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# Rate of tooth movement and dentoskeletal effects of rapid canine retraction by dentoalveolar distraction osteogenesis: A prospective study

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**Introduction:** The purpose of this study was to test the null hypothesis that duration of orthodontic treatment can be significantly reduced by accelerating canine retraction using dentoalveolar distraction (DAD). **Methods:** Thirty-six maxillary canines of 19 patients comprised the DAD group, and 28 canines of 14 patients were included in the distalization group (DG). The initial mean ages were 15.8 ± 1.96 years for the DAD group and 16.02 ± 2.8 years for the DG. A custom-made, rigid, tooth-borne intraoral distraction device was used for the DAD group, and intraoral elastics were applied for canine distalization in the DG. Six skeletal and 11 dental variables were measured for the cephalometric evaluation. **Results:** Canine retraction was 7.9 ± 1.49 mm in 11.8 ± 1.3 days and canine distal tipping was 11.48° ± 4.37° after DAD; the canines were distalized 5.29 ± 2.01 mm and tipped 13.64° ± 9.54° in 200 ± 57 days in the DG. The rates of posterior canine movement were 0.67 ± 0.14 mm per day after DAD and 0.03 ± 0.01 mm per day in the DG. No significant first molar anchorage loss was observed after DAD, although the DG showed some vertical and sagittal first molar movement. **Conclusions:** We failed to reject the null hypothesis. DAD can reduce the duration of orthodontic treatment time by accelerating canine retraction in extraction patients without undesirable side effects. (Am J Orthod Dentofacial Orthop 2017;152:204-13)

A shorter orthodontic treatment duration has a positive impact on a patient's lifestyle[1] and can also be desirable to prevent possible harmful side effects.[2] Various factors have been suggested for prolonged treatment duration such as malocclusion characteristics, treatment method, patient cooperation, impacted maxillary canines, and earlier initiation of orthodontic treatment.[1,2]

Extraction treatment on average was found to require more treatment time to complete than did nonextraction treatment.[3] Mavreas and Athanasiou[2] concluded that there are indications that extraction treatment lasts longer than nonextraction therapy. Alger[4] found that the treatment of nonextraction patients finished 4.6 months faster than for those in whom he extracted teeth for orthodontic treatment. Vig et al[3] examined 5 practices to determine whether a systematic relationship existed between the relative frequency of extraction treatments and the duration of active appliance therapy; their findings showed that extraction treatment had a longer duration than nonextraction therapy. Skidmore et al[1] suggested that extractions have a significant effect on treatment duration that is independent of their association with more complex cases.

Nonextraction orthodontic techniques including miniscrew and orthodontic implant-supported distalization methods have become popular during recent years. However, patients with severe or moderate crowding still require treatment based on tooth extractions. Tooth extractions can also be beneficial for some problems including caries, periodontitis, endodontic problems, or even some developmental defects that are not within the orthodontist's control.[5]

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**Table I.** Number of patients, number of canines, mean ages, distalization times and rate of tooth movement in the DAD and DG

| *Group* | *Patients (n)* | *Canines (n)* | *Mean age (y)* | *Retraction time (d)* | *Rate of tooth movement* |
|---|---|---|---|---|---|
| DAD | 19 | 36 | 15.8 ± 1.96 | 11.8 ± 1.3 | 0.67 ± 0.14 mm/d |
| DG | 14 | 27 | 16.02 ± 2.8 | 200 ± 57 | 0.03 ± 0.01 mm/d |

Various surgical procedures have been used to reduce the orthodontic treatment or the canine distalization duration including alveolar surgery,[6] distraction osteogenesis,[7-18] corticotomy,[19-22] and piezosurgery.[23-25] The dentoalveolar distraction (DAD) technique was introduced in 2001; rapid tooth movement is achieved within the principles of distraction osteogenesis.[9-16] The dentoskeletal effects of this technique have previously been reported with a small sample and no control group.[11] The aim of this clinical prospective study was to test the null hypothesis that the duration of orthodontic treatment can be significantly reduced by decreased canine retraction time using DAD. The rate of tooth movement and the effects of DAD on dentoalveoler and skeletal structures were evaluated, and these effects were compared with a conventional canine distalization group.

## MATERIAL AND METHODS

A priori power analysis was completed by G*Power (version 3.1.9.2; Franz Faul, Kiel, Germany) software. Based on a 1:1 ratio between the groups, a sample size of 17 canines in each group would give 90% power to detect significant differences at a significance level of $\alpha = 0.05$. This prospective study consisted of 33 patients (13 boys, 20 girls). Thirty-six maxillary canines of 19 patients (8 boys, 11 girls) comprised the DAD group, and 28 canines of 14 patients (5 boys, 9 girls) were included in the distalization group (DG). Mean ages in the DAD group and the DG were 15.8 ± 1.96 and 16.02 ± 2.8 years, respectively (Table I). Inclusion criteria for both groups were the following: (1) permanent dentition, (2) first premolar extractions indicated for correcting the existing dental malocclusion (to eliminate overjet or crowding), and (3) no history of systemic disease causing medical difficulty after tooth extractions or any surgical intervention.

