Posttreatment Status of Palatally Impacted Maxillary Canines Treated Applying 2 Different Surgical-Orthodontic Methods

Dalia Smailienė[1], **Aistė Kavaliauskienė**[1], **Ingrida Pacauskienė**[2]
[1]*Department of Orthodontics, Medical Academy, Lithuanian University of Health Sciences,*
[2]*Department of Dental and Oral Pathology, Medical Academy, Lithuanian University of Health Sciences, Lithuania*

Key Words: *surgical-orthodontic treatment; impacted canines; periodontal evaluation; radiograph.*

Summary. *Background and Objective. There is considerable debate on the issues of the choice of a surgical technique for the treatment of palatally impacted maxillary canines. The aim of the study was to evaluate the posttreatment status of palatally impacted canines treated applying 2 different surgical methods, i.e., an open technique with free eruption and a closed flap technique, and to compare it with the status of naturally erupted canines.*

Material and Methods. In total, 43 patients treated for unilateral palatally impacted maxillary canines were examined at a mean follow-up of 4.19 months (SD, 1.44; range, 3–6) after a fixed appliance had been removed. The patients were distributed into 2 groups: the open technique with free eruption (group 1, n=22) and the closed technique (group 2, n=21). The posttreatment examination consisted of an intraoral and a radiological examination.

Results. The findings of tooth position, inclination, color, shape, and function did not differ between the groups. There was no significant difference in the measurements of the periodontal pocket depth and bone support between the groups: the mean periodontal pocket depth was 2.14 mm (SD, 0.38) in the group 1 and 2.28 mm (SD, 0.69) in the group 2; the mean bone support was 91.51% (SD, 5.78%) and 89.9% (SD, 5%) in the groups, respectively. However, differences were found when comparing the measurements of the quadrant of impacted canines with the quadrant of the contralateral normally erupted canines. The distal contact point of the lateral incisor and the medial contact point of the canine showed a significant bone loss in comparison with the contralateral corresponding teeth.

Conclusions. The posttreatment status of palatally impacted canines and adjacent teeth after the surgical-orthodontic treatment did not differ significantly between the groups of the open and the closed surgical method.

Introduction

Canines are important in establishing the shape, esthetics, and functional occlusion of the dentition. The maxillary canine is one of the most frequently impacted teeth with impaction affecting about 2% of the population (1, 2) and with palatal impaction being more common than labial (1, 3–5).

A combined surgical-orthodontic treatment is commonly used to resolve tooth impaction. There are 2 basic surgical methods for the exposure of a palatally impacted canine, i.e., the open and the closed ones. There is considerable debate on the issues of the choice of the surgical technique. The anatomical structure of the soft tissue that covers the impacted tooth is one of the major factors that determine the choice of a surgical exposure method. The surgical-orthodontic treatment should simulate the natural eruption pattern of the impacted tooth through the attached gingival tissue. All palatal gingiva is attached; therefore, both the closed and the open surgical methods are appropriate. Other advantages of the surgical techniques are discussed when comparing the operating time and the extent of the surgical procedure (6), the patient's comfort after surgery (7, 8), the need for repeated surgery (6, 9, 10), the time of the eruption/extrusion of the impacted tooth, the overall treatment time (6, 11, 12), the success of treatment (9), relapse, and posttreatment periodontal results (13–22). A lot of investigations concerning the posttreatment status have been limited to the evaluation of only one of the surgical methods.

The aim of the present study was to evaluate the posttreatment status of palatally impacted canines treated applying 2 different surgical methods, i.e., the open technique with free eruption and the closed flap technique, and to compare it with the status of naturally erupted canines.

Material and Methods

Study Population. The study was conducted at the Department of Orthodontics, Lithuanian University of Health Sciences, between June 2007 and January 2012. Approval for the study was obtained

Correspondence to D. Smailienė, Department of Orthodontics, Medical Academy, Lithuanian University of Health Sciences, J. Lukšos-Daumanto 6, 50106 Kaunas, Lithuania
E-mail: dsmailiene@gmail.com

from the University Ethics Committee (No. BC-OK(R)-163). In total, 43 patients (35 women and 8 men; mean age, 15.81 years; SD, 3.04) with a newly diagnosed unilateral palatally impacted maxillary canine were selected to participate in this study. The inclusion criteria to this prospective study were as follows: 1) nonsyndromic patients with a unilateral palatally impacted maxillary canine, i.e., unerupted after a complete root development or if the contralateral tooth was erupted for at least 6 months with a complete root formation (23); 2) no previous orthodontic treatment; 3) no metabolic disorders or other medical conditions that may influence treatment; and 4) good oral hygiene (Simplified Oral Hygiene Index [OHI-s], <1.3).

