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Short- and long-term periodontal evaluation of impacted canines treated with a closed surgical–orthodontic approach

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Abstract

Aim: The aims were to evaluate and compare the periodontal status of unilateral impacted maxillary canines treated by a combined surgical–orthodontic technique with that of normally erupted controlateral canines.

Material and Methods: One hundred and twenty-five patients, consecutively enrolled, aged between 12.8 and 52.0 years, 31 males and 94 females, presented one impacted maxillary canine (test group) and the controlateral canine normally erupted (control group). All cases were treated by a surgical flap and orthodontic traction directed to the centre of the crest and evaluated periodontally at the end of treatment. Fifty-eight patients were followed up for a mean of 3.4 ± 0.5 years. Pocket depth (PD), keratinized tissue width (KT) and gingival recession were recorded. Multilevel models were created.

Results: At the end of the orthodontic treatment, PD and KT of the 125 impacted canines were slightly, but statistically significantly higher than controls. Only one treated canine showed a recession (1 mm). At follow-up (58 patients), this difference decreased and the two groups were not significantly different.

Conclusions: The combined technique permitted the traction of the impacted canines to the centre of the crest, thus simulating a physiological eruption pattern. Correct alignment and good periodontal status were obtained.

Key words: closed surgical approach; impacted canines; keratinized tissue width; probing pocket depth; surgical–orthodontic treatment

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The impacted canine has always implied a difficult therapeutical management for the clinician. The therapy of this condition can be considered successful only if the forced eruption and the subsequent alignment lead the tooth to a stable position in the dental arch along with the presence of a healthy periodontium. The treatment has to be considered unsuccessful in cases where the forced eruption is not possible, like in the case of an ankylotic-impacted tooth, as well as when, at the end of the alignment, the tooth presents severe periodontal, functional and/or aesthetic problems, such as alveolar bone resorption, reduced gingival tissue or, at the worst, the presence of a periodontal pocket or recession.

From the physiological standpoint, ''when a permanent tooth erupts ideally it will break through the gingiva near the crest of the ridge so that some gingiva will be present on the facial and some on the lingual surface'' (Hall 1977). The adequate amount of gingiva is associated with a shallow sulcus, a junctional epithelium in contact only with the enamel, connective tissue attachment and crestal bone close to the cemento-enamel junction (CEJ). On the other hand, ''if the tooth erupts in facial or lingual version, it may break through the existing gingiva near the mucogingival junction'' (Hall 1977). Therefore, buccal/lingual eruption is often associated with the absence of the attached gingiva (Bowers 1963, Gormann 1967, Maynard & Ochsenbein 1975, Boyd 1978, Årtun et al. 1986) or with a high incidence of gingival recessions (RECs; Parfitt & Mjör 1964, Gormann 1967).

Eccentric eruption causes the irreversible destruction of the gingiva that is ''entrapped'' between the erupting permanent tooth and the corresponding deciduous tooth (Agudio et al. 1985, Pini Prato et al. 2000a, b). In a longitudinal

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clinical trial, Årtun et al. (1986) demonstrated that, in the same patient, buccally erupted canines presented with more apically positioned clinical attachment and alveolar bone levels when compared with the controlateral teeth erupted at the centre of the alveolar ridge. Additionally, buccal eruption may cause the thinning of the cortical bone plate up to the formation of a dehiscence/fenestration often associated with a REC (Hirschfeld 1923, Bernimoulin & Curilovic 1977, Sperry et al. 1977). Therefore, the most appropriate treatment should be able to simulate the physiological eruption pattern that occurs at the centre of the alveolar ridge as some authors have already suggested (Shiloah & Kopczyk 1978, Mathews 1995, Kokich 2004). Orthodontic appliances and techniques specifically designed for this purpose have been proposed for the re-positioning of the impacted canine on the maxillary arch (Jacoby 1979, Mc Bride 1979, Taylor 1979, Seong-Seng 1983, Mc Donald & Yap 1986, Crescini et al. 1994).

The surgical procedures performed to expose the impacted canine should respect the soft tissues as much as possible. In the case of submucosal buccal impaction, where only the soft tissue is involved, the keratinized gingiva must be preserved and an apically positioned flap should be raised (Levin & D'Amico 1974, Vanarsdall & Corn 1977, Shiloah & Kopczyk 1978, Boyd 1984).

In the case of deep intra-osseous impaction, a more delicate management of the soft tissues and bone is required to access the crown of the impacted tooth adequately and to avoid subsequent severe periodontal damage. Some authors have proposed performing a gingivectomy to access the crown of the impacted tooth directly (Thilander et al. 1973, Archer 1975). The advantages of the ''open approach'' include the orthodontist's ability to observe the impacted tooth movement directly (Wisth et al. 1976, Vanarsdall & Corn 1977). However, this approach may cause some surgical problems such as bleeding, difficulty in the placement of the attaching device and, most of all, if the localization is not precise, excessive removal of bone and soft tissues. Moreover, this technique is often associated with subsequent periodontal concerns, including REC (Di Biase 1971, Vanarsdall & Corn 1977, Odenrick & Modeer 1978, Boyd 1984, Tegsjo et al. 1984), bone loss (Vanarsdall & Corn 1977), decreased width of keratinized tissue (Kohavi et al. 1984a, Tegsjo et al. 1984), delayed periodontal healing (Becker et al. 1996) and gingival inflammation (Tegsjo et al. 1984).

A re-positioned flap has to be considered a valid alternative in case of intra-osseous dental impaction (Begg & Kesling 1971, Thilander et al. 1973, Wisth et al. 1986, Crescini et al. 1994). The flap approach seems to be an appropriate surgical choice for several reasons. In fact, the flap approach allows for minimal exposure of the impacted tooth, reduces surgical bleeding and facilitates the placement of the attaching device. Some authors reported that the healing process (Chaushu et al. 2004a, b) and the final periodontal status (Tegsjo et al. 1984) appear optimal following this technique. In addition, the marked improvements in bonding materials have virtually eliminated the risk of accidental loss of the attaching device during orthodontic traction.

The periodontal status of impacted canines following surgical–orthodontic treatments has been investigated in the past with short-term follow-up evaluations (Heaney & Atherton 1976, Wisth et al. 1976, Odenrick & Modeer 1978, Boyd 1982, 1984, Becker et al. 1983, Kohavi et al. 1984a, b, Tegsjo et al. 1984, Crescini et al. 1994, Hansson & Rindler 1998). A long-term evaluation on a small sample size was performed by Quirynen et al. (2000). The long-term evaluation is needed in order to establish the success of therapy of impacted canines, not only from an orthodontic perspective but also in terms of the long-term health of the periodontal tissues.

The aims of this study were (1) to evaluate and (2) to compare the periodontal status, in terms of pocket depth (PD), keratinized tissue width (KT) and REC of unilateral intra-osseous-impacted canines treated by means of a combined surgical (flap approach) and orthodontic (direct traction to the centre of the alveolar ridge) treatment, with that of normally erupted canines on the controlateral side.

Material and Methods

Study population

A total of 218 patients with impacted maxillary canine/s were visited and treated in a private practice by a single operator over a period of 17 years. Patients with unilateral osseous impaction of the maxillary permanent canine associated with normally erupted controlateral canine and with indication for a direct orthodontic traction of the impacted canine to the centre of the alveolar ridge were enrolled in the study. On the contrary, cases showing submucosal impaction, need for extraction of first pre-molars and without indication for direct orthodontic traction were excluded from the study.

One hundred and thirty-one patients (131 unilateral-impacted maxillary canines) met the entry criteria. During the treatment, six cases were excluded due to the lack of movement of the impacted canine (ankylosis).

Therefore, 125 patients with 125 unilateral osseous canine impactions were included in this study and evaluated at the end of orthodontic treatment.

Out of the 125 treated patients, 58 patients could be reached for the follow-up examination (mean 3.4 ± 0.5 years).

The impacted canines were included in the test group, while the spontaneously erupted canines were enrolled in the control group.