The treatment procedure was explained in detail to all patients and parents, and informed consent was obtained before surgery. This research project was approved by the ethics committee at the University of Ankara in Turkey.[26]

The DG consisted of 7 Class I, 5 Class II Division 1, and 2 Class III patients. Fixed orthodontic appliances were used in all DG patients; 120 g of horizontal intraoral elastic force was used for canine distalization. The magnitude of force was measured at each appointment and arranged with a gram gauge. The patients were ordered to change the elastics daily. Lateral cephalometric, panoramic and periapical films were taken before fixed orthodontic treatment and after canine-second premolar contact was achieved. The mean distalization duration for the DG was 200 ± 57 days. No intraoral or extraoral appliance was used for maintaining anchorage during canine retraction.

The DAD group consisted of 4 Class I, 14 Class II Division 1, and 1 Class III patients. Lateral cephalometric and panoramic films were taken before and after DAD and, in 11 patients, after fixed orthodontic therapy. One-sided DAD was achieved in 2 patients, and bilateral DAD was done in 17 patients. The total number of canines of the DAD group was 36. The periapical films were obtained before DAD, during DAD, and after DAD.

A custom-made, rigid, tooth-borne intraoral distraction device was used for DAD. The device was made of stainless steel and had a distraction screw and 2 guidance bars (Fig 1, *A*). The patient or the parent turned the screw clockwise with a special apparatus for distal movement of the canine. The canines and the first molars were banded with 0.06 × 1.80-in band material, and an impression was obtained when the canine and first molar bands were placed on the teeth. The distractor was then soldered to the bands on the dental cast with consideration of both the biomechanical principles of tooth movement and the rotation center of the canine. The distractor was positioned buccally at the highest position permitted by the soft tissue to minimize tipping (Fig 1, *B*).

The surgical procedure of DAD was described previously.[9] Surgery was performed under local anesthesia. Briefly, a vestibule flap was opened without touching the gingival margin of the canines and neighboring teeth. Complete vertical and horizontal osteotomies at a distance of 3 to 5 mm from the apex and the roots were performed to mobilize the alveolar segment. Then the first premolar was extracted, and the buccal bone was removed between the outlined distal bone cut of the canine and the second premolar with a round bur. The palatal shelf was preserved, but the apical bone near the sinus wall was removed to leave an intact sinus

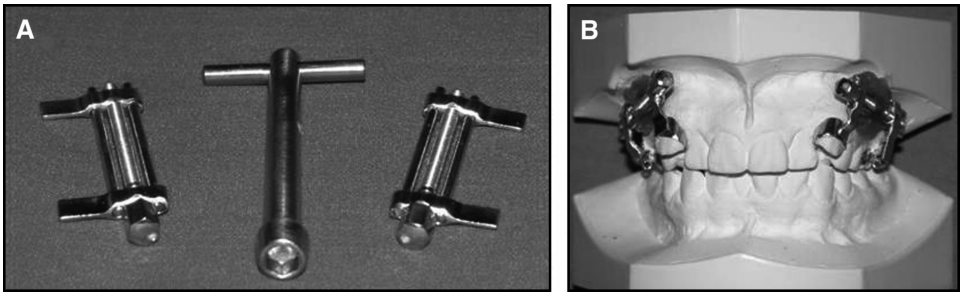


**Fig 1.** **A,** DAD appliance; **B,** construction of the appliance.

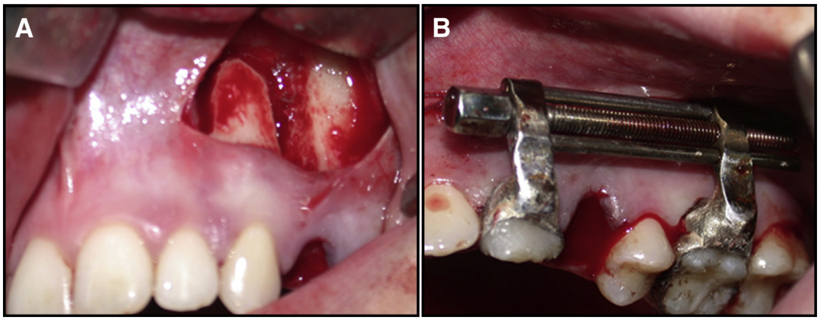


**Fig 2.** **A,** DAD surgery; **B,** cementation of the DAD appliance after surgery.

membrane to prevent interferences during canine retraction. Osteotomes were used on the vestibule side of canines to split the surrounding bone around its root from the palatal cortex and neighboring teeth. The transport dentoalveoler segment included the buccal cortex and the underlying spongy bone that envelopes the canine root, leaving intact palatinal cortical plates and the bone around the apex of the canine (Fig 2, *A*).