All the patients were informed about the content of the study, treatment methods, and potential risks and benefits before providing written informed consent to take part in this clinical trial. All the 43 patients were assigned to receive either an open approach with free eruption (group 1, n=22) or closed flap surgery (group 2, n=21). In every second patient, the open technique was used. All the patients were treated by one of the authors and underwent surgery performed by the same oral surgeon.

The initial position of the impacted canine was assessed on a panoramic image using a modified version of the criteria used by Ericson and Kurol (24). All radiographs were taken using the same x-ray procedure and machine.

Surgical-Orthodontic Treatment. The open and the closed surgical techniques were performed according to the method described by Kokich and Mathews (25) and Kokich (26). Fixed appliances were used for the treatment. A rectangular stabilization archwire was used to obtain adequate anchorage and maintain sufficient space in the dental arch. The canine was brought into position by applying light continuous force. In the group 1, periodontal dressing was removed 1 week after surgery, and then the tooth was allowed to erupt. In the group 2, extrusion of the impacted tooth was initiated 1 week after surgery. The ballista loop on the additional 0.016-inch stainless steel archwire was used to extrude the impacted teeth (27). An additional 0.014-inch Sentalloy archwire was used to move the canine toward the dental arch.

Each patient was instructed concerning proper oral hygiene measures. The patients were recalled every 4 weeks to adjust their appliances.

The posttreatment examination was performed by other author at a mean follow-up of 4.19 months (SD, 1.44; range, 3–6) after fixed appliance removal and removable retainer placement. At the time of the examination, the patients' mean age was 18.6 years (SD, 3.45) in the open eruption group and 19.7 years (SD, 4.37) in the closed eruption group ($P>0.05$). The posttreatment examination consisted of an intraoral and a radiological examination. The patients were asked to evaluate the treatment results as either satisfactory or unsatisfactory.

The intraoral examination included the visual assessment of the color and the shape of the crown of the previously impacted canine, the inclination and the position in the dental arch of the previously impacted canine, its function (occlusal contacts), as well as a periodontal examination.

Tooth shape was recorded as either a normal cusp or a cusp with signs of wear. Tooth color was recorded as normal or different in comparison with the color of the contralateral side canine. Tooth position was recorded as normal, intrusion (the incisal edge of the canine situated higher compared with the contralateral side canine), mesial rotation (the mesial aspect of the tooth situated labially to the line of the dental arch), or distal rotation (the distal aspect of the tooth situated labially to the line of the dental arch). Inclination was registered as normal, lingual (the occlusal portion of the tooth crown angulated lingually to the gingival portion relative to the occlusal plane), or buccal (the occlusal portion of the tooth crown angulated buccally to the gingival portion relative to the occlusal plane).

Occlusal contacts on the nonworking and working sides were registered during lateral mandible excursions up to 3 mm and during anterior excursions up to the edge-to-edge incisor contact.

The periodontal examination was carried out by one calibrated periodontist. Two measurements were taken for each site, several minutes apart, and 2 values were averaged. The periodontal status of the first premolar, the canine, and the lateral incisor was evaluated by assessing the periodontal pocket depth and the gingival recession in the impacted canine quadrant and the contralateral canine quadrant.

Periodontal pocket depth (PPD) was measured from the base of the pocket to the gingival margin with an accuracy of 0.5 mm using a Williams probe (American Eagle Instruments, Inc., USA) at 6 tooth surfaces (points): mesiobuccal (MBP), buccal (BP), distobuccal (DBP), distopalatal (DPP), palatal (PP), and mesiopalatal (MPP). The same technique was also used to evaluate gingival recession, but in this case, the distance from the cement-enamel junction (CEJ) to the gingival margin was measured.

Oral hygiene was evaluated by using the OHI-s proposed by Green and Vermilion (28).