Diagnosis of impaction

The diagnosis of unilateral impaction was clinically evaluated when one of the permanent maxillary canines was absent in the dental arch after the expected eruption time, with the presence of the normally erupted controlateral canine. The deciduous canine might still be present on the impaction side of the maxillary dental arch. The diagnosis of impaction was confirmed by conventional panoramic X-rays and lateral chephalograms that were taken with the same device for all the examined patients. In some cases, additional radiographic examinations, such as occlusal films and periapical X-rays, taken with or without Clark's object rule (Richards 1980, Goaz & White 1994), were used to assess properly the location (buccal or palatal) of the impacted canine. In the more complex cases, computed tomographic scanning examinations were performed (Schmuth et al. 1992, Elefteriadis & Athanasiou 1996, Preda et al. 1997, Ericson & Kurol 2000a) to evaluate the location of the impacted canine and its relationship with the adjacent dental roots (Ericson & Kurol 1987, 2000b).

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 plane (from the first molar to the incisal edge of the central incisor); and
- *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; and

sector 3, between the axis of the lateral incisor and the axis of the first pre-molar.

Surgical–orthodontic treatment

All of the patients consecutively underwent the same standardized 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 (Figs 2 and 3): 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 paramarginal incisions were extended mesially, in correspondence of the central incisor and distally, in correspondence of the second pre-molar. In some cases, vertical-releasing incisions were made to facilitate the elevation of the flap. Once the flap was raised, a small portion of cortical bone, if present, was gently removed by means of a low-speed bur and the follicular socket was eliminated using a periodontal curette.

The impacted canine cusp tip was exposed and the enamel was dried with gentle suction and a dry gauge; a fine mesh was bonded as closely as possible to the cusp of the impacted canine. The bonding agent was light cured for 60 s. A handmade wire chain of rings approximately 1.5 mm in diameter was prepared with a 0.011′′ ligature wire and fixed to the fine mesh. The bonding was tested by a traction force of 150 g applied with a dynamometer. The flap was then re-positioned and sutured into its original site with interrupted silk sutures. The chain emerged from the

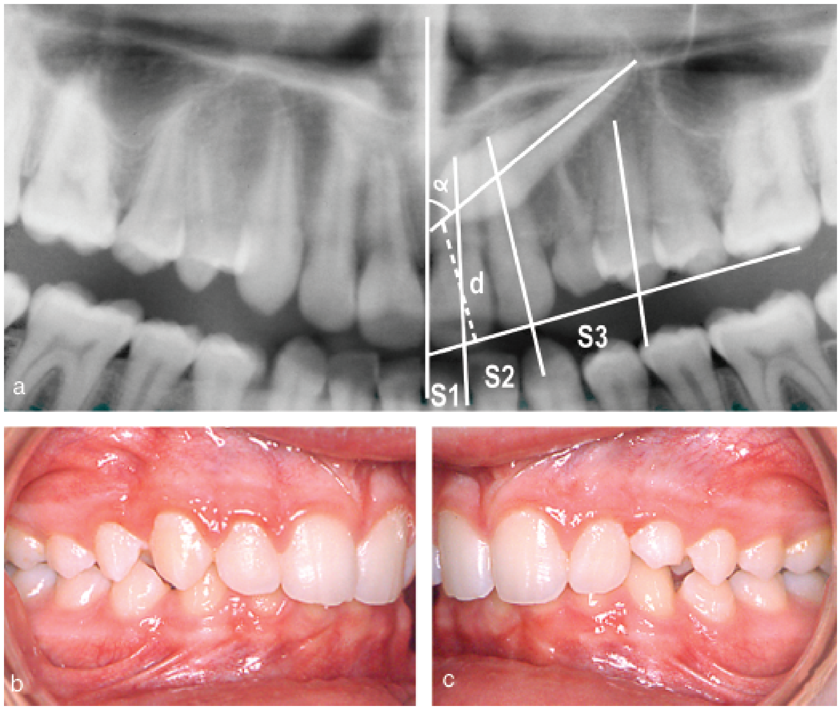

Fig. 1. (a) Panoramic X-ray, left-impacted upper canine: its position in relation to α-angle, *d*-distance and *s*-sector; (b) spontaneously erupted canine; (c) left-impacted canine and presence of deciduous canine.

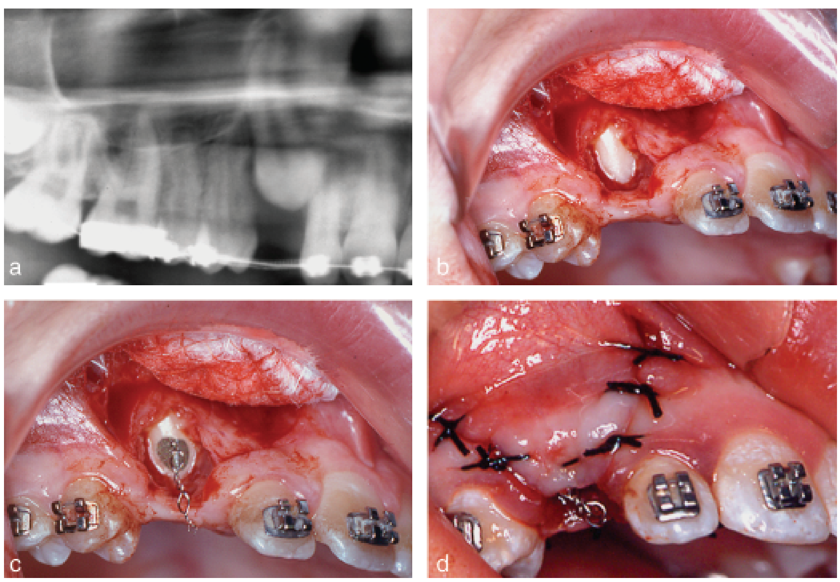

Fig. 2. (a) Right buccally impacted canine; (b) flap access; (c) fine mesh and handmade chain bonded close to the cusp; (d) flap sutured in its original position.

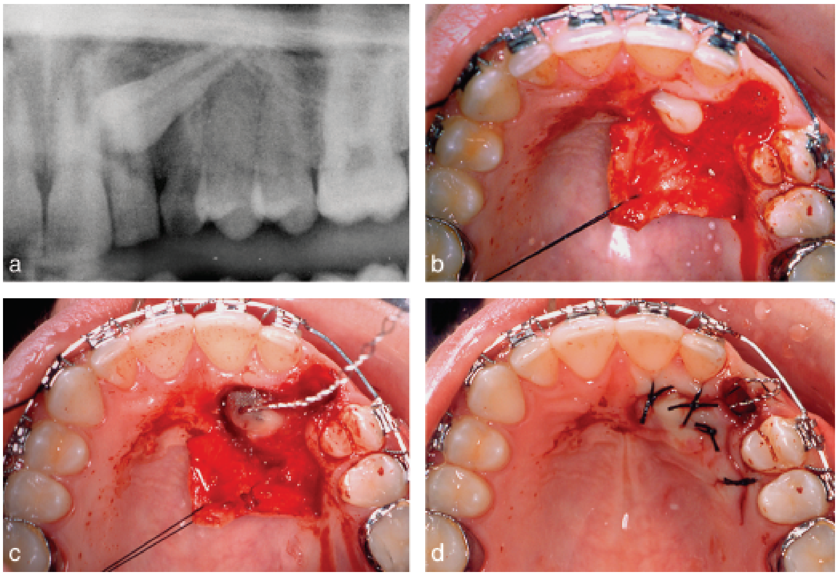

Fig. 3. (a) Left palatally impacted canine; (b) flap access; (c) fine mesh and handmade chain bonded close to the cusp; (d) flap sutured in its original position.

