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A study to clinically assess the efficacy of modified hyrax device during periodontal ligament distraction of canines

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Abstract
According to the American Association of Orthodontists, the length of comprehensive orthodontic treatment "can range from one to three years." Nowadays, there is an increased tendency for researches to focus on accelerating methods for tooth movement due to the huge demand for adults for a shorter orthodontic treatment time. This increases the demand to find the best method to increase tooth movement with the least possible disadvantages. The aim of this research is to evaluate the effects of rapid canine distalization on dentoalveolar tissues and effects on anchor units during rapid canine retraction with semirigid, individual tooth-borne distractors.

A new concept of "distracting the periodontal ligament" is undertaken to elicit rapid canine retraction in 3 weeks called 'dental distraction'. Following osteotomy favoured surgical procedure on the day of maxillary first premolar extraction,the distraction protocol is initiated.The distractor device is a modified hyrax screw 13 mmconsisted of an anterior section, a posterior section, a screw, and a hex wrench to activate the screw. The distractor is activated on the day of surgery consisting of one turn on left side(0.25mm per day) and two turns on the right side 0.5mm per day(0.25x2) activation. The mean movement achieved on right side after 14 days is found to be 5.68 mm. The mean movement achieved on left side after 14 days is found to be 4.19 mm.

Keywords*: Periodontal ligament distraction, Rapid canine retraction, Distractor device, Hyrax.*

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I. Introduction

Prolonged orthodontic treatment brings about increased risk of root resorption,decalcification, and periodontal problems. In an effort to minimize these risks, orthodontists are continually trying to reduce treatment time while providing treatment results equal to or better than those currently being delivered. One way to reduce treatment time in orthodontic patients is to increase the rate of tooth movement.

Studies on treatment time have found durations ranging from 21-27 months for non-extraction treatment and 25-35 months for extraction treatment[1-7].Treatment times are influenced by many factors including type of malocclusion, amount of tooth movement required, mechanics utilized and patient compliance.Much research has been done to quantify the rate of tooth movement possible, with most studies showing approximately 1 mm of tooth movement per month.

One factor that has long been believed to affect rate of tooth movement is the amount of force applied to teeth. Boester and Johnston in 1974[8] conducted a split-mouth study comparing space closure rates while retracting canines using retraction springs of 2, 5, 8, and 11 oz of force (approximately 55, 140, 225, and 310 g of force). However, the results showed that space closure occurred at the same rate for forces from 5-11 ounces. Boester and Johnston[8] suggested that within this force range, bone resorption may be occurring at a maximal rate and thus be the rate-limiting factor. Another factor that possibly influences the rate of tooth movement is mode of force application. Nightingale and Jones in 2003[9]conducted a split-mouth study of canine retraction rates comparing the use of elastomeric chain and NiTi coil springs. Elastomeric chains delivered initial forces from 70-450 g (mean of 209 g) and coil springs delivered initial forces from 150-460 g (mean of 300 g). Space closure with elastomeric chains occurred at a rate of 0.21 mm per week while space closure with coil springs

occurred at 0.26 mm per week. The results indicated no statistically significant difference in canine retraction rate between the two modes of force application.

However, in one study done by Liou and Huang in 1998[10] faster canine retraction was done by the process called periodontal ligament distraction. Here the canine was retracted through the alveolar bone by weakening the bony resistance distal to canine through surgical procedure. The process of osteogenesis in the periodontal ligament during orthodontic tooth movement is similar to the process in the midpalatal suture during RPE or to that in the midface sutures in the growing animal during midface distraction.They reported that rapid orthodontic tooth movement was a form of distraction osteogenesis of the periodontal ligament. In this study they demonstrated the rapid distalization of 26 canine teeth in humans using distraction of the periodontal ligament. They achieved an average of 6.5 mm distraction of the canines and called this technique ‘‘dental distraction.’’ The aim of this research was the rapid distalization of canine teeth with semirigid, unidirectional, individual tooth-borne distractors and the statistical evaluation of the effects of rapid canine distalization on dentoalveolar structures. Therefore, it will be pertinent work to see whether the appliance can bring about an interesting result.

