Effect of surgical exposure technique, age, and grade of impaction on ankylosis of an impacted canine, and the effect of rapid palatal expansion on eruption: A prospective clinical study

Stylianos I. Koutzogloua and Anastasia Kostakib
Rethymno and Athens, Greece

Introduction: This study had 2 aims: (1) to assess whether the surgical exposure technique, the patient's age, and the grade of impaction are associated with ankylosis of the impacted canine; and (2) to investigate the effect of rapid palatal expansion on an impacted canine's automatic eruption. Methods: The sample for this prospective longitudinal study consisted of 118 orthodontic patients (72 female, 46 male) who were treated surgically and orthodontically by the first author (S.I.K.) over 18 years. The patients' ages at the beginning of therapy ranged from 11.2 to 46.1 years. They had 157 impacted canines (150 maxillary, 7 mandibular), grouped in 7 categories (grades I-VII) according to their radiographic position in the orthopantomogram at the onset of treatment. Univariate and multivariate generalized estimating equation logistic regression analyses were used to assess the effect of the predictors of interest on ankylosis. (In this research, a broad definition of "ankylosis" was used, to include impacted canines immobilized a priori or during traction, due to all the possible causes that could contribute to immobilization, such as all types of external tooth resorption and other known or unknown factors.) Results: Thirty-eight canines erupted spontaneously after space gaining, and the other 119 were treated surgically with an open (57 cases) or a closed (62 cases) exposure technique. Eleven canines of the 119 that were treated surgically had ankylosis, either a priori or during orthodontic traction. The percentages of ankylosis were 3.5% in the open technique and 14.5% in the closed technique. Evidence of statistical association was found between age and ankylosis, grade of impaction and ankylosis, and rapid palatal expansion and automatic eruption of the impacted canine. Conclusions: Evidence of an association between exposure technique and ankylosis was found. Additionally, there was evidence that the grade of impaction and the patient's age are significant predictors of ankylosis, as is the use of rapid palatal expansion a predictor of automatic eruption. (Am J Orthod Dentofacial Orthop 2013;143:342-52)

There are numerous surgical procedures to expose an impacted canine and to bring it to its proper position in the dental arch.1-11 The open exposure technique allows natural eruption of the impacted canine; the closed exposure technique involves placement of an auxiliary attachment, which is then used for orthodontic traction. When the neighboring teeth are intruded and the canine remains immobile despite the application of orthodontic force, this is commonly recognized by clinicians as an indication of "ankylosis."12

The term ankylosis is generally associated with resorption (replacement root resorption).13 In ankylosis-related resorption, immobilization is observed clinically, since the root surface (cement or dentin) of the tooth is fused with the alveolar bone. In this study, we broadened the definition to include impacted canines immobilized a priori or during traction, due to the many possible causes that could contribute to immobilization, such as all the types of external tooth resorption13,14 and other known12,15,16 or unknown factors.

In the literature, the failure in the therapy of the impacted canine has been studied12,15,16 but there are aspects of this failure that have yet to be considered. Indicatively, an unusual a priori ankylosis in the form of...
of an ankylosis-related resorption of the crown (not the root) of the impacted canine is shown in Figure 1. This process could lead to the failure of the therapy of the impacted canine.

Additionally, whether there is an association between surgical exposure technique, age of the patient, or severity of impaction and ankylosis has not yet been fully determined. Hence, the main objective of this study was to assess whether there is an association between ankylosis of the impacted canine and either the surgical exposure technique, the grade of its impaction, or the patient’s age. A secondary objective was to assess the effect of rapid palatal expansion on the automatic eruption of the impacted canine without surgical intervention.

MATERIAL AND METHODS

All participants in this clinical study came from the private practice of the first author, who treated all the impacted canines surgically and orthodontically over a period of 18 years (1994-2012). No specific inclusion or exclusion criteria were applied, since all patients who agreed to undergo therapy were included.

The canines were considered impacted when their roots were fully developed but the teeth were still covered with bone or mucosa.

We implemented a new grading method to categorize the severity of canine impaction. The impacted canines were grouped into 7 categories, according to their radiographic position in the orthopantomogram at the onset of treatment. The position of the cusp tip and its relationship to concrete anatomic structures of the neighboring lateral and central incisors determined the grade of impaction (I-VII) as follows (Figs 2 and 3).

Grade I: The tip of the cusp has no contact with the distal aspect of the lateral incisor, regardless of the distance between the cusp tip and the plane of occlusion.

Grade II: The tip of the cusp touches, or can reach as far as, the distal aspect of the root canal of the lateral incisor.

Grade III: The tip of the cusp appears radiographically through the root canal of the lateral incisor and can reach as far as its mesial aspect.

Grades IV and V: The tip of the cusp appears as far as the mesial aspect of the root canal of the central incisor; in grade V impaction, the tip of the cusp appears...
radiographically through the root canal of the central incisor and can reach as far as its mesial aspect or even the midline of the respective jaw.

