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Alterations in gingival dimensions following rapid canine retraction using dentoalveolar distraction osteogenesis

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SUMMARY The aim of this clinical prospective study was to evaluate the alterations that occurred in the gingival dimensions of canine teeth following dentoalveolar distraction (DAD) during a 12 month follow-up period.

The study sample comprised 36 maxillary canines of 18 growing or adult subjects with a mean age of 16.94 years (13.08–25.58 years) at the start of treatment. Full retraction of the canines was achieved in 10.36 ± 1.93 days (range 8–14 days) at a rate of 0.8 mm/day using a custom-made intraoral rigid tooth-borne distraction device. Before surgery (pre-DAD), immediately after removal of the device (post-DAD), and at 1, 6, and 12 months post-DAD, the plaque index (PI), gingival index (GI), pocket depth (PD) and width of keratinized gingiva were recorded and the width of attached gingiva was calculated. The alterations in clinical measurements among different evaluation periods were analysed by Friedman and repeated measure ANOVA tests.

There were significant differences between pre- and post-DAD for PD measurements for all sites, with the highest at the distal site. The palatal sites likewise showed significant differences at the 1, 6, and 12 month follow-up periods compared with the post-DAD period. The buccal sites showed no significant changes at any time point. The width of keratinized gingiva also showed no significant change during the follow-up period, while the width of attached gingiva was significant only between the pre- and post-DAD periods ($P < 0.01$). On the basis of the above findings, it could be concluded that DAD is an innovative technique with no unfavourable long-term effects on the gingival tissues of rapidly retracted canine teeth.

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Introduction

It is a well-known fact that most orthodontic subjects have a shortage of space and crowding. Although non-extraction treatment approaches have become popular during the last decade, there is still a considerable number of patients who need treatment based on tooth extraction (Vig *et al.*, 1990). The first phase of treatment in premolar extraction cases is retraction of the canines. Using conventional orthodontic treatment techniques, biological tooth movement can be achieved at a limited rate (Reitan, 1967; Rygh, 1974), and the canine retraction phase often lasts 6–8 months. Besides this, special extra- or intraoral mechanics are required to secure anchorage during the retraction phase, particularly in subjects where maximum anchorage is necessary. Therefore, under normal circumstances, conventional treatment with fixed appliances is likely to last approximately 20–24 months, and the duration of orthodontic treatment often provokes the most complaints, especially by adults. Many attempts have been made to shorten the duration of orthodontic tooth movement (Davidovitch *et al.*, 1980a, b; Liou and Huang, 1998), and recently a technique of rapid canine movement (within the dentoalveolar segment) in compliance with dentoalveolar distraction (DAD) osteogenesis has been described and used (İşeri *et al.*, 2001, 2005; Kişnişci *et al.*, 2002). Although a limited number of studies (Liou and Huang, 1998; Liou *et al.*, 2000; Kişnişci *et al.*, 2002; Sayin *et al*., 2004) has been published on the effects of rapid canine retraction using distraction osteogenesis, there has been no detailed investigation regarding the effects on the gingival tissues. Therefore, it was the aim of this clinical prospective study to evaluate alterations occurring in the gingival dimensions of the canine teeth during a 12 month period following DAD.

Materials and methods

Thirty-six canine teeth from 18 patients (nine females and nine males) scheduled for orthodontic treatment with bilateral first premolar extractions were included in this study. All were in the permanent dentition and demonstrated moderate to severe crowding and/or an increased overjet. The mean age of the patients was 16.94 ± 3.0 years with a range of 13.08–25.58 years at the start of treatment (Table 1). The patients and their parents were informed about the proposed treatment plan involving surgery, and also the alternative conventional treatment option. Informed consent was obtained from each patient before the DAD procedure and the research project was approved by the ethical committee of the University of Ankara, School of Dentistry.

Table 1 Age and duration of dentoalveolar distraction of 36 canines in 18 subjects.

	Mean	SD	Minimum	Maximum
Age, start of distraction (years)	16.94	3.00	13.08	25.58
Duration of distraction (days)	10.36	1.93	8	14
Distraction rate (mm/day)	0.8	–	–	–

SD, standard deviation.

