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Pre-treatment radiographic features for the periodontal prognosis of treated impacted canines

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Abstract

Aim: The aim of this study is to evaluate the prognostic role of the pre-treatment radiographic features on the post-treatment periodontal status of intra-osseous impacted maxillary canines.

Material and Methods: A study population of 168 patients (211 canines) was evaluated at the end of the overall surgical-orthodontic treatment consisting of a combined surgical (flap) and orthodontic (direct traction to the centre of the ridge) approach. The pre-treatment variables on the panoramic radiograph were α-angle, d-distance and s-sector while the post-treatment periodontal variables were pocket depth (PD) and keratinized tissue width (KT). Multilevel statistical analysis was used to evaluate the role of the pre-treatment radiographic factors on the post-treatment periodontal variables at patient, tooth and site levels.

Results: No significant differences in PD or KT were found at the end of surgical-orthodontic treatment with respect to age, gender, site of impaction or pre-treatment radiographic position of the impacted canine. The only statistically, but not clinically, significant difference (about 0.5 mm) was found for the KT that was greater for the palatally impacted canines than for the buccally impacted ones.

Conclusions: α-angle, d-distance and s-sector measured on the pre-treatment panoramic radiographs did not represent prognostic indicators of final periodontal status of orthodontically re-positioned canines.

Key words: impacted canine; panoramic radiographs; periodontal evaluation; prognosis; surgical-orthodontic approach

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The treatment of an impacted maxillary canine is not completed merely by its orthodontic alignment. Final periodontal health is a fundamental factor for evaluating the success of the treatment undertaken for impacted maxillary canines, especially those that are deeply impacted. As described in previous publications (Crescini et al. 1994, 2007), a combined surgical (flap approach) and orthodontic approach (direct traction towards the centre of the ridge), simulating the physiological eruption pattern of the tooth, provides alignment of intra-osseous impacted canines and, generally, leads to a healthy periodontium.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.

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The prognosis for impacted canines was investigated on the basis of information obtained from variables on panoramic X-rays aimed to define the position of the canine: the depth of inclusion, the angulation of the tooth, the distance from the occlusal plane and the possible superimposition on the roots of adjacent teeth (Ericson & Kurol 1997, 2000a, b). These measurements are able to describe features of canine displacement in the bony structures during mixed dentition, and they characterize the severity of subsequent impaction of the canine in permanent dentition. The radiographic signs have been correlated with the probability of spontaneous eruption of displaced canines (Ericson & Kurol 1986, 1988).

More recently, the same indicators visible on panoramic films have been studied as predictors for the outcomes of interceptive treatment of palatally displaced canines by means of the extraction of the corresponding deciduous canine and space maintenance on the maxillary dental arch (Leonardi et al.

2004), as well as predictors of the duration of orthodontic treatment to re-position the impacted tooth (Stewart et al. 2001, Zuccati et al. 2006). The more severely displaced the canine with regard to the adjacent maxillary incisors, the longer the duration of orthodontic treatment (Stewart et al. 2001, Olive 2005).

However, the final success of treatment requires a healthy periodontium surrounding the re-positioned tooth. A number of articles evaluated the periodontal health of re-positioned impacted teeth. Crescini et al. (1994) observed a healthy periodontium following a combined surgical (tunnel technique) and orthodontic (traction to the centre of the alveolar ridge) approach used to treat maxillary impacted canines. Similar results were achieved by Quirynen et al. (2000) who used different surgical techniques: closed eruption technique with conservative surgery or apically re-positioned flap for labially impacted (palpable) canines (window flap), according to the pre-treatment position of the impacted teeth. On the contrary, negative aesthetic and periodontal effects [increase in the mesio-labial pocket depth (PD), reduction in bone level, increase of crown length and reduction in width of the attached gingiva] were found by Chaushu et al. (2003) following surgical-orthodontic alignment of impacted central incisors treated with an open eruption technique.

On the other hand, no data are available in the literature concerning the possible influence of the initial intra-osseous position and inclination of maxillary impacted canines on their periodontal status at the end of treatment.

The purpose of this study is to evaluate the periodontal status in terms of PD and keratinized tissue width (KT) of intra-osseous impacted maxillary canines at the end of a combined surgical (flap approach) and orthodontic treatment (direct traction towards the centre of the ridge) on the basis of the initial radiographic features.

