Original Article

Interseptal bone reduction on the rate of maxillary canine retraction

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ABSTRACT

Objective: To propose and evaluate a novel surgical approach with minimal trauma, termed interseptal bone reduction, combined with the use of a conventional orthodontic fixed appliance to accelerate canine retraction.

Materials and Methods: A split-mouth design study was conducted in 18 female subjects (mean age, 21.9 years) whose bilateral upper first premolars were extracted and who subsequently received canine distalization. The extraction socket on the experimental side was deepened, and interseptal bone distal to the maxillary canine was reduced in thickness using a surgical bur; conventional extraction was performed on the control side. The canines were then distalized using elastomeric chains on both the labial and palatal sides, with a net force of 150 g. The extent of canine movement and rotation was determined from study models, and the angulation was analyzed based on lateral cephalograms.

Results: A Wilcoxon signed rank test demonstrated that the extent of canine movement in the mesio-distal direction after 3 months was significantly greater on the experimental side than on the control side (5.4 and 3.4 mm, respectively, $P = .002$). However, there was no statistically significant difference in canine angulation or rotation after 3 months between the experimental and control sides.

Conclusions: In combination with the use of conventional orthodontic appliances, interseptal bone reduction can enhance the rate of canine movement when interseptal bone is sufficiently reduced in both thickness and depth following surgical criteria. (*Angle Orthod.* 2014;84:839–845.)

KEY WORDS: Accelerated tooth movement; Mini-implant; RAP; Surgical approach; Optimum force

INTRODUCTION

Orthodontic tooth movement is a process whereby the application of a force induces bone resorption on the pressure side and bone apposition on the tension side.[1,2] The rate of biologic tooth movement in response to the application of optimum mechanical force is approximately 1 to 1.5 mm over 4 to 5 weeks.[3] Therefore, in cases of maximum anchorage premolar extraction, canine distalization usually takes 6 to 9 months, leading to an overall treatment time of 1.5 to 2 years. Many attempts have been made to shorten the duration of orthodontic treatment; one such mechanical manipulation is dentoalveolar surgery, which includes techniques such as distraction of the periodontal ligament, dentoalveolar distraction osteogenesis, periodontally accelerated osteogenic orthodontics, and other modified surgical techniques. With these techniques, active orthodontic treatment can be completed within less than 1 year. However, most of these techniques require flap surgery to perform invasive corticotomy or osteotomy and the use of

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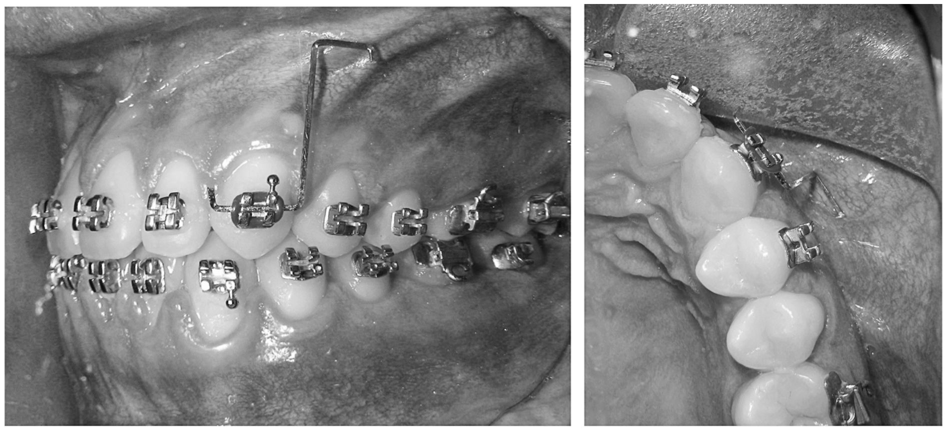

Figure 1. Position of the surgical guide wire, as shown intraorally.

heavy orthodontic force to move teeth rapidly, which may increase the risk of periodontal problems and pulpal vitality loss over the longer term. Therefore, the study of less invasive dentoalveolar surgical approaches combined with the use of conventional orthodontic appliances with optimum force to accelerate the rate of tooth movement is currently of significant interest.

