Original Article

Rapid maxillary canine retraction by dental distraction: A clinical study

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ABSTRACT

Aim: The aim of this clinical study was to perform rapid maxillary canine retraction through distraction of the periodontal ligament and investigate the rate and amount of canine retraction, amount of anchor loss, the nature of tooth movement achieved, and radiographic changes in the periodontal ligament region during and after canine distraction. **Materials and Methods:** This study was conducted on 10 distractions ranging in age from 14 years to 25 years who needed canine retraction and first premolar extraction in the maxillary arch. Ten canine distractions were carried out with custom-made, tooth-borne intra-oral distraction device. **Results:** The results indicate that the periodontal ligament can be distracted just like the mid-palatal suture in rapid palatal expansion and the maxillary canines are retracted rapidly into the first premolar extraction space at the rate of about 2.53 mm/week. **Conclusion:** Though this study indicates that the periodontal ligament can be distracted to elicit rapid tooth movement, the long-term effects of canine distraction are not well known and need close monitoring. **Clinical Significance:** This technique has the potential to significantly reduce orthodontic time.

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Key words: Dental distraction, rapid tooth movement, osteotomy

Introduction

Orthodontic research has always been focused on the development of faster and more effective tooth movement. One of the most commonly used procedures in orthodontics is the retraction of canines into the space created by the extraction of first premolars. Their unique position connects anterior and posterior segments of the dental arch and makes their orthodontic movement of great clinical importance, especially in the first premolar extraction cases.

Conventional methods of canine retraction are generally grouped into frictional and frictionless mechanics. The fastest rate of canine retraction achieved by these methods as reported in the literature is about 2 mm/month[1-5] Thus, it takes a minimum time period of 4-6 months to retract the canines completely into the first premolar extraction space by current conventional methods.

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Distraction osteogenesis (DO) was applied first for correction of the Craniofacial skeleton in the early 1990s. Since then, numerous experimental and clinical studies have considered the use of this technique. DO is a process of growing new bone by mechanical stretching of the reparative bone tissue by a distraction device through an osteotomy or corticotomy site.[6-8] The first principal response to orthodontic force was the bending of alveolar process, which was proposed by Angle and supported by Baumrind,[9] Grimm,[10] and other workers. Picton[11] demonstrated that bending of alveolar bone could constitute as much as 25% of the initial tooth movement.

Light, continuous force generated by orthodontic force was not heavy enough to keep bending the interseptal bone distal to canine and carrying it with tooth movement. By using a distraction appliance and undermining the interseptal bone surgically, the interseptal bone bends and moves along the extraction socket. Liou and Huang[12] pointed out that after first premolar extraction, the interseptal bone distal to the canine is the only significant obstacle of canine retraction. They proposed that rapid canine retraction could be achieved through distraction of its periodontal ligament and surgically weakening and bending the interseptal bone distal to the canines into the first premolar extraction space.

This study was undertaken to prove the clinical efficacy of dental distraction through which maxillary canines were distalized in about 3 weeks' time period with a custom-made intra-oral distraction appliance.

Aims and Objectives

This clinical study was undertaken with the aim of performing rapid maxillary canine retraction through distraction of the periodontal ligament and investigating the following parameters.

1. Rate and amount of canine retraction
2. Amount of anchor loss
3. The nature of tooth movement achieved
4. Radiographic changes in the periodontal ligament during and after canine distraction and incidence of root resorption
5. Pulpal status of the distracted and anchor teeth.

Materials and Methods

This study was conducted on 10 distractions (four girls and one boy) ranging in age from 14 years to 25 years who needed canine retraction and first premolar extraction in the maxillary arch. Ten canine distractions were carried out with custom-made, tooth-borne intra-oral distraction device.

Case selection criteria

The patients included in the study met the following criteria:

1. Treatment plan required the bilateral extraction of maxillary first premolars followed by individual maxillary canine retraction.
2. The dentition did not exhibit any gross anatomic root anomalies as assessed from panoramic radiographs.
3. Cases with deep carious lesions or endodontic lesions involving the maxillary canines and buccal segments were not selected.
4. Cases with severely rotated or grossly malpositioned canines were not selected for the study.