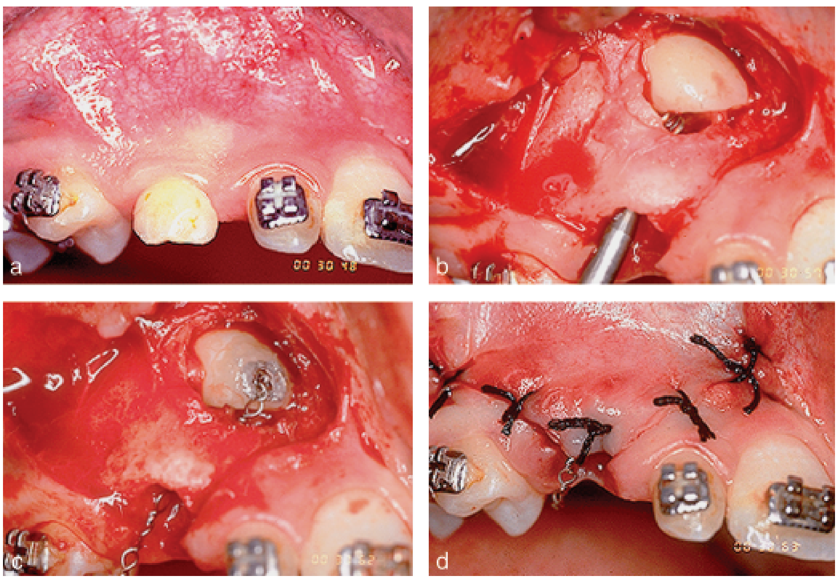

Fig. 4. (a) Right impacted canine and presence of deciduous canine; (b) tunnel technique; (c) the chain passes through the empty socket; (d) flap sutured in its original position.

gingival tissue at the incision made in the middle of the alveolar ridge.

In 22 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'' (Fig. 4), was performed (Crescini et al. 1994). After the elevation of the flap and the exposure of the cusp of the impacted tooth, the deciduous canine was removed. A low-speed bur, under careful cooling, was inserted into the empty socket to perforate the bone in order to reach the crown of the impacted canine. The perforation and the socket of the extracted deciduous tooth formed a tunnel that was used for the traction. The wire chain fastened to the cusp of the permanent canine passed through the empty socket reaching the centre of the alveolar ridge. Then, the flap was repositioned and sutured into its original site with interrupted silk sutures. The sutures were removed 10 days after the surgery and the traction phase began.

Orthodontic traction (Fig. 5): Orthodontic traction of the impacted tooth consisted of a double-arch technique and it 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 impacted canine towards the centre of the alveolar ridge. The latter was formed by loops that allowed for progressive modification of the direction of the orthodontic traction towards the centre of the alveolar ridge. The chain was tied to an elastic device that passed through the loops of the traction arch, perpendicular to the alveolar ridge. The elastic device was fastened to the first permanent molar. In cases of palatal impaction, the traction was directed buccally, and palatally if the canine was positioned buccally. An orthodontic force of approximately 100 g was applied.

Patients were recalled every 4 weeks to adjust their appliance, and every 3 months for professional oral hygiene.

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 (Fig. 5). 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.

Follow-up: During the follow-up period, the patients were recalled every 6 months for professional hygiene and orthodontic control.

One of the treated patients with a follow-up observation at 3 years and 3 months after the completion of orthodontic treatment is shown in Fig. 6.

Periodontal evaluation

The treated teeth underwent two periodontal evaluations: at the end of overall orthodontic treatment (end of Phase 3), and at follow-up visit for a subgroup of 58 patients (after a period ranging from 2.4 to 4.5 years). Examinations and chartings were always conducted by the same examiner who performed both surgical and orthodontic procedures in all the patients.

The following periodontal variables were considered for both the treated (test) and the normally erupted (control) canines:

1. Probing PD. The measurements were made by means of a William's offset

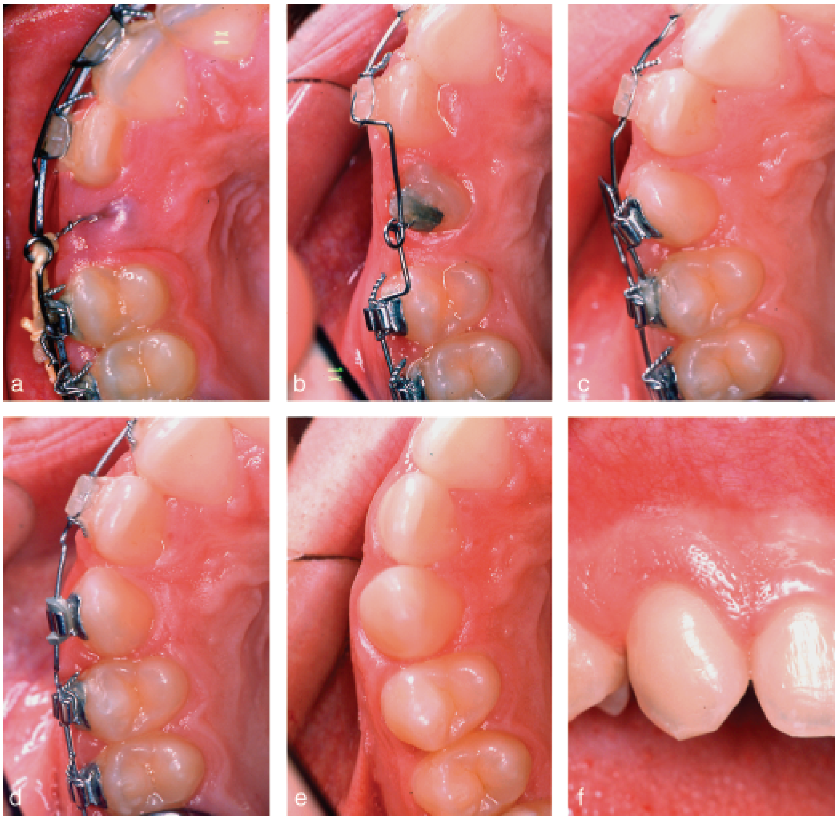

Fig. 5. (a) Orthodontically guided eruption at the centre of the ridge; (b, c) progressive emergence of the cusp; (d) derotation of the tooth; (e, f) final result: tooth properly aligned and surrounded by a healthy periodontium.

periodontal probe at six sites – mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual and distolingual – on each of the test and control canines.

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. REC, if any, was measured on the buccal midpoint of the crown.

Statistical analysis

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

The inferential analysis aimed at evaluating differences in PD and KT between impacted and normally erupted canines at the end of orthodontic treatment and at follow-up visit.

Multilevel models (Goldstein 1995) were created at three levels for PD: the covariates used at the Patient level were ''gender'' and ''age''; at the Tooth level, ''side'' (right or left) and at the Site level, ''measurement location'' (inter-proximal *versus* buccal or palatal). The explicative variable at the Tooth level was ''impaction''. This variable was 1 for impacted canines and 0 for normally erupted canine.

Multilevel models (Goldstein 1995) were also created at two levels for KT: at the Patient level, the covariates used were ''gender'' and ''age'', and at the Tooth level, ''side'' (right or left). The explicative variable at the Tooth level was ''impaction''. The Site level was not reported because KT was measured on only one site per tooth, and thus analysed at the Tooth level.

Results

The study population consisted of 125 patients, 31 males and 94 females, ranging in age from 12.8 to 52.0 years. The clinical characteristics are described in Table 1.

None of the patients complained of significant discomfort. All the 125 impacted canines were successfully moved and aligned in the dental arch.

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 orthodontic treatment (Phases 1–3) was 20.6 ± 4.2 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 8.1 ± 2.4 months.

Periodontal evaluation at the end of orthodontic treatment

All the 125 patients were evaluated at the end of the overall orthodontic treatment (end of Phase 3).

PD

Descriptive statistics (Table 2) show that the mean PD was 1.9 ± 0.6 mm in the test group, while it was 1.7 ± 0.6 mm in the control group.