The process of rapid tooth movement facilitated by dentoalveolar surgery has been explained by a variety of mechanisms. For example, Liou and Huang[4] stated that the canines could be rapidly distracted after dentoalveolar surgery, as the first premolar extraction socket was less resistant and not yet refilled by solid bone tissue, which takes at least 3 weeks to form. However, using this technique, the interseptal bone distal to the canine, which was surgically undermined to weaken its strength, was bent and fractured by the heavy force generated by the distraction device.

The aim of this study was to propose and evaluate a novel surgical approach with minimal trauma distal to the canine combined with the use of a conventional orthodontic appliance with optimum force to increase the rate of maxillary canine retraction.

MATERIALS AND METHODS

The study was approved by the ethical committee of the Faculty of Dentistry at the Prince of Songkla University. Adult patients receiving orthodontic treatment in the Orthodontic Clinic at the Dental Hospital, Prince of Songkla University, had been indicated for maxillary first premolar extraction and bilateral maxillary canine distalization and demonstrated good oral hygiene, with probing depth values not exceeding 3 mm. This study was a split-mouth design in which the experimental side was allocated by randomization.

Each patient was fitted with Roth's prescription preadjusted edgewise brackets (3M Gemini metal brackets; 3M Unitek, Monrovia, Calif). The teeth were aligned and leveled until complete on 0.016 $\times$ 0.022–inch stainless-steel archwire. Mini-implants (#SH 1413-07 AbsoAnchor; Dentos, Daegu, Korea) were placed between the roots of the second premolars and first molars on both the left and right sides about 1 month before the surgical procedure to observe the stability of mini-implants.

Surgical Procedure

Traditional extraction of the first premolar was performed on one side as a control, while extraction combined with interseptal bone reduction was performed on the experimental side. The surgical procedure was performed by two surgeons inside the extraction socket of the maxillary first premolar without flap surgery under local anesthesia. The extraction socket was deepened to the length of the canine apex, and the interseptal bone distal to the canine was reduced to 1 to 1.5 mm in thickness using round and cylindrical carbide burs. If present, the interradicular septal bone of the socket was also removed. The first premolar extraction socket was surgically widened in the buccopalatal dimension along the curvature of the root of the canine. The bur was held parallel to the surgical guide wire (Figure 1) and advanced buccopalatally, while the alveolar crest of interseptal bone was left untreated (Figure 2). A periapical radiograph was taken prior to and after the surgical procedure (Figure 3).

Orthodontic Mechanics

The mechanism for canine distalization consisted of a power arm fabricated from 0.021 $\times$ 0.025–inch stainless-steel archwire attached to the mesial end of each canine bracket, with the height of the hook approximately the same as the vertical position of the mini-implant, to produce a vector force parallel to the occlusal plane. The power arm was inserted into the

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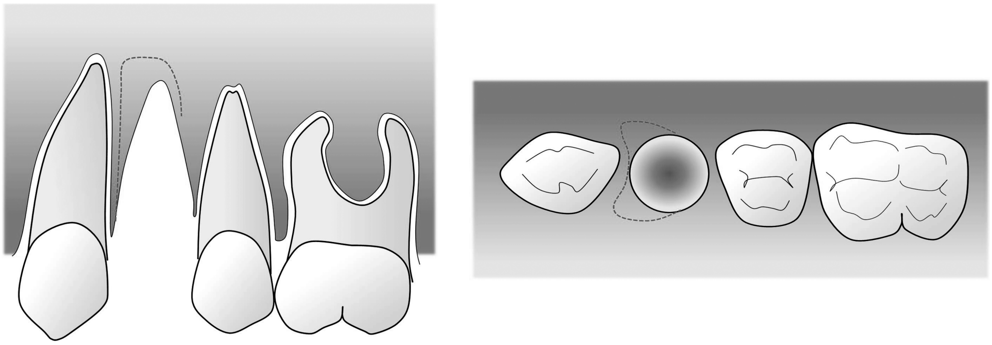

Figure 2. Interseptal bone reduction technique: Dashed lines indicate the areas of interseptal bone reduction.

canine bracket, and an elastomeric chain attached to the mini-implant was used to retract the canine. In addition, a lingual button (3M Unitek) was placed on the palatal surface of each canine and first molar. Retraction force was applied on the palatal side by attaching an elastomeric chain (Alastik™; 3M Unitek) between the buttons of the canine and first molar. Both the labial and palatal chains were adjusted to generate an approximately equal magnitude of force, producing a net force of 150 g with a force gauge (Figure 4).