Device selection

The procedure of canine retraction through distraction of periodontal ligament is accomplished by bending the interseptal bone distal to the canines into the extraction socket. To keep bending the interseptal bone and carrying it with tooth movement, the light continuous force generated by conventional orthodontic appliances was not expected to be strong enough. Thus, it was necessary to fabricate a rigid, segmental tooth-bone intra-oral distraction device for performing canine distraction. The distraction device consisted of an anterior section, a posterior section, a screw, and screw activator [Figure 1].

Clinical procedure

A fixed orthodontic appliance 0.22 both prescriptions was placed before the first premolar extraction in all the cases. Bands were fabricated on canines bilaterally in the maxillary arch. The tooth to be distracted was canine, the first molar and second premolars were the anchor units. After initial leveling and aligning with round wires, a rectangular 017 × 025 stainless steel archwire was placed in the maxillary arch for 1 month.

Right after the first premolar extraction, the interseptal bone distal to the canine was undermined with a bone bur, grooving vertically inside the extraction socket, along the buccal and lingual sides, and extending obliquely toward the base of the interseptal bone to weaken its resistance. The surgical procedure used in this study is similar to Liou and Huang[12] [Figure 1].

Then, a custom-made intra-oral distraction device was delivered for canine retraction. It was activated two quarter closing turns each day in the morning, thus a total activation of 0.4 mm/day. Patients were seen weekly till canine distraction was completed. The appliance was left in place for 1 month after complete distraction Figures 2-5.

Record analysis

The following records were taken at weekly intervals till complete retraction of canines.

1. Measurements made intra-orally with digital calipers (Mututoya Digimatic Caliper)
2. Sequential orthopantogram and intraoral periapical radiographs of maxillary canines and molars
3. Study models pre-operative and post-operative
4. Pulp vitality testing of lateral incisors, distracted canines, second premolars, and molars was carried out and recorded with electric pulp tester (Parkell)
5. Intra-oral clinical photographs.

Data analysis

The distance between the contact point of the canine and lateral incisor (amount of distraction) was recorded to 0.1 mm with a digital calipers preoperatively, after 1 week of retraction, after 2 weeks of retraction, and at the end of retraction. Each measurement was done twice and the mean of the two values was recorded. The number of days taken to complete each canine retraction was recorded.

