Original Article

Orthodontic and Periodontal Outcomes of Treated Impacted Maxillary Canines

An Appraisal of Prognostic Factors

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ABSTRACT

Objective: To evaluate the influence of pretreatment radiographic features (α-angle, *d*-distance, and *s*-sector) on (1) the duration of active orthodontic traction and (2) the posttreatment periodontal status (pocket depth [PD] and keratinized tissue width [KT]) of impacted maxillary canines treated by a combined surgical (flap approach) and orthodontic (direct traction to the center of the ridge) treatment.

Material and Methods: A study population of 168 patients (168 canines) was evaluated. Multiple regression analysis was used.

Results: Pretreatment radiographic variables were associated significantly with the duration of orthodontic traction. Age, sex, and site of impaction did not significantly affect the duration of traction. No significant differences in PD and KT were present at the end of surgical-orthodontic treatment with respect to any of the variables considered. The analysis of PD and KT variables after orthodontic treatment revealed a healthy periodontium.

Conclusions: α-angle, *d*-distance, and *s*-sector are valid indicators for the duration of orthodontic traction. They are not prognostic indicators of final periodontal status of orthodontically-repositioned canines.

KEY WORDS: Impacted canine; Panoramic radiographs; Prognosis; Surgical-orthodontic approach; Periodontal evaluation

INTRODUCTION

The prevalence of impaction of maxillary canines in Western populations ranges from 1% to 3%.[1] An impaction is diagnosed when the tooth is in an infraosseous position after the expected time of eruption, whereas tooth displacement is identified as an anomalous infraosseous position of the canine before the expected time of eruption. Interceptive treatment strategies have been proposed for the displaced canine,[2–4] whereas a surgical-orthodontic approach is needed in case of impaction.

The treatment of an impacted maxillary canine is not completed merely with its orthodontic alignment. Final periodontal health is a fundamental key to evaluate the success of therapy for impacted maxillary canines. In previous publications,[5,6] a combined surgical (flap) and orthodontic (direct traction towards the center of the ridge) approach has been proposed with the aim of simulating the physiological eruption pattern of the canine.

From the point of view of prognostic evaluation of canines with an anomalous infraosseous position, radiographic variables visible on panoramic radiographs have been used: the angulation and the position of the tooth, the distance from the occlusal plane, and the possible superimposition on the roots of the adjacent teeth.[2] The radiographic signs have been correlated to the probability of spontaneous eruption of displaced canines.[2] More recently, the same indicators have been studied as pretreatment predictors for the outcomes of interceptive therapy of palatally displaced

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canines by means of the extraction of the corresponding deciduous canine and space maintenance at the maxillary dental arch,[3] and as predictors of overall duration of orthodontic treatment to reposition the impacted canine.[7,8]

The purpose of the present study was to evaluate the influence of pretreatment variables (with special regard to the initial radiographic features) on (1) the duration of active orthodontic traction and (2) the posttreatment periodontal status (pocket depth [PD] and keratinized tissue width [KT]) of impacted maxillary canines treated by a combined surgical (flap approach) and orthodontic (direct traction towards the center of the alveolar ridge) technique.

MATERIALS AND METHODS

Study Population

An initial sample of 208 patients with unilateral or bilateral impacted maxillary canines was consecutively treated in a private practice by a single operator over a period of 17 years. Because of the purpose of this study, 40 patients were not considered for the analysis: 24 patients with canine impactions that did not allow for direct traction to the center of the alveolar ridge,[6] and 16 patients with submucosal buccal impaction.

A total of 168 patients with unilateral or bilateral infraosseous impacted maxillary canines were included in this study and evaluated at the end of both active orthodontic traction and overall orthodontic treatment: One hundred twenty-five patients presented with unilateral impaction of the maxillary canine and 43 presented with bilateral impaction. A random selection was made on the 86 bilateral impacted canines in order to evaluate only one canine per patient. The final study population consisted of 168 patients (168 impacted canines), 40 males and 128 females, ranging in age from 12.8 to 52.0 years (mean age 17.2 $\pm$ 6.0 years).