II. Materials And Methods

It is an in-vivo study on adult human subjects requiring orthodontic treatment.Our research is carried out on 10 (irrespective of gender) patients who requires first premolar extractions and requires Group-A anchorage because anterior crowding or dentoalveolar protrusion is present. Patients with permanent maxillary canines in palatoversion or excessive labioversion and having impacted or ankylosed canines ,molars and premolars are not included in the study. The average age of the treatment group is 16- 20 years. The sample consists of 20 canine teeth as observation sites. Any systemic illness like hyper-parathyroidism, hypothyroidism, hyperglycemia and decreased serum calcium levels is excluded. The patients who have healthy periodontium are the population under study.As effects of systemic illness rapid tooth movement would be inhibited and healthy periodontium is required to support enhanced tooth movement. Patients with prolonged history of corticosteroids and other immunosuppressive drugs are not considered under study population (Fig. 1).

After clinical, radiographic examination and evaluating the other diagnostic aids like cephalograms and study models analysis are performed and treatment plan has been derived. All patients (parents or guardians) are verbally informed of the study rationale and design. All patients following review of the study gave their consent to participate in the study.

Following informed consent, all participating patients are monitored to rule out systemic diseases and their oral hygiene is examined until onset of treatment procedure.

Orthodontic models, cephalometric and panoramic radiographs, and standard photographs of all the patients are obtained before treatment and after the consolidation period. Periapical radiographs of the canines and first molars are taken before distalization and repeated every week during the distraction period to observe the root resorption and the changes in the periodontal ligament and alveolar bone. The study is reviewed and approved for scientific validity and methodology by the Guru Nanak Institute of Dental Sciences & Research, Department of Orthodontics and Dentofacial Orthopedics. All protocols are approved by the Ethics Board, Guru Nanak Institute of Dental Sciences & Research, Department of Orthodontics and Dentofacial Orthopedics.

The case record of patients and bonding of distractor appliance for the study has been done in the Department of Orthodontics and DentofacialOrthopedics, Guru Nanak Institute of Dental Sciences and Research, Kolkata 700114 ,extraction of the first premolars and osteotomy has been conducted in the Department of Periodontics.

Bilateral maxillary canine retraction through periodontal ligament distraction

Pre-surgical preparation

Dental prophylaxis using an ultrasonic scaler irrigated with 0.12% chlorhexidine gluconate is performed. Orthopantomograms are taken;right and left periapical radiographs in the canine region are taken using a size 4 film.Digital calipers (RadioShack, Fort Worth,TX) are used to measure the distance between cuspal tip of canine and mesiobuccalcuspal tip of first molar.Five replicate caliper measurements are made for each distance and averaged.

Appliance design

The individual canine distractor is a tooth-borne, semirigid device which is designed based on established protocol. Orthodontic band material(Dentaurum, Ispringen, Germany) is custom made and welded to fit the maxillary canines and first molars. After the bands are fabricated for the canines and first molars, an impression is obtained, the bands are transferred into the impression material, and the study cast is made. Open Hyrax screw of 13 mm length (Leonne); length of the screw is arranged according to the distance between the

distal point of the canine and the mesial point of the first molar is soldered to the canine bands and first molar bands (Figure 2).The Hyrax screw is designed to have the anterior arm near the center of resistance of canine to achieve bodily movement of canine. The posterior arm is designed to adapt to the buccal surface of the first molar (Fig. 2).The interior aspect of each band is micro-abraded and the soldered junctions are sand papered for smooth finishing prior to cementation.

Surgical Protocol and Appliance Activation

All patients are prescribed pre-operative systemic antibiotic coverage Tab Doxycycline 200mg (loading dose) followed by 100 mg daily for three weeks. Vital signs are monitored throughout. Local anaesthesia (2% Lidocaine with 1:100,000 epinephrine) is administered with 5 ml syringe at the surgical sites via nerve block until positive symptoms of anesthesia is confirmed by patients. Firstly right maxillary first premolar is elevated and extracted followed by extraction of left maxillary first premolar. Bleeding is arrested with gauge pieces. On the experimental site at the distal wall of right and left canines vertical osteotomies are carried out at the mesiobuccal and mesiolingual line angles of the interseptal bone through the extraction socket with a straight fissure bone bur. The vertical osteotomies are connected with an oblique osteotomy extending towards the base of the interseptal bone to weaken the resistance. The distractor appliances are cemented in place after the surgery. The depth of the vertical grooves is 1.5mm on the interseptal bone away from the root apex of the canine(Fig.3). Patients are prescribed post-operative analgesic(generic name=morphine) if required on pain after meal. Patients are advised 10 ml 0.2% Chlorhexidine Gluconate mouthwash thrice daily for seven days.All canines are tested positively to the electronic pulp tester before surgical procedure and for one month of distraction.