Material and Methods

Study population

Initial study population

A total of 218 patients with unilateral or bilateral impacted maxillary canines were consecutively treated in a private practice by a single operator over a period of 17 years. For this study, 40 patients were not considered for the analysis: 24 patients with canine impactions that did not allow for direct traction to the centre of the alveolar ridge (Crescini et al. 2007) and 16 patients with submucosal buccal impaction.

Population evaluated at the end of orthodontic treatment

Out of the 178 patients with unilateral or bilateral impacted maxillary canines, 10 patients were not included in the statistical analysis: six cases presented lack of movement of the impacted canine (ankylosis), thus the treatment was not completed and four patients underwent extractions of first premolars. Therefore, 168 patients with unilateral or bilateral intra-osseous impacted maxillary canines were included in this study and evaluated at the end of orthodontic treatment: 125 patients presented unilateral impaction of the maxillary canine and 43 bilateral. Of the 211 impacted canines, 125 were unilateral and 86 bilateral.

Diagnosis of impaction

The diagnosis of impaction was clinically evaluated when one or both of the permanent maxillary canines were absent in the dental arch after the expected eruption time. The deciduous canine might still be present in the maxillary dental arch. The diagnosis of impaction was confirmed in all 211 cases by conventional panoramic X-rays (Ortopantomograph 5E, Siemens, Bensheim, Germany) and lateral chephalograms (Ortophos C, Siemens) that were taken with the same devices for all the examined patients. In the more complex cases, additional radiographic examination, such as occlusal films (seven cases) and periapical X-rays (28 cases) (Castellini Radiografico X70, Bologna, Italy), taken with or without Clark's object rule (Richards 1980, Goaz & White 1994) were used to properly assess the location (buccal or palatal) of the impacted canine and its relationship with the adjacent roots (Ericson & Kurol 1997, 2000b). In more recent cases (13 patients), instead of occlusal and periapical X-rays, computed tomographic scanning examinations (Schmuth et al. 1992, Elefteriadis & Athanasiou 1996, Preda et al. 1997, Ericson & Kurol 2000a) were performed.

Following diagnosis of impaction, the position of the impacted canines was further analysed on the panoramic X-ray using a modified version of the criteria proposed by Ericson & Kurol (1986, 1988) (Fig. 1):

- α-angle: angle measured between the long axis of the impacted canine and the midline, to determine the intra-osseous inclination of the maxillary canine;
- *d*-distance: distance between the canine cusp tip and the occlusal

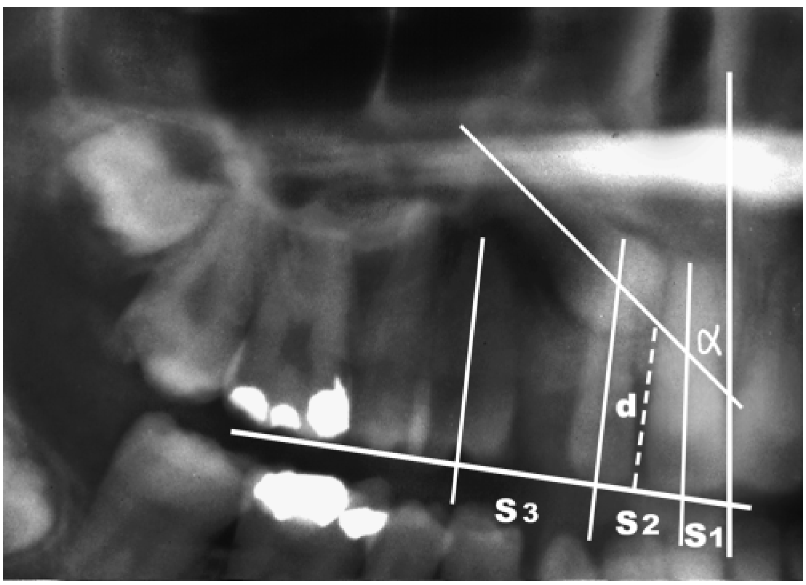

Fig. 1. Panoramic X-ray features showing displacement of the upper right canine: α-angle, *d*-distance, *s*-sector.

plane (from the first molar to the incisal edge of the central incisor);
- *s*-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;
sector 3 – between the axis of the lateral incisor and the axis of the first pre-molar.