The device was cemented on the canine and the first molar immediately after the surgical procedure, and no other appliance was placed on the other teeth during the distraction procedure (Fig 2, *B*). The device was activated intraoperatively by several millimeters and set back to its initial position to ensure the mobility of the transport segment. The incision was closed with absorbable sutures, and a nonsteroidal anti-inflammatory drug and an antibiotic were prescribed for 5 days. The duration of the surgical procedure was approximately 30 minutes for each canine. The patients were also instructed not to brush their teeth to prevent trauma around the surgical site for 3 days. A 0.2% chlorhexidine gluconate rinse was prescribed twice a day during the distraction procedure.[9,11,14]

Distraction was initiated after 3 days of latency. The distractor was activated twice per day, in the morning and in the evening, for a total of about 0.8 mm per day. DAD was finished when the canines came into contact with the second premolars or the necessary amount of movement was achieved. The distractor was then removed, and fixed orthodontic treatment was immediately initiated with the leveling of both dental arches. Ligatures were placed under the archwire between the distracted canine and the first molar and kept for at least 3 months after the DAD procedure to prevent mesial movement of the canine (Figs 3-6). A meticulous oral hygiene program was initiated before and after the DAD and during fixed appliance orthodontic therapy; it was controlled by a periodontologist with monthly appointments.

The stages of DAD treatment were the following.

1. Dentoalveolar distraction.
2. Initiation of fixed appliance orthodontic treatment on both dental arches with 0.018-in stainless steel brackets, an 0.008-in ligature wire between the first molar and the canine, a 0.014-in nickel-titanium wire for leveling, and a 0.016-in nickel-titanium wire for leveling (if necessary).
3. A 0.016 $\times$ 0.016-in stainless steel wire with reverse closing loops for incisor retraction and torque control.
4. A 0.017 $\times$ 0.025-in stainless steel wire for the finishing phase.
5. End of orthodontic treatment.

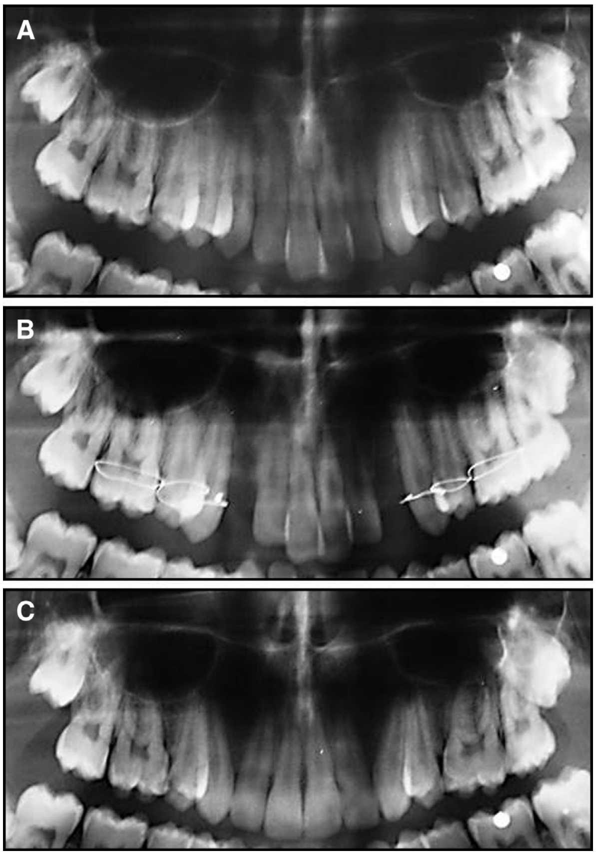


**Fig 3.** Panoramic films of a patient: **A,** before DAD; **B,** after DAD (11 days); and **C,** after orthodontic treatment (9 months).

The stages of the DG treatment were the following.

1. Initiation of fixed appliance orthodontic treatment on both dental arches with 0.018-in stainless steel brackets, a 0.014-in nickel-titanium wire for leveling, a 0.016-in nickel-titanium wire for leveling, and a 0.016-in stainless steel wire for leveling.
2. Canine distalization with horizontal intraoral elastic force.
3. A 0.016 × 0.016-in stainless steel wire with reverse closing loops for incisor retraction and torque control.
4. A 0.017 × 0.025-in stainless steel wire for the finishing phase.
5. End of orthodontic treatment.

A comfort/patient satisfaction survey was used; discomfort levels between the 2 study groups were similar.