Pretreatment Radiographic Variables

The position of the impacted canine was evaluated on the panoramic radiograph by using a modified version of the criteria proposed by Ericson and Kurol[2] (Figure 1):

- α-angle: Angle measured between the long axis of the impacted canine and the midline.
- *d*-distance: Distance between the canine cusp tip and the occlusal plane (from the first molar to the incisal edge of the central incisor).
- *s*-sector: Sector where the cusp of the impacted canine is located: sector 1, between the midline and the axis of the central incisor; sector 2, between the axis of the central incisor and the axis of the lateral incisor; or sector 3, between the axis of the lateral incisor and the axis of the first premolar.

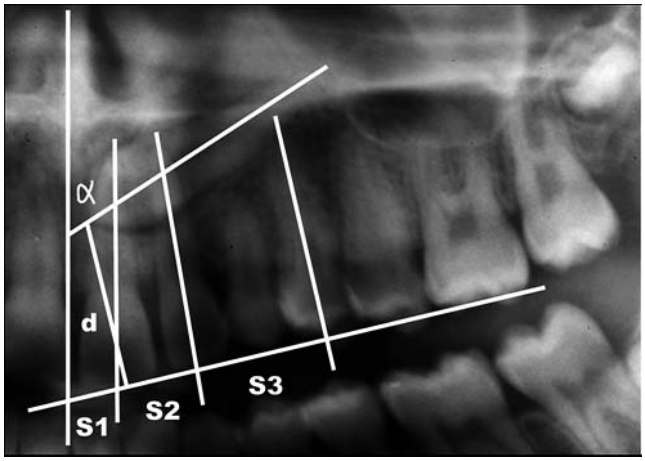

Figure 1. Panoramic radiographic features showing displacement of the upper left canine: α-angle, *d*-distance, and *s*-sector.

Surgical-Orthodontic Treatment

All of the patients underwent consecutively the same standardized surgical-orthodontic approach.[5,6] The teeth were exposed by means of a repositioned flap. Orthodontic traction was applied to guide the impacted canine directly towards the center of the alveolar ridge. The combined technique was performed by the same operator (Dr Crescini) on all the patients.

The overall combined treatment was divided into three phases.

- Phase 1: Initial orthodontic treatment aimed at creating space on the maxillary arch by means of fixed appliance therapy.
- Phase 2: Surgical exposure and orthodontic traction of the impacted tooth towards the center of the alveolar ridge.[6] A handmade chain was connected to the attaching device on the impacted tooth and to the elastic for the orthodontic traction. A rectangular stabilization arch was used to obtain adequate anchorage and maintain sufficient space in the dental arch, and a round arch was used as an attachment for the elastic traction in order to guide the impacted canine towards the center of the alveolar ridge. The duration of this phase (duration of traction) was calculated as the time elapsed between the application of the traction device and the emergence of the cusp of the impacted canine.
- Phase 3: Final orthodontic treatment to align the canine in the maxillary arch.

Periodontal Evaluation

The treated teeth were evaluated periodontally at the completion of the overall orthodontic treatment (Phases 1, 2, and 3).

The following periodontal variables were considered for the treated canines:

- Probing PD. The measurements were made by means of a Williams offset periodontal probe on six sites—mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual—on each of the treated teeth.
- KT, from the gingival margin to the mucogingival junction, measured on the medial position of the buccal aspect of the crown. The keratinized tissue and the alveolar mucosa were identified using Lugol's liquid stain.

Statistical Analysis

Descriptive statistics were calculated as mean ± SD for metric variables and as frequency and percentage for nominal variables.

The inferential analysis aimed at evaluating the role of pretreatment factors on the duration of orthodontic traction (end of Phase 2), and on PD and KT variables at the end of orthodontic treatment (Phases 1, 2, 3). A multiple regression analysis was created. The duration of orthodontic traction was used as a dependent variable, and the following variables were considered independent: sex, age, impaction (unilateral or bilateral impaction), side (right or left position), location (palatal or buccal impaction of the canine), α-angle, *d*-distance, and *s*-sector.

Regression analysis also tested the prognostic value of pretreatment radiographic variables on posttreatment periodontal variables PD and KT. The posttreatment PD analysis included only the deepest pocket measurement (PD_{max}) of the six probing sites of the treated teeth. Post hoc comparison for *s*-sector was made by a Tukey honestly significant difference test.