Surgical-orthodontic treatment

All the patients consecutively underwent the same standardized (Crescini et al. 1994, 2007) combined surgical-orthodontic treatment. The teeth were exposed by means of a re-positioned flap and orthodontic traction was applied to guide the impacted canine directly towards the centre of the alveolar ridge. The combined procedure was performed by the same operator on all the patients.

The overall combined treatment was divided into three phases.

Phase 1. Initial orthodontic treatment

The orthodontic problems associated with canine impaction were addressed and sufficient space for the allocation of the impacted canine was created in the maxillary dental arch by means of the edgewise technique. Deciduous canines were not extracted until the time of treatment.

Phase 2. Surgical exposure and orthodontic traction of the impacted tooth towards the centre of the alveolar ridge

Surgical technique. A full-thickness mucoperiosteal flap was raised by making one mesiodistal incision in the middle of the alveolar ridge and a second, paramarginal incision positioned buccally or lingually, depending on the location of the impacted tooth (Abrams et al. 1988). The impacted canine cusp tip was exposed and a fine mesh was bonded as closely as possible to the cusp of the impacted canine. A handmade wire chain of rings approximately 1.5 mm in diameter was prepared with 0.011 in. ligature wire and fixed to the fine mesh. The flap was then re-positioned and sutured into the original site with single silk sutures. The chain emerged from the gingival tissue at the incision made in the middle of the alveolar ridge.

In 25 cases where intra-osseous impaction of the canine was associated with the presence of the deciduous canine in the dental arch, a specific recovering procedure, ''tunnel traction'', was performed (Crescini et al. 1994). The sutures were removed 10 days after the surgery and the traction phase began.

Orthodontic traction. Orthodontic traction of the impacted tooth consisted of a double-arch technique and aimed at guiding the impacted tooth directly towards the centre of the alveolar ridge. A rectangular stabilization arch was used to obtain adequate anchorage and maintain sufficient space in the dental arch while a round traction arch was used to guide the tooth towards the centre of the alveolar ridge. Patients were recalled every 4 weeks to adjust their appliance, and every 3 months for professional oral hygiene. Intra-oral X-ray exams were performed during the orthodontic traction in order to check for the movement of the impacted tooth: a single periapical film was used in 42 cases, two subsequent periapical films in 19 cases and three periapical films in six cases.

The duration of this phase was calculated as the time elapsed between the application of the traction device and the eruption of the cusp of the impacted canine.

Phase 3. Final orthodontic treatment

In this phase the erupting canine was aligned within the dental arch, and any tooth rotation was corrected. At the end of active orthodontic treatment the patients were discharged with Hawley's plates and lingual retainers.

Periodontal evaluation

The treated teeth were periodontally evaluated at the conclusion of the orthodontic treatment (end of phase 3). Examinations and chartings were always carried out by the same examiner.

The following periodontal variables were considered for the treated canines:

(1) Probing PD. The measurements were made by means of a William's offset periodontal probe on six sites – mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, distolingual – on each of the treated teeth.
(2) 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.
(3) Gingival recession (Rec), if any, was measured on the buccal midpoint of the crown.

Statistical analysis

Descriptive statistics were expressed as means $\pm$ standard deviation for metric variables and as frequency and percentage for nominal variables.

The inferential analysis aimed at evaluating the role of some possible prognostic factors influencing PD and KT variables at the end of orthodontic treatment.

Multilevel models (Goldstein 1995) were created. The following variables were evaluated at three levels for PD outcome variable analysis:

At the patient level:

- Age
- Gender

At the tooth level:

- Impaction (unilateral or bilateral impaction)
- Side (right or left position of the impacted canine)
- Location (palatal or buccal impaction of the canine)
- α-angle
- *d*-distance
- *s*-sector (sector 3 *versus* sectors 1 and 2)

At the site level:

- Measurement location (inter-proximal *versus* buccal or palatal, used as a covariate for the PD outcome variable analysis).

A similar model was prepared for the KT outcome variable analysis. The site level was not included because KT was measured at only one site per tooth, and thus analysed at the tooth level.