The duration of the experimental period was 3 months; the patients were scheduled for monthly examinations, and the elastomeric chains were replaced at each appointment during the experimental period.

Measurement of Canine Movement

The parameters of canine movement assessed in this study included the extent of canine movement, rotation, and angulation, which were determined from study models and lateral cephalograms. A series of models from each subject was used to assess the change in the position of the canines relative to the stable landmark of the ipsilateral median end of the third rugae for each canine. The initial model was used for making the palatal plug with reference wires and for measuring canine movement and rotation.[5]

Periapical radiographs were taken every 4 weeks to determine the changes in size of the periodontal space and extraction socket. Lateral cephalograms were taken together with the angulation-indicating wires before extraction of the first premolars (T0) and once again after canine retraction for 3 months (T3) to evaluate the change in canine angulation (Figure 5). The radiographs were traced and determined by a single investigator.

Statistical Analysis

Each linear and angular measurement on each sample was repeated twice at least 4 weeks apart and averaged. Paired *t*-tests and the Dahlberg's formula were used to determine the intraobserver reliability. All variables are presented as the mean values. The Wilcoxon signed rank test was used to compare the extent of canine movement between the experimental and control sides; *P* values of $<.05$ were considered statistically significant. Spearman rank correlation analysis was applied to identify any correlations between potential influencing factors for canine movement.

RESULTS

The samples included in this study were from 18 female patients. The mean patient age at the start of

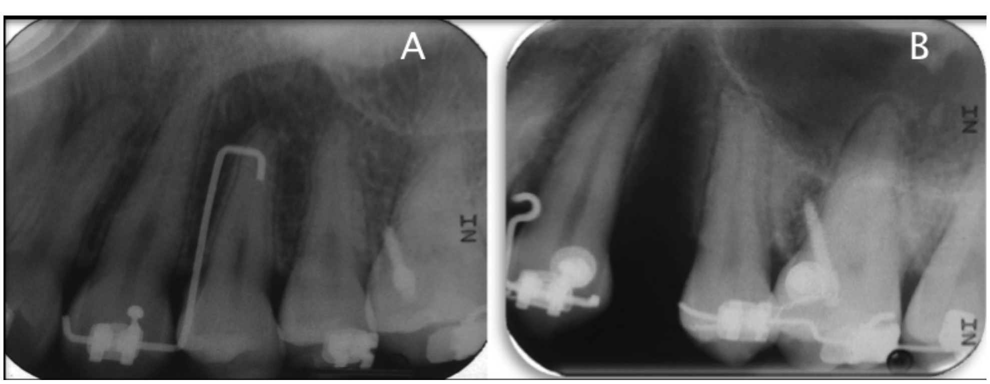

Figure 3. Periapical radiographs before (A) and after (B) extraction and interseptal reduction.

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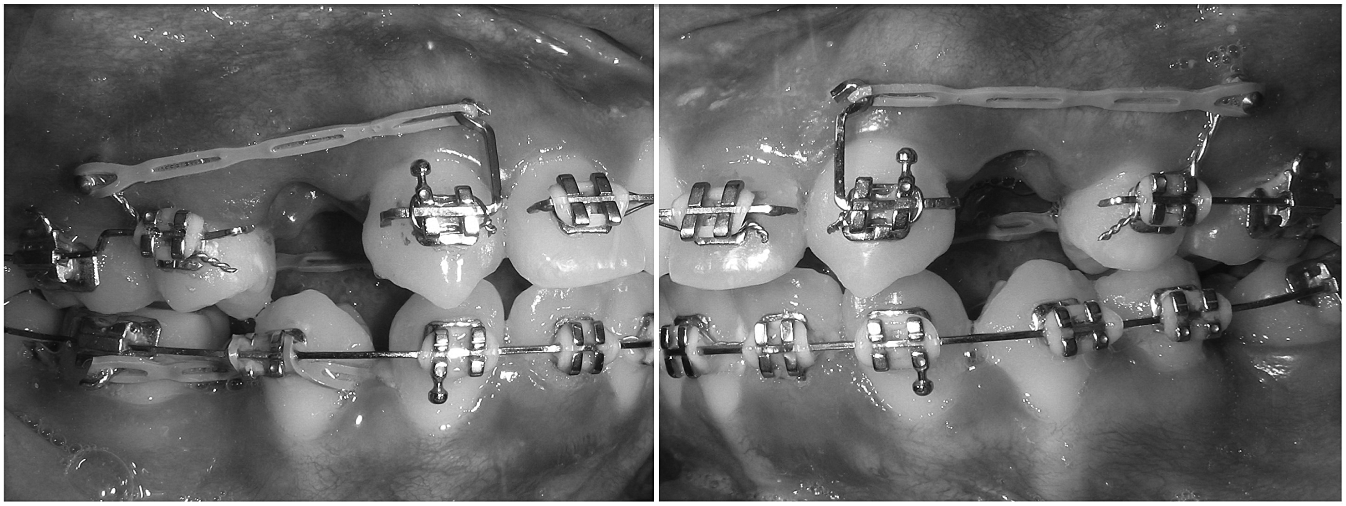