The multilevel model (Table 3) does not show any statistically significant differences for age and gender at the Patient level, or for right or left position at the Tooth level. On the contrary, at the Tooth level the model estimates that the PD of the impacted canines is 0.18 mm deeper than normally erupted canines: the difference is statistically significant ($p<0.0001$). At the Site level, the inter-proximal sites show a PD 0.65 mm deeper than the buccal/lingual sites ($p<0.0001$).

KT

Descriptive statistics (Table 2) show that the mean KT was 4.5 ± 1.2 mm in the test group, while it was 4.2 ± 0.9 mm in the control group.

The multilevel model (Table 4) does not show any statistically significant differences for age and gender at the Patient level or for right or left position at the Tooth level. On the contrary, at the Tooth level the model estimates that the KT of the impacted canines is 0.28 mm greater than normally erupted canines: the difference is statistically significant ($p = 0.0028$).

REC

One patient showed a REC (1 mm) on the treated tooth (test).

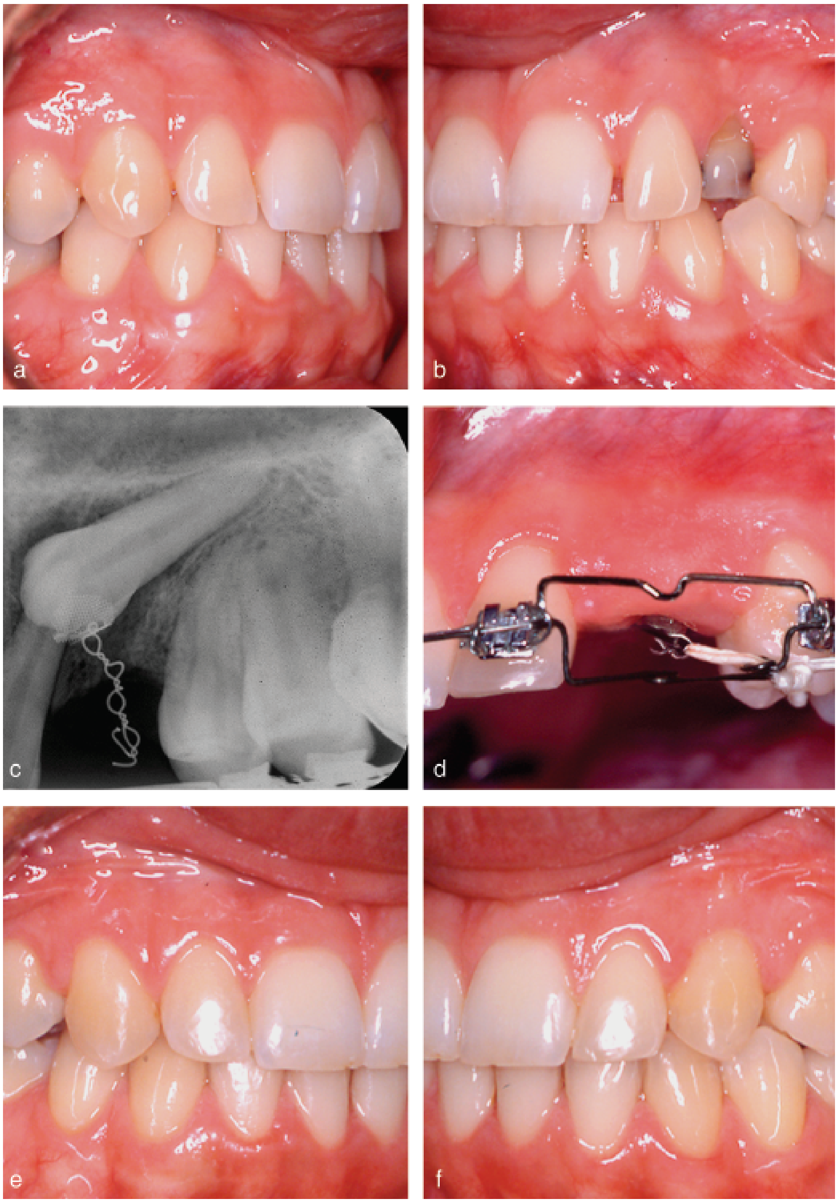

Fig. 6. E. D., male, 35 years old. (a) Spontaneously erupted right canine; (b) left-impacted canine and presence of deciduous canine; (c) intra-oral X-ray; (d) orthodontic traction at the centre of the ridge; follow-up evaluation: (e) spontaneously erupted canine and (f) treated canine: a proper alignment of the canine was provided along with an healthy periodontium.

Periodontal evaluation at follow-up visit

A subgroup of 58 patients, 23 males and 35 females (mean age of 21.2 ± 5.6 years at follow-up visit), could be reached for the follow-up examination (after a mean period of 3.4 ± 0.5 years, ranging from 2.4 to 4.5 years). The subgroup of 58 patients available for follow-up examination presented with similar pre-treatment features with regard to the total study sample (125 patients) in terms of initial average age, severity of canine impaction, intra-osseous position of the impacted tooth and periodontal conditions.

PD

Descriptive statistics (Table 2) show that the mean PD was 1.6 ± 0.6 mm both in the test and in the control groups. With regard to this subgroup of 58 patients, at the end of treatment, the mean PD was 1.9 ± 0.6 mm in the test group, while it was 1.8 ± 0.6 mm in the control group.

The multilevel model relative to the subgroup of 58 patients evaluated at the end of orthodontic treatment (end of Phase 3) showed results similar to the multilevel model relative to the 125 patients evaluated at the same time. In fact, the PD of the impacted canines was estimated to be 0.19 mm deeper than normally erupted canines: the difference was statistically significant ($p < 0.0001$).

The multilevel model relative to the subgroup of 58 patients evaluated at follow-up visit (Table 5) does not show any statistically significant differences for age and gender at the Patient level or for right or left position at the Tooth level. At the Tooth level, the difference (0.03 mm) in PD of the impacted canines compared with normally erupted canines is not statistically significant ($p = 0.3014$). At the Site level, a difference (0.81 mm) is still detectable between the inter-proximal and the buccal/lingual sites ($p < 0.0001$).

KT

Descriptive statistics (Table 2) show that the mean KT was 3.5 ± 0.9 mm in the test group, while it was 3.5 ± 0.8 mm in the control group. Relative to this subgroup of 58 patients, at the end of treatment, the mean KT was 4.5 ± 1.2 mm in the test group, while it was 4.0 ± 0.8 mm in the control group.

The multilevel model relative to the subgroup of 58 patients evaluated at the end of orthodontic treatment (end of Phase 3) showed results similar to the multilevel model relative to the 125 patients evaluated at the same time. In fact, the KT of the impacted canines was estimated to be 0.45 mm greater than normally erupted canines: the difference was statistically significant ($p = 0.0002$).

The multilevel model relative to the subgroup of 58 patients evaluated at follow-up visit (Table 6) does not reveal statistically significant differences for age and gender at the Patient level or for right or left position at the Tooth level. At the Tooth level, the difference (0.02 mm) in KT of the impacted canines compared with normally erupted canines is not statistically significant ($p = 0.8518$).

REC

At follow-up, one adult patient presented with 1 mm RECs on both the test and control canines, while one other young patient showed a 0.5 mm recession on the orthodontically treated canine only. RECs were not observed in any other case.

