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Clinical investigation of periodontal ligament distraction osteogenesis for rapid orthodontic canine retraction

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Aims: To investigate rapid canine distalisation by periodontal ligament distraction and to determine the effects of periodontal ligament distraction on the canine root and pulpal vitality.

Methods: The sample consisted of 16 upper canines in eight patients who required first premolar extractions. The upper first premolars were extracted and the interseptal bone distal to each canine was thinned and undermined surgically. Custom-built distractors were placed and activated immediately to distract the canines into the extraction spaces. Radiographs were taken before canine distraction and at regular intervals thereafter. The upper canine pulps were tested with an electronic pulp tester before and after the distraction and the canines were examined on the post-distraction radiographs for evidence of apical and lateral root resorption.

Results: The canines were retracted to proximal contact with the second premolars in 20.33 ± 1.87 days. The average amount of retraction was 5.25 mm and the canines tipped distally 15.33 degrees. Although the upper molars did not move mesially, they extruded almost 1 mm. Root resorption was minimal and there was no deterioration in pulp vitality.

Conclusion: Canines can be rapidly retracted by periodontal ligament distraction without complications. However, the efficacy of the method depends upon the surgical procedure, which is technique sensitive. Resistance offered by the interseptal bone distal to the apex of the canine was thought to be the reason for the canine tipping during distraction.

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Introduction

Orthodontic tooth movement is a unique process by which a tooth is made to move through bone by the application of an appropriate force. The force induces bone resorption on the pressure side of the root and bone deposition on the tension side, maintaining the width of the periodontal ligament (PDL).[1–4]

Many orthodontic patients have a shortage of space and crowding.[1] Although nonextraction treatment approaches have become popular, there are still a number of patients who need treatment requiring the extraction of teeth.[1] The first phase in the treatment of many premolar extraction cases is the retraction of the upper canines. Using conventional methods the teeth move at a slow rate (about 1 mm per month) and it takes between 6 and 8 months to retract the upper canines and between 18 and 24 months to complete treatment. In some cases special extra-oral and intra-oral mechanics are required to conserve anchorage during canine retraction, particularly in so-called maximum anchorage cases. With inter-dental/

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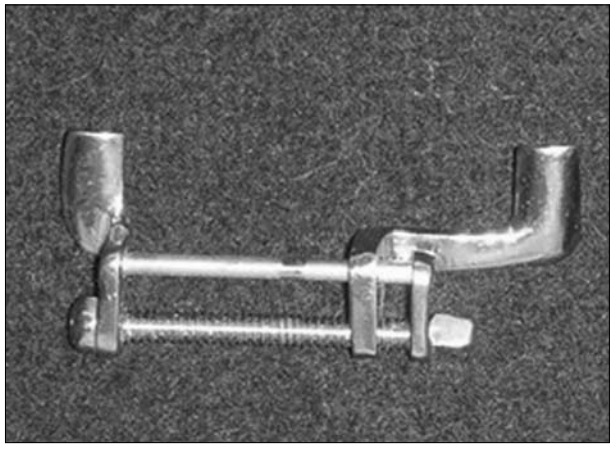


Figure 1. Design of the distractor. The anterior section is soldered to the canine band, and the posterior section is soldered to the molar band. The horizontal sliding stainless steel bar and stainless steel screw join both sections.

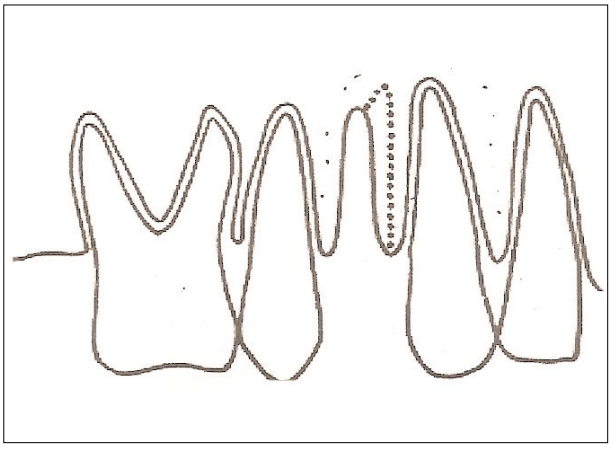


Figure 2. Interseptal bone removed to deepen the socket (dotted line).