The appliances are activated immediately after surgery(Fig.4). Activation of appliances are done by giving four turns(1 mm) of activation on right side per day and two turns(0.5mm)of activation on left side per day. The patients are closely monitored during the distraction period, and a Class I canine relationship is attained after an average of three weeks. After a two-week consolidation period, the distractors are removed and the edgewise mechanics started.

Intra- oral Measurements

Intra-oral caliper measurements and pulp vitality of canines are tested before distraction and every one week for three weeks after surgery. Peri-apical radiographs are taken every one week for three weeks of distraction (Figure 4,5,6).

Amount of canine retraction:

Measurements of the rate of canine movement are taken at three time points:

- Time point 0 (T0) = Day of initiation of canine retraction.
- Time point 1 (T1) = 1 week after the initiation of canine retraction (T0)
- Time point 2 (T2) = 2 weeks after (T1)

At each time point the amount of canine retraction are undertaken by 5 observers who are blinded to each other. A total of 5 measurements are taken and averaged. The amount of canine movement is defined by the horizontal distance between the cuspal tips of the canines and the mesio-buccal cuspal tips of first molars. That is, the millimetric measurements are taken with a digital caliper which measured the distance between the two points.
The rate of tooth movement for each patient is calculated by dividing the millimetric change in distance between the two registration points by the total days for each time period.

Statistical methods

The change in distance per week and total magnitude of movement are recorded, tabulated and subjected to statistical analysis. For statistical analysis data were entered into a Microsoft excel spreadsheet and then analyzed by SPSS 20.0.1and Graph Pad Prism version 5. Data have been summarized as mean and standard deviation for numerical variables and count and percentages for categorical variables. The median and the interquartile range have been stated for numerical variables that are not normally distributed. The results areshown as mean +/- standard deviation. Values of $P > .05$ are evaluated as statistically significant.

Fig.1 : Pre-Operative Intra-Oral View

Fig.2:During distraction

Fig.3 : Pre-Operative right lateral

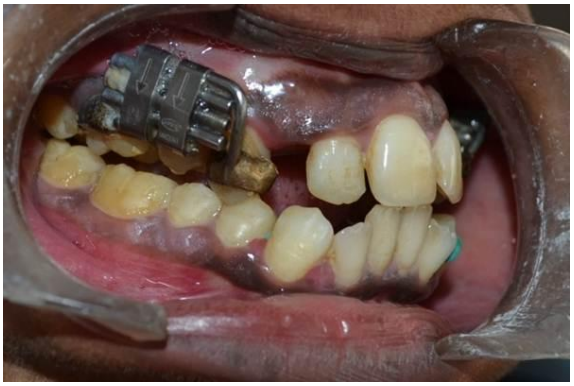

Fig.4: During distraction

III. Results

The activation of the distractor device (Hyrax 13 mm) is distributed as 1 mm(4 turns) per day on right side and 0.50 mm(2 turns) per day on left side. The distance between the mesio-buccal cusp tip of maxillary first molar and canines cusp tip is measured T_0. This distance is designated as T_0left (2 turns) and T_0 right (4 turns) of left and right side respectively. The measurement is repeated after 7 days (one week) from the day of surgery and this is designated as T_1 left and T_1 right. In this manner the measurement is repeated on 14th day (7 days after T_1) and the measurement is designated at T_2 left and T_2 right.

The rate of canine retraction in the first week (T_0- T_1) is calculated on the left side and right side, thus the rate of canine retraction is calculated for every 7 days, i.e, T_0- T_1, T_1- T_2,T_0- T_2

The rate of tooth movement, i.e. retraction of canine, calculated in the first week (T_0-T_1) is found to be 3.29mm ± 2mm (sd) on the left side and on the right side it is found to be 3.42mm± 2mm (sd). The difference means between the left and right side is found to be statistically insignificant (P< 0.8)

Whereas, the maximum rate of tooth movement is found in the second week (T_1-T_2). The rate of tooth movement is statistically significantly higher on right side (4 turns) which is found to be 2.26mm ±0.84mm (sd) than on the left side which is found to be 0.89mm ±0.81mm (sd).The difference means between the left and right side is found to be statistically significant (P < 0.0017) On the right side with 1 mm of distraction per day the rate of movement ranges between 0.26 mm to 0.548 mm/day compared with the left side with 0.5 mm of distraction per day where the rate of movement ranges between 0.15 mm to 0.44 mm per day which is clinically significant.