For grades II to V, the tip of the cusp appears vertically on or below the border between the apical and coronal halves of the root of the lateral or central incisor in the maxilla, and on or above this border in the mandible.

Grade VI: The tip of the cusp is located above the border between the apical and coronal halves of the lateral or central incisors’ roots in the maxilla and below this border in the mandible.

Grade VII includes canines that are in transposition or transmigration in the maxilla or the mandible (Fig 1).

The accurate location of the crown of the impacted canine was evaluated by examining the orthopantomogram and by clinical examination before the surgical exposure. This included intraoral palpation and meticulous observation of the characteristics of the anatomic structures (crown and root) of the adjacent teeth (premolars, deciduous canine, and incisors) and especially the lateral incisors.

Digital volume tomography (specifically, cone-beam computed tomography images) was used for diagnosis of the accurate position and verification of the ankylosis of the impacted tooth only in complicated cases (Fig 1).

The following open surgical technique, with minimal modifications, was used. For palatally dislocated canines after local anesthesia, an incision was made as far as the cortical bone, following the palatal contour of the teeth in most patients from the mesial aspect of the central incisor up to the distal aspect of the first premolar. Then, a full-thickness mucoperiosteal flap was raised so that the exposed cortical plate allowed the surgeon, using a low-speed bur with careful cooling, to remove the bone that covered the canine’s crown approximately 1 to 2 mm above the cementoenamel junction as well as the follicular tissue from its

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Fig 2. A, Orthopantomogram of a 15-year-old female patient; B, schematic presentation of the positions of all 4 impacted canines. The mandibular left canine is grade I, the maxillary right canine is grade II, the maxillary left canine is grade III, and the mandibular right canine is grade VI of impaction.

Fig 3. A, Orthopantomogram of a boy (age, 13½ years) with 2 palatally impacted canines; B, schematic presentation of the impacted maxillary canines. The left canine is grade IV, and the right canine is grade V of impaction.
The cementoenamel junction area and other anatomic structures, such as the roots of the adjacent incisors, were respected. Consequently, the full-thickness flap was repositioned apically and sutured with 3-0 silk sutures. Finally, the tooth and the operative area were covered with a eugenol-free periodontal dressing (Coe-Pak; GC America, Alsip, Ill) for wound protection and short-term patient comfort. The dressing was positioned carefully, and we tried to place the dressing cover as apically as possible over the exposed crown, so that between the mucosa and the tooth crown there would be a layer of dressing. Under these circumstances, the proliferation of the gingival tissue was controlled, a quick covering of the tooth was prevented, and the tooth could erupt more freely without being impeded by the gingival tissue. The sutures were removed a week after the operation. After eruption, an auxiliary attachment was bonded onto the crown, and orthodontic traction was initiated.

The following closed surgical technique was performed. For palatally dislocated canines, the same surgical procedure as in the open surgical exposure technique was used under local anesthesia. For enamel surface preparation, 35% phosphoric acid in gel form was applied for 10 seconds, and an eyelet with a small metallic chain was bonded onto the tooth. This attachment (eruption appliance; GAC, Central Islip, NY) was the same for the whole period of the study. Finally, the full-thickness mucoperiosteal flap was placed in its original position and sutured with 3-0 silk sutures. One week after surgery, the sutures were removed, and the orthodontic traction began.

**Fig 4.** CONSORT flowchart of the study.
The rapid palatal expansion technique (banded rapid maxillary expander) was used extensively in our treatment to reduce premolar extraction therapy.

Statistical analysis

Demographic and clinical characteristics were investigated with descriptive statistics. Univariate and multivariate generalized estimating equation logistic regression with robust standard errors modeling was applied to assess whether surgical exposure technique, age (as a continuous variable), grade of impaction, sex, and location of the maxillary impaction (labial or palatal) were associated with ankylosis. For assessment of the effect of grade of impaction on the ankylosis, the grade VII category, which includes the most severe impaction in our categorization and the rarest cases, was excluded from the analysis, and the variable was dichotomized to the “nonsevere” group (grades I-V) or the “severe” group (grade VI). Additionally, the effect of rapid palatal expansion on the automatic eruption of the impacted canines was assessed. All analyses were implemented in the SPSS statistical package (version 15.0; SPSS, Chicago, Ill) and Stata (version 12.1; StataCorp, College Station, Tex).

RESULTS

From 1994 to 2010, the number of patients who came to the surgery and remained for therapy after the diagnosis of a dental or skeletal problem of their maxillofacial system was 2899 (number of canines, 11,596). In 118 (4.1%) of these patients, the impaction of at least 1 canine was diagnosed.