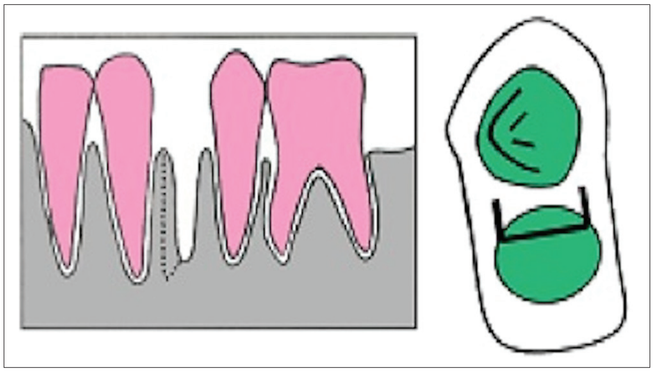

Figure 1: Surgical technique for undermining interseptal bone distal to canine

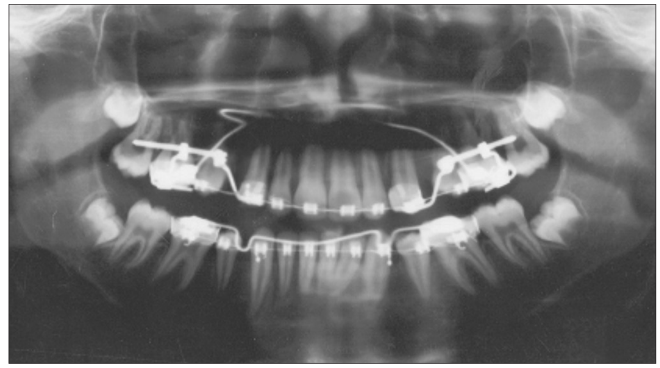

Figure 2: Pre-treatment with distractors in place

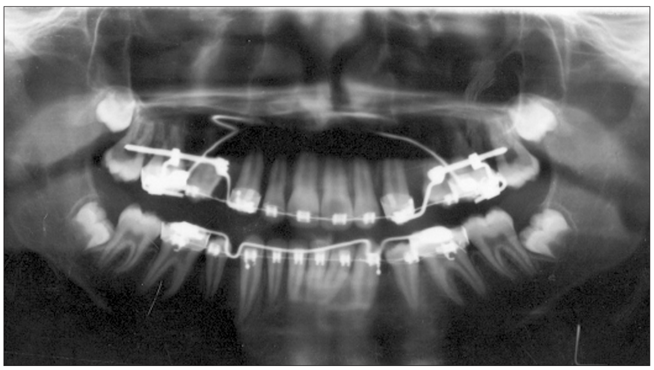

Figure 3: One week after rapid maxillary canine distraction

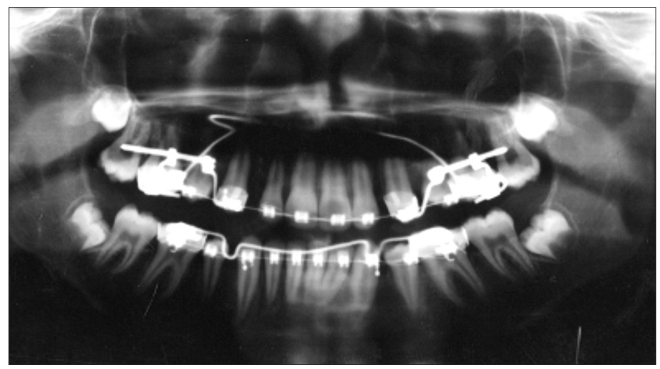

Figure 4: Two weeks after rapid maxillary canine distraction

Figure 5: Three weeks after rapid maxillary canine distraction

Pulp vitality tests of those 10 distracted maxillary canines and the lateral incisors and second premolars and molars were recorded with an electronic pulp tester (Parkell). Testing was done pre-operatively, immediately after the distraction.

Tooth mobility was subjectively graded according to the following scale.[13] Photocopies were made for the pre-treatment and post-retraction maxillary casts on a photocopy machine in 1:1 duplication.[14]

All linear measurements were done to the nearest 0.1 mm with a digital caliper and all angular measurements were done to the nearest 0.5° with a protractor. Each measurement was made twice and the mean of the two values recorded.

The following tooth movements were measured by calculating the difference between the pre-treatment and post-retraction tooth position on the dental casts.

1. Anchor loss, i.e., amount of forward movement of the maxillary first molars
2. Amount and direction of rotation of the maxillary canines
3. Amount and direction of rotation of the maxillary first molars.

Estimating rate of canine retraction

Canine retraction was measured by subtracting the anchor loss as measured from dental casts from the total space closure achieved at the end of retraction as measured clinically. The rate of retraction is measured in millimeters per week.

The radiographs were placed on a view box and observed under magnification to assess the changes in the periodontal ligament and alveolar bone during the canine distraction and after 1 month.

Pre-treatment and post-distraction radiographs of the canines were evaluated for the incidence and severity of apical and lateral root resorption. The apical root resorption was assessed by the following scores.[4,12]

Statistical analysis

The arithmetic mean (Mean), standard deviation (SD), and maximum and minimum values for each variables were calculated. For paired data, Student's *t* test for paired samples was performed.

The level of significance used was $P < 0.001$ (***), $P > 0.05$ was not considered significant (ns). Student's paired *t* test was employed to compare the change between pre- and post-treatment.