RESULTS

The clinical characteristics of the 168 patients/canines are reported in Table 1. In particular, the mean age of the patients was 17.2 ± 6.0 (range 12.8–52.0). The orthodontic treatment lasted overall 22.0 ± 4.8 months (range 13–34) and the active traction (phase 2) lasted 8.0 ± 2.3 months (range 4–13).

None of the patients complained of significant discomfort. All of the 168 impacted canines were successfully moved and aligned into the dental arch. None of the patients lost the attaching device. In two cases the orthodontic traction was interrupted because of breakage of the wire chain. In these patients, a flap was raised, a new wire chain was put into place, and traction was resumed. None of the patients required selective grinding of the occlusion.

Table 1. Descriptive Statistics[a]

Variable	Mean	SD	Range
Age, y	17.2	6.0	12.8–52.0
Overall treatment (Phases 1, 2, and 3), mo	22.0	4.8	13–34
Orthodontic traction (Phase 2), mo	8.0	2.3	4–13
α-angle, °	35.0	13.0	5–71
d-distance, mm	15.3	3.8	6–24

Variable	Frequency	Percentage
Sector 1	23	13.7
Sector 2	80	47.6
Sector 3	65	38.7
Rigth impaction	90	53.6
Left impaction	78	46.4
Palatal impaction	118	71.2
Buccal impaction	50	29.8

[a] Age is recorded at the beginning of the traction of the impacted tooth; overall treatment refers to the duration of overall orthodontic treatment (Phases 1, 2, and 3); orthodontic traction refers to the duration of Phase 2 of the treatment; α-angle is the angle measured between impacted canine long axis and the midline; *d*-distance is the distance between canine cusp tip and the occlusal plane; and *s*-sector refers to the site where the cusp of the impacted canine is located.

Role of Pretreatment Variables in the Duration of Orthodontic Traction

Regression analysis (Table 2) revealed that the three pretreatment radiographic variables (α-angle, *d*-distance, and *s*-sector) significantly influenced ($P < .01$) the duration of orthodontic traction (end of Phase 2). The Tukey honestly significant difference test showed that *s*-sector 1 was statistically significantly different from *s*-sector 3, but not from *s*-sector 2. The statistical analysis of the relationship between the duration of traction and the values of the pretreatment radiographic variables leads to the following outcomes:

- α-angle: Every 5° of opening of the angle required approximately 1 more week of active orthodontic traction.
- *d*-distance: Every 1 mm of distance of the cusp of the impacted canine from the occlusal plane required approximately 1 more week of active orthodontic traction.
- *s*-sector: Impaction in sector 1 required approximately 6 more weeks of active orthodontic traction when compared to impaction in sector 3.

The other pretreatment variables (sex, age, impaction, side, and location) were not associated significantly with the duration of active orthodontic traction.

Table 2. Multiple Regression Analysis for Duration of Traction (End of Phase 2) for the 168 Treated Patients/Canines

Term	Estimate	SE	*P*
Intercept	1.44	0.76	.0603
Age	0.03	0.02	.1446
Sex	0.21	0.15	.1566
Impaction (unilateral or bilateral)	0.01	0.15	.9678
Side (right or left)	0.05	0.13	.6693
Location (palatal or buccal)	−0.11	0.16	.4654
α-angle, °	0.05	0.01	<.0001
d-distance, mm	0.27	0.04	<.0001
s-sector 1	0.71	0.26	.0072
s-sector 2	−0.01	0.18	.9765
s-sector 3	−0.71	0.22	.0016

[a] Theoretic model: duration of traction = β_0 + β_1 Age + β_2 Sex + β_3 Impaction + β_4 Side + β_5 Location + β_5 *a*-angle + β_7 *d*-distance + gb_8 *s*-sector. R^2 = 0.58. In the model, age is recorded at the beginning of the traction. The nominal variables have the following values: Sex is 1 if female and −1 if male. Impaction is 1 in case of unilateral impaction and −1 in case of bilateral impaction. Side is 1 if the tooth is on the left side and −1 if it was on the right. Location is 1 in case of buccal impaction and −1 in case of palatal impaction. α-angle is the angle measured between the long axis of the impacted canine and the midline. *d*-distance is the distance between the canine cusp tip and the occlusal plane. *s*-sector has the value measured according to the corresponding sector (*s*-sector 1, *s*-sector 2, or *s*-sector 3).