Results

The study population consisted of 168 patients, 40 males and 128 females,

Table 1. Descriptive statistics

Variable	Unit	Mean	Standard deviation	Range
Age	Years	17.39	6.04	12.8–52.0
Overall treatment (phases 1, 2, 3)	Months	22.02	4.77	13–34
Orthodontic traction (phase 2)	Months	8.02	2.29	4–13
d-distance	mm	15.13	3.72	6–24
α-angle	Deg.	35.09	12.66	5–71

Variable	Frequency	Percentage
Sector 1	30	14
Sector 2	103	49
Sector 3	78	37
Right impaction	114	54
Left impaction	97	46
Palatal impaction	155	73
Buccal impaction	56	27

Age: age at the beginning of the traction of the impacted tooth.
Overall treatment: duration of overall orthodontic treatment (phases 1, 2, 3).
Orthodontic traction: duration of phase 2 of the treatment.
d-distance: distance between the canine cusp tip and the occlusal plane.
α-angle: angle measured between impacted canine long axis and the midline.
s-sector: site 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; sector 3, between the axis of the lateral incisor and the axis of the first pre-molar.

Table 2. Multilevel model for pocket depth (PD) at the end of overall orthodontic treatment (end of phase 3) for the 168 treated patients

Term	Estimate	Standard error	*p*-value
Intercept	1.11	0.14	
Patient level			
Age	0.00	0.00	0.3173
Gender	− 0.04	0.06	0.4343
Tooth level			
Impaction (unilateral or bilateral)	0.07	0.05	0.1976
Side (right or left)	0.01	0.03	0.6617
Location (palatal or buccal)	0.09	0.05	0.0943
d-distance	0.01	0.01	0.1531
α-angle	0.00	0.00	0.3173
s-sector	0.06	0.05	0.2005
Site level			
Measurement location	0.61	0.03	<0.0001

Age: age at the beginning of the traction.
Gender: 1, male; 0, female.
Impaction: 1, bilateral impaction; 0, unilateral impaction.
Side: 1, right impaction; 0, left impaction.
Location: 1, palatal impaction; 0, buccal impaction.
d-distance: distance between canine cusp tip and the occlusal plane.
α-angle: angle measured between impacted canine long axis and the midline.
s-sector: 1, canine impacted in sector 3; 0, canine impacted in sectors 1 or 2.
Measurement location: 1, inter-proximal site; 0, buccal or palatal site.
Theoretic model: $\mathrm{PD}_{ijk} = \beta_{0ijk}+\beta_{1k}$ Age$+\beta_{2k}$ Gender$+\beta_{3jk}$ Impaction$+\beta_{4jk}$ Side$+\beta_{5jk}$ Location$+\beta_{6jk}$ *d*-distance$+\beta_{7jk}$ α-angle$+\beta_{8jk}$ *s*-sector$+\beta_{9ijk}$ Measurement location$+v_{0k}+u_{0jk}+e_{0ijk}$.
In the theoretic model formula, the subscript ''*k*'' refers to the patient level. The subscript ''*j*'' refers to the tooth level. The subscript ''*i*'' refers to site level. β_{0ijk} is the ''Intercept''.

aged between 12.8 and 52.0 years. Two hundred and eleven impacted canines were treated by means of the same standardized surgical-orthodontic technique by the same operator (Crescini et al. 2007): 125 patients showed unilateral impaction and 43 showed bilateral impaction. The clinical characteristics are described in Table 1. All the 211 impacted canines were successfully moved and aligned in the dental arch. None of the patients complained of significant discomfort. None of the patients lost the attaching device. In one case orthodontic traction was interrupted due to breakage of the wire chain. In this patient, 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.

The duration of the overall combined treatment (phases 1–3) was 22.02 ± 4.77 months. The duration of phase 2 (calculated as the time elapsed between the application of the traction device and the eruption of the cusp of the impacted canine) was 8.02 ± 2.29.

Periodontal evaluation at the end of orthodontic treatment

PD

Mean PD was 1.94 ± 0.59 mm.

The multilevel model (Table 2) does not show any statistically significant difference for age and gender at the patient level; no difference for unilateral or bilateral impaction, for right or left position, for palatal or buccal impaction; no difference for α-angle, *d*-distance and *s*-sector at the tooth level.

At the site level, the inter-proximal sites show a PD 0.61 mm deeper than the buccal/lingual sites ($p<0.0001$).

KT

Mean KT was 4.41 ± 1.16 mm.

The multilevel model (Table 3) does not show any statistically significant difference for age and gender at the patient level; no difference for unilateral or bilateral impaction and for right or left position at the tooth level; no difference for α-angle, *d*-distance and *s*-sector.

At the tooth level, the model estimates the KT of the impacted canines to be 0.45 mm greater in case of palatal impaction: the difference is statistically significant ($p = 0.0149$).