Panoramic films and periapical radiographs of the canines and first molars were taken to evaluate root structures. Root resorption scores were detected according to the root resorption scale modified from the study of Sharpe et al[27] using panoramic and periapical radiographs.

In the DAD group, tooth vitality tests were used before DAD, after fixed orthodontic treatment, and at the sixth month of retention in patients whose orthodontic fixed therapies were finished. Electric pulp testing was done with Digitest (model D626D; Parkell Electronics Division, Edgewood, NY), and thermal stimulation was provided with chloraethyl spray (IG Sprühtechnik, Wehr, Germany). No pulpal sensibility test was performed in teeth with restorations because of possible incorrect responses. Tooth vitality was scored as positive or negative according to the response to both electric and pulpal tests.

Lateral cephalometric films were obtained under standardized conditions (the film-focus distance was 155 cm, and the distance from the midsagittal plane to the film was 12.5 cm). Fourteen anatomic reference points were digitized with a computer program, Purpose on Request Digitizer Input Output System. Six skeletal and 11 dental variables were measured (Table II and Fig 7).

## STATISTICAL ANALYSIS

The initial descriptive statistics are presented in Table III. Intergroup changes and intragroup differences were evaluated with 2-sample *t* tests and paired *t* tests, respectively.

Twenty-two randomly selected cephalograms were retraced 1 month later by the same examiner (G.K.), and the second measurements were obtained. The reliability of the measurements was evaluated by the formula described by Winner.[28] No significant differences were found, and the reliability coefficients ranged between 0.954 and 0.997.

## RESULTS

The canines of the DAD group were retracted 7.9 ± 1.49 mm in 11.8 ± 1.3 days, whereas 5.29 ± 2.01 mm of canine distal movement was achieved in 200 ± 57 days in the DG. Therefore, the rates of posterior canine movement were 0.67 ± 0.14 mm per day in the DAD group and 0.03 ± 0.01 mm per day in the DG (Table I). Thus, we failed to reject the null hypothesis.

The DAD group and the DG showed generally similar initial values. The s n sm ($P < 0.05$) and NL/MLs ($P < 0.01$) measurements were higher in the DG, and NL-is ($P < 0.05$), overjet ($P < 0.05$), and ss n sm ($P < 0.05$) were higher in the DAD group (Table III).


**Fig 4.** Frontal intraoral photographs of a DAD patient.


**Fig 5.** Right intraoral photographs of a DAD patient.

In the DAD group (Table IV), no statistically significant changes were found in the maxillary and mandibular measurements after DAD, except for overbite, which showed a statistically significant decrease ($P$ <0.01).

In the dentoalveoler measurements, 0.79° ± 1.51° of maxillary incisor and 11.48° ± 4.37° of canine tipping were significant ($P$ <0.05 and $P$ <0.001, respectively). Nonsignificant tipping (0.01° ± 1.80°) was observed in the maxillary first molars.

No significant sagittal movement was found in the maxillary incisors and first molars, but the maxillary canines showed 7.91 ± 1.49 mm of significant retraction ($P$ <0.001).

Vertical displacements of the maxillary incisors and first molars relative to the nasal line were not significant. The maxillary canines showed 2.09 ± 1.66 mm of significant vertical movement ($P$ <0.001).

In the DG (Table IV), as a result of a significant decrease in s n sm ($P$ <0.05), a significant increase in vertical dimension (NSL/ML angle) ($P$ <0.05) was found after canine-second premolar contact was achieved. No other maxillary or mandibular parameters showed significant changes.

For the dentoalveoler measurements, 13.64° ± 9.54° of tipping was observed in the maxillary canines ($P$ <0.001), whereas the maxillary incisors and first molars showed no statistically significant tipping.

The distal displacements of the maxillary incisors (1.96 ± 2.79 mm) and canines (5.29 ± 2.01 mm) were significant ($P$ <0.05 and $P$ <0.001, respectively). The maxillary first molars showed 1.98 ± 1.16 mm of


**Fig 6.** Left intraoral photographs of a DAD patient.

anchorage loss after canine-second premolar contact was achieved.

Vertical movement of the maxillary incisors was nonsignificant, but extrusions in the canines (2.81 ± 2.75 mm) and first molars (0.69 ± 1.03 mm) were significant ($P < 0.01$ and $P < 0.05$, respectively).

Neither study group showed any significant difference in maxillary measurements. The changes in s n sm and mandibular plane angles in the DG were significantly different from those in the DAD group ($P < 0.05$). No significant maxillomandibular measurement difference was found between the 2 groups.

For the dentoalveolar measurements, the maxillary incisor distal movement was significantly greater in the DG ($P < 0.05$), and more maxillary canine distalization was found in the DAD group ($P < 0.001$). Molar mesialization, which indicates molar anchorage loss, was significantly higher in the DG ($P < 0.01$). No other dental changes were significant between the 2 groups after canine distalization.