Appliance design

Custom-made rigid, tooth-borne, intraoral distraction devices were designed and used in all the patients (Figure 1). The device was made of stainless steel, with one distraction screw and two guidance bars. The distractor was activated by turning the screw with a special apparatus in a clockwise direction. As a first step in the distractor procedure, the canines and first molars were banded with 0.06 × 1.80 inch (0.15 × 4.55 mm) band material and an impression was made with the bands placed on the teeth. In the second step, the distractor was soldered to the canine and first molar bands on the dental cast. In order to minimize tipping, the distractor was positioned as high as possible buccally.

Surgical procedure

The operation technique has been described in detail previously (Kişnişci *et al.*, 2002). All surgery was undertaken on an outpatient basis using local anaesthesia, with some patients receiving nitrous oxide sedation. A horizontal mucosal incision, 2–2.5 cm in length, was made parallel to the gingival margin of the canine and premolar beyond the depth of the vestibule. On the medial aspect of the canine teeth to be distracted posteriorly, a vertical line was outlined between the canine and the second incisor by means of multiple cortical holes made in the alveolar bone with a small, round, carbide bur. The osteotomy was continued and curved apically at a distance of 3–5 mm from the apex. The same procedure was applied on the distal aspect of the canine close to the extraction area, and the holes around the canine root were connected by a thin and tapered fissure bur. Fine osteotomes were then introduced and advanced in a coronal direction (Figure 2). The first premolar was extracted at this stage and the buccal bone was removed using larger round burs between the outlined bone cut at the distal canine region anteriorly and the second premolar posteriorly. Larger osteotomes of appropriate sizes were then used to fully mobilize the alveolar segment that included the canine tooth by fracturing the surrounding spongious bone around its root. The buccal and apical bone through the extraction socket and the possible bony interferences at the buccal aspect that may be encountered during the distraction process were also eliminated or smoothed between the canine and the second premolar teeth with preservation of



Figure 1 Intraoral view of the dentoalveolar distraction device. The canine and molar bands were fabricated and the distractor was soldered to the bands on the cast, taking the biomechanical principles of tooth movement into consideration.



Figure 2 Intraoral view of the operation site. View of the corticotomy of the cortical bone and extraction socket of the first premolar. The dentoalveolar segment is used as a transport unit to carry the maxillary canine posteriorly.

the palatal cortical shelf. The palatal shelf was preserved whereas the apical bone of the sinus wall was removed leaving the sinus membrane intact. This was undertaken in order to avoid interferences during the active distraction process. Osteotomes along the anterior aspect of the canine tooth were then used to split the surrounding bone around its root from the palatal cortex and neighbouring teeth. The transport dentoalveolar segment with the canine tooth, included the buccal and palatal cortex and the underlying spongious bone surrounding the canine root. Finally, the DAD device was cemented on the canine and the first molar immediately following surgery. In order to ensure that the transport segment was fully mobilized, the device was activated several millimetres and set back to its original position intraoperatively. The incision was then closed with resorbable sutures and the patients were prescribed antibiotics and a non-steroidal anti-inflammatory drug for 5 days. The patients were also instructed to discontinue tooth brushing to avoid trauma around the surgical site. A 0.2 per cent chlorhexidine gluconate (Klorhex®, Drogsan,

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Ankara, Turkey) solution rinse was prescribed twice a day during the distraction period.

Distraction protocol and DAD

DAD was started within 3 days following surgery and continued at a rate of 0.4 mm twice a day (a total of 0.8 mm). It was discontinued when the canine tooth had moved posteriorly into the desired position. The DAD device was then removed, and fixed appliance orthodontic therapy was immediately started.

All patients were included in a meticulous oral hygiene programme, which was initiated before and after the DAD procedure and reinforced monthly, together with professional tooth cleaning, during fixed appliance orthodontic treatment.

Clinical measurements

All clinical measurements were performed by one examiner (CAG). Prior to the study, the examiner was calibrated to reduce intra-examiner error. The clinical periodontal conditions of the patients were evaluated using the following parameters:

1. Plaque index (PI) (Löe, 1967): the presence or absence of plaque at the gingival margin.
2. Gingival index (GI) (Löe, 1967): the presence or absence of bleeding at the gingival margin.
3. Pocket depth (PD): the distance from the gingival margin to the bottom of the sulcus.
4. Width of keratinized gingiva: the distance from the gingival margin to the mucogingival junction.