Table 1. Descriptive statistics (125 patients)

Variable	Unit	Mean	SD	Range
Age	Years	16.9	5.9	12.8–52.0
Overall treatment (Phases 1–3)	Months	20.6	4.2	13–30
Orthodontic traction (Phase 2)	Months	8.1	2.4	4–13
d-distance	mm	15.5	3.7	6–24
α-angle	Deg.	35.3	13.8	5–71

Variable	Frequency	Percentage
Sector 1	16	13%
Sector 2	60	48%
Sector 3	49	39%
Right impaction	71	57%
Left impaction	54	43%
Palatal impaction	78	62%
Buccal impaction	47	38%

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

Table 2. Mean values and standard deviations of pocket depth (PD) and keratinized tissue width (KT) at the end of overall orthodontic treatment (end of Phase 3) for all the 125 patients and for the subgroup of 58 patients; and at follow-up visit (mean 3.4 ± 0.5 years) for the subgroup of 58 patients

Treatment phase	Variable	Mean ± SD	
		test side (mm)	control side (mm)
End of treatment (125 patients)	PD	1.9 ± 0.6	1.7 ± 0.6
	KT	4.5 ± 1.2	4.2 ± 0.9
End of treatment (58 patients)	PD	1.9 ± 0.6	1.8 ± 0.6
	KT	4.5 ± 1.2	4.0 ± 0.8
Follow-up (58 patients)	PD	1.6 ± 0.6	1.6 ± 0.6
	KT	3.5 ± 0.9	3.5 ± 0.8

SD, standard deviation.

The patient showing one recession at the end of orthodontic treatment was not reached for the follow-up evaluation.

Discussion

The management of impacted canines requires a demanding multidisciplinary approach. The treatment of impacted, ectopic or malpositioned maxillary canines is accomplished when the tooth has reached a proper alignment on the dental arch, with an adequate attached gingiva, and when there is no periodontal damage such as pockets or RECs. As spontaneous tooth eruption, when harmonious, leads to dental alignment with adequate periodontal tissues, the surgical–orthodontic treatment of an impacted tooth should simulate the physiological eruption pattern as much as possible. Consequently, the aim of orthodontic therapy is to guide tooth eruption to the centre of the alveolar ridge, whereas periodontal–surgical management must guarantee the respect of the gingival tissues to avoid severe periodontal damage at the end of treatment.

The aim of the present study was to evaluate the periodontal conditions (PD, KT and REC) of intra-osseous maxillary impacted canines re-positioned in the dental arch by means of a combined surgical–orthodontic treatment, based on a ''closed''-flap approach and orthodontic traction directed towards the centre of the alveolar ridge.

In the examined cases, a full-thickness flap was raised, allowing for minimal exposition of the impacted tooth. Paramarginal incisions of the flap were always made in order to avoid damage to the gingival margin and to the connective tissue attachment of the adjacent teeth. Delicate elevation of such flaps allowed for reducing surgical bleeding, which facilitated the placement of the attaching device and permitted to eliminate only a minimal amount of cortical bone and pericoronal tissues at the cusp of the impacted canine. The minimal bone removal has been stressed by several authors (Kohavi et al. 1984a, Kokich & Mathews 1993); in fact, extensive bone removal around the impacted tooth's crown to facilitate tooth eruption is considered too risky (Kohavi et al. 1984a). In addition, this type of access makes it possible to avoid dangerous involvement of the CEJ and of the root of the impacted tooth during the placement of the attaching device as well as to avoid exposure of the roots of the adjacent teeth. Some researchers claim that exposing an impacted tooth's CEJ results in more REC and greater bone loss (Vanarsdall & Corn 1977, Boyd 1984, Kohavi et al. 1984a, b, Bishara 1992). Therefore, extensive bone removal that might involve the CEJ should be avoided. Finally, the repositioned flap maintains the entire amount of keratinized tissue and reduces discomfort during healing.

In case of an intra-osseous-impacted canine associated with the persistence of the correspondent deciduous tooth in the dental arch, the tunnel technique was used as originally described by Crescini et al. (1994). The extraction of the deciduous tooth provides a natural osseous tunnel. Traction through this tunnel follows an eruption path that closely simulates the physiological one. The impacted teeth are then orthodontically moved between two normally spaced cortical plates towards the centre of the alveolar ridge, allowing the attached gingiva present on the facial aspect to be preserved.

Once the tooth is exposed, the main objective of the orthodontic technique is to guide the dental movement directly towards the centre of the alveolar ridge (Fig. 7). To obtain a proper traction, the double-arch technique was used. In case of palatal impaction, the force was directed buccally, and directed palatally if the canine was positioned buccally.

With the above-described technique, 125 patients with unilateral impacted canines were treated while the contralateral tooth was normally erupted. These patients were part of a larger group of 218 patients with impacted canines treated over a period of 17 years. Out of this group, some cases

Table 3. Multilevel model for pocket depth (PD) at the end of overall orthodontic treatment (end of Phase 3) for the 125 treated patients

Term	Estimate	SE	p-Value
Intercept	1.25	0.09	
Patient level			
Age	0.00	0.01	0.6892
Gender	– 0.01	0.06	0.9216
Tooth level			
Side	0.01	0.03	0.6170
Impaction	0.18	0.03	< 0.0001
Site level			
Measurement location	0.65	0.02	< 0.0001
Variances			
σ_v^2	0.06	0.01	
σ_u^2	0.02	0.01	
σ_e^2	0.17	0.01	

Theoretic model

$$\begin{aligned}\mathrm{PD}_{ijk} = \beta_{0ijk} &+ \beta_{1k}\,\mathrm{Age} + \beta_{2k}\,\mathrm{Gender} \\ &+ \beta_{3jk}\,\mathrm{Side} + \beta_{4jk}\,\mathrm{Impaction} \\ &+ \beta_{5ijk}\,\mathrm{Measurement\ location} + v_{0k} \\ &+ u_{0jk} + e_{0ijk}.\end{aligned}$$

''Age'' is recorded at the beginning of the traction. ''Gender'' is 1 if male and 0 if female. ''Side'' is 1 if the tooth was on the right side and 0 if it was on the left. The explicative variable ''impaction'' is 1 in case of impacted canine and 0 in case of normally erupted canine. ''Measurement location'' is 1 if the site was inter-proximal and 0 if buccal or palatal. σ_v^2, σ_u^2 and σ_e^2 indicate the variances at the Patient, at the Tooth and at the Site level, respectively. 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 the Site level. β_{0ijk} is the ''intercept''.
SE, standard error.

Table 4. Multilevel model for keratinized tissue width (KT) at the end of overall orthodontic treatment (end of Phase 3) for the 125 treated patients

Term	Estimate	SE	p-Value
Intercept	4.25	0.27	
Patient level			
Age	– 0.01	0.01	0.6170
Gender	– 0.17	0.20	0.3906
Tooth level			
Side	0.15	0.10	0.1270
Impaction	0.28	0.10	0.0028
Variances			
σ_v^2	0.63	0.12	
σ_u^2	0.55	0.07	

Theoretic model

$$\begin{aligned}\mathrm{KT}_{jk} = \beta_{0jk} &+ \beta_{1k}\,\mathrm{Age} + \beta_{2k}\,\mathrm{Gender} \\ &+ \beta_{3jk}\,\mathrm{Side} + \beta_{4jk}\,\mathrm{Impaction} + v_{0k} \\ &+ u_{0jk}.\end{aligned}$$

''Age'' is recorded at the beginning of the traction. ''Gender'' is 1 if male and 0 if female. ''Side'' is 1 if the tooth was on the right side and 0 if it was on the left. The explicative variable ''impaction'' is 1 in case of impacted canine and 0 in case of normally erupted canine. σ_v^2 and σ_u^2 indicate the variances at the Patient and at the Tooth levels. In the theoretic model formula, the subscript k refers to the Patient level. The subscript j refers to the Tooth level. β_{0jk} is the ''intercept''.
SE, standard error.