No root resorption was observed in the DAD group. Six canines of the DG showed widening of the periodontal ligament space at the root apex, but there was no root resorption in 21 canines of the DG.

No loss of tooth vitality in any maxillary canine was observed in the DAD group. Moreover, no color change was observed in any teeth before and after DAD, and after 6 months of follow-up.

## DISCUSSION

Several techniques have been described for accelerated tooth movement in conjunction with surgical interventions. In 1959, Köle[19] reported combined orthodontics and corticotomy surgery for rapid tooth movement, and the active tooth movement finished in 6 to 12 weeks in adult patients with no root resorption, no loss of vitality, and no pocket formation. In 2001, Wilcko et al[20] reported the results of modification of corticotomy-assisted tooth movement called the "periodontally accelerated osteogenic orthodontics procedure", which uses aggressive surgery. Decortications almost reaching into the medullary bone between the roots of teeth and bone grafting were done after full-thickness labial and lingual alveolar flaps were opened.[21,25] The authors attributed the rapid tooth movement primarily to the induced increase in bone turnover and secondarily to the decreased mineral content of the bone (demineralization).[22] These observations are well known in orthopedics as the regional acceleratory phenomenon, where an increased healing process occurs at the site of the surgical intervention.[29]

Dibart et al[24] presented "piezocision" as a minimally invasive technique without flap surgery that uses a piezoelectric knife to decorticate the alveolar bone to induce the regional acceleratory phenomenon effect. In a recent study, Aksakalli et al[23] compared the extent of canine distalization in maxillary premolar extraction patients with or without piezocision. The maxillary canines retracted in 3.54 ± 0.81 months in the piezocision group with 2.04 ± 0.52 mm of molar anchorage loss, and the duration of canine distalization was 5.59 ± 0.94 months with 3.01 ± 0.37 mm of molar mesialization in the no-piezocision group. The canines showed 7.9 ± 1.49 mm of retraction in 11.8 ± 1.3

**Table II.** Measurements used in this study

| *Measurement* | *Description* |
|---|---|
| NSL | Anterior cranial base; line between sella (s) and nasion (n) |
| NL | Nasal line; line between anterior nasal spine (sp) and posterior maxilla (pm) |
| NLv | Perpendicular vertical line constructed from sp point of nasal line |
| ML | Mandibular plane; line between menton (me) and tangent menton (tg.me) |
| ILs | Long axis of the central incisors—line between incisal edge (is) and apex (as) of maxillary central incisors |
| CLs | Long axis of the maxillary canines-line between tip (uc) and apex (uca) of canines |
| MLs | Long axis of the maxillary molars—line between the tip (ms) and apex (msa) of the mesiobuccal cusp of the maxillary first molars |
| s n ss (°) | Angle between NSL and subspinale |
| NSL/NL (°) | Nasal line angle in relation to anterior cranial base |
| s n sm (°) | Mandibular prognathism |
| NSL/ML (°) | Mandibular inclination in relation to anterior cranial base |
| ss n sm (°) | Sagittal intermaxillary relationship |
| NL/ML (°) | Mandibular inclination in relation to the nasal line |
| Overbite (mm) | Vertical distance between the incisal edges of the most prominent maxillary and mandibular central incisors |
| Overjet (mm) | Sagittal distance between the incisal edges of the most prominent maxillary and mandibular central incisors |
| NL/ILs (°) | Maxillary incisor inclination—angle between the long axis of the first incisors in relation to NL |
| NL/CLs (°) | Maxillary canine inclination-angle between the long axis of the canines in relation to NL |
| NL/MLs (°) | Molar inclination in relation to the NL |
| NLv-is (mm) | Sagittal position of the maxillary incisors in relation to the NLv |
| NLv-uc (mm) | Sagittal position of the maxillary canines in relation to the NLv |
| NLv-ms (mm) | Sagittal position of the maxillary first molars in relation to the NLv |
| NL-is (mm) | Vertical position of the maxillary incisors in relation to the NL |
| NL-uc (mm) | Vertical position of the maxillary canines in relation to the NL |
| NL-ms (mm) | Vertical position of the maxillary first molars in relation to the NL |