No gingival recession was observed in any of the patients in this study and, thus, no measurement for the location of the gingival margin in relation to the cemento-enamel junction was performed.

All clinical measurements were made to the nearest 0.5 mm using a NF-14 periodontal probe (Safico®, Vence Cedex, France). The location of the mucogingival junction was assessed visually after staining with 10 per cent iodine solution (Batticon, Adeka, Ankara, Turkey). The solution was applied to the patient's gingiva and alveolar mucosa by means of a cotton pledget, using a light pressure burnishing technique. The application time was determined as the time needed to result in a sharp demarcation between keratinized tissue and alveolar mucosa (Guglielmoni *et al.*, 2001). The PI, GI, and PD measurements were taken from all sites of the canine teeth (i.e. mesial, mid-buccal, distal and mid-palatal). The PD at the proximal sites was measured from the deepest site between the buccal and the palatal surfaces. The width of keratinized gingiva measurements were taken from the mid-buccal surface of the canine teeth, separately.

The clinical measurements were carried out before surgery (pre-DAD), immediately after removal of the DAD device (post-DAD), and 1, 6, and 12 months after the post-DAD period. In addition to the clinical measurements, the width of attached gingiva was calculated by subtracting the PD measurements from the width of keratinized gingiva values at the mid-buccal surfaces at each evaluation time point.

Statistical analysis

Alterations in the clinical measurements for the different evaluation periods were analysed by Friedman and repeated measure ANOVA tests. When the *P*-value obtained from the Friedman test was statistically significant, multiple comparison tests were used to analyse which time point differed from the others. Differences between the clinical measurements for the right and left sides were analysed using Wilcoxon and Mann–Whitney *U* tests, respectively, at the pre-DAD period. The analyses were performed with the statistical software package SPSS for Windows 10.0 (SPSS Inc., Chicago, Illinois, USA).

At the pre-, post-DAD, and 1, 6, and 12 month time points, the measurements of PD, width of keratinized and of attached gingiva, and recording procedure of the PI and GI scores were repeated for 18 randomly selected canine teeth, in order to estimate the reliability of the measurements. The reliability of the continuous variables was expressed as the standard deviation of the differences divided by two. The range of mean errors for PD and the width of keratinized gingiva were 0.11–0.16 and 0.14–0.21, respectively, and indicated stable reliability during the evaluation period. Cohen's kappa (κ) was employed to describe the reliability of discrete PI and GI values. Based on the duplicate measurements, the κ values of PI and GI were 0.76 ± 0.04 and 0.86 ± 0.05, respectively.

Results

The canines moved into the socket of the extracted first premolars, in compliance with distraction osteogenesis principles. The procedure was completed in 8–14 days at a rate of 0.8 mm/day and the mean distraction time was 10.36 ± 1.93 days (Table 1, Figure 3).

The anchorage teeth (first molars and second premolars) were able to withstand the retraction forces with virtually no anchorage loss during retraction of the canines (Figure 4a, b) (İşeri *et al.*, 2005). The DAD device was well tolerated and nearly all the patients demonstrated minimal to moderate oedema following the surgery. No clinical and/or radiographic evidence of root fracture, root resorption or dental ankylosis was detected in the post-DAD period in any of the patients (Figure 5). No discolouration or clinical evidence of loss of tooth vitality was noted (İşeri *et al.*, 2004).

Table 2 shows the descriptive values of the clinical measurements obtained at each evaluation period. No significant differences were found between right and left canine teeth for any of the clinical measurements at the pre-DAD period.