Radiographic bone support was diagnosed from long-cone parallel intraoral periapical radiographs. The digital image was analyzed using ImageJ (public domain Java image-processing program available on the Internet at http://rsb.info.nih.gov/ij/) by one of the authors without knowledge of the impaction side. Bone support was assessed on the mesial and distal surfaces of the lateral incisors and the canines (Fig. 1). The ratio of the apex-crest to the apex-

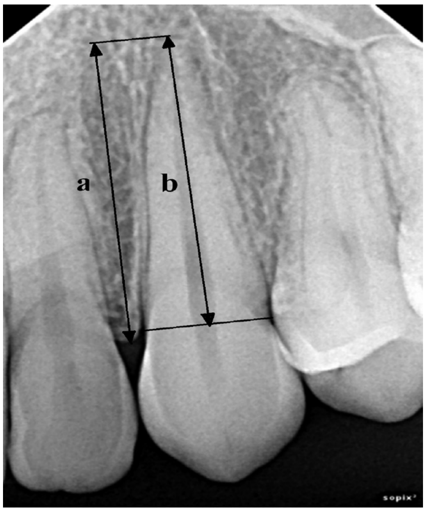

Fig. 1. A scheme representing the bone support measurement on the mesial surface of the canine

Bone level (a), the distance from the root apex to the alveolar crest; root length (b), the distance from the midpoint of a line connecting the mesial and the distal cement-enamel junction to the root apex. The distances are measured parallel to the long axis of the tooth.

CEJ were calculated to represent the percentage of bone support using the method proposed by Becker et al. (29). The bone support was not measured at the premolars because the radiographs were not diagnostic in that area due to the superimposition of the structures. Nonmeasurable sites were omitted. Pulpal obliteration was recorded as either present or absent.

Statistical analysis was performed using the statistical software package SPSS 20.0 for Windows. Means, standard deviation (SD), and 95% confidence intervals (CI) of the mean were calculated for each group of the patients. The Kolmogorov-Smirnov test was used for the assessment of the normality distribution of the quantitative data. The Student *t* test and the nonparametric Mann-Whitney *U* test were used for the comparison of the variable means between 2 independent samples, and the Student *t* paired test and the nonparametric Wilcoxon test were used for the comparison of the variable means between 2 dependent samples. The hypotheses about the relationship between the qualitative variables were tested by applying the chi-square (χ^2) test. The difference was considered to be statistically significant when $P<0.05$.

Results

The groups 1 and 2 were homogeneous concerning the initial vertical and the horizontal position of the impacted canines on the panoramic image and with respect to the patients' age at the beginning of the treatment ($P>0.05$).

All the patients were satisfied with the treatment results.

Intraoral Examination. The findings of tooth position, inclination, color, and shape did not differ between the groups (Table 1). In 3 cases (6.98%), a slightly darker color of the previously impacted canine was observed, but an electro-odontometric test showed that these teeth were viable.

No significant differences in the occlusal contacts were found between the groups or between the previously impacted and the contralateral sides. During the lateral mandibular excursions, canine protection was observed in 81.3% of the cases on the side of the previously impacted canine and in 69.8% of the

Table 1. Frequency of Posttreatment Canine Shape and Color Abnormality, Malalignment, and Function of Impacted Canines After Surgical-Orthodontic Treatment Applying 2 Different Surgical Methods

Posttreatment Morphology and Function of the Canine		Group 1 (n=22)	Group 2 (n=21)	*P*
Tooth color	Normal Different	20 (90.9) 2 (9.1)	20 (95.2) 1 (4.8)	NS
Tooth shape	Normal cusp Cusp with signs of wear	21 (95.5) 1 (4.5)	19 (90.5) 2 (9.5)	NS
Tooth position in the dental arch	Normal Intruded Mesial rotation Distal rotation	17 (77.3) 1 (4.5) 3 (13.6) 1 (4.5)	19 (90.5) 1 (4.8) 0 (0) 1 (4.8)	NS
Tooth inclination	Normal Lingual Buccal	12 (54.5) 3 (13.6) 7 (31.8)	16 (76.2) 1 (4.8) 4 (19.0)	NS
Lateral mandible excursions	Canine protection Group guidance Anomalous guidance	19 (86.4) 3 (13.6) 0 (0)	16 (76.2) 2 (9.5) 3 (14.3)	NS
Anterior mandibular excursions	Normal guidance Anomalous guidance	21 (95.5) 1 (4.5)	20 (95.2) 1 (4.8)	NS

Values are number (percentage). NS, not significant.

cases on the side of the normally erupted canine. Anomalous lateral guidance was detected in 7% of the cases on the side of the previously impacted canine and in 7% of the cases on the side of the normally erupted canine.