Gingival recession

One patient showed a gingival recession (1 mm) on the treated canine at the end of orthodontic treatment.

One clinical case is shown in Figs 2–8.

Discussion

The purpose of the present longitudinal study was to assess the utility of

Table 3. Multilevel model for keratinized tissue width (KT) at the end of overall orthodontic treatment (end of phase 3) for the 168 treated patients

Term	Estimate	Standard error	*p*-value
Intercept	5.02	0.51	
Patient level			
Age	– 0.01	0.02	0.5050
Gender	– 0.15	0.21	0.4920
Tooth level			
Impaction (unilateral or bilateral)	– 0.25	0.21	0.2320
Side (right or left)	– 0.07	0.10	0.4839
Location (palatal or buccal)	0.45	0.19	0.0149
d-distance	– 0.02	0.03	0.4237
α-angle	– 0.01	0.01	0.2113
s-sector	0.16	0.17	0.3647

Age: age at the beginning of the traction.
Gender: 1, male; 0, female.
Impaction: 1, bilateral impaction; 0, unilateral impaction.
Side: 1, right impaction; 0, left impaction.
Location: 1, palatal impaction; 0, buccal impaction.
d-distance: distance between canine cusp tip and the occlusal plane.
α-angle: angle measured between impacted canine long axis and the midline.
s-sector: 1, canine impacted in sector 3; 0, canine impacted in sectors 1 or 2.
Measurement location: 1, inter-proximal site; 0, buccal or palatal site.
Theoretic model: $KT_{jk} = \beta_{0jk} + \beta_{1k}$ Age $+ \beta_{2k}$ Gender $+ \beta_{3jk}$ Impaction $+ \beta_{4jk}$ Side $+ \beta_{5jk}$ Location $+ \beta_{6jk}$ *d*-distance $+ \beta_{7jk}$ α-angle $+ \beta_{8jk}$ *s*-sector $+ v_{0k} + u_{0jk}$.
In the theoretic model, the subscript ''*k*'' refers to the patient level. The subscript ''*j*'' refers to the tooth level. β_{0ijk} is the ''Intercept''.

Fig. 2. Panoramic X-ray: J. B., male, 15 years old, impacted right upper canine: α-angle = 43°, *d*-distance = 18 mm, *s*-sector = 2.

Fig. 3. Same patient as in Fig. 2, 6 months later. Clinical aspect.

Fig. 4. Pre-surgical view: the upper right deciduous canine is still in place with an increased space created orthodontically.

pre-treatment radiographic indicators of intra-osseous displacement of permanent maxillary canines evaluated on panoramic X-rays with regard to the periodontal conditions following surgical-orthodontic therapy.

Fig. 5. Extraction of the deciduous canine and surgical approach.

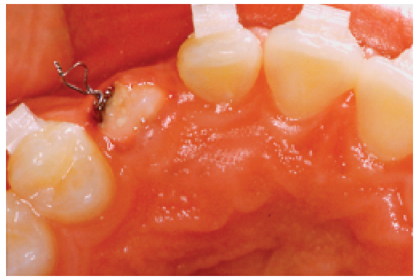

Fig. 6. Emergence of the permanent canine at the centre of the alveolar ridge following orthodontic traction.

At least two major aspects deserve to be highlighted. The anomalous intra-osseous position of the maxillary canine has a different diagnostic meaning before and after the expected time of eruption. Before the expected time of tooth emergence on the dental arch (about 12 years for females and 13 years for males – Peck et al. 1994), the abnormal intra-osseous position of the canine is diagnosed as ''displacement''. This period usually coincides with the late mixed dentition. After the time of expected eruption, the intra-osseous position of the canine is diagnosed as ''impaction'', which mainly corresponds with the permanent dentition. Radiographic measurements of canine position on panoramic X-rays (Ericson & Kurol 1986) have been proposed with a different diagnostic/prognostic significance according to the phase of development of the canine and dentition. In case of displaced canines, the radiographic variables (α-angle, *d*-distance and *s*-sector) can provide information about the probability of spontaneous eruption of the tooth (Ericson & Kurol 1986) or the anticipated success rate of interceptive treatment of the displaced permanent tooth. Interceptive treatment consisted of extraction of the corresponding deciduous canine (Ericson & Kurol 1988) and increases in the available space on the maxillary arch (Olive

Fig. 7. Panoramic X-ray: J. B., 16 years 10 months, post-treatment results.