Table 3 shows the mean values for PI and GI at each evaluation period. The mean PI and GI values were

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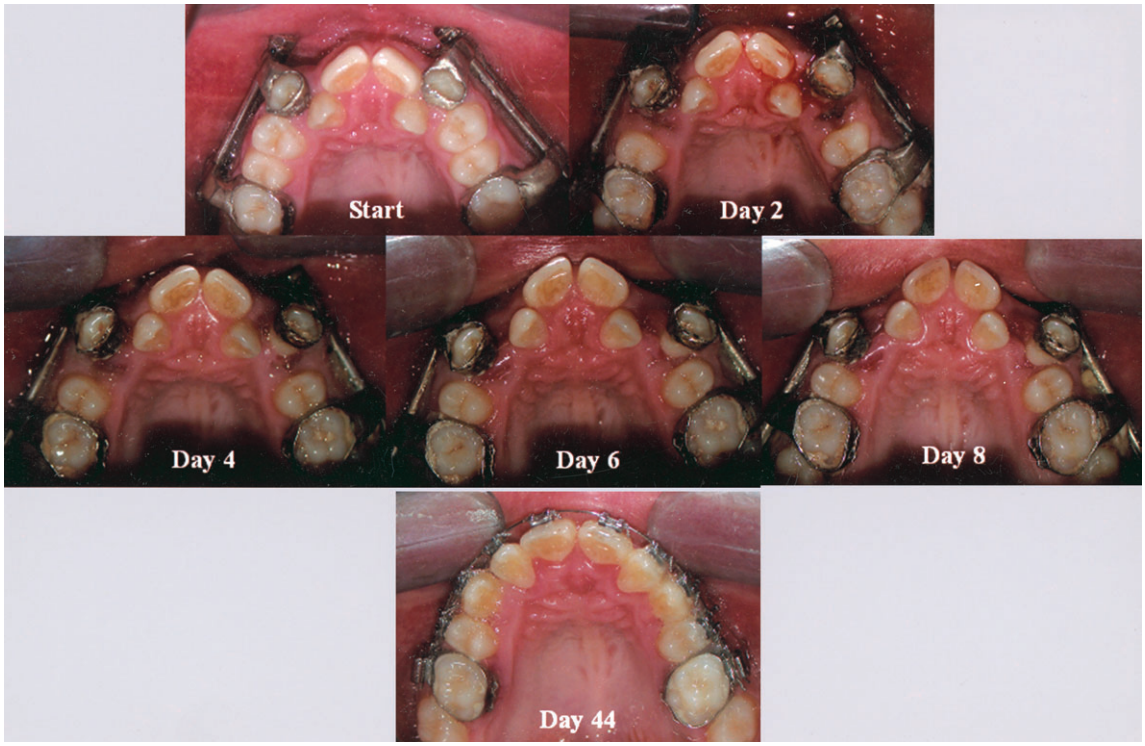


Figure 3 Dentoalveolar distraction of the maxillary canines from the start to the end of distraction, occlusal views. Full distraction of the canines was completed in 8 days and the teeth were aligned in 44 days. This is a skeletal and dental Class III maxillary deficiency case with severe maxillary crowding of 12 mm treated by orthognathic surgery (Le Fort 1 osteotomy).

significantly different between the pre- and post-DAD and the pre-DAD and 1 month evaluation periods ($P < 0.01$). The mean PI was the same as the pre-DAD value at the 6 and 12 month evaluation periods. However, the mean GI value at the 6 month evaluation period was still significantly different from the pre-DAD value.

No gingival recession was observed in any of the subjects, either pre- or post-DAD or during the 12 month evaluation period.

There were significant differences between the pre- and post-DAD periods for the mean PD measurements for all sites, except the buccal site (Figure 6a). The mean PD value of the buccal site showed no significant change at any evaluation period (Figure 6a). All of the other three sites showed significant increases at the post-DAD period, with the greatest change found for the distal site. The differences between the mean PD values pre- and post-DAD for the mesial site ($P < 0.05$) and also between post-DAD and 1 month for the distal site were significant ($P < 0.01$). Only the palatal site showed significant differences at the 1, 6, and 12 month follow-up periods compared with the post-DAD evaluation.

No significant changes were observed in the mean width of keratinized gingiva values during the distraction and follow-up periods (Figure 6b). Individual analysis of alterations for the width of keratinized gingiva measurements between the post-DAD and 12 month evaluation periods revealed that the ratio of increase versus decrease was 11:5, with 20 canines showing no change (Table 4). However, the ratio of the width of keratinized gingiva increase versus the width of keratinized gingiva decrease was 11:16 when the pre-DAD period was compared with the 12 month period. Nine teeth showed no change.