During the anterior mandibular excursions, normal guidance was detected in 95.3% of the cases.

Periodontal Examination. The mean periodontal pocket depth on the side of the previously impacted canine was 2.2 mm (SD, 0.55), whereas on the contralateral side, it was 2.01 mm (SD, 0.42) ($P<0.05$). The measurements of the PPD did not significantly differ between the groups: the mean PPD on the side of the previously impacted canine was 2.14 mm (SD, 0.38) in the open eruption group and 2.28 mm (SD, 0.69) in the closed eruption group, and on the contralateral side, it was 1.95 mm (SD, 0.38) in the open eruption group and 2.20 mm (SD, 0.42) in the closed eruption group. However, the differences were found comparing the PPD of the quadrant of the impacted canines with the quadrant of the contralateral normally erupted canines at the DPP and MBP points on the lateral incisors in the group 1 and at the MBP point on the canines and the first premolars in both groups ($P<0.05$) (Table 2).

Two (4.7%) treated canines in the group 2 (BP and PP points) were found to have gingival recession. Gingival recession was also found on 3 (6.98%) premolars (DBP and BP points) and 3 (6.98%) lateral incisors (PP and BP points). The greatest recession (2 mm) was found on previously impacted canines. The differences in the gingival recession between the groups 1 and 2 and between the experimental and the contralateral sides of the dental arch were not significant.

None of the canines, premolars, or lateral incisors showed any signs of pulp obliteration. The measurements of the bone support did not significantly differ between the groups (the mean bone support of 89.33% [SD, 6.87%] in the group 1 and 86.66% [SD, 6.94%] in the group 2). However, the comparison of bone support between the contralateral side and the groups 1 and 2 on the medial side of the canines and on the distal side of the lateral incisors showed significant differences (Fig. 2).

Oral hygiene was good in all the patients (OHI-s 0.38 [SD, 0.34] in the group 1 and 0.33 [SD, 0.38] in the group 2; $P>0.05$).

Discussion

Surgical exposure of the impacted canines and the treatment with fixed appliances is the most

Table 2. Periodontal Pocket Depth of Impacted Canines, Adjacent Teeth, and Contralateral Control Quadrant After Surgical-Orthodontic Treatment Applying 2 Different Surgical Methods

Point of Measurement	Periodontal Pocket Depth, mm						P*
	Group 1 (n=22)			Group 2 (n=21)			
	Impaction Side	Contralateral Side	P	Impaction Side	Contralateral Side	P	
Lateral incisor							
MPP	1.93 (0.39)	2.00 (0.34)	NS	2.00 (1.01)	2.24 (0.67)	NS	NS
PP	1.87 (0.56)	1.83 (0.38)	NS	1.93 (0.75)	1.84 (0.58)	NS	NS
DPP	2.41 (0.73)	2.00 (0.45)	$P<0.05$	2.21 (0.82)	2.32 (0.73)	NS	NS
DBP	2.05 (0.65)	2.14 (0.84)	NS	2.14 (0.73)	2.61 (0.84)	NS	NS
BP	1.71 (0.67)	1.78 (0.43)	NS	1.86 (0.64)	1.74 (0.61)	NS	NS
MBP	2.27 (0.63)	1.86 (0.64)	$P<0.05$	2.12 (0.84)	2.32 (0.56)	NS	NS
Total	2.04 (0.41)	1.94 (0.32)	NS	2.04 (0.66)	2.18 (0.48)	NS	NS
Canine							
MPP	2.39 (0.72)	2.06 (0.64)	NS	2.57 (1.11)	2.18 (0.69)	NS	NS
PP	1.84 (0.52)	1.83 (0.62)	NS	2.24 (0.99)	2.13 (0.57)	NS	NS
DPP	2.32 (0.48)	2.14 (0.68)	NS	2.43 (0.99)	2.47 (0.63)	NS	NS
DBP	2.68 (0.85)	2.25 (0.65)	NS	2.81 (1.18)	2.40 (0.77)	NS	NS
BP	1.48 (0.63)	1.44 (0.51)	NS	1.79 (0.70)	1.84 (0.63)	NS	NS
MBP	3.00 (1.07)	2.06 (0.64)	$P<0.05$	2.62 (0.93)	2.11 (0.68)	$P<0.05$	NS
Total	2.28 (0.45)	1.96 (0.49)	NS	2.41 (0.80)	2.19 (0.46)	NS	NS
First premolar							
MPP	2.16 (0.57)	2.11 (0.50)	NS	2.52 (0.81)	2.34 (0.82)	NS	NS
PP	1.80 (0.59)	1.50 (0.52)	NS	2.21 (0.89)	2.00 (0.67)	NS	NS
DPP	2.09 (0.53)	1.97 (0.40)	NS	2.29 (1.06)	2.16 (0.60)	NS	NS
DBP	2.05 (0.55)	2.22 (0.58)	NS	2.50 (1.14)	2.5 (0.61)	NS	NS
BP	1.71 (0.63)	1.50 (0.52)	NS	1.86 (0.53)	1.92 (0.53)	NS	NS
MBP	2.80 (0.85)	2.36 (0.84)	$P<0.05$	2.86 (0.96)	2.47 (0.75)	$P<0.05$	NS
Total	2.10 (0.43)	1.94 (0.46)	NS	2.37 (0.73)	2.24 (0.47)	NS	NS