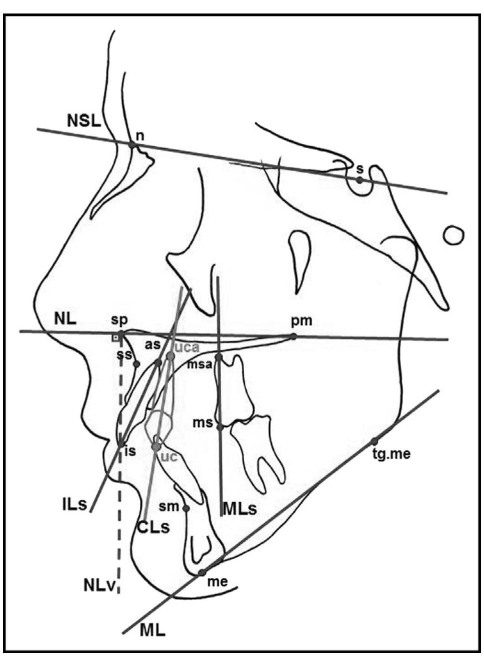


**Fig 7.** Cephalometric landmarks and lines used for this study.

days after DAD without anchorage loss, and 5.29 ± 2.01 mm of canine distalization was measured in 200 ± 57 days in the distalization group with 1.98 ± 1.16 mm of molar mesialization. The advantage of piezocision is its minimal surgery, but this procedure is not effective in patients with ankylosed teeth, preexisting root resorption, or teeth with angulated roots.[24]

Pilon et al[30] studied the relationship between the magnitude of a constant continuous orthodontic force and the rate of bodily tooth movement, and found tooth movement of 1 to 1.5 mm in 4 to 5 weeks and a maximum rate of tooth movement of about 2.5 mm per month. Yee et al[31] evaluated the rate and the amount of orthodontic tooth movement under heavy (300 g) and light (50 g) continuous forces in 12 weeks, and found 4.10 ± 1.68 mm of canine retraction in the heavy-force group and 1.70 ± 0.58 mm of canine retraction in the light-force group. The rate of canine retraction was almost 1 mm per month in the DG with 120 g of intraoral elastic traction; this finding was compatible with the results of similar studies in the literature. The daily rates of tooth movement of the studies using interseptal bone reduction,[32] corticotomies,[33,34] piezocision,[23] and periodontal ligament distraction[7,8,15] for accelerating canine distalization range from 0.05 to 0.31 mm. The rate of posterior canine movement was 0.67 ± 0.14 mm per day in the DAD group, and this rate is the fastest orthodontic tooth movement in the literature.

İşeri et al[11] showed that full retraction of canines was finished in 10.01 ± 2.01 days by 0.8 mm of DAD

**Table III.** Comparison initial values of the DAD group and the DG

| | *DAD group (mean ± SD)* | *DG (mean ± SD)* | *Difference (t test)* |
|---|---|---|---|
| Maxillary measurements | | | |
| s n ss (°) | 79.09 ± 3.90 | 80.25 ± 3.40 | NS |
| NSL/NL (°) | 9.58 ± 2.94 | 9.06 ± 3.06 | NS |
| Mandibular measurements | | | |
| s n sm (°) | 73.72 ± 5.43 | 77.93 ± 3.63 | * |
| NSL/ML (°) | 38.73 ± 7.86 | 35.13 ± 5.07 | NS |
| Maxillomandibular measurements | | | |
| ss n sm (°) | 5.36 ± 4.28 | 2.33 ± 3.68 | * |
| NL/ML (°) | 29.16 ± 6.43 | 26.07 ± 4.35 | NS |
| Overbite (mm) | 2.94 ± 2.28 | 2.93 ± 2.35 | NS |
| Overjet (mm) | 7.17 ± 2.77 | 4.27 ± 2.86 | * |
| Dentoalveoler measurements | | | |
| NL/ILs (°) | 110.74 ± 6.75 | 112.05 ± 7.02 | NS |
| NL/CLs (°) | 103.53 ± 6.74 | 106.88 ± 9.94 | NS |
| NL/MLs (°) | 88.23 ± 5.89 | 95.75 ± 7.76 | † |
| NLv-is (mm) | 2.65 ± 2.79 | 1.85 ± 2.02 | NS |
| NLv-uc (mm) | 9.11 ± 4.05 | 10.14 ± 4.05 | NS |
| NLv-ms (mm) | 31.05 ± 4.11 | 30.32 ± 4.30 | NS |
| NL-is (mm) | 31.22 ± 2.45 | 29.29 ± 2.06 | * |
| NL-uc (mm) | 27.15 ± 3.87 | 25.84 ± 4.32 | NS |
| NL-ms (mm) | 26.12 ± 3.06 | 24.62 ± 2.21 | NS |

*NS*, Nonsignificant.
*$P < 0.05$; †$P < 0.01$.

distractor activation per day. Kharkar et al[17] achieved canine retraction in 12.5 ± 0.5 days with DAD and 19.5 ± 1.70 days with periodontal ligament distraction. Şukuriça et al[18] achieved 5.25 ± 1.22 mm of canine retraction in 14.65 ± 3.49 days with DAD. The canine retraction time of 11.8 ± 1.3 days in our DAD group was supported by the previous clinical DAD studies, and small differences can be attributed to the amounts of appliance activation and the designs of the distraction devices.