Role of Pretreatment Variables in Periodontal Status at the End of Orthodontic Treatment

Pocket depth. Descriptive statistics showed that the mean PD_{max} after overall orthodontic treatment (Phases 1, 2, and 3) was 2.54 ± 0.45 mm (ranging from 1.5 to 4.5 mm). The PD_{max} of seven canines was deeper than 3 mm (in particular, three canines presented with PD_{max} = 3.5 mm, three with PD_{max} = 4.0 mm, and one with PD_{max} = 4.5 mm).

The regression analysis (Table 3) revealed no statistically significant differences for age or sex, and no differences for unilateral or bilateral impaction, for right or left position, or for α-angle, *d*-distance, or *s*-sector. On the contrary, the analysis estimated that the PD_{max} of palatally impacted canines was 0.26 mm deeper than that of the buccally impacted teeth.

Keratinized tissue width. Descriptive statistics showed that the mean KT after overall orthodontic treatment (Phases 1, 2, and 3) was 4.42 ± 1.19 mm. The regression analysis (Table 4) revealed no statistically significant differences for age or sex, and no differences for unilateral or bilateral impaction, for right or left position, for palatal or buccal impaction, or for α-angle, *d*-distance, or *s*-sector.

Recession (distance from the gingival margin to the cemento-enamel junction). Only one patient presented with a gingival recession of 1 mm at the final observation. One clinical case is shown in Figures 2 through 8.

Table 3. Multiple Regression Analysis for Pocket Depth (PD) at the End of Overall Orthodontic Treatment (Phases 1, 2, 3) for the 168 Treated Patients/Canines[a]

Term	Estimate	SE	*P*
Intercept	2.16	0.22	<.0001
Age	0.00	0.01	.6832
Sex	−0.00	0.04	.9734
Impaction (unilateral or bilateral)	−0.02	0.04	.6312
Side (right or left)	−0.04	0.04	.3069
Location (palatal or buccal)	−0.13	0.04	.0049
α-angle, °	0.00	0.00	.2426
d-distance, mm	0.01	0.01	.4221
s-sector 1	−0.08	0.07	.2802
s-sector 2	−0.01	0.05	.8360
s-sector 3	0.09	0.06	.1476

[a] Theoretic model: PD = β_0 + β_1 Age + β_2 Sex + β_3 Impaction + β_4 Side + β_5 Location + β_6 α-angle + β_7 *d*-distance + β_8 *s*-sector. R^2 = 0.08. In the model, age is recorded at the beginning of the traction. The nominal variables have the following values: Sex is 1 if female and −1 if male. Impaction is 1 in case of unilateral impaction and −1 in case of bilateral impaction. Side is 1 if the tooth is on the left side and −1 if it was on the right. Location is 1 in case of buccal impaction and −1 in case of palatal impaction. α-angle is the angle measured between the long axis of the impacted canine and the midline. *d*-distance is the distance between the canine cusp tip and the occlusal plane. *s*-sector has the value measured according to the corresponding sector (*s*-sector 1, *s*-sector 2, or *s*-sector 3).

Table 4. Multiple Regression Analysis for Keratinized Tissue Width (KT) at the End of Overall Orthodontic Treatment (Phases 1, 2, 3) for the 168 Treated Patients/Canines[a]

Term	Estimate	SE	*P*
Intercept	4.46	0.58	<.0001
Age	−0.00	0.02	.8240
Sex	0.06	0.11	.5619
Impaction (unilateral or bilateral)	0.12	0.11	.2677
Side (right or left)	−0.06	0.10	.5535
Location (palatal or buccal)	−0.21	0.12	.0826
α-angle, °	−0.01	0.01	.5850
d-distance, mm	−0.00	0.03	.9001
s-sector 1	−0.29	0.20	.1452
s-sector 2	0.04	0.13	.7487
s-sector 3	0.25	0.17	.1394

[a] Theoretic model: PD = β_0 + β_1 Age + β_2 Sex + β_3 Impaction + β_4 Side + β_5 Location + β_6 α-angle + β_7 *d*-distance + β_8 *s*-sector. R^2 = 0.08. In the model, age is recorded at the beginning of the traction. The nominal variables have the following values: Sex is 1 if female and −1 if male. Impaction is 1 in case of unilateral impaction and −1 in case of bilateral impaction. Side is 1 if the tooth is on the left side and −1 if it was on the right. Location is 1 in case of buccal impaction and −1 in case of palatal impaction. α-angle is the angle measured between the long axis of the impacted canine and the midline. *d*-distance is the distance between the canine cusp tip and the occlusal plane. *s*-sector has the value measured according to the corresponding sector (*s*-sector 1, *s*-sector 2, or *s*-sector 3).