The mean width of attached gingiva values were found to be significantly different only between the pre- and post-DAD periods ($P < 0.01$) (Figure 6b).

Discussion

The duration of orthodontic treatment and use of extraoral anchorage is one of the aspects of orthodontics about which there are more complaints, and many attempts have been made to shorten the time of orthodontic tooth movement (Davidovitch *et al.*, 1980a, b; Liou and Huang, 1998; Liou *et al.*, 2000). Distraction osteogenesis has become a popular technique in the treatment of craniofacial anomalies and also holds potential for correcting dentoalveolar discrepancies. Therefore, a technique of rapid canine retraction using the distraction osteogenesis concept has been described and used (İşeri *et al.*, 2001, 2005; Kişnişci *et al.,* 2002), namely DAD. In this concept, horizontal and vertical osteotomies surrounding the canines are carried out to achieve rapid movement of the canines within the dentoalveolar segment, in compliance with distraction osteogenesis principles. The effects of DAD on the dentofacial structures have

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Figure 4 Intraoral photographs of the patient presented in Figure 3. (a) Frontal view, (b) lateral view. The bottom photographs represent the follow-up views.

been previously reported (İşeri *et al.*, 2005). However, no data regarding the effects on the gingival tissues are available. Moreover, there are few comparable published data regarding changes in the gingival tissues around teeth moved into an extraction site with fixed appliance treatment (Gantes *et al*., 1990).

The mean distraction time was approximately 10 days and the distraction procedure was completed in 8–14 days, with full retraction of the canines without apparently any posterior anchorage loss (İşeri *et al.*, 2005). Moreover, no clinical or radiographic evidence of complications, such as root fracture, root resorption, ankylosis and soft tissue dehiscence, was observed (İşeri *et al.*, 2005). Therefore, DAD is an effective method for canine retraction, as in subjects requiring extractions it reduces orthodontic treatment time by about 6–9 months (approximately a 50 per cent reduction in overall orthodontic treatment time).

Oral hygiene conditions

The highest mean PI and GI values were observed at the post-DAD and 1 month evaluation periods and these were significantly higher than the pre-DAD values (Table 3). On the other hand, there was a gradual decrease throughout the follow-up period. In spite of using an antimicrobial rinse, these high values could be related to the lack of effective

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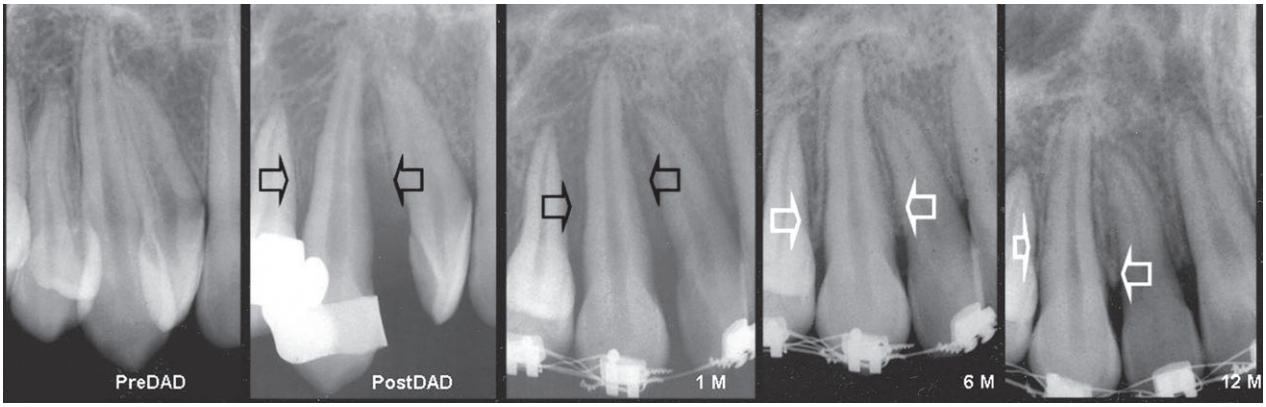