Table 5. Multilevel model for pocket depth (PD) at follow-up visit for the subgroup of 58 patients

Term	Estimate	SE	p-Value
Intercept	1.06	0.12	
Patient level			
Age	– 0.00	0.01	0.5486
Gender	0.01	0.06	0.8288
Tooth level			
Side	0.05	0.03	0.0956
Impaction	0.03	0.03	0.3014
Site Level			
Measurement location	0.81	0.03	< 0.0001
Variances			
σ_v^2	0.04	0.01	
σ_u^2	0.01	0.01	
σ_e^2	0.14	0.01	

Theoretic model

$$\begin{aligned}\mathrm{PD}_{ijk} = \beta_{0ijk} &+ \beta_{1k}\,\mathrm{Age} + \beta_{2k}\,\mathrm{Gender} \\ &+ \beta_{3jk}\,\mathrm{Side} + \beta_{4jk}\,\mathrm{Impaction} \\ &+ \beta_{5ijk}\,\mathrm{Measurement\ location} + v_{0k} \\ &+ u_{0jk} + e_{0ijk}.\end{aligned}$$

''Age'' is recorded at follow-up. ''Gender'' is 1 if male and 0 if female, ''Side'' is 1 if the tooth was on the right side and 0 if it was on the left. The explicative variable ''impaction'' is 1 in case of impacted canine and 0 in case of normally erupted canine. ''Measurement location'' is 1 if the site was inter-proximal and 0 if buccal or palatal. σ_v^2, σ_u^2 and σ_e^2 indicate the variances at the Patient, at the Tooth, and at the Site level, respectively. 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''.
SE, standard error.

were excluded for different reasons. Some patients were excluded because either the impacted canines were transposed (with the lateral incisor or the first pre-molar) or obstacles (roots of adjacent teeth) were present along the traction pathway, so that a direct traction of the tooth towards the centre of the alveolar ridge was not allowed. Other cases with submucosal buccal impactions were treated with a different surgical approach (apically positioned flap) and therefore did not meet the entry criteria. Cases that required pre-molar extractions to create space for the orthodontic re-positioning of the impacted canine were excluded as well. Furthermore, during the treatment, six cases were excluded as the impacted tooth showed lack of movement (ankylosis).

The results of the present investigation show that the comprehensive duration of treatment to obtain an optimal re-positioning of the impacted canines (about 21 months) was relatively shorter when compared with the data available in the literature for unilateral impacted canines: 28.8 months (Iramaneerat et al. 1998) and 25.8 months (Stewart et al. 2001). The treated canines showed physiological periodontal conditions without periodontal pockets or RECs at the end of orthodontic treatment. Only one patient showed a small recession (1 mm). In particular, it is interesting to note that at the end of the overall orthodontic treatment (end of Phase 3), the PD of the impacted canines was slightly deeper than that of the control teeth (Fig. 8). In the absence of bone loss, the greater measurement of PD shows the presence of pseudopockets at the end of orthodontic treatment, indicating that the eruption process is not completed. The KT was slightly greater on the test side compared with the control side at the end of orthodontic treatment (Fig. 8). Quirynen et al. (2000) found similar periodontal results, with the exception of the amount of KT, which was larger for the normally erupted than for the treated canines.

It must be noted that the attachment device on the impacted tooth was never detached during orthodontic traction. At least part of this outcome can be ascribed both to the skill of the surgeon and to the quality of bonding agents. Further, the design of the fine mesh of the attachment device allowed for proper adaptation to the anatomy of the cusp of the impacted canine and for increased retention by means of light-cured bonding agents.

Out of the 125 patients, 58 could be reached and evaluated at the follow-up examination. With regard to this subgroup of patients, during the follow-up period a slight decrease of PD was noted in the test group and at the end of follow-up period the PD of the treated sides became even more similar to that of the control sides. As to the amount of gingiva, a reduction of KT was noted both on the test and control sides. This

Table 6. Multilevel model for keratinized tissue width (KT) at follow-up visit for the subgroup of 58 patients

Term	Estimate	SE	*p*-Value
Intercept	3.28	0.42	
Patient level			
Age	0.01	0.02	0.5986
Gender	− 0.17	0.21	0.4122
Tooth level			
Side	0.11	0.09	0.2354
Impaction	0.02	0.09	0.8518
Variances			
σ_v^2	0.51	0.12	
σ_u^2	0.22	0.04	

Theoretic model

$$KT_{jk} = \beta_{0jk} + \beta_{1k}\,\text{Age} + \beta_{2k}\,\text{Gender} + \beta_{3jk}\,\text{Side} + \beta_{4jk}\,\text{Impaction} + v_{0k} + u_{0jk}.$$

''Age'' is recorded at follow-up. ''Gender'' is 1 if male and 0 if female. ''Side'' is 1 if the tooth was on the right side and 0 if it was on the left. The explicative variable ''impaction'' is 1 in case of impacted canine and 0 in case of normally erupted canine. σ_v^2 and σ_u^2 indicate the variances at the Patient and at the Tooth level. In the theoretic model formula, the subscript k refers to the Patient level. The subscript j refers to the Tooth level. β_{0jk} is the ''intercept''.
SE, standard error.

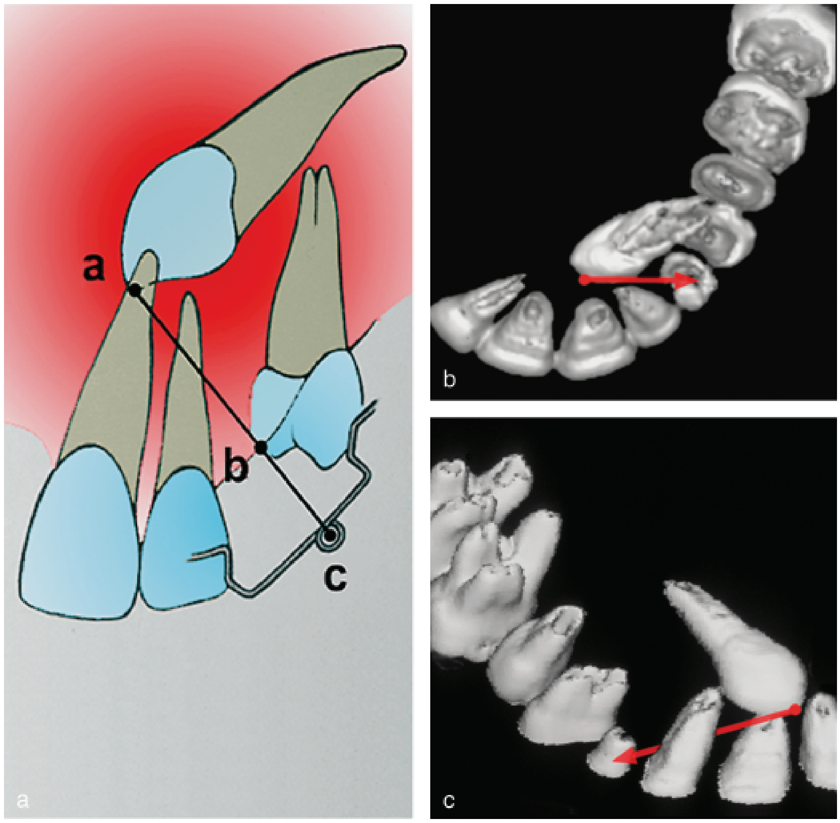

Fig. 7. (a) The ''direct'' traction from the impacted canine cusp tip (point *a*) through the centre of the ridge (point *b*) to the traction arch (point *c*); (b) the ''direct'' traction towards the centre of the ridge is allowed; (c) the ''direct'' traction is not allowed due to the presence of the root of the lateral incisor.

reduction was more pronounced on the test sides but, at the end of the follow-up period, the amount of gingiva was similar on both sides (Fig. 9). On the test sides, the pronounced reduction of PD and KT over time could be associated with the delayed re-modelling of the periodontal tissues following the forced eruption compared with the normal early eruption of the controlateral canine. Nonetheless, at the end of follow-up, the re-positioned teeth presented similar PD and KT when compared with the normally erupted canines. The very scarce presence of recessions at follow-up (two patients) might be ascribed not only to the fact that the treatment simulated a physiological eruption pattern but also to correct motivation of the patients, to the implementation of a proper tooth brushing technique and to the frequent oral hygiene recalls during treatment (3 months) and during follow-up (6 months).