The formula used was Where SE (d) = Standard error of d' = $S/\sqrt{n}$

$$\mathrm{SD} = \frac{\sqrt{n\sum_{i=1}(d_i - d)^2}}{\sqrt{n-1}}$$

$$\mathrm{d} = \frac{n\sum_{i=1} d_i}{n}$$

Results

The maxillary canines rotated distopalatally by an average of 13.5 ± 3.54 [Table 1] which was highly significant statistically. The maxillary molars showed a mean mesio palatal rotation of −0.20° ± 0.42° [Table 1] which was statistically significant. Clinically and radiographically, the canines showed varying amounts of tipping, with the crowns moving more than the roots. Slight extrusion of the canines was also seen during the distraction procedure.

Pulp vitality

Pre-operatively, all the maxillary canines tested positively to the pulp tester. Post-operatively, all the distracted canines gave a positive response to the pulp tester. All the maxillary first molars and second premolars gave a positive response to the pulp tester pre-operatively and at the end of distraction. There was no change in the color and translucency of any of the distracted or anchor teeth during the period of the study.

Among all the ten canines selected for the study, six had grade 0 mobility and four had graded I mobility. At the end of the distraction, three canines had grade I mobility, and seven canines had grade II mobility. The molars and premolars did not demonstrate any increase in mobility in any of the 3 time periods.

Root resorption was assessed for 10 maxillary canines by comparing the pre-treatment and post-distraction peri-apical radiographs. No incidents of apical root resorption were observed on the distracted canines. For the lateral surface root resorption, nine showed no resorption, while one canine showed slightly irregular distal root surface after canine distraction.

Discussion

The fastest rate of canine retraction achieved by conventional methods as reported in the literature is about 2 mm/month.[1-5] Thus, it takes a minimum time period of 4-6 months to retract the canines completely into the first premolar extraction space by the current conventional methods.

Liou *et al*.[15] demonstrated that, by orthodontically moving a tooth into fibrous bone tissue just created by DO in the mandible of a canine model, the rate of orthodontic tooth movement could be as much as 1.2 mm/week. Studies have shown that orthodontic tooth movement is faster in an alveolar bone which is less dense or where bone resorption is stimulated. The hypothesis that periodontal ligament can be rapidly distracted just like the midpalatal suture in rapid palatal expansion to achieve rapid orthodontic tooth movement lead to "Dental Distraction"[12] for rapid canine retraction.

This study was undertaken to prove the clinical efficacy of dental distraction through which maxillary canines were distalized in about 3 weeks' time period with a custom-made intra-oral distraction appliance.

The results showed that maxillary canines were rapidly retracted into the first premolar extraction space by distraction procedure. A mean space closure of 7.58 mm [Table 2] was obtained in an average time period of about 3 weeks. The mean rate of space closure was about 2.43 mm/week [Table 3], which is much faster than that obtained by current conventional methods. It was observed during the study that some of the patients failed to follow instructions regarding screw activation during the initial days of retraction. This could

Table 1: Changes in maxillary canine and maxillary first molar position

Variable	Mean	SD	Minimum	Maximum	*P* value	Significance
Rate of canine retraction mm/week (X_{12})	2.43	0.17	2.13	2.60	<0.001	***
Canine rotation (degree) (X_{13})	13.5	3.54	8	19	<0.001	***
Molar rotation (degree) (X_{14})*	−0.20	0.42	−1	0	>0.17	NS
Anterior movement of maxillary 1st molar (mm) (X_{11})	0.30	0.48	0	1	>0.08	NS