Although the DAD device has 2 guidance bars and was positioned as high as possible within the limits of the vestibule sulcus, 11.48° ± 4.37° of canine tipping was observed after DAD. İşeri et al[11] found 13.15° ± 4.65° of tipping by DAD, and Sayın et al[8] measured 11.47° ± 0.46° of tipping after periodontal ligament distraction of canines. The center of resistance is important for tooth movement; teeth move parallel when force is passing through this point. Since teeth are embedded in alveolar bone, orthodontic force is applied on the exposed part of a tooth, which is at a distance from the center of resistance. Therefore, some tipping observed in canine distraction studies can be attributed to the distance between the point of force application that is near the gingiva and the center of resistance of the canines.

No significant maxillary first molar tipping, vertical displacement, and mesial movement indicating anchorage loss were observed in the DAD group; in the DG, the maxillary first molars showed significant vertical and mesial movements, which mean anchorage loss (0.69 ± 1.03 mm and 1.98 ± 1.16 mm, respectively). Tipping of the maxillary first molars was insignificant in the DG. No extraoral or intraoral anchorage appliances or mechanics were usd in either group during canine retraction, so approximately 2 mm of maxillary first molar mesialization in the DG would be attributed to horizontal intraoral elastic traction between first molar and the canine. On the other hand, no significant vertical or mesial molar movement was observed after DAD. During biologic tooth movement, there is a 2- to 3-week lag period for the removal of hyalinized tissue.[30,35,36] Canine retraction was achieved at 11.8 ± 1.3 days in the DAD patients of our study, during the hyalinization period and therefore before the maxillary first molars started to move. In periodontal ligament distraction, canine retraction lasts slightly longer than DAD.[17] Liou and Huang[7] found less than 0.5 mm of mesial movement in 27% of maxillary first molars. Sayın et al[8] showed 0.56 and 0.64 mm of sagittal and vertical anchorage loss, respectively, whereas Kharkar et al[17] observed 0.25 ± 0.05 mm of mesial movement of the maxillary first molars with periodontal ligament distraction. A significant mandibular plane angle increase was found in the DG, and due to posterior rotation of the mandible, the s n sm angle showed a significant decrease. These changes can be attributed to the significant vertical movement of the maxillary first molars in the DG. The

**Table IV.** Comparison of dentoskeletal changes between the DAD group and the DG

| | *DAD before (mean ± SD)* | *DAD after (mean ± SD)* | *Paired t test (mean ± SD)* | *DG before (mean ± SD)* | *DG after (mean ± SD)* | *Paired t test (mean ± SD)* | *DAD vs DG 2-sample t test (mean ± SD)* |
|---|---|---|---|---|---|---|---|
| Maxillary measurements | | | | | | | |
| s n ss (°) | 79.09 ± 3.90 | 79.16 ± 4.03 | 0.08 ± 1.12 | 80.25 ± 3.40 | 79.59 ± 3.05 | −0.66 ± 1.18 | NS |
| NSL/NL (°) | 9.58 ± 2.94 | 9.53 ± 2.76 | −0.05 ± 1.12 | 9.06 ± 3.06 | 9.60 ± 3.15 | 0.55 ± 1.51 | NS |
| Mandibular measurements | | | | | | | |
| s n sm (°) | 73.72 ± 5.43 | 74.08 ± 5.52 | 0.36 ± 1.44 | 77.93 ± 3.63 | 77.28 ± 3.74 | −0.65 ± 0.85* | * |
| NSL/ML (°) | 38.73 ± 7.86 | 38.61 ± 7.41 | −0.13 ± 1.47 | 35.13 ± 5.07 | 36.12 ± 5.59 | 0.99 ± 1.40* | * |
| Maxillomandibular measurements | | | | | | | |
| ss n sm (°) | 5.36 ± 4.28 | 5.08 ± 4.31 | −0.29 ± 0.81 | 2.33 ± 3.68 | 2.31 ± 3.16 | −0.02 ± 1.01 | NS |
| NL/ML (°) | 29.16 ± 6.43 | 29.08 ± 6.34 | −0.08 ± 0.98 | 26.07 ± 4.35 | 26.52 ± 4.35 | 0.45 ± 1.38 | NS |
| Overbite (mm) | 2.94 ± 2.28 | 2.34 ± 2.38 | −0.60 ± 0.91† | 2.93 ± 2.35 | 2.98 ± 1.92 | 0.05 ± 1.90 | NS |
| Overjet (mm) | 7.17 ± 2.77 | 6.85 ± 3.42 | −0.32 ± 1.27 | 4.27 ± 2.86 | 4.73 ± 2.79 | 0.46 ± 2.37 | NS |
| Dentoalveoler measurements | | | | | | | |
| NL/ILs (°) | 110.74 ± 6.75 | 109.95 ± 6.70 | −0.79 ± 1.51* | 112.05 ± 7.02 | 108.47 ± 6.22 | −3.59 ± 9.86 | NS |
| NL/CLs (°) | 103.53 ± 6.74 | 92.05 ± 6.17 | −11.48 ± 4.37‡ | 106.88 ± 9.94 | 93.25 ± 6.07 | −13.64 ± 9.54‡ | NS |
| NL/MLs (°) | 88.23 ± 5.89 | 88.24 ± 5.32 | 0.01 ± 1.80 | 95.75 ± 7.76 | 97.55 ± 7.70 | 1.80 ± 6.59 | NS |
| NLv-is (mm) | 2.65 ± 2.80 | 2.88 ± 2.43 | 0.23 ± 0.75 | 1.85 ± 2.02 | 3.81 ± 2.21 | 1.96 ± 2.79* | * |
| NLv-uc (mm) | 9.11 ± 4.05 | 17.02 ± 3.81 | 7.91 ± 1.49‡ | 10.14 ± 4.05 | 15.43 ± 4.17 | 5.29 ± 2.01‡ | ‡ |
| NLv-ms (mm) | 31.05 ± 4.11 | 31.12 ± 3.74 | 0.07 ± 0.64 | 30.32 ± 4.30 | 28.34 ± 3.98 | −1.98 ± 1.16† | † |
| NL-is (mm) | 31.22 ± 2.45 | 31.63 ± 2.31 | 0.41 ± 0.98 | 29.29 ± 2.06 | 30.27 ± 2.27 | 0.98 ± 1.86 | NS |
| NL-uc (mm) | 27.15 ± 3.87 | 29.24 ± 3.32 | 2.09 ± 1.66‡ | 25.84 ± 4.32 | 28.65 ± 2.64 | 2.81 ± 2.75† | NS |
| NL-ms (mm) | 26.12 ± 3.06 | 26.36 ± 2.94 | 0.24 ± 0.71 | 24.62 ± 2.21 | 25.31 ± 2.22 | 0.69 ± 1.03* | NS |