In conclusion, the combined surgical–orthodontic technique (flap approach associated with direct orthodontic traction towards the centre of the alveolar ridge) allowed for the guided eruption of intra-osseous maxillary impacted canines at the centre of the alveolar ridge, simulating the physiological eruption pattern. This favourable outcome resulted in a correct alignment of the re-positioned canine in the

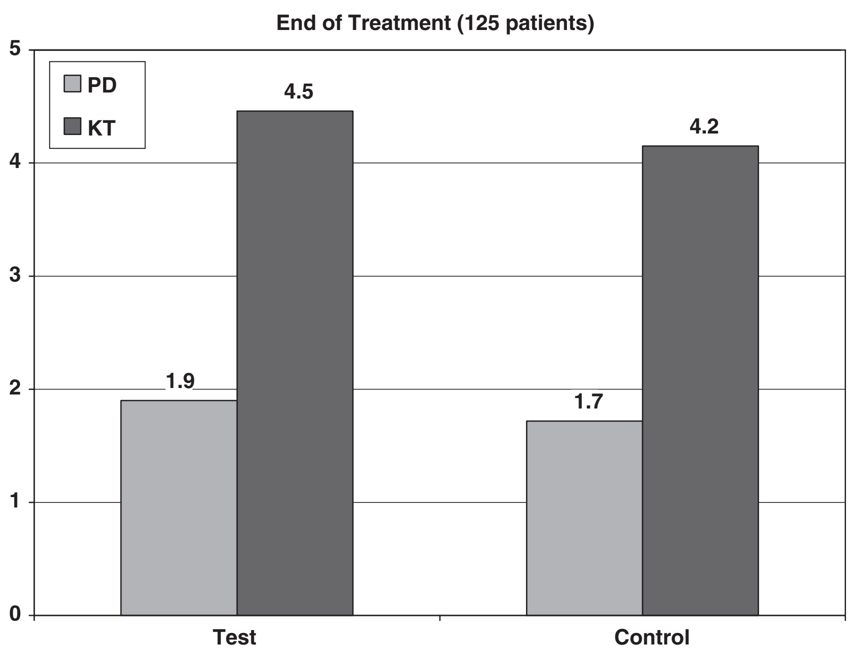

Fig. 8. Pocket depth (PD) and keratinized tissue width (KT) of test and control groups (125 patients) at the end of overall orthodontic treatment (end of Phase 3).

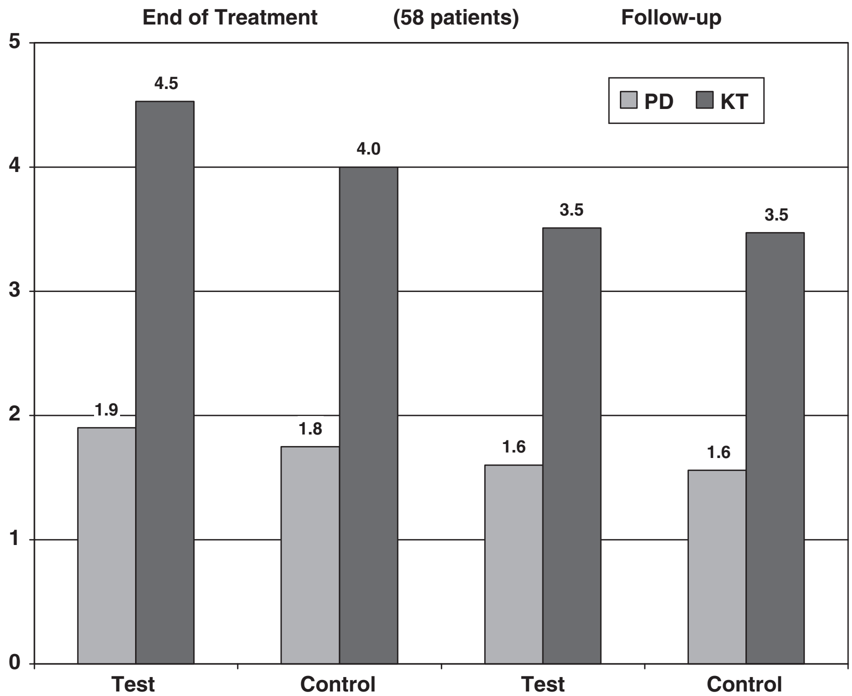

Fig. 9. Pocket depth (PD) and keratinized tissue width (KT) of test and control groups (subgroup of 58 patients) at the end of overall orthodontic treatment (end of Phase 3) and at follow-up examination.

dental arch associated with an adequate amount of gingiva and physiological probing PDs.

References

Abrams, H., Gossett, S. E. & Morgan, W. J. (1988) A modified flap design in exposing the palatally impacted canine. *Journal of Dentistry for Children* **4**, 285–287.

Agudio, G., Pini Prato, G. P., De Paoli, S. & Nevins, M. (1985) Mucogingival interceptive therapy. *International Journal of Periodontics and Restorative Dentistry* **5**, 48–59.

Archer, W. H. (1975) *Oral and Maxillofacial Surgery*, 5th edition, pp. 338–342. Philadelphia: WB Saunders.

Årtun, J., Osterberg, S. K. & Joondeph, D. R. (1986) Long-term periodontal status of labially erupted canines following orthodontic treatment. *Journal of Clinical Periodontology* **13**, 856–861.

Becker, A., Kohavi, D. & Zilberman, Y. (1983) Periodontal status following the alignment of palatally impacted canine teeth. *American Journal of Orthodontics* **84**, 332–336.

Becker, A., Shpack, N. & Shteyer, A. (1996) Attachment bonding to impacted teeth at the time of surgical exposure. *European Journal Orthodontics* **18**, 457–463.

Begg, P. & Kesling, P. C. (1971) *Begg Orthodontic Theory and Technique*, pp. 632–663. Philadelphia: WB Saunders.

Bernimoulin, J. P. & Curilovic, Z. (1977) Gingival recession tooth mobility. *Journal of Clinical Periodontology* **4**, 107–114.

Bishara, S. E. (1992) Impacted maxillary canines: a review. *American Journal of Orthodontics and Dentofacial Orthopedics* **101**, 159–171.

Bowers, G. M. (1963) A study of the width of attached gingiva. *Journal of Periodontology* **34**, 201–209.

Boyd, R. L. (1978) Mucogingival considerations and their relationship to orthodontics. *Journal of Periodontology* **49**, 67–76.

Boyd, R. (1982) Clinical assessment of injuries in orthodontic movement of impacted teeth. I. Methods of attachment. *American Journal of Orthodontics* **82**, 478–486.

Boyd, R. (1984) Clinical assessment of injuries in orthodontic movement of impacted teeth. II. Surgical recommendations. *American Journal of Orthodontics* **86**, 407–418.

Chaushu, G., Becker, A., Zeltser, R., Branski, S. & Chaushu, S. (2004a) Patients' perceptions of recovery after exposure of impacted teeth with a closed-eruption technique. *American Journal of Orthodontics and Dentofacial Orthopedics* **125**, 690–696.

Chaushu, S., Becker, A., Zeltser, R., Vasker, N. & Chaushu, G. (2004b) Patients' perceptions of recovery after exposure of impacted teeth with an open-eruption technique. *European Journal of Orthodontics* **26**, 591–596.

Crescini, A., Clauser, C., Giorgetti, R., Cortellini, P. & Pini Prato, G. P. (1994) Tunnel traction of infraosseous impacted canines. A three years periodontal follow-up. *American Journal of Orthodontics and Dentofacial Orthopedics* **105**, 61–72.

Di Biase, D. D. (1971) Mucous membrane and delayed eruption. *The Dental Practitioner and Dental Record* **21**, 241–250.

Elefteriadis, J. N. & Athanasiou, A. E. (1996) Evaluation of impacted canines by means of computerized tomography. *The International Journal of Adult Orthodontics and Orthognathic Surgery* **11**, 257–264.

Ericson, S. & Kurol, J. (1986) Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. *European Journal of Orthodontics* **8**, 133–140.

Ericson, S. & Kurol, J. (1987) Incisor resorption caused by maxillary cuspids. A radiographic study. *The Angle Orthodontist* **57**, 332–346.

