# Comparison of maxillary canine retraction with sliding mechanics and a retraction spring: a three-dimensional analysis based on a midpalatal orthodontic implant

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SUMMARY The purpose of this study was to compare maxillary canine retraction with sliding mechanics and a Ricketts canine retraction spring, using a midpalatal orthodontic implant as a measuring reference. Eight patients (three males and five females) were examined. Because maximum posterior anchorage was required in all subjects, osseointegrated midpalatal implants were used. To examine tooth movement, impressions of the maxillary arch were made at each appointment and cast in die stone. A threedimensional (3D) surface-scanning system using a slit laser beam was used to measure the series of dental casts.

The results demonstrated that 3D analysis of tooth movement based on a midpalatal orthodontic implant provided detailed information on canine retraction. The results also suggested that a canine retracting force of 1 N or less was more effective not only for sliding mechanics but also for the retraction spring. However, the sliding mechanics approach was superior to the retraction spring with regard to rotational control.

# Introduction

Orthodontic tooth movement is greatly influenced by the characteristics of the applied force, including its magnitude, direction, moment-force ratio, and the physiological condition of the periodontal tissue of individual patients (Hayashi et al., 2002). The characteristics of the applied force also depend on the orthodontic appliance used (Proffit, 1992). Canine retraction is a common orthodontic procedure, and many retraction appliances have been used (Ricketts, 1974; Burstone, 1982; Gjessing, 1985; Samuels et al., 1993; Tripolt et al., 1999). Generally, the undesirable side-effects observed in canine retraction involve friction mechanics, e.g. tipping, binding, and a lack of vertical control, as well as the risk of anchorage loss and incisor extrusion (Gjessing, 1985). To address these problems, frictionless mechanics have been used (Rhee et al., 2001).

There has been considerable discussion concerning the relative merits of friction and frictionless mechanics (Ziegler and Ingervall, 1989; Rhee *et al.*, 2001). However, the optimal magnitude of force for tooth movement has not yet been identified (Iwasaki *et al.*, 2000). In measuring tooth movement, an immovable reference has not been identified and the reliability of the measuring methods has varied. However, it appears from recent studies that these problems will shortly be solved. The optimal magnitude of force for tooth movement is probably 1 N or less (Iwasaki *et al.*, 2000). Furthermore, osseointegrated implants in the midpalatal region have

been used to provide anchorage in orthodontic therapy (Martin *et al.*, 2002; Tosun *et al.*, 2002). At present, such implants are the best measuring reference.

The purpose of this study was to compare maxillary canine retraction with sliding mechanics and a Ricketts canine retraction spring using a midpalatal orthodontic implant as a measuring reference.

### Subjects and methods

Eight patients (three males and five females, mean age 23 years 2 months; range 19 years 4 months to 29 years 2 months) from the orthodontic clinic of the Health Sciences University of Hokkaido were selected. All subjects were informed of the experimental protocols and signed an informed consent form that was previously approved by the Institutional Review Board.

Because maximum posterior anchorage was required in all eight subjects, osseointegrated midpalatal implants (Institute Straumann AG, Waldenburg, Switzerland) were used. Three months after implant placement, as a healing period, impressions were made using a conventional technique for transferring the impression post (molar bands if necessary) to a dental cast. A 1.2 mm square stainless steel rigid wire was soldered to mesh plates on the molar palatal surface or to molar bands and connected to the implant abutment on the casts. As a registration reference on the dental casts for three-dimensional (3D) tooth movement analysis, three markers (steel ball bearings; diameter 2.778 mm) were soldered to the rigid wire (Figure 1). After the laboratory procedures, the rigid wire was fixed to the palatal implant. Orthodontic bands were cemented and the mesh plates were bonded to the first molars. In all subjects, the maxillary first premolars were extracted as part of treatment. Overall, canine retraction was started approximately 4 months after implant placement.

#### Sliding mechanics

The labial arch was made of 0.45 mm (0.018 inch) stainless steel wire and included the second molars, first molars, second premolars, canines and incisors. Standard edgewise brackets (Micro-LOC, Tomy International Inc., Tokyo, Japan) with a  $0.022 \times 0.028$  inch slot were used. The retraction force was obtained from a nickel titanium (NiTi) closed-coil spring (Sentalloy, Tomy International Inc.). The Sentalloy closed-coil spring was light grade (blue), and the manufacturer reported that it provided a force of 1 N when stretched within a range of 3-15 mm. To confirm this characteristic, each closed-coil spring was measured with a tension gauge (dial tension gauge, Mitutovo, Kawasaki, Japan). The NiTi closed-coil spring was engaged between the first molar tube hook and the sliding hook placed mesially on the canine bracket. The NiTi closed-coil springs were stretched weekly to a length of 12 mm (Figure 2a).