Figure 2. Panoramic radiograph: D.F., female, 13 years 8 months old, impacted right upper canine: α-angle = 33°; *d*-distance = 21 mm; *s*-sector = 2. The left upper canine is erupting normally.

DISCUSSION

The purpose of the present longitudinal study was to assess the utility of pretreatment radiographic indicators of infraosseous displacement of the permanent maxillary canine with regard to (1) the duration of orthodontic traction and (2) the periodontal conditions following surgical-orthodontic therapy of the impacted tooth.

In the past, pretreatment variables visible on panoramic radiographs were employed to predict the success rate of both interceptive treatment and overall surgical-orthodontic therapy in patients with impacted canines.[2–4,7,8] As for the interceptive treatment of displaced canines by means of enhanced space on the maxillary arch, Olive[4] reported that canines displaced in more unfavorable sectors emerged after a period of time that was significantly longer than that for canines displaced in more favorable sectors.

With regard to overall orthodontic treatment of impacted canines, in a sample of 47 patients Stewart et al[7] found that the younger the patient, the more severely impacted the canine, and the longer the duration of orthodontic treatment. As for the *d*-distance on panoramic radiographs, the authors reported an average treatment duration of 23.8 months in case of a distance from the occlusal plane of less than 14 mm, whereas treatment duration averaged 31.1 months when the distance was more than 14 mm. Recently, Zuccati et al[8] reported that the amount of chairside time in patients with impacted canines was proportional to the patient's age, the *d*-distance, and the *s*-sector, and it was inversely proportional to the α-angle of impaction.

The present study on a large sample of impacted canines (168 canines) showed lack of significant associations between age, sex, site of impaction, and duration of orthodontic treatment. It must be emphasized that the variable observed in terms of treatment duration was calculated as the actual amount of active orthodontic traction, ie, as the time elapsed between the application of the traction device and the emergence of the cusp of the impacted canine.

On the other hand, pretreatment radiographic variables on panoramic radiographs significantly influenced the duration of active orthodontic traction. In particular, the outcome of multiple regression analysis indicated that every 1 mm of *d*-distance of the cusp of the impacted canine from the occlusal plane requires approximately 1 more week of traction, every 5° of opening of the α-angle require approximately 1 more week of traction, and impaction in sector 1 requires approximately 6 more weeks of active orthodontic traction when compared to impaction in sector 3. To predict the duration of active orthodontic traction, the clinician can insert the variables of the given patient in the formula of the theoretical model (Table 2).

In addition, in the present study the overall duration of orthodontic treatment (Phases 1, 2, and 3) lasted on average 22.1 months, with an average pretreatment *d*-distance of 15.3 $\pm$ 3.80 mm. This duration of treatment was inferior to that reported by Stewart and coworkers for favorable cases (*d*-distance less than 14 mm).[7] This outcome is probably because of the orthodontic technique employed here, which, in all the cases treated, applied a direct traction of the impacted tooth towards the center of the ridge, which probably minimized the duration of overall orthodontic treatment

Figure 3. (a,b,c) Clinical aspects: pretreatment intraoral views.

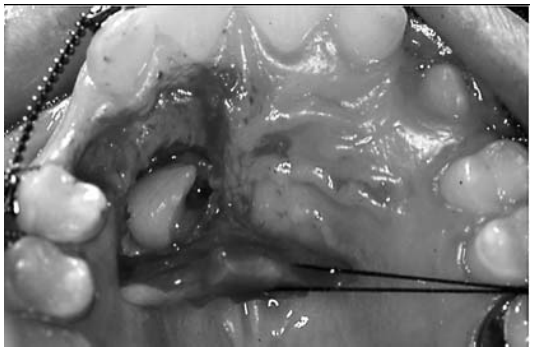

Figure 4. Surgical exposure of the impacted canine (flap approach) following the increase of the upper arch perimeter.

(Phases 1, 2, and 3). In fact, the cases in which direct traction was not allowed (transposition of the impacted tooth, presence of obstacles on the traction pathway) were excluded from the study.