*Negative implies mesiopalatal rotation

Table 2: Space closure and time taken

Variables	Mean	SD	Minimum	Maximum	*P* value	Significance
Total space closure (mm) (X_1)	7.58	0.15	7.4	7.8	<0.001	***
Total time taken (days) (X_5)	20.8	1.7	19	24	<0.001	***
Space closure in 1st interval (mm) (X_2)	2.22	0.15	2	2.5	<0.001	***
Space closure in 2nd interval (mm) (X_3)	2.87	0.09	2.7	3	<0.001	***
Space closure in 3rd interval (mm) (X_4)	2.49	0.21	2	2.8	<0.001	***
Time taken for 3rd interval (days) (X_{10})	6.8	1.7	5	10	<0.001	***

Table 3: Rate of space closure (mm/week)

Variable	Mean	SD	Minimum	Maximum
Over all rate of space closure (X_6)	2.43	0.17	2.13	2.60
Rate of space closure in 1st interval (X_7)	2.22	0.15	2	2.5
Rate of space closure in 2nd interval (X_8)	2.87	0.09	2.7	3
Rate of space closure in 3rd interval (X_9)	2.19	0.5	1.5	2.8

have contributed to the slower rate of retraction in the 1st week of distraction. Canine retraction by distraction of the periodontal ligament is thus, much faster than the maximal rate of about 2 mm/month[1-5] observed during canine retraction by conventional mechanics.

This study has shown less mesial movement of molars compared to Liou and Huang[12] and Sayin S *et al*.[16] Studies using conventional mechanics have reported 1.6-4 mm of mesial molar movement when canines were retracted without the use of adjunctive appliances to control anchorage. When adjunctive anchorage control appliances were used, a range from complete absence of molar movement to 2.4 mm of mesial molar movement has been reported.

After the initial tooth movement by a light or heavy orthodontic force, a lag period of minimal tooth movement persists for approximately 2-3 weeks before tooth movement again proceeds. Current conventional mechanics takes about 4-6 months for completing canine retraction. After the elimination of hyalinized tissues, not only the canines get retracted, but the anchor unit also starts moving forward. This leads to anchorage loss seen in canine retraction in conventional mechanics.

In this study, canine retraction was completed by periodontal ligament distraction and bone bending within a time range of 19-24 days. During this period, the maxillary molars were still in lag period or just initiating their mesial movement, thus explaining the minimal anchor loss. The rotation of molars was found to be insignificant in this study probably due to reinforcement with transpalatal arch.

After tooth extraction, the regenerative bone tissue fills the extraction socket in 3-4 weeks and becomes resistant and solid in about 3 months.[17] In conventional mechanics, canine retraction initiates after lag period and proceeds by resorption of the bone distal to the canines. However, solid bone starts filling the socket while canine retraction is being done and offers resistance to the retracting canines. This explains the long time period required for canine retraction in conventional mechanics.

The canines showed a mean distopalatal rotation of about 13.5° ± 3.54° [Table 1] which was both clinically and statistically significant. This was a consequence of the distraction force being applied entirely from the buccal surface, away from the center of resistance of the canines.

Radiographic changes in the distracted periodontal ligament

The periodontal ligament of the maxillary canines was distracted by about 7-8 mm in 19-24 days. Some of the ligaments could even be torn during the canine distraction. However, they healed completely within 1 month after completing the distraction, and new bone was formed in the distraction gap [Figures 6-11].

Studies regarding the healing process and osteogenesis in the midpalatal suture after rapid palatal expansion indicate that the distracted suture initially fills with disorganized fibrous connective tissue. However, it ossifies rapidly with the mineral content in the distracted suture rising rapidly during the 1st month after completing the distraction. The process of mineralization becomes fairly well established 3 months after completing rapid palatal expansion.[18] Though the midpalatal suture becomes nearly normal radiographically at this stage, it is still not properly calcified and mineralized. It takes about 6 months after distraction for the suture to appear totally normal.