Fig. 8. (a, b, c, d): Clinical aspect: J. B., 16 years 10 months, post-treatment results.

2005). A recent prospective study (Leonardi et al. 2004) failed to find a prognostic value for radiographic measurements of canine displacement for the final success of interceptive orthodontic treatment.

When the radiographic measurements are taken on an ''impacted'' maxillary canine (that is after the expected time of eruption), they are used to describe the spatial relationships of the unerupted tooth with regard to the surrounding structures and to assess the severity of impaction. In these cases the radiographic variables (more specifically the sector of impaction) have been employed to predict the duration of orthodontic treatment to re-position the impacted tooth (Stewart et al. 2001, Zuccati et al. 2006).

No previous data are available in the literature concerning the possible significance of pre-treatment radiographic measurements with respect to the periodontal status of orthodontically re-positioned impacted canines, which is the purpose of this study. It should be noted that in the more complex cases, additional radiographic examination, such as occlusal films, periapical X-rays and/or computed tomographic scanning, examinations were used to properly assess the location of the impacted canine, its relationship with the adjacent roots and progression of tooth movement during orthodontic traction. Prognostic information derived from these examinations was not included in the analysis here, because the specific aim of this study focused on the predictive variables assessed on pre-treatment panoramic radiographs.

The second aspect that merits attention is that in the present investigation patients with impacted canines were consistently treated by means of the same surgical-orthodontic approach aimed to guide the impacted canine to the centre of the alveolar ridge in the maxillary arch (Crescini et al. 1994, 2007). This technique permits the re-positioned canine to be surrounded by a physiological amount of gingiva at the end of orthodontic treatment. In addition, the technique was used here to treat maxillary canines that were in intra-osseous impaction in the maxillary bony structures. No superficial/submucosal impaction was included for the analysis of treatment outcomes.

The findings of this longitudinal study showed that re-positioned canines exhibited an average PD of <2 mm and an average KT of about 4.5 mm. Only one patient presented a gingival recession (1 mm) at the final observation. At the end of the surgical-orthodontic treatment, there were no significant differences in PD and KT with respect to age, gender, site of impaction or pre-treatment radiographic position of the impacted canine. The only statistically, but not clinically, significant difference (about 0.5 mm) was detected for the KT that was larger 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 the orthodontically re-positioned canines.

Similar results were reported by Quirynen et al. (2000) in a retrospective study on 38 patients. The authors compared the periodontal outcomes of surgically exposed (closed eruption technique) and orthodontically extruded impacted teeth with the spontaneously erupted controlateral teeth. No significant differences of periodontal parameters were detected between test and control teeth. The width of keratinized tissue was 1 mm larger for the spontaneously erupted teeth. In this study, the width of keratinized tissue was similar in both sites (control/test) after the follow-up period.

From a clinical standpoint on the basis of radiographic appearance of intra-osseous impacted canines with different degrees of intra-osseous displacement, the combined surgical-orthodontic approach protocol investigated here can be recommended. The limitations of the technique are the complete or incomplete transposition of the impacted canine with adjacent teeth and ankylosis. As a matter of fact, 24 patients were excluded from the initial population of this study, precisely for these reasons.

In conclusion, the pre-treatment radiographic features (α-angle, d-distance and s-sector) aimed to define the position of the canine on a panoramic X-ray are not valid predictors of the final periodontal status of impacted canines treated by the combined surgical-orthodontic approach. Further research might analyse improvement of diagnostic radiologic approaches to impacted canines by using recently developed technology, such as cone beam CT and 3-D imaging. These techniques could help visualizing aspects related to impacted canines (3-D location, lateral incisor resorption, ankylosis) that may assist in treatment planning.

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Clinical Relevance

Scientific rationale for the study: The need to assess prognostic factors for the periodontal outcomes of orthodontically treated impacted canines.
Principal findings: Pre-treatment radiographic variables on panoramic X-rays aimed to define canine position are not predictive of the final periodontal success rate in patients with impacted canines treated by means of a combined surgical (flap approach) and orthodontic treatment (direct traction to the centre of the ridge).

Practical implications: The proposed surgical-orthodontic approach can be used to treat intra-osseous impacted canines with different degrees of intra-osseous displacement, regardless of age, gender and site of impaction.