Figure 5 Radiographic appearance of a maxillary canine at the evaluation periods. Alterations in the alveolar bone at the proximal side were a loss (black arrows) and gain (white arrow) in mineralization. There is a clear view of the lamina dura at the proximal side of the canine at the 6 and 12 month evaluation periods. There is no radiographic evidence of complications such as root fracture, root resorption or anklylosis.

individual tooth cleaning because of the surgical intervention and/or the presence of the DAD device. A gradual reduction in the PI and GI values 1 month after DAD surgery indicated that the meticulous oral hygiene programme and healing of the surgery site might have significantly contributed to these changes. A temporary increase in gingival inflammation during orthodontic treatment has been shown (Atack *et al.*, 1996; Ong *et al.*, 1998). This condition was only observed at the 6 month evaluation period where a significant difference ($P < 0.05$) was noted compared with the pre-DAD period. However, the GI values for the 12 month period were similar to the pre-DAD period.

PD measurements

At the post-DAD evaluation, approximately 25 per cent of the canine teeth had PD values ≥ 4 mm (Table 2). The mean PD score for the distal site showed the highest value (4.32 ± 2.38), followed by the palatal (4.14 ± 2.98) and mesial (3.73 ± 2.44) sites. The reason for the higher PD values at the proximal and palatal sites just after termination of the DAD procedure was related to rapid distalization of the canines. Moreover, surgically created bone loss around the roots of canine teeth might also cause some loss of supporting tissues.

Although the mean PD values observed at the end of the 1 month evaluation were temporary changes, these were also analysed to estimate the changes in the early healing period following DAD. In fact, 1 month after the post-DAD evaluation there were significant decreases in the mean PD values for both the mesial ($P < 0.05$) and palatal ($P < 0.05$) sites. The change in the mean PD value at the distal site was less than at the mesial and palatal sites, and insignificant compared with post-DAD (Figure 6a).

At the 6 month evaluation period, the mean PD values were decreased at all sites other than mesially where there was a slight increase. However, only the changes at the distal and palatal sites were significant at the 6 month evaluation compared with post-DAD (Figure 6a). These changes observed at the 6 month period were considered as a consequence of the ongoing adaptation process of the periodontal tissues around the canine teeth that were moved to their correct positions in the dental arch by means of orthodontic treatment.

At the 12 month evaluation, only the mean PD value of the palatal site showed a significant decrease compared with the post-DAD period ($P < 0.001$). Moreover, slight and insignificant increases in the mean PD values of all sites were found compared with the 6 month evaluation period. These insignificant increases might also be related to the fixed appliance orthodontic treatment.

Therefore, PD measurements at the mesial, distal and palatal sites were significantly increased at the post-DAD period. On the other hand, PD measurements at the same sites were significantly decreased at the 1 and/or 6 month evaluation periods, compared with post-DAD. These findings indicate that the periodontal condition following surgery and the DAD procedure was remarkably improved, even though there was a slight and insignificant increase in the PD values at the end of the fixed appliance orthodontic treatment (month 12).

The most interesting finding of the present study was the insignificant change in the mean PD value at the buccal site. Although the pattern of alteration of PD measurements was almost similar at the other sites, the buccal site showed no significant change at any evaluation period (i.e. post-DAD, 1, 6, and 12 months) compared with the pre-DAD period (Figure 6a). This clinical finding indicates that as long as the tooth is moved within the alveolar segment, the risk of harmful side-effects on the marginal soft tissues will be minimal. As a consequence of the philosophy of the DAD technique, the dentoalveolar segment was designed as a bone transport segment for the posterior movement. Vertical corticotomies were performed around the root of the canine teeth, followed by splitting of the spongious

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Table 2 Descriptive values of clinical measurements at the evaluation periods.