Values are mean (standard deviation). MPP, mesiopalatal point where pocket depth was probed; PP, palatal point; DPP, distopalatal point; DBP, distobuccal point; BP, buccal point; MBP, mesiobuccal point; NS, not significant.
*Comparing the groups.

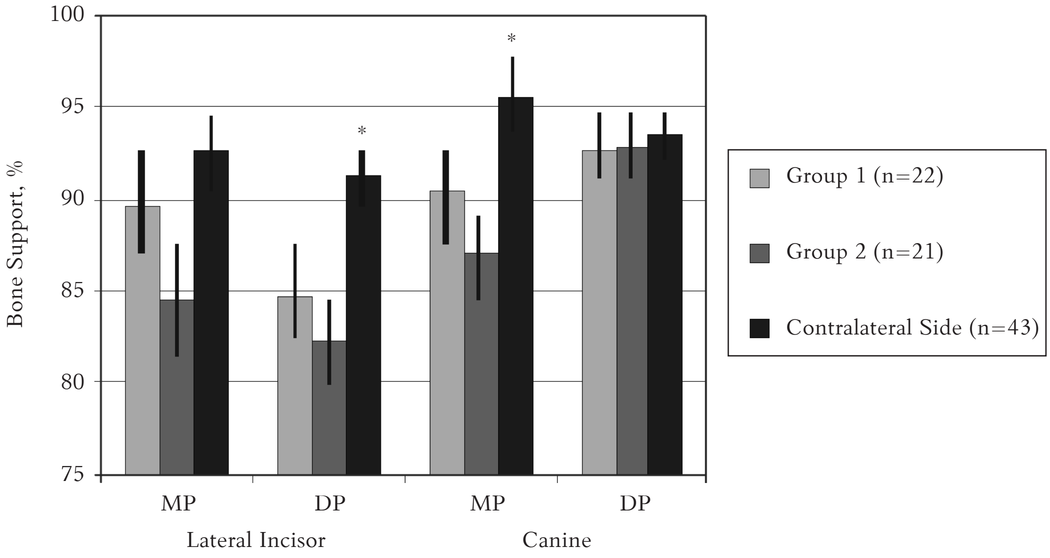

Fig. 2. Bone support of the impacted canines and the lateral incisors after the surgical-orthodontic treatment applying 2 different surgical methods

MP, mesial point of the tooth where bone support was measured; DP, distal point.
Vertical bars represent 95% CI of the mean. *P<0.05 compared with the group 1 and the group 2.

commonly used treatment method. The treatment is considered successful when the impacted tooth is aligned in the dental arch with the adequate attached gingiva, and there is no damage to the periodontium, bone loss, or gingival recession. This study was designed to evaluate if the type of the surgical technique influences the posttreatment status of palatally impacted canines.