Figure 4. Mechanics used for canine distalization.

treatment was 21.9 ± 4.7 years (range, 18–25 years). Dahlberg's error was less than 0.5, indicating intraobserver reliability, and paired *t*-tests indicated that the two series of replicate measurements by the same investigator were not significantly different.

After clinical observation, the canine on the experimental side was considered clinically significant in four of the 18 cases. In one case, the experimental canine contacted the second premolar within only 2 months, and in another three cases the experimental canines made contact within 3 months, whereas the corresponding canines on the control side were still in the middle of extraction spaces (Figure 6). Neither periodontal problems nor discoloration of the experimental canine was evident in any case.

Extent of Canine Movement

The average extent of canine movement per month, as measured from the models, is presented in Figure 7. The extent of canine movement in each month was greater on the experimental side than on the control side. The Wilcoxon signed rank test demonstrated that the total extents of canine movement in the first and second months were significantly greater on the experimental side than on the control side ($P = .002$).

The average accumulated extent of canine movement and the rate of canine movement in each month, as measured from the models, are shown in Figure 8. The accumulated extent of canine movement on the experimental side was greater than that of the control

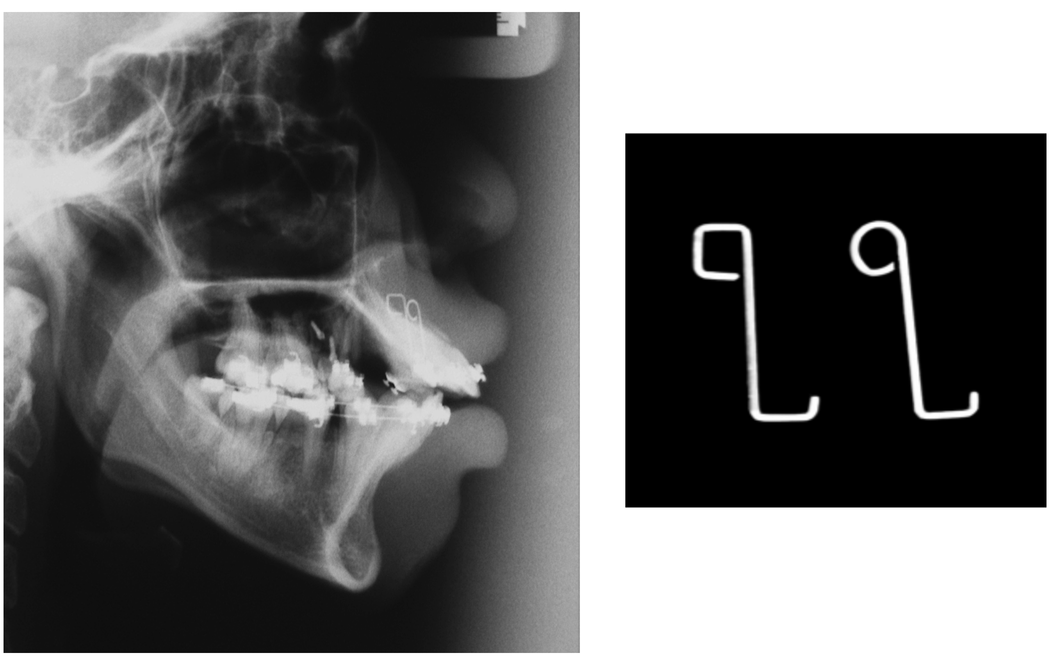

Figure 5. Angulation-indicating wires on the canine brackets.