*NS*, Nonsignificant.
**P* <0.05; †*P* <0.01; ‡*P* <0.001.

DAD group showed no vertical first molar movement, so no significant change was found in mandibular plane angle. İşeri et al[11] found nonsignificant slight changes in the mandibular plane angle (0.67° ± 0.80°) after DAD. Therefore, DAD can be advantageous in patients with increased skeletal vertical dimensions.

Reduced anterior tooth retraction time was observed in the DAD patients during fixed orthodontic therapy. İşeri et al[11] also stated that the lateral incisors showed accelerated tooth movement into the new bone tissue after DAD. This observation may be related to movement of the incisors into immature bone mesial to the canines with less resistance. Similar to the periodontally accelerated osteogenic orthodontics procedure and piezocision, the rapid incisor retraction phase can also be due to the regional acceleratory phenomenon, which is induced after DAD surgery. Liou et al[37] demonstrated successful tooth movement in 4 mature beagle dogs immediately after mandibular distraction. The teeth moved 1.2 mm per week without gingival dehiscences and infrabony defects while maintaining their vitality, when the new bone was still fibrous and the trabeculae not well developed. On the other hand, El Sharaby et al[38] evaluated the orthodontic tooth movement into bone regenerate histologically in 9 male mongrel dogs after mandibular distraction osteogenesis and found adverse tissue reactions. They did not recommend early tooth movement into the distraction gap and advised a radiographic examination of the distraction regenerate before starting tooth movement. In DAD, the surgical technique is different from mandibular distraction surgery. No distraction gap exists between bone segments in DAD as seen after lengthening of the mandibular corpus during distraction osteogenesis. The palatal bone and the maxillary sinus wall remained untouched during DAD surgery, so the new bone mesial to the distracted transport segment forms within neighboring healthy maxillary bone tissue. Because controversial findings exist in the literature about the health of teeth moved into distraction regenerate, further studies are needed. No complications such as root resorption, root fracture, soft tissue dehiscence, or fenestration were observed after DAD.[9-11]

## CONCLUSIONS

The mean tooth movement (canine retraction) rates were 0.67 ± 0.14 mm and 0.03 ± 0.01 mm per day in the DAD group and the DG, respectively. In the DAD group, 7.9 ± 1.49 mm of canine posterior movement was achieved in 11.8 ± 1.3 days; this is the fastest orthodontic tooth movement in the literature with no molar anchorage loss. Adults seeking shorter treatments, and patients with periodontal problems, root size and shape anomalies, preexisting root resorption, and ankylosed teeth can be good candidates for DAD.

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