Intraoral Examination. All the canines moved into the dental arches. Only some minor and esthetically satisfactory malpositions of the treated teeth were found. The buccal inclination was more common in the open technique group (31.8%), which could be related to the different mechanics of tooth alignment. Palatally impacted canines that are allowed to erupt naturally usually adopt the more anterior and palatal position. Such a location is related to the difficulty in sufficiently moving their root buccally. The treatment with the closed extrusion technique begins immediately, and consequently, the dental root position is corrected from the beginning. In a study by Schmidt et al., incorrect inclination was the most common criterion for identifying previously impacted canines (20). Incomplete alignment was also recorded by D'Amico et al.: 3.5 years after an orthodontic treatment, a normal position of treated canines was recorded only in 44%–52% of cases and a normal inclination in 55%–57% of cases (19). The rotation and the intrusion of the tested teeth could also be related to the tendency toward relapse.

In 3 cases, a slightly darker color of the previously impacted canine was observed. Evrena et al. also reported that the alterations in the periodontal health of palatally ectopic canines, compared with their contralaterals, were in the form of an alveolar bone loss, an increased probing depth, higher gingival levels, and a higher electric pulp testing score (30). D'Amico et al. found that the color of treated canines was abnormal in 34% of unilateral impaction cases and in 50% of bilaterally impacted canines (19).

Our results on the canine function during the lateral mandibular excursions were similar to those of D'Amico et al., where cuspid protection and group contact were found in 46%–47% and 49%–53% of cases, respectively (19). In contrast, we found no significant differences in the occlusal contacts between the groups or between the sides with the normally erupted canines and those with the previously impacted canines. The proper establishment of the occlusal contact is complicated not only due to the correction of the inclination of the canine, but it also depends on the difficulty in improving other adjacent orthodontic anomalies.

Periodontal Status. Periodontal status of the treated canines almost always was physiological; the mean PPD did not exceeded 3 mm. The measurements of the mean PPD did not significantly differ between the groups treated with different surgical methods; however, the differences were found when comparing the PPD of the quadrant of the impacted canines with that of the normally erupted canines.

The results of our study are in agreement with those presented by other researchers. Crescini et al. found that the PPD of impacted canines was 0.18 mm deeper than that of normally erupted canines (21). The distopalatal aspect of lateral incisors is challenging during treatment; thus, a deeper PPD on the distopalatal point of the lateral incisor has been found in many studies (17, 19, 20). Similarly to our results, Zasciurinskiene et al. reported that the PPD on the impacted side was significantly greater at the mesial aspect of the canine compared with the respective findings in the contralateral control teeth (15). Woloshyn et al. found a deeper PPD on the mesial and the distal sides of canines (13).

The localization of deeper periodontal pockets could depend on the initial localization of the impacted canines and on the treatment mechanics. Frequently, the impacted tooth is located in close relationship to the roots of incisors, and the thin interproximal septum between the impacted tooth and the root of the adjacent maxillary lateral incisor might be resorbed because of an unfavorable orthodontic force vector (31). Kohavi et al. also established that orthodontic mechanics may be an important factor influencing long-term periodontal health; ectopic canines requiring root torque movements had the bone support lower by 4% than those aligned by tipping or extrusive movements (32). The type of the surgical technique determines the type of orthodontic mechanics; however, we did not find any significant differences in the mean PPD between the groups treated with different surgical methods.

The findings of the radiographic investigation confirmed the results of the periodontal examination: the distal contact point of the lateral incisor and the medial contact point of the canine showed a significant bone loss compared with the contralateral corresponding teeth. The mean values of the bone support were lower on both sides of the lateral incisors and the mesial side of the canines in the group 2; however, the differences between the groups treated by applying a different surgical approach were not significant. Similar results were found in the study by Becker et al. (29), where the bone support of the treated canine (89.6%) was significantly lower than the bone support of the canine on the control side (93.3%) (6), compared with the bone support of 91.51% (SD, 5.78%) in the group 1, 89.9% (SD, 5%) in the group 2, and 94% (SD, 4.15%) on the control side in our study.

In our study, the bone loss was measured on periapical radiographs. Conventional 2-dimensional radiographic imaging is the most common modality used clinically as the primary diagnostic radiograph for the localization of impacted canines, treatment planning, and evaluation of treatment results (13, 17, 25, 29, 32). Panoramic and periapical radiography has been considered as a routine method for the examination of the periodontal tissues as well. The high resolution of intraoral radiography allows small details of the surrounding alveolar bone to be visualized. Computed tomography (CT) was found to be superior to conventional radiographs for the localization of impacted canines and in the assessment of incisor root resorption (33, 34). However, an effective dose of radiation on CT is much higher than that of conventional radiography, and the procedure is relatively expensive. Cone-beam computed tomography (CBCT) has been recently introduced with reduced exposure to radiation and 3-dimensional imaging capability for dental structures (35, 36). However, some authors have found that the surgical treatment planning of impacted maxillary canines was not significantly different using panoramic or cone CBCT images (37). Despite its accuracy, the use of CBTC in our study was limited by its higher cost.