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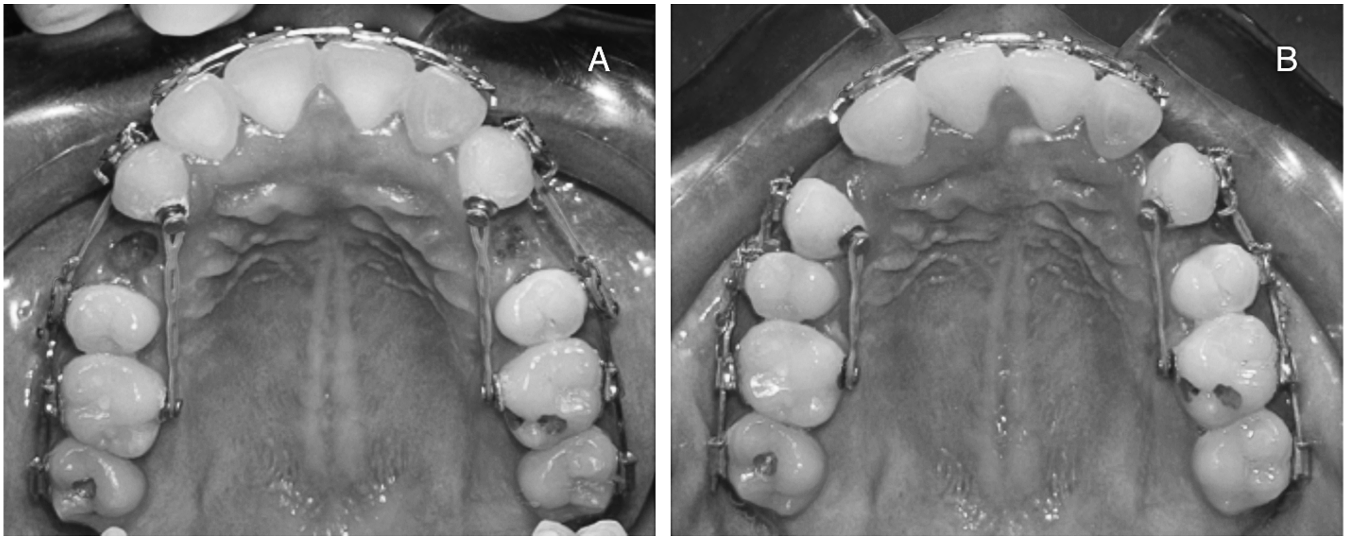


Figure 6. Example of a case between the experimental (right) and control (left) sides: canine retraction was complete within 3 months. (A) Before; (B) After.

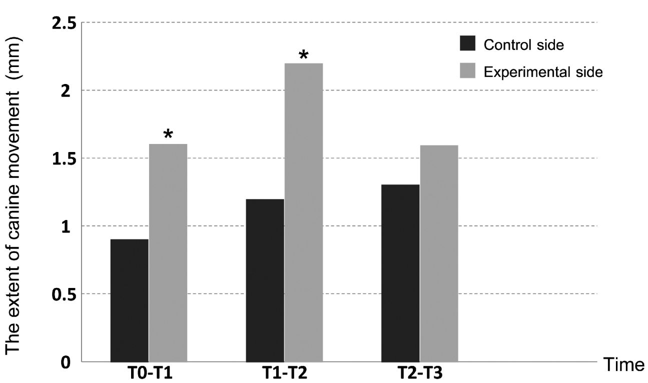
side throughout the experimental period; however, the extent of canine movement per month on the experimental and control sides was significantly different. The rate of canine movement per month was significantly higher on the experimental side than on the control side, with average values of 1.8 mm and 1.1 mm, respectively.

Radiographic analysis indicated that the experimental canine tipped more distally than did the canine on the control side; however, the Wilcoxon signed rank test revealed that the values for total tipping and tipping per millimeter of movement were not significantly different ($P > .05$; Table 1). Analysis of the models demonstrated that the canine on the experimental side rotated more significantly in total than did the canine on the control side. However, there was no significant difference between the rotation per millimeter of movement between the control and experimental sides ($P > .05$; Table 2).