periodontal ligament distraction osteogenesis the upper canines can be retracted into the first premolar extraction spaces in about three weeks with minimal loss of anchorage and little/no root resorption.[5–7]

Interdental/periodontal ligament distraction osteogenesis is a major advance in orthodontics in terms of reducing the duration of treatment and conservation of anchorage.[5] However, there is little information with regard to the efficacy of this procedure and, as a result, it is not used by many orthodontists. The present study was undertaken to investigate the efficacy of rapid canine retraction by interdental/periodontal ligament distraction osteogenesis and to evaluate its effects on the canine root and pulpal vitality. We hypothesised that interdental/periodontal ligament distraction can be used as a treatment modality in patients with high anchorage demands, and that the duration of treatment could be reduced without any complications.

Material and methods

The study sample consisted of eight subjects, 17 to 25 years of age, who needed canine retraction, extraction of the upper first premolars due to either anterior crowding or dentoalveolar protrusion and had high anchorage demands. Since the treatment involved surgery, only subjects 16 years or older were included. All patients attended the Department of Orthodontics and Dentofacial Orthopedics, KLE Institute of Dental Sciences, Belgaum, for treatment. Informed consent was obtained for all subjects and approval for the study was granted by the ethics committee of KLE University.

Distractor construction and surgical method

The upper canines and first molars were banded and a working model obtained. The distractors used in this study were intra-oral, custom-made tooth-borne distracters (SK Surgical, Pune, India) cast in high-grade stainless steel and soldered to the canine and first molar bands (Figure 1). A custom-made key was used to activate the distractor.

The surgical procedure[5,6,8] was performed under local anaesthesia as a routine outpatient procedure (Figure 2). The first premolars were extracted and the interseptal bone distal to the canine was undermined and thinned to 1–2 mm. As the roots of the premolars are shorter than the canine roots, the premolar sockets were extended to the same depths as those of the canines using a round carbide bur. This stage was performed carefully with the aid of radiographs to avoid damaging the canine root. Two vertical grooves were made on the mesio-lingual and mesio-buccal line angles of the extraction socket. The vertical osteotomies were then connected with an oblique osteotomy at the base of the socket, creating a U-shaped groove. The objective of these osteotomies was to weaken the interseptal bone and allow the canine to move bodily. The wound was thoroughly irrigated