No previous data are available in the orthodontic literature with regard to the possible significance of pretreatment radiographic measures with respect to the periodontal status of orthodontically-repositioned impacted canines. In this regard, it should be emphasized that in the present investigation, patients with impacted canines were consistently treated by the same standardized surgical-orthodontic approach aimed to guide the impacted canine towards the center of the alveolar ridge in the maxillary arch.[5,6] This technique is intended to allow the repositioned canine to be surrounded by a physiological amount of gingiva at the end of orthodontic treatment.[9] The amount of PD and KT at posttreatment periodontal evaluation of treated impacted canines was indicative of healthy periodontal tissues. This outcome is similar to the findings of the longitudinal investigation by Quirynen et al.[10]

The findings of the present longitudinal study showed that repositioned canines exhibited an average PD (evaluated by taking into consideration the

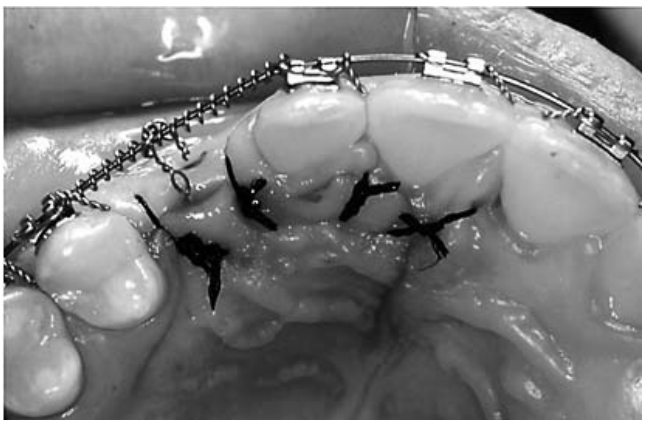

Figure 5. Closed flap traction to the center of the alveolar ridge.

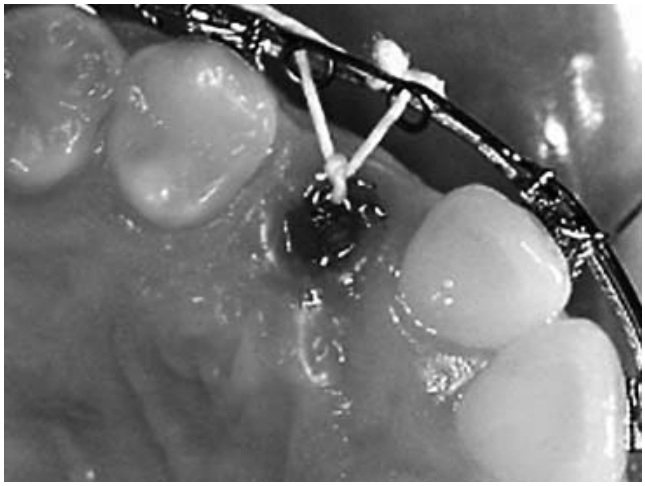

Figure 6. Emergence of the permanent canine at the center of the alveolar ridge (11 months after surgical exposure).

PD_{max} of the six measurements on each of the treated teeth) of about 2.5 mm and an average KT of about 4.4 mm. These values for PD and KT are representative of an adequate periodontal status of the repositioned canines.[11] Only one patient presented with a gingival recession of 1 mm at the final observation. No significant differences in PD and KT were present at the end of surgical-orthodontic treatment with respect to age, sex, site of impaction, or the pretreatment radiographic position of the impacted canine. The only statistically ($P = .0049$), but not clinically significant (about 0.3 mm), difference was detected for PD_{max}, which was deeper for the palatally impacted canines than for the buccally impacted ones.

α-angle, *d*-distance, and *s*-sector did not represent prognostic indicators of final periodontal status of orthodontically-repositioned canines.

CONCLUSIONS

- The pretreatment radiographic features assessed on the panoramic radiographs are useful indicators for the duration of orthodontic traction.

Figure 7. Panoramic radiograph: E.D., 15 years 4 months, posttreatment results.

Figure 8. (a,b,c) Clinical aspects: posttreatment results.

- The pretreatment radiographic features assessed on the panoramic radiographs are not valid predictors of the final periodontal status of orthodontically-repositioned impacted canines.

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