## Retraction spring

A Ricketts maxillary canine retractor (Cuspid Retractor, RMO, Denver, USA) and standard edgewise brackets with an  $0.018 \times 0.025$  inch slot were used. These encompassed the second molars, first molars, second premolars, and canines. A gable angle of 45 degrees in the canine portion and an anti-rotation angle of 45



Figure 1 Three markers soldered to the rigid wire as a registration reference on the dental casts.



Figure 2 (a) Sliding mechanics and (b) retraction spring used in the study.

degrees were used in this study. The retraction force of the spring was approximately 1 N, as measured with the tension gauge. Because the force decreased with space closure, the springs were reactivated each week to 1 N (Figure 2b).

#### Dental cast analysis

To examine tooth movement, impressions of the maxillary arch were made at each appointment with hydrophilic vinyl polysiloxane impression material (JM Silicone, J. Morita, Tokyo, Japan) using customized acrylic impression trays lined with tray adhesive, and cast in die stone (Noritake super rock, J. Morita). A 3D surface-scanning system using a slit laser beam (VMS-150RD, UNISN, Osaka, Japan) was used to measure the series of dental casts. The system consisted of a slit laser projector, two charge-coupled device cameras, an auto-rotating mounting unit, and a personal computer with post-processing software (Figure 3). The accuracy of this measuring device has previously been reported (Hayashi et al., 2002): the resolution in the X direction was 0.01 mm, and the Z direction could be measured to within  $\pm 0.05$  mm. The 3D shape data analysis system consisted of a graphical workstation (Zx1, Intergraph, Huntsville, USA) and data processing and analysing software (I-DEAS, SDRC, Milford, USA).



Figure 3 The three-dimensional surface-scanning system.

The position of the dental casts on the auto-rotating units during scanning was arbitrary. To estimate tooth movement three dimensionally based on the 3D shape, a common co-ordinate system had to be established. Several immovable structures that were common to each model were chosen as reference points for superimposition (Yamamoto et al., 1991). In this study, the three markers (steel ball bearings) soldered to the rigid wire that fixed the midpalatal implant were selected as registration structures, as they were considered to be stable during treatment. Registration was carried out automatically by the least-squares method. The discrepancy between normalized images of the maxillary canine was recognized as tooth movement. The movement of an individual tooth could be expressed by a translation vector and a rotation matrix obtained by automatic registration using the least-squares method for the 3D shapes before and after tooth movement.

To represent the change in the position of a canine in 3D space, six parameters were introduced. These were defined by the translation  $\Delta x$ ,  $\Delta y$ , and  $\Delta z$ , and by the rotation  $\psi$ ,  $\theta$ , and  $\phi$ , which denote the flaring, tipping, and rotation angles, respectively (Figure 4). The significance of the differences between the results with the two types of mechanics was tested with a two-sample *t*-test.

# Results

As shown in Table 1, the amount of distal movement of the canine crown tip with the sliding mechanics was 3.62 mm per 2 months. With the retraction spring, this value was 3.95 mm per 2 months. These values were not significantly different (P = 0.1583). The canine tipping values per 2 months were 7.94 degrees with the sliding mechanics and 7.89 degrees with the retraction spring. Again, these values were not significantly different



**Figure 4** The co-ordinate system for analysing canine retraction by automatic registration. The six parameters were defined by the translation  $\Delta x$ ,  $\Delta y$ , and  $\Delta z$ , and by the rotation  $\psi$ ,  $\theta$ , and  $\phi$ , which denote the flaring, tipping, and rotation angles, respectively.

(P = 0.9731). However, the retraction spring caused significantly greater rotation of the canine than the sliding mechanics (22.06 versus 4.07 degrees per 2 months; P < 0.0001).

## Discussion

#### Measuring accuracy

To examine the mean fitting error for the automatic registration of 3D shapes, the mean 3D distance from each point of the tooth to its corresponding point (most adjacent point) on the second registered shape was calculated using the least-squares method for each phase. The mean fitting error in the canine was  $0.05 \pm 0.01$  mm (range 0.03-0.07 mm). Therefore, the accuracy of the present method is sufficient for analysis of tooth movement.