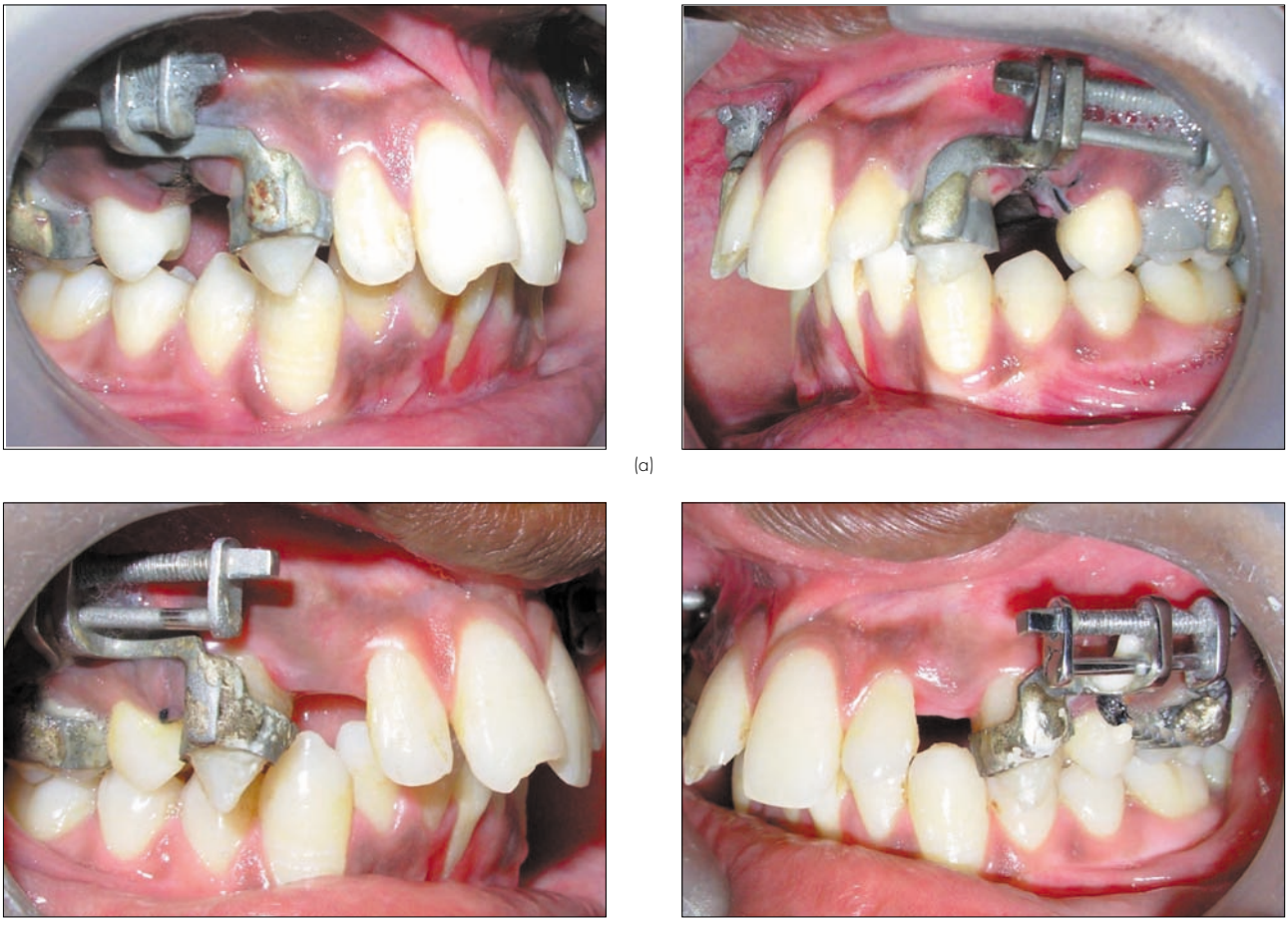


Figure 3. (a) Before distraction. (b) After distraction.

with saline and sutured. The bands holding the distractor were then cemented to the canine and first molar.

The distractors were activated one complete turn twice a day, with 8 hours between activations. Activation was started immediately after surgery and continued until the canine contacted the mesial surface of the second premolar (Figure 3).[5,6,8]

Radiographic monitoring

The canines were monitored both clinically and radiographically before and after distraction. Lateral cephalograms and orthopantomograms were taken of all subjects at the following times:

T1, before the placement of distractor i.e. immediately before the periodontal ligament distraction surgical procedure.

T2, when canine distraction was complete i.e. when the canine contacted the mesial surface of the second premolar.

All cephalometric radiographs were taken with the Frankfort plane parallel to the floor, and traced and measured by the same examiner. The measurements are shown in Figure 4. Periapical radiographs were also taken at T2, one month and six months after the completion of canine retraction.

Assessment of root resorption

The apical root resorption was assessed after canine distraction by the following score.[5,6]

0, no apical root resorption.

1, slight blunting of the canine root apex.

2, moderate resorption of the root apex beyond blunting and up to one quarter of the root length.

3, excessive root resorption of the root apex beyond one quarter of the root length.

Lateral root resorption was also assessed after canine distraction using the method described by Liou et al.[5,6]

