring teeth, as in the case of ectopic canines, or irregularity between spaced or severely malaligned teeth probably diminished the capability of the anchorage unit to resist forward movement. Another factor that could partially explain individual variation is the anatomical characteristics of the palatal vault. Patients with insufficient seating of the Nance button because of a reduced palatal vault inclination might not be suitable candidates for noncompliance maxillary molar distalization.

It has been shown previously that the palatal rugae can be used as reference landmarks for the assessment of tooth movements.\textsuperscript{33–35} The zone of the palate along the midline raphe was also used because it significantly enhanced the reliability of the 3-D superimposition.\textsuperscript{36} The previous studies using models to assess orthodontic movements used a photographic approach by projecting the rugae on the occlusal plane. This, unfortunately, implies a considerable methodological error because it depends entirely on the assumption that the occlusal plane remains unchanged, which is rarely the case. The use of a 3-D superimposition helps overcome these problems.

In this study, the zone of the palate along the midline raphe was also used because it has been shown to enhance the reliability of the whole procedure.\textsuperscript{36} The superimposition area is thus a multiplanar surface with uniform relief characteristics clearly and easily defined in the three planes of space even in the case of partially missing information (eg, errors in the pouring technique or elastic deformation of the palatal rugae because of the Nance appliance). Further studies would be needed to compare the molar position at the end of distalization to its position at the end of the orthodontic treatment. On the basis of our clinical observations, we recommend a 2-month stabilization of the distalized molar to allow the distal drift of the premolars and canines of the ipsilateral side.

CONCLUSIONS

- The noncompliance intraoral appliance, Keles slider, was successful in achieving unilateral upper molar distalization into a Class I molar relationship in all cases under investigation. Close to parallel molar distalization was achieved on average.
- Anchorage loss accounted for half the space created between the first molar and the first premolar, but substantial variation was present among patients.
- Case selection is strongly recommended because significant anterior crowding, ectopic canines, or spacing can lead to significant anchorage loss.
- The advantage of the Keles slider is that it can be easily converted into a sort of Nance holding appliance at the end of molar distalization.

REFERENCES

13. Papadopoulos MA, Mavropoulos A, Karamouzos A. Cephalometric changes following simultaneous first and second