Ericson, S. & Kurol, J. (1988) Early treatment of palatally erupting maxillary canines by extraction of the primary canines. *European Journal of Orthodontics* **10**, 283–295.

Ericson, S. & Kurol, J. (2000a) Incisors root resorption due to ectopic maxillary canines imaged by computerized tomography: a comparative study in extracted teeth. *The Angle Orthodontist* **70**, 276–283.

Ericson, S. & Kurol, J. (2000b) Resorption of incisors after ectopic eruption of maxillary canines. *The Angle Orthodontist* **70**, 415–423.

Goaz, P. W. & White, S. C. (1994) *Oral Radiology: Principles and Interpretation*, 3rd edition, pp. 102–105. St Louis: Mosby.

Goldstein, H. (1995) *Multilevel Statistical Models*, 2nd edition, pp. 1–65. London: Edward Arnold.

Gormann, W. J. (1967) Prevalence and etiology of gingival recession. *Journal of Periodontology* **38**, 316–322.

Hall, W. H. (1977) Recent status of soft tissue grafting. *Journal of Periodontology* **48**, 587–597.

Hansson, C. & Rindler, A. (1998) Periodontal conditions following surgical and orthodontic treatment of palatally impacted maxillary canines – a follow-up study. *The Angle Orthodontist* **68**, 167–172.

Heaney, T. G. & Atherton, J. D. (1976) Periodontal problems associated with the surgical exposure of unerupted teeth. *British Journal of Orthodontics* **3**, 79–85.

Hirschfeld, I. (1923) A study of skulls in the American Museum of Natural History relation to periodontal disease. *Journal of Dental Research* **5**, 241–265.

Iramaneerat, S., Cunnigham, S. J. & Horrocks, E. (1998) The effect of two alternative methods of canine exposure upon subsequent duration of orthodontic treatment. *International Journal of Pediatric Dentistry* **8**, 123–129.

Jacoby, H. (1979) The ''ballista spring'' system for impacted teeth. *American Journal of Orthodontics* **75**, 143–151.

Kohavi, D., Becker, A. & Zilberman, Y. (1984a) Surgical exposure, orthodontic movement, and final tooth position as factors in periodontal breakdown of treated palatally impacted canines. *American Journal of Orthodontics* **85**, 72–77.

Kohavi, D., Zilberman, Y. & Becker, A. (1984b) Periodontal status following the alignment of buccally ectopic maxillary canine teeth. *American Journal of Orthodontics* **85**, 78–82.

Kokich, V. G. (2004) Surgical and orthodontic management of impacted maxillary canines. *American Journal of Orthodontics and Dentofacial Orthopedics* **126**, 278–283.

Kokich, V. G. & Mathews, D. P. (1993) Surgical and orthodontic management of impacted teeth. *The Dental Clinics of North America* **37**, 181–204.

Levin, M. & D'Amico, R. (1974) Flap design in exposing unerupted teeth. *American Journal of Orthodontics* **65**, 419–422.

Mathews, D. P. (1995) Commentary: uncovering labially impacted teeth. *The Angle Orthodontist* **65**, 33.

Maynard, J. G. & Ochsenbein, D. (1975) Mucogingival problems, prevalence and therapy in children. *Journal of Periodontology* **46**, 543–552.

Mc Bride, L. J. (1979) Traction. A surgical–orthodontic procedure. *American Journal of Orthodontics* **76**, 287–299.

Mc Donald, F. & Yap, W. (1986) The surgical exposure and application of direct traction of unerupted teeth. *American Journal of Orthodontics* **89**, 331–340.

Odenrick, L. & Modeer, T. (1978) Periodontal status following surgical–orthodontic alignment of impacted teeth. *Acta Odontologica Scandinavica* **36**, 233–236.

Parfitt, G. J. & Mjör, I. A. (1964) A clinical evaluation of local gingival recession in children. *Journal of Denistry for Children* **31**, 257–262.

Pini Prato, G. P., Baccetti, T., Giorgetti, R., Agudio, G. & Cortellini, P. (2000a) Mucogingival interceptive surgery of buccally-erupted premolars in patients scheduled for orthodontic treatment. II. Surgically treated versus non surgically treated cases. *Journal of Periodontology* **71**, 182–187.

Pini Prato, G. P., Baccetti, T., Giorgetti, R., Agudio, G. & Cortellini, P. (2000b) Mucogingival interceptive surgery of buccally-erupted premolars in patients scheduled for orthodontic treatment. A 7-year longitudinal study. *Journal of Periodontology* **71**, 172–181.

Preda, L., La Fianza, A., Di Maggio, E. M., Dore, R., Schifino, M. R., Campani, R., Segu, C. & Sfondrini, M. F. (1997) The use of spiral computed tomography in the localization of impacted maxillary canines. *Dento-Maxillo-Facial Radiology* **26**, 236–241.

Quirynen, M., Op Heij, D. G., Adriansens, A., Opdebeeck, H. M. & van Steenberghe, D. (2000) Periodontal health of orthodontically extruded impacted teeth. A split-mouth, long-term clinical evaluation. *Journal of Periodontology* **71**, 1708–1714.

Richards, A. (1980) The buccal object rule. *Dental Radiography and Photography* **55**, 37–56.

Schmuth, G. P., Freisfeld, M., Koster, O. & Schuller, H. (1992) The application of computerized tomography (CT) in cases of impacted maxillary canines. *European Journal of Orthodontics* **14**, 296–301.

Seong-Seng, T. (1983) Canine extrusion auxiliary. *Journal of Clinical Orthodontics* **17**, 130–131.

Shiloah, J. & Kopczyk, R. (1978) Mucogingival considerations in surgical exposure of maxillary impacted canines. *Journal of Dentistry for Children* **45**, 79–81.

Sperry, T. P., Speidel, T. M., Isaacson, R. J. & Worms, F. W. (1977) The role of dental compensation in the orthodontic treatment of mandibular prognatism. *The Angle Orthodontist* **47**, 293–299.

Stewart, J. A., Heo, G., Giover, K. E., Williamson, P. C., Lam, E. W. N. & Major, P. W. (2001) Factors that relate to treatment duration for patients with palatally impacted maxillary canines. *American Journal of Orthodontics and Dentofacial Orthopedics* **119**, 216–225.

Taylor, G. S. (1979) Simplified sectional arch to align palatally displaced maxillary canines. *Journal of Clinical Orthodontics* **13**, 847.

Tegsjo, U., Valerius-Olsson, H. & Andersson, L. (1984) Periodontal conditions following surgical exposure of unerupted maxillary canines – a long term follow-up study of two surgical techniques. *Swedish Dental Journal* **8**, 257–263.

Thilander, H., Thilander, B. & Persson, G. (1973) Treatment of impacted teeth by surgical exposure. A survey study. *Swedish Dental Journal* **66**, 519–525.

Vanarsdall, R. & Corn, H. (1977) Soft tissue management of labially positioned unerupted teeth. *American Journal of Orthodontics* **72**, 53–64.

Wisth, P. J., Norderval, K. & Boe, O. E. (1976) Periodontal status of orthodontically treated impacted maxillary canines. *The Angle Orthodontist* **46**, 69–76.

Wisth, P. J., Norderval, K. & Boe, O. E. (1986) Comparison of the surgical methods in combined surgical–orthodontic correction of impacted maxillary canines. *Acta Odontologica Scandinavica* **34**, 52–57.

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Clinical Relevance

Scientific rationale for study: The objective of this study was to present a periodontal evaluation of impacted maxillary canines treated with a combined surgical–orthodontic technique based on guided traction of the tooth towards the centre of the crest in order to simulate the physiological eruption pattern.

Principal findings: The combined surgical–orthodontic treatment presented, which simulates the physiological eruption pattern, achieves a proper alignment and an adequate periodontal status.

Practical implications: In the presence of an impacted maxillary canine, the proposed surgical–orthodontic approach is recommended.