Point-biserial correlation analysis demonstrated that the total extent of canine movement on the experimental side was strongly correlated with the presence of remaining interseptal bone. However, the surgical site (left or right) and the two surgeons had no significant correlation with the total extent of canine movement (Table 3).

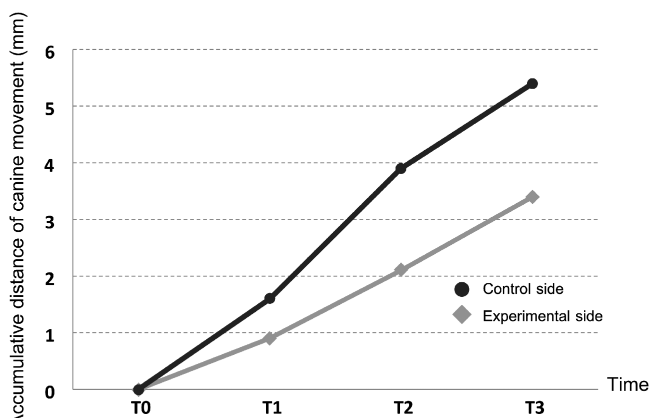
DISCUSSION

A variety of dentoalveolar surgical techniques have been reported[4,6–9] to accelerate the rate of tooth movement and reduce the overall orthodontic treat-



	T0–T1	T1–T2	T2–T3
control	0.9±0.3	1.2±0.5	1.3±0.7
experimental	1.6±1.08	2.3±1.1	1.6±0.8

Figure 7. The average extent of canine movement (mean ± standard deviation [SD], * $P = .002$).



	T0	T1	T2	T3
control	0	0.9±0.3	2.1±0.9	3.4±0.9
experimental	0	1.6±1.08	3.9±1.8	5.4±1.5

Figure 8. The average accumulated extent of canine movement (mm) ± standard deviation (SD) on the experimental side and control side (T1 and T3; $P = .002$, T2; $P = .003$).

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Table 1. Median Extent of Total Tipping and Tipping per Millimeter of Movement (in Degrees) for the Canines on the Experimental Side and Control Side[a]

	Control, °	Experimental, °	Wilcoxon Signed-Rank Test
Total tipping	4.50	7.50	NS
Tipping per mm	1.06	2.75	NS

[a] NS indicates nonsignificant.

Table 3. Correlation Between the Total Extent of Canine Movement and Other Factors[a]

	Total Extent of Canine Movement	
	R Value	*P* Value
Remaining interseptal bone	0.926	<.001
Surgeon	−0.367	NS
Surgical site	−0.001	NS

[a] NS indicates nonsignificant; Spearman rank correlation analysis.

ment time. Using these techniques, active orthodontic treatment can be completed within 1 year. The mechanism of rapid tooth movement facilitated by dentoalveolar surgery has been explained to be the result of a number of different processes, including bending of the interseptal bone and reduced bone resistance,[4,7] dentoalveolar block movement,[8] and the regional acceleratory phenomenon (RAP) after bone injury,[9] which can increase the bone turnover rate.

In this study, we propose a novel approach to accelerate the rate of maxillary canine movement. We performed a less invasive surgical procedure without flap surgery, which is not much more invasive or complicated than a simple extraction for orthodontic treatment. To simplify clinical practice, we also used a conventional orthodontic appliance instead of the custom-made distraction devices employed in other studies[4,6–9]; herein, an elastomeric chain was employed with the application of optimal force to move teeth within normal biologic limits. However, this approach is versatile enough to be applied to various types of brackets and mechanics.

Our surgical intervention resembles the technique for distraction of the periodontal ligament presented by Liou and Huang; however, buccal and lingual vertical grooving of the interseptal bone was not performed. During periodontal ligament distraction, vertical grooving is conducted to weaken the interseptal bone; however, this technique contributed to fracture of the bone to be moved along with the canine during distraction with the use of a distractor. In our study, we expected the surgical procedure to reduce resistance due to the bone and promote alveolar bone bending during canine retraction in the absence of interseptal bone breakage. Additionally, we expected that the RAP would be initiated as a result of the alveolar surgery, which in turn would lead to transient osteoporosis on the experimental side. As a result of these mechanisms, we hypothesized the experimental canine should move faster than the control canine. As the RAP was anticipated to occur following alveolar surgery, we used mini-implants as an anchorage to minimize the risk of anchorage loss during canine retraction.