	Pocket depth				Width of keratinized gingiva	Width of attached gingiva
	Mesial	Buccal	Distal	Palatal		
Pre-dentoalveolar distraction						
Mean	2.91	2.03	2.89	2.84	4.22	2.19
SD	0.92	0.68	0.62	1.25	1.71	1.85
Minimum	2	1	1	1	2	1
Maximum	5	3	4	7	8	6
Post-dentoalveolar distraction						
Mean	3.73	2.65	4.32	4.14	3.51	1.22
SD	2.44	0.88	2.38	2.98	1.93	1.34
Minimum	2	1	2	1	0	0
Maximum	10	5	10	10	8	6
1 month						
Mean	2.73	2.38	3.78	3.14	3.86	1.50
SD	0.76	0.85	1.48	1.76	1.55	1.56
Minimum	2	1	2	1	1	0
Maximum	5	5	8	8	8	6
6 months						
Mean	2.92	2.02	3.03	2.41	3.38	1.45
SD	0.80	0.62	0.87	0.82	1.48	1.55
Minimum	2	1	2	1	0	0
Maximum	5	3	5	5	7	6
12 months						
Mean	3.19	2.11	3.38	2.43	3.86	1.76
SD	0.74	0.61	1.06	0.76	1.47	1.64
Minimum	2	1	2	1	1	0
Maximum	5	3	7	5	8	7

SD, standard deviation.

Table 3 Comparison of plaque (PI) and gingival (GI) indices at the evaluation periods.

	Pre-DAD	Post-DAD	1 month	6 months	12 months
PI	0.26 ± 0.53	0.50 ± 0.41**	0.45 ± 0.23**	0.24 ± 0.23	0.26 ± 0.26
GI	0.23 ± 0.65	0.78 ± 0.67**	0.53 ± 0.54*	0.32 ± 0.32*	0.26 ± 0.34

DAD, dentoalveolar distraction.
*$P < 0.05$ compared with pre-DAD; **$P < 0.01$ compared with pre-DAD.

bone surrounding it. The design of the surgical technique did not rely on periodontal stretching, which obviates overloading and stress accumulation on the periodontal tissues. Therefore, the finding of insignificant mean PD change at the buccal site also confirms that the canines were moved along with the bone segment as a consequence of the DAD.

Keratinized gingiva

Similar to the PD values at the buccal sites, the alterations that occurred in the width of keratinized gingiva measurements were not significant between the evaluation periods. However, a possible explanation for the decrease in the mean width of keratinized gingiva value post-DAD (3.51 ± 1.93, range 0–8 mm) compared with the pre-DAD period might be related to the presence of scar tissue close to the mucogingival junction, as a result of mucoperiosteal flap elevation. Nevertheless, comparisons of the mean width of keratinized gingiva values at the 1 month evaluation period with the successive evaluation periods did not reveal any significant difference. Although the mean width of keratinized gingiva value pre-DAD (4.22 ± 1.71, range 2–8 mm) was higher than clinically healthy sites in normally positioned teeth reported in the literature (Coatoam *et al.*, 1981; Andlin-Sobocki, 1993; Andlin-Sobcki and Bodin, 1993; Kornhauser *et al.*, 1996; Lindhe and Karring, 1997), a slight but clinically insignificant fluctuation in the mean

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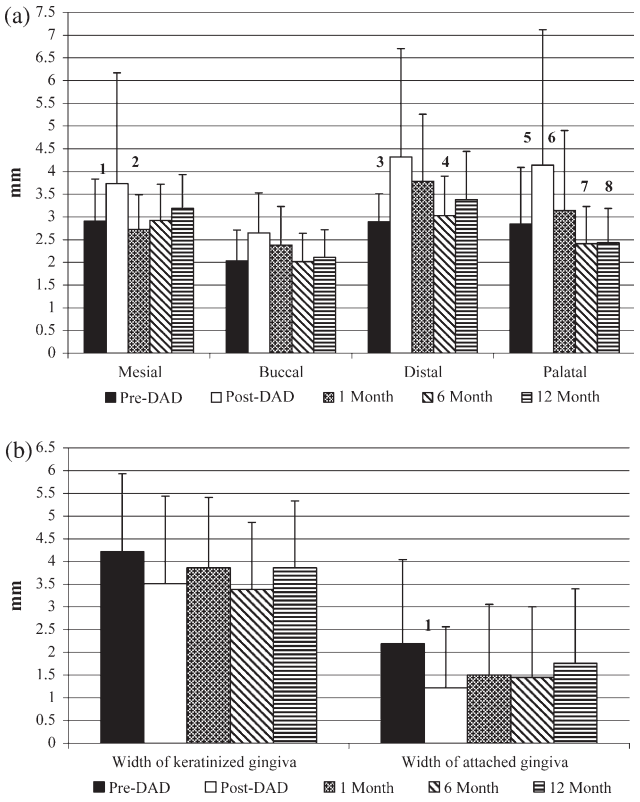