Summarizing the results of our study, we did not find any evidence that the posttreatment status of the palatally impacted canines and the adjacent teeth could depend on different surgical methods. While both techniques are acceptable for the treatment, the choice of the surgical technique and the orthodontic treatment tactics could depend on other features of individual cases, such as the probability of the resorption of adjacent dental roots, the depth of impaction and the proximity of an impacted tooth to adjacent teeth, and the patient's comfort.

The current study was limited by relatively small study groups formed according to the treatment method: the group that underwent an open approach with free eruption (n=22) and the group that underwent closed flap surgery (n=21). The sample size in this study is comparable with the sample sizes in similar studies (15, 18, 20) and could be explained by a low incidence of maxillary canine impaction. However, such a sample size is not sufficient for sound conclusions.

Conclusions

The posttreatment status of the palatally impacted canines and the adjacent teeth after the surgical-orthodontic treatment did not significantly differ between the groups treated with 2 different surgical methods, i.e., the open technique with free eruption and the closed flap technique. Both treatment methods can be considered as acceptable for the treatment of palatally impacted canines.

Statement of Conflict of Interest

The authors state no conflict of interest.

References

1. Thilander B, Jakobsson SO. Local factors in impaction of maxillary canines. Acta Odontol Scand 1968;26:145-68.
2. Ericson S, Kurol J. Longitudinal study and analysis of clinical supervision of maxillary canine eruption. Community Dent Oral Epidemiol 1986;14:112-6.
3. Jacoby H. The etiology of maxillary canine impactions. Am J Orthod 1983;84:125-32.
4. Stellzig A, Basdra EK, Komposch G. The etiology of canine impaction – a space analysis. Fortschr Kieferorthop 1994; 55:97-103.
5. Ericson S, Kurol J. Resorption of incisors after ectopic eruption of maxillary canines: a CT study. Angle Orthod 2000;70:415-23.
6. Pearson MH, Robinson SN, Reed R, Birnie DJ, Zaki GA. Management of palatally impacted canines: the findings of a collaborative study. Eur J Orthod 1997;19:511-5.
7. Chaushu S, Becker A, Zeltser R, Branski S, Vasker N, Chaushu G. Patients perception of recovery after exposure of impacted teeth: a comparison of closed- versus open-eruption techniques. J Oral Maxillofac Surg 2005;63:323-9.
8. Gharaibeh TM, Al-Nimri KS. Postoperative pain after surgical exposure of palatally impacted canines: closed-eruption versus open-eruption, a prospective randomized study. Oral Surg Oral Med Oral Path Oral Radiol Endod 2008;106:339-42.
9. Becker A, Chaushu S. Success rate and duration of orthodontic treatment for adult patients with palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2003; 124:509-14.
10. Fournier A, Turcotte JY, Bernard C. Orthodontic considerations in the treatment of maxillary impacted canines. Am J Orthod 1982;81:236-9.
11. Iramaneerat S, Cunnningham SJ, Horrocks EN. The effect of two alternative methods of canine exposure upon subsequent duration of orthodontic treatment. Int J Paediatr Dent 1998;8:123-9.
12. Zuccati G, Ghobadlu J, Nieri M, Clauser C. Factors associated with the duration of forced eruption of impacted maxillary canines: a retrospective study. Am J Orthod Dentofacial Orthop 2006;130:349-56.
13. Woloshyn H, Artun J, Kennedy DB, Joondeph DR. Pulpal and periodontal reactions to orthodontic alignment of palatally impacted canines. Angle Orthod 1994;64:257-64.
14. Blair GS, Hobson RS, Leggat TG. Posttreatment assessment of surgically exposed and orthodontically aligned impacted maxillary canines. Am J Orthod Dentofacial Orthop 1998;113:329-32.