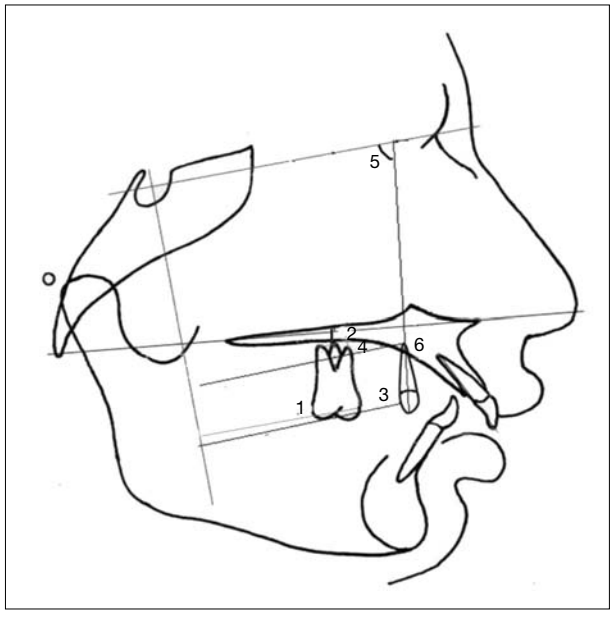


Figure 4. Cephalometric measurements.
U6M-SV, perpendicular distance from the mesial of U6 to the vertical reference line (SV).
U6M-PP, vertical distance between U6 and the palatal plane (PP).
U3D-SV, perpendicular distance from the mesial of U3 to the vertical reference line.
U3D-PP, vertical distance between U3 and the palatal plane.
U3A, inclination of U3 to the SN line.

Table I. Comparison of the cephalometric measurements before and after distraction.

Measurements	Before distraction		After distraction		*p*
	Mean	SD	Mean	SD	
U6M-SV (mm)	41.58	3.54	41.33	4.49	0.916
U6M-PP (mm)	21.41	2.22	22.08	2.34	**0.011**
U3D-SV (mm)	56.00	5.39	50.75	5.06	**0.002**
U3A-PP (mm)	2.75	1.69	3.33	2.20	0.063
U3A (degrees)	94.50	7.66	79.16	10.7	**0.002**

Paired *t*-test, significant values in bold

Table II. Apical and lateral root resorption.

Scores for root resorption	Numner of teeth affected by apical root resorption	Number of teeth affected by lateral root resorption
0	5	4
1	11	12
2	0	0
3	0	0

0, smooth lateral root surface and periodontal ligament.

1, slightly irregular lateral root surface not beyond one third of the dentine width between the distal side of the periodontal ligament and the pulp chamber.

2, moderate irregular lateral root surface beyond one third and up to two thirds of the dentine width between the distal side of the periodontal ligament and the pulp chamber.

3, excessive irregularity of the lateral root surface beyond two thirds of the dentine width between the distal side of periodontal ligament and pulp chamber.

Assessment of pulp vitality

The vitality of each upper canine was tested with an electronic pulp tester before distraction, immediately after removal of the distractor, one month and six months after the surgical procedure.[5,6]

Statistical methods

Statistical analyses were performed using the statistical package for social sciences (SPSS version 13.0) for Windows. The means and standard deviations were calculated and the differences between the before and after distraction measurements compared with the paired *t*-test. Probabilities ≤ 0.05 were considered to be significant.

Results

The mean time taken to distract the upper canines was 20.33 ± 1.87 days (Range: 17 – 22 days). The rate of movement was 0.25 mm per day and the mean total distance the canines were distracted was 5.25 mm.

The cephalometric findings are given in Table II. The horizontal distance U6M-SV increased by 0.25 mm and distance between the upper first molar and the palatal plane (U6M-PP) increased significantly by 0.66 mm. The canines were retracted (U3M-SV) on average 5.2 mm and extruded (U3A-PP) by 0.58 mm. The inclination of the upper canines to the SN line (U3A) reduced by 15.33 degrees.

Apical and lateral root resorption was minimal and not statistically significant for the upper canines (Table II). There were no fractured or ankylosed canines before or after distraction.

Before starting the distraction procedure, the canines and first molars were tested with an electronic pulp tester and all the teeth tested positive. The same test was repeated after removal of the distractor and again the canines tested positive. The pulp vitality tests were not done immediately after the canines were distracted as it would have given a false reading with the distractors *in situ*.

Discussion

We studied the radiographic changes, pulp vitality, occurrence of root resorption and ankylosis affecting the upper canines retracted into the first premolar extraction spaces by periodontal ligament distraction. The canines were retracted 5 mm and extruded less than 1 mm in 20 days with virtually no loss of anchorage. However, they 'uprighted' 15 degrees indicating that some tipping occurred, possibly because of resistance offered by the interseptal bone adjacent to the apex of the canine and/or deformation of the distractor guide rod and screw. There was no detectable deterioration in pulpal vitality, root resorption was minimal and there were no ankylosed teeth. Using this technique it is possible to substantially reduce the duration of treatment and conserve anchorage, even in severe malocclusions.