Figure 6 (a) Pocket depth and (b) width of keratinized gingiva and attached gingiva measurements at each site during the treatment and evaluation periods. Means and standard deviations (SD) are presented in Table 2. DAD, dentoalveolar distraction. (a) **1**, $P < 0.05$, between pre- and post-DAD for mesial sites; **2**, $P < 0.05$, between post-DAD and 1 month for mesial sites; **3**, $P < 0.001$, between pre- and post-DAD for distal sites; **4**, $P < 0.01$, between post-DAD and 6 months for distal sites; **5**, $P < 0.001$, between pre- and post-DAD for palatal sites; **6**, $P < 0.05$, between post-DAD and 1 month for palatal sites; **7**, $P < 0.001$, between post-DAD and 6 months for palatal sites; **8**, $P < 0.001$, between post-DAD and 12 months for palatal sites; ┬, SD. (b) **1**, $P < 0.01$, between pre- and post-DAD; ; ┬, SD.

Table 4 Frequency of alterations in the width of keratinized gingiva measurements ($n = 36$ canines).

	Increased	No change	Decreased
Pre-DAD–post-DAD	10	12	14
Post-DAD–1 month	8	24	4
1 month–6 months	5	17	14
6 months–12 months	10	23	3
Post-DAD–6 months	9	18	9
Post-DAD–12 months	11	20	5
Pre-DAD–6 months	8	8	20
Pre-DAD–12 months	11	9	16

DAD, dentoalveolar distraction.

width of keratinized gingiva value was observed post-DAD to the end of the 12 month evaluation period.

In the patients in the present study, a horizontal mucosal incision of 2–2.5 cm was made parallel to the gingival margin of the canine and premolar beyond the depth of the vestibule (Figure 2). Although this was far apical to the mucogingival junction, the keratinized gingiva coronal to the incision was also elevated in order to manage the osteotomy on the coronal part of the buccal bone. Therefore, the observed slight changes in the width of keratinized gingiva values were the result of soft tissue healing and the adaptation of the mucogingival junction to the new position of the canine teeth (Figure 4a, b).

When alterations in the width of keratinized gingiva measurements were evaluated at tooth level (Table 4), 14 of the 36 canines showed a decrease post-DAD compared with pre-DAD. This was most probably a result of the surgical procedure. However, the successive evaluations of the 1 (24 canines), 6 (17 canines) and 12 (23 canines) month periods revealed that the width of keratinized gingiva values did not change in most of the subjects. The same finding was also observed when the alterations from post-DAD to the 12 month period were evaluated. For the 16 canines where changes occurred, the ratio of increase versus decrease was 11:5 at the 12 month evaluation period. This supports the findings of a previous study concerning the change in keratinized gingiva following orthodontic treatment (Coatoam *et al.*, 1981). When the alterations between the pre-DAD and 12 month period were evaluated, the mean values indicated the opposite because of the wide range of individual values (Table 2, Figure 6b), and only nine canines showed no change and the ratio of increase versus decrease was 11:16.

The same fluctuation pattern was also consistently observed for the mean width of the attached gingiva values in which the only significant difference was detected between the pre- compared with the post-DAD period (Figure 6b). This was probably due to the elevation of keratinized gingiva coronal to the incision. Nevertheless, this fluctuation resulted in the re-establishment of connective tissue attachment at the root surface, continuing to reform the periodontal conditions of the canine teeth in the pre-DAD period. In addition, the measurements of the width of the attached gingiva obtained by calculation were influenced by changes in the measurements of keratinized gingiva and PD. Therefore, it was not surprising to observe the same pattern of alterations as seen in both keratinized gingiva and PD measurements. There was a tendency for attached gingiva to regain its dimension. This condition could be observed when the 12 month data were compared with those for 6 months and pre-treatment.

Conclusions

The DAD technique was found to be a viable innovative method to reduce orthodontic treatment time in extraction cases. Without unfavourable long-term effects on the gingival tissues of the retracted canine teeth, the treatment time could be reduced by 6–9 months.

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