Minimal root resorption

Root resorption initiates 14-20 days after orthodontic force is applied and continues for the duration of force[19,20] application. However, most studies suggest treatment time to be the most significant factor in determining root resorption.[21-25]

In this study, there was no incidence of root resorption as assessed from periapical radiographs. Though the exact magnitude of force during canine distraction

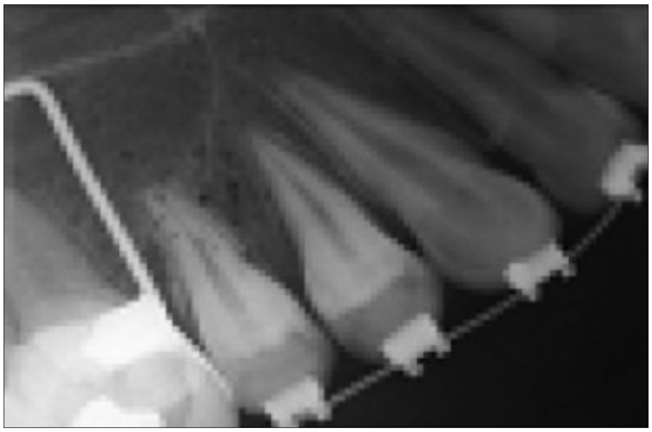

Figure 6: Radiographic changes of maxillary canine

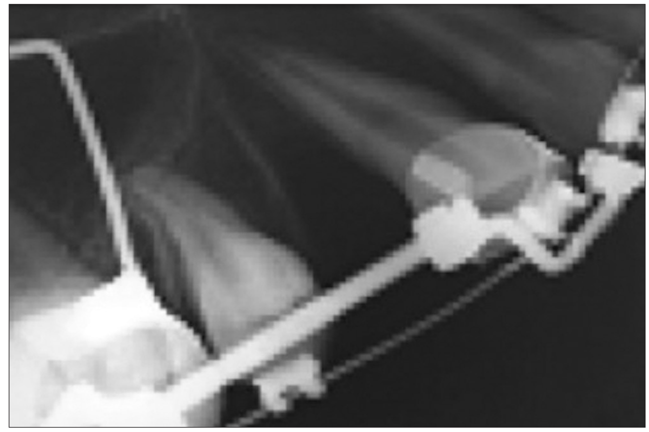

Figure 7: Immediately after surgery

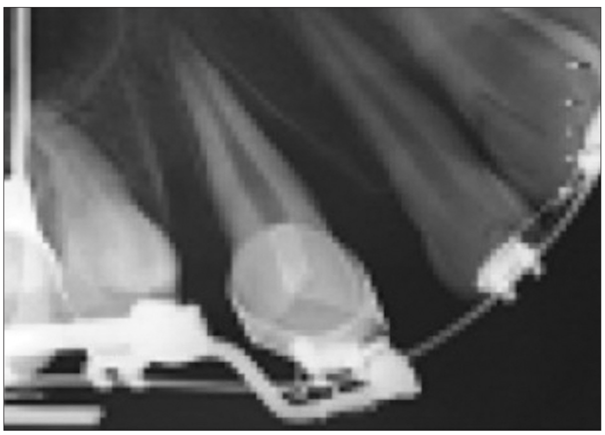

Figure 8: One week post-dental distraction

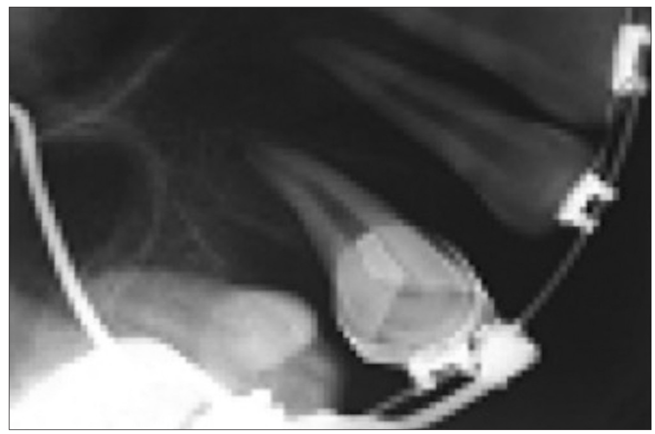

Figure 9: Two weeks post-dental distraction

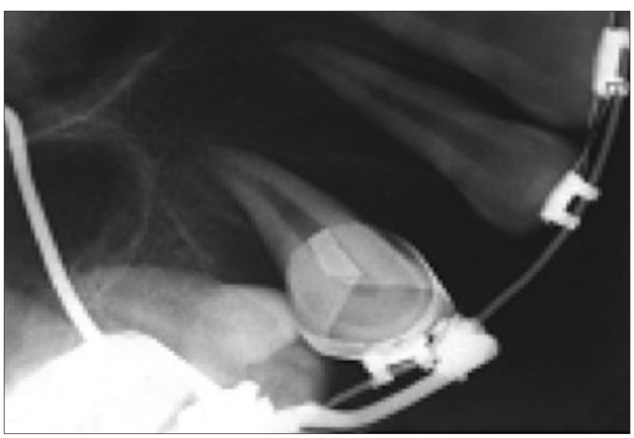

Figure 10: Three weeks post-dental distraction

Figure 11: One month post-dental distraction

was not assessed, the surgical procedures ensured that the resistance to canine distalization was significantly reduced. Moreover, the canines were distalized before the extraction socket became resistant and solid. The maximum time taken for canine distraction was 24 days which is minimal by orthodontic standards. Tooth movement was hence completed as the resorption process may be just initiating.

A certain degree of tooth mobility is observed during orthodontic treatment. This occurs primarily due to widening of the periodontal ligament by bone resorption.[26]

Most of the canines immediately after distraction manifested grade 11 mobility. The canine periodontal ligament was stretched and widened 7-8 mm during distraction. Some of the fibers could have been torn during this process, thus leading to hypermobility of the canines. After 3 months of retention, all the canines were as stable as before initiating the distraction. There was rapid osteogenesis in the distracted periodontal ligament and the same returned to normal width within 1 month of completing the distraction. The distracted canines were stabilized and their mobility reduced to normal levels after 3 months of retention due to osteogenesis and healing of the periodontal ligament.

Pulp vitality