During canine retraction on first week it is found that both the maxillary canines showed increased neural response (T_0), whereas, after two weeks there is gradual decrease in neural response on both the canines.

IV. Discussion

Classically, the rate of orthodontic tooth movement depends on the magnitude and duration of the force, the number and shape of the roots, the quality of the bony trabeculae, the patient's response, and the patient's compliance. The rate of biologic tooth movement with optimum mechanical force is approximately 1 to 1.5 mm in 4 to 5 weeks[13]. Therefore, in maximum anchorage demand and first premolar extraction cases, canine distalization usually takes 6 to 9 months, contributing to an overall treatment time of 1.5 to 2 years[55,57]. The duration of orthodontic treatment is one of the issues patients complain about most, especially adult patients. Many attempts have been made to shorten orthodontic tooth movement. Liou and Huang in 1998 reported a rapid canine retraction technique involving distraction of the PDL after extraction of the first

premolars[16].The method was described as an innovative approach; however, refinements in the surgical technique, such as the use of corticotomies versus full osteotomies and the applicability of the technique to teeth close to the mandibular dental nerve, were suggested.

The subjects selected for this study all had a Class I bimaxillary protrusion with high anchorage situation. The sample was purposely selected within 16 to 20 years because the density of inter-radicular bone is more compared to children and adolescents. The treatment plan required the extraction of the maxillary first premolars and thesubsequent retraction of the maxillary canines. It was started with 15 patients, but five patients were excludedfrom the studybecause of multiple missed appointments, one because of repeated breakage of distractor device and two because of poor oral hygiene. A considerable amount of patient cooperation was necessary; the patients were expected to comply with the instructions regarding strict attention to oral hygiene measures and keeping the follow-up visits. In this study, it was hypothesized that the periodontal ligament distraction technique could be used to reduce treatment time while the anchor unit i.e. the molars were in lag phase. Anabolic and catabolic activities required for tooth movement occur following a shift in cell dynamics in response to applied biomechanical forces. Until sufficient osteoclasts and osteoblasts have accumulated within the PDL, tooth movement after initial force application is limited to the width of the PDL space; this 3–5-week "lag" phase dissipates as PDL cell populations supportive of tooth movement have accumulated and hyalinization has diminished (Von Bohl and Kuijpers-Jagtman, 2009)[46-49].Under conditions of orthodontic tooth movement, cell-free hyalinization is nearly impossible to avoid; it is the PDL hyalinization process that is used to explain the tooth movement arrest or lag phase as well as a process that precedes external root resorption (Ren*et al.*, 2003; Von Bohl and Kuijpers-Jagtman, 2009)[47,48,55].PDL distraction has been proved to drastically reduce the treatment time because the bony resistance is removed from the inter-radicular bone distal to the canine. It is well established that tooth movement rate is, in part, a function of alveolar bone density (Verna *et al.*, 2000)[16,22,24], and that tooth movement is accelerated under conditions of low bone density. Bone densities change regularly as bone re-news itself. Moreover, neither the buccal nor the apical bone through the extraction site nor the palatal cortical plate interfered with the movement of the canine-dento-alveolus segment during the distraction procedure[31,32,36] In this study no extra- or intraoral appliance is utilized for enhancing anchorage throughout the whole study. The posterior anchorage unit is formed merely by the second premolars and first molars. On the other hand, with the custom-made, rigid, tooth-borne distraction device, the canines are retracted at a faster rate and moved into the socket of the extracted first premolars in compliance with distraction osteogenesis principles. The distraction procedure is completed in all cases within a range of 12 to 18days(canines are retracted until they came into contact with the second premolar) although the measurement is taken on 14th day (Figure 7 A,B,C,D,E,F,G,H). It is found the amount of distal movement of maxillary canines followed by periodontal distraction to be a mean movement of 5.68 mm on the right side and 4.19 mm on the left side within a range of 12 to 14 days. The results concerning the amount of canine displacement are consistent with those of the previous studies where the canines moved a mean of 5.35 mm distally on the experimental side compared with the control side. (Sukurica et al)[56].