When a tooth is subjected to an orthodontic force there is a lag period of two to three weeks before tooth movement occurs, which has been attributed to the formation of a hyalinised zone in the periodontal ligament. The aim of periodontal ligament distraction osteogenesis is to retract the upper canines in this period before the first molars move mesially.[2,9,10] In the present study the first molars, which were the sole means of anchorage, stayed more-or-less in their initial positions although they extruded slightly. Forces acting more than three weeks can result in loss of anchorage as the canine and the anchor unit move towards each other after the lag period.[5,6] When periodontal ligament distraction is expected to take longer than two to three weeks the second premolars and/or second molars should be included in the anchor unit or adjuncts, such as extra-oral traction, a transpalatal arch, miniscrews or a Nance button, employed. Without some means of reinforcing the anchorage 2 to 3 mm of space can be lost during conventional orthodontic treatment.[11,12]

Our finding that the first molars extruded slightly during treatment and that the canines tipped distally is in contrast to previous reports.[5,6,8] Our distractor was designed to facilitate translation: the screws and rods passed through the centres of resistance of both teeth. In spite of this the canines tipped distally 15 degrees. Because the device was robustly constructed we consider that extrusion was due to the root tips 'catching' on a ledge of bone during retraction rather than deformation of the guide rods and screws. The final osteotomy linking the two vertical cuts was difficult to achieve and completeness of the cut could not be verified.

Faster orthodontic tooth movement and less root resorption occur when teeth are moved in trabecular alveolar bone.[5,6] After tooth extraction, healing tissue fills the extraction socket which becomes resistant and 'solid' in about three months. If the canine is not retracted across the first premolar socket in the first three weeks, the rate of tooth movement slows, the likelihood of external root resorption increases and the anchor unit moves forward. Initially, the interseptal bone distal to the canine is the only obstacle to distraction and failure to reduce or weaken it will impede movement of the canine.[5,6,8] Liou and Huang[6] moved the upper canines about 6 mm into the first premolar extraction sockets within three weeks. Despite all efforts to move the canines bodily they reported 17 degrees of distal tipping occurred, which is similar to the 15 degrees we found.

It is generally accepted that varying amounts of root resorption occur in patients undergoing orthodontic treatment. Although external root resorption has been reported as early as one week after the application of a force, appreciable root resorption occurs during the third week of force application.[2,13] We found little evidence of apical and/or lateral root resorption. An association has been reported between root resorption and the duration of an applied force which is more critical than the magnitude of the force.[14] The amount of external root resorption is also less in alveolar bone with 'loose', bony trabeculae.[5] Therefore, the best way to minimise root resorption during periodontal ligament distraction is to complete canine distraction within three weeks and begin overjet reduction before the canine sockets fill with bone.[5,15]

It is generally accepted that pulp vitality tests are not reliable when a tooth is being moved orthodontically.[5] We recorded pulp vitality with an electronic pulp tester and found no change in vitality and no darken-

ing of the distracted canines. However, electronic pulp testing can be unreliable so we suggest that future studies use the more reliable laser Doppler flowmeter. Liou and coworkers reported that the pulp remained vital, even when a tooth was moved at the rate of 1.2 mm/week.[7] It has also been reported that the inferior alveolar nerve and blood vessels regenerate a short period of time after mandibular distraction.[16] The long-term effects of periodontal ligament distraction on the pulp vitality are still unknown so future studies should closely monitor pulp vitality.[7,8]

Rapid canine retraction by periodontal ligament distraction is an attractive method because it substantially reduces the duration of treatment and conserves anchorage. However, it has several potential drawbacks such as root resorption, loss of tooth vitality, ankylosis, tooth discolouration and excessive tipping. Furthermore, the surgical procedure is invasive and technique sensitive and can be uncomfortable, the distractor is bulky, the patient requires close monitoring during the distraction period and excellent patient compliance is essential for success.

Conclusions

The results of our study led to the following conclusions:

1. Rapid canine retraction with distraction of the periodontal ligament reduced the time needed to completely retract an upper canine. The method is suitable for severe malocclusions requiring maximum anchorage control.

2. The canines undergoing distraction should be closely monitored.

3. No signs of root resorption, loss of pulp vitality or ankylosis were found during interdental/periodontal ligament distraction.

4. Less bulky distractors need to be developed.

5. The long-term effects of interdental/periodontal ligament distraction are unknown.

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