Table 2. Median Extent of Total Rotation and Rotation per Millimeter of Movement (in Degrees) for the Canines on the Experimental Side and Control Side[a]

	Control, °	Experimental, °	Wilcoxon Signed Rank Side
Total rotation	14.00	23.50	<.05
Rotation per mm	4.26	4.18	NS

[a] NS indicates nonsignificant.

The results of this study demonstrate that the rate of tooth movement on the control side (3.4 mm in 3 months) was similar to the reported rate of biologic tooth movement rate using optimum force, which is approximately 1 to 1.5 mm in 4 to 5 weeks.[3] Statistical analysis confirmed that the accumulated extent of canine movement on the experimental side was significantly higher than that of the control side throughout the experimental period (5.4 mm in 3 months).

As is the case with the periodontal ligament distraction technique, one possible explanation for the increased rate of canine movement observed after our intervention may be reduced bone resistance and increased alveolar bone bending, including the RAP. In the initial period after the surgical procedure, the remaining interseptal bone on the pressure side was resorbed. If enough interseptal bone was surgically reduced, the entire bone could be completely resorbed within 1 month. Therefore, the experimental canine could be retracted into the extraction socket, which was not yet refilled by solid bone,[10] whereas the interseptal bone on the control side was still being resorbed. In the study of Ren et al.,[11] in which the interseptal bone was undermined using a distraction of the periodontal ligament technique combined with the use of a 150-gauge nickel-titanium coil spring to accelerate the rate of tooth movement in dogs, histological analysis demonstrated that the undermined interseptal bone became discrete as a result of bone resorption during the third and fourth weeks, and the periodontium fused with the extraction socket. A similar mechanism may explain the rapid tooth movement in the experimental group of this human study. Moreover, bending of alveolar bone may be another mechanism by which to explain the accelerated canine retraction observed in this study. Picton[12] demonstrated that the bending of alveolar bone could constitute as much as 25% of initial tooth movement.

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In the third month, the rate of canine movement was not significantly different between the experimental and control sides. One possible explanation for this observation may be that after tooth extraction, regenerative bone tissue refilled the extraction socket within 3 weeks and became resistant and solid within 3 months.[13] The more resistant the bone tissue, the slower the rate of tooth movement expected. Additionally, the RAP may decrease over time, as it is thought to peak at 1 to 2 months and last for about 6 months after the completion of the surgical procedure.[14] Additionally, in some cases, the canine in the experimental group could not move further, as there was no more space in which to move. However, if the study time was lengthened, the result would have been more obvious.

Although interseptal bone reduction was performed for 18 canines on the experimental side, the rate of canine movement was only considered to be clinically significant in four subjects (ie, the canine moved to contact the second premolar within 3 months). This could imply that other factors, apart from the mesiodistal thickness of the interseptal bone, may have affected the extent of canine retraction in the other subjects. In terms of root anatomy, it is known that the root of the canine in the buccolingual dimension is greater than that of the first premolar. Hence, the first premolar extraction socket should be surgically widened to the width of the root of the canine in the buccolingual dimension.

Unfortunately, the success of this procedure could not be determined from the periapical radiographs. Furthermore, the rate of canine retraction may be limited by resistance from the cortical bone. If the labiolingual width of the canine root is greater than the width of the alveolar ridge between the canine and first premolar, the canine can only be distalized when the cortical plate is resorbed. Consideration of these factors implies that our surgical technique is quite sensitive to case selection, as is the case with the periodontal ligament distraction technique.[15]

Despite the increased rate of canine movement, it must be kept in mind that the long-term effects of this technique on pulpal vitality, root resorption, and periodontal tissue were not investigated in this study. However, no subjects presented any sign or symptom of pulp necrosis, root resorption, or periodontal defect after treatment.

CONCLUSIONS

- Interseptal bone reduction combined with the use of a conventional orthodontic appliance with optimum force can effectively accelerate maxillary canine retraction when the bone is sufficiently reduced in both thickness and depth following surgical criteria.
- Anatomical structures, such as the maxillary sinus and a narrowed alveolar ridge, may be limiting factors for tooth movement after this surgical procedure; thus, appropriate case selection must be made.

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