In the study done by Haluk Iseriet al[22]**,** rapid canine retraction through distraction osteogenesis was introduced. 20 maxillary canines in 10 growing or adult subjects were distracted in the first premolar extraction space. Distraction was initiated within 3 days after surgery. The distractor was activated twice per day, in the morning and in the evening, for a total of 0.8 mm per day. The canines were moved rapidly into the extraction sites in 8 to 14 days, at a rate of 0.8 mm per day.

In another study reported by Aboul-Ela *et al.* (2011)[10]clinically evaluated miniscrew implant-supported maxillary canine retraction with corticotomy- facilitated orthodontics. Corticotomy facilitated orthodontics was randomly assigned to one side of the maxillary arch at the canine–premolar region, and the other side served as the control. Using miniscrews as anchorage, canine retraction was initiated via closed nickel–titanium coil springs applying 150 g of force per side. Average daily rate of canine retraction was significantly higher on the corticotomy side than the control side by two times during the first 2 months after the corticotomy surgery. This rate of tooth movement declined to only 1.6 times higher in the third month and 1.06 times higher by the end of the fourth month.

In the study done by Liou et al[16], 26 canines, including 15 uppers and 11 lowers were distracted in the first premolar extraction space by periodontal ligament distraction. Activation was done 0.5 to 1.0 mm/day immediately after the extraction. The upper and lower canines were distracted bodily 6.5 mm into the extraction space within 3 weeks. New alveolar bone was generated and remodeled rapidly in the mesial periodontal ligament of the canine during and after the distraction.

In one of the studies done by Suryavanshi, *et al* the mean velocity was compared between two groups, one in which maxillary canine movement was done by conventional method and the other was done by modified corticotomy procedure. It was found that higher mean velocity (mm/month) is recorded in modified corticotomy group i.e, 1.02 mm/month compared to the conventional group i.e, 0.81 mm/month.

Liou et al[18]demonstrated in mature beagles that the best time to initiate tooth movement was immediately after distraction when the edentulous space is still fibrous and bone formation is just starting; they

suggested that tooth movement should be initiated when the osteogenic activity brought about by the distraction process is active, the new bone is still fibrous, and the trabeculae not well developed.

No clinical and radiographic evidence of complications, such as root fracture, root resorption, ankylosis, and soft tissue dehiscence, was observed in any of the patients. It is generally accepted that the best way to minimize root resorption is to complete the tooth movement in a short time. Root resorption begins 2 to 3 weeks after the orthodontic force is applied and can continue for the duration of force application. Complete retraction of the canines with PDL distraction occurred in 14 days in this study, an extremely short time for root resorption to begin. Previous investigations regarding rapid canine distraction and distalization by Liou and Huang[16], Sayın et al[19], and Kisnisci et al[20] stated that there was no significant change in the periodontal tissues. Although no meaningful findings were achieved with the electronic pulp tester, it can be still taken that the distracted canines preserved their pulp vitality at the end of dentoalveolar distraction. The pulp-vitality test is not a reliable technique when performed during orthodontic tooth movement. Moreover, no color change was observed in any teeth during the observation period of this study. Liou and Huang[16]reported that 9 of 26 teeth reacted positively to the electrical vitality test that was performed after the distraction. Sayın et al[19] did not report pulp vitality in their study. Kisnisci et al[20] reported that the vitality of the distractedcanines was within a normal range. However, further investigationof pulp vitality is needed in patients subjected torapid tooth movement with dentoalveolar distraction.

V. Conclusion

The present study draws the following conclusions:

1. The periodontal ligament can be distracted just like the mid-palatal suture in rapid palatal expansion in the teen age group.
2. By using this procedure, canines can be successfully distracted distally without significant complication up to a distance of 5.68 mm within a period of 14 days.
3. Comparing both the activation of the device with 1 mm per day to 0.5 mm per day it can be concluded that faster tooth movement can be achieved with 1 mm retraction per day without compromising pulpal response, whereas, an added advantage is noticed that, along with distraction irrespective of the distraction rate, simultaneous de-crowding occurred in the anterior segment which further reduced the time of first phase of orthodontic treatment i.e. alignment of teeth.

However, better conclusion can be drawn by increasing the sample size and including the mandibular arch in the study.

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