## Canine retraction mechanics

With sliding mechanics, a sliding tooth along an archwire requires at least 0.002 inches of clearance,

Sliding mechanics		Retraction spring		Р	
Mean	SD	Mean	SD		
3.62	0.19	3.95	0.34	NS	
7.94	1.83	7.89	2.32	NS	
4.07	2.52	22.06	3.73	***	
	Sliding mechanic Mean 3.62 7.94 4.07	Sliding mechanics   Mean SD   3.62 0.19   7.94 1.83   4.07 2.52	Sliding mechanicsRetraction springMeanSDMean3.620.193.957.941.837.894.072.5222.06	Sliding mechanics Retraction spring   Mean SD Mean SD   3.62 0.19 3.95 0.34   7.94 1.83 7.89 2.32   4.07 2.52 22.06 3.73	

**Table 1** The amount of distal movement (mm) and tipping and rotation (degree) of a canine per 2 months of treatment.

\*\*\* P < 0.0001; NS, non-significant.

SD, standard deviation.

and even more clearance may be desirable. The greater strength of an 0.018 inch archwire compared with a 0.016 inch wire can be an advantage in sliding teeth. The 0.018 inch wire should offer excellent clearance in a 0.022 inch slot bracket (Proffit, 1992). Stainless steel brackets have been found to have lower coefficients of friction than ceramic brackets, and stainless steel wire to generate less friction than NiTi wire (Pratten *et al.*, 1990). Therefore, in this study, the labial arch was made of 0.018 inch stainless steel wire and standard edgewise brackets with a  $0.022 \times 0.028$  inch slot were used.

With a retraction spring (Ricketts retractor), it has been recommended that approximately a 90 degree gable be placed in the canine arm of the spring at its initial placement (Ricketts, 1974). It has been reported that a gable angle of 45 degrees in the canine portion gives a moment-to-force ratio of 6.6 for a spring with a 13 mm span when activated to produce a retraction force of 0.5 N (Shaw and Waters, 1992). Using the 3D analysis of dental casts, no significant difference was found between groups with and without an anti-rotation bend of 20 degrees (Yamamoto et al., 1991). In the present study, a 45 degree gable angle in the canine portion and a 45 degree anti-rotation angle were used. However, these values, and especially the gable angle, were still less than the ideal values required for bodily tooth movement with a retraction force of 1 N.

#### Distal movement of a canine

The efficiency of canine retraction using sliding mechanics with an elastic chain has been compared with that of a Gjessing retraction spring (Ziegler and Ingervall, 1989). The amount of canine retraction per 30 days of treatment was 1.41 mm with sliding mechanics and 1.91 mm with the retraction spring. Generally, retraction forces greater than 3 N result in a lag phase caused by necrotic tissue at the periodontal ligament (Gianelly, 1969). The retraction force of 1 N used in the present investigation resulted in tooth movement without a lag phase and occurred at clinically significant velocities with both sliding mechanics and the retraction spring (Table 1).

A previous study also suggested that the canine is retracted faster and with less distal tipping with a retraction spring than with sliding mechanics, and the retraction spring is not superior to sliding mechanics for controlling canine rotation (Ziegler and Ingervall, 1989). In another comparison of sliding mechanics with a NiTi closed-coil spring and a Gjessing retraction spring, the results suggest that the sliding mechanics approach is superior to the retraction spring in terms of rotation control, while the retraction spring is more effective at reducing tipping (Rhee et al., 2001). Although the present findings support the above previously reported tests regarding the control of canine rotation during retraction, no significant difference was found in the control of tipping between the two techniques. There are several possible explanations for this result. For example, the canine retraction force of 1 N was less than that used in other studies. With sliding mechanics, a swing effect did not occur, resulting in a light continuous force. Furthermore, at low loads, saliva can act as a lubricant (Pratten et al., 1990).

# Conclusion

A 3D analysis of tooth movement based on a midpalatal orthodontic implant as a measuring reference was established, which can provide detailed information on canine retraction and may become a useful tool for evaluating orthodontic appliances. The results suggest that a canine retracting force of 1 N or less may be more effective not only with sliding mechanics but also with a retraction spring. However, sliding mechanics give superior rotational control compared with the retraction spring. However, it is necessary to consider the limitations of this small study. An investigation with a larger sample size will be required to support the findings.

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