15. Zasciurinskiene E, Bjerklin K, Smailiene D, Sidlauskas A, Puisys A. Initial vertical and horizontal position of palatally impacted maxillary canine and effect on periodontal status following surgical-orthodontic treatment. Angle Orthod 2008;78:275-80.
16. Crescini A, Clauser C, Giorgetti R, Cortellini P, Pini Prato GP. Tunnel traction of infraosseous impacted maxillary canines: a three-year periodontal follow-up. Am J Orthod Dentofacial Orthop 1994;105:61-72.
17. Hansson C, Rindler A. Periodontal conditions following surgical and orthodontic treatment of palatally impacted maxillary canines – a follow-up study. Angle Orthod 1998; 68:167-72.
18. Quirynen M. Periodontal health of orthodontically extruded impacted teeth. A split-mouth, long-term clinical evaluation. J Periodontol 2000;71:1708-14.
19. D'Amico RM, Bjerklin K, Kurol J, Falahat B. Long-term results of orthodontic treatment of impacted maxillary canines. Angle Orthod 2003;73:231-8.
20. Schmidt AD, Kokich VG. Periodontal response to early uncovering, autonomous eruption, and orthodontic alignment of palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2007;131:449-55.
21. Crescini A, Nieri M, Buti J, Baccetti T, Mauro S, Pini Prato GP. Short- and long-term periodontal evaluation of impacted canines treated with a closed surgical-orthodontic approach. J Clin Periodontol 2007;34:232-42.
22. Crescini A, Nieri M, Buti J, Baccetti T, Pini Prato GP. Orthodontic and periodontal outcomes of treated impacted maxillary canines. Angle Orthod 2007;77:571-7.
23. Lindauer S, Rubenstein L, Hang W, Andersen W, Isaacson R. Canine impaction identified early with panoramic radiographs. J Am Dent Assoc 1992;123:91-2, 95-7.
24. Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. Eur J Orthod 1986;8:133-40.
25. Kokich VG, Mathews DP. Surgical-orthodontic management of impacted teeth. Dent Clin North Am 1993;37: 181-204.
26. Kokich VG. Preorthodontic uncovering and autonomous eruption of palatally impacted maxillary canines. Semin Orthod 2010;16:205-11.
27. Kornhausen S, Abed Y, Harari D, Becker A. The resolution of palatally impacted canines using palatal-occlusal force from a buccal auxiliary. Am J Orthod Dentofacial Orthop 1996;110:528-34.
28. Newman MG, Takei HH, Carranza FA. Carranza's clinical periodontology. 9th ed. Philadelphia: Saunders; 2002. p. 74-94.
29. Becker A, Kohavi D, Zilberman Y. Periodontal status following the alignment of palatally impacted canine teeth. Am J Orthod 1983;84:332-6.
30. Evrena AD, Nevzatoglub Ş, Arunc T, Acard A. Periodontal status of ectopic canines after orthodontic treatment. Angle Orthod 2013 Jul 11. [Epub ahead of print]
31. Frank CA, Long M. Periodontal concerns associated with the orthodontic treatment of impacted teeth. Am J Orthod Dentofacial Orthop 2002;121:639-49.
32. Kohavi D, Becker A, Zilberman Y. Surgical exposure, orthodontic movement, and final tooth position as factors in periodontal breakdown of treated palatally impacted canines. Am J Orthod 1984;85:72-7.
33. Heimisdottir K, Bosshardt D, Ruf S. Can the severity of root resorption be accurately judged by means of radiographs? A case report with histology. Am J Orthod Dentofacial Orthop 2005;128:106-9.
34. Alqerban A, Jacobs R, Fieuws S, Willems G. Comparison of two cone beam computed tomographic systems versus panoramic imaging for localization of impacted maxillary canines and detection of root resorption. Eur J Orthod 2011;33:93-102.
35. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75-80.
36. Lai CS, Bornstein MM, Mock L, Heuberger BM, Dietrich T, Katsaros C. Impacted maxillary canines and root resorptions of neighbouring teeth: a radiographic analysis using cone-beam computed tomography. Eur J Orthod 2013;35: 529-38.
37. Alqerban A, Hedesiu M, Baciut M, Nackaerts O, Jacobs R, Fieuws S, at el.; SedentexCT Consortium. Pre-surgical treatment planning of maxillary canine impactions using panoramic vs cone beam CT imaging. Dentomaxillofac Radiol 2013;42:20130157.

Received 10 January 2013, accepted 30 August 2013