The pulpal status of the distracted and anchor teeth was evaluated with an electric pulp tester before distraction, immediately after distraction and after 3 months of retention. All the evaluated teeth responded positively to the pulp tester prior to commencement of the distraction. There was no change in the color and translucency of any of the distracted or anchor teeth for the duration of the study.

Rapid correction of malocclusion by repositioning of dentoalveolar segments with the aid of corticotomies or osteotomies has been advocated by various researchers.[7,27-30] These studies report minimum incidence of non-vital teeth in the repositioned dentoalveolar segments. Ducker[31] and Gantes *et al*.[32] have reported that rapid orthodontic treatment using heavy forces in conjunction with corticotomy does not affect tooth vitality.

Numerous studies on blood supply during DO show that osteogenesis is accompanied by intense vascular proliferation and that the angiogenesis maintains normal blood supply to the distracted segment.[33-36]

No evidence of loss of vitality in any of the distracted or anchor teeth was observed in the duration of this study. However, circulatory disturbances of the pulp have been noticed during conventional orthodontic tooth movement also.

The results of the study indicate that the periodontal ligament can be distracted just like the mid-palatal suture in rapid palatal expansion to elicit rapid orthodontic tooth movement. By using this concept, maxillary canines can be rapidly retracted into the first premolar extraction space at the rate of about 2.43 mm/week.

This technique has the potential to significantly reduce the orthodontic treatment time. But its use may be limited to those cases in which canines are reasonably well positioned within the alveolar ridge, as distraction of labially positioned canines may compromise their thin labial cortical plate and soft tissue attachment.

Conclusion

The canines can be distracted rapidly and almost all of extraction space can be used for anterior dental alignment or retraction. After distraction, the anterior tooth retraction can be rapid as well, while the new bone tissues distal to the lateral incisors are still fibrous. Biomechanical principles underlying this procedure should be properly assessed and applied to maintain control over the rapid tooth movement before the routine application of this approach.

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