This clinical study was based on 118 orthodontic patients, 72 female and 46 male, with 157 impacted canines. The CONSORT flowchart (Fig 4) shows patient flow, and Table 1 gives the baseline characteristics of the study participants.

From June 1994 to October 1996, the open surgical procedure was performed on all patients who came to the surgery. From November 1996 to May 2006, the closed surgical procedure was strictly used; for the latter period of the study (June 2006 to March 2010), the open surgical exposure was performed on all other patients who came to the surgery, except in 3 cases: 2 in the maxilla and 1 in the mandible.

The study sample included 150 impacted canines in the maxilla and 7 in the mandible. Thirty-eight canines erupted spontaneously after space gaining, and the other 119 were treated surgically by using open (57 cases) and closed (62 cases) exposure techniques.
The patients’ ages at the beginning of therapy ranged from 11.2 to 46.1 years (mean, 18.11 years; SD, 7.88). Eleven of the 119 surgically treated canines had the complication of ankylosis a priori or during their orthodontic traction.

The risk of ankylosis in the open exposure technique was 3.5% (2 of 57 canines); for the closed exposure technique, the risk was 14.5% (9 of 62 canines). In the younger age group (<18 years), 5.0% (4 of 77) showed ankylosis, whereas in the older group (>18 years), 17.9% (7 of 39) had ankylosis. In the “nonsevere” group (grades I-V), 6 cases (5.9%) showed ankylosis; in the “severe” group (grade VI), there were 5 cases (35.7%). The risks of ankylosis were 4.5% (2 of 44) and 12% (9 of 75) in male and female patients, respectively. Finally, the risk of ankylosis was 8.3% (1 of 12) in labiabally and 8.8% (9 of 102) in palatally impacted canines in the maxilla (Table II).

Rapid palatal expansion was performed in 51 of the 150 maxillary cases. Twenty-three of those resulted in automatic eruption (45.1%), whereas, of the other 99 cases in the maxilla that did not receive rapid palatal expansion, only 13 (13.1%) resulted in automatic eruption (odds ratio [OR], 5.43; 95% confidence interval [CI], 2.43-12.14; P <0.001).

The results of the univariate and multivariate generalized estimating equation logistic regression with ankylosis as the dependent variable and surgical exposure technique (open or closed), age (continuous), severity of impaction (“nonsevere” group, grades I-V; “severe” group, grade VI), sex (male or female); and location of impaction in the maxilla (labial or palatal) as ankylosis predictors are shown in Table III. The automatic eruption cases (n = 38), the cases of grade VII (n = 3), and the impaction cases in the mandible (n = 7) were excluded from this analysis. The univariate analysis showed weak evidence of an association between ankylosis and surgical exposure technique, and evidence of association between age, grade of impaction, and ankylosis. No evidence of association between ankylosis and either sex or location of the impaction in the maxilla was detected. The multivariate analysis showed similar findings and reaffirmed that sex and location of impaction in the maxilla make no significant contribution to the prediction of ankylosis, whereas surgical exposure technique, age, and severity of impaction appear to be significant ankylosis predictors.

The ankylosis analysis of our 11 cases showed 4 cases of a priori ankylosis (Figs 1 and 5); 3 cases of ankylosis-related resorption in the roots of the impacted canines; 3 cases of fibrous connective tissue fusion, in which the tissue fuses to the bonded attachment and the chain (Fig 6), or even to the crown of the tooth (Fig 7); and 1 case in which the impacted canine was pulled in an inappropriate direction (Table IV).

In 4 cases of 157 (2.5%; 2 spontaneous eruption, 1 open surgical procedure, and 1 closed surgical procedure), the proximal lateral incisor was extracted during therapy because of severe root resorption.

Premolar extraction therapy was performed in only 11 of 157 (7%) impacted canine cases.

**DISCUSSION**

Our clinical study focused first on the complication of ankylosis regarding the surgical exposure technique (open or closed), the patient’s age, and the grade of impaction, and then on the effect of rapid palatal expansion on the automatic eruption of the impacted canines in the maxilla.

All participants for this clinical study came from the private practice of the first author, who treated all impacted canines orthodontically and surgically. In this way, every patient, at each stage of the orthodontic or surgical therapy, was examined by the same clinician, who thus had full and direct control of, and information about, the outcome of every treatment method.

Evidence of an association between the closed surgical exposure technique and ankylosis was found. There was also evidence that older patients have a higher risk of developing ankylosis, either a priori or during therapy.

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**Table II.** Occurrence of ankylosis by surgical exposure technique, age, grade of impaction, sex, and location of impaction in the maxilla in the surgically treated cases (n = 119)

<table>
<thead>
<tr>
<th>Surgical exposure technique</th>
<th>Ankylosis nc (%)</th>
<th>No ankylosis nc (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP1 (nc = 57)</td>
<td>2 (3.5)</td>
<td>55 (96.5)</td>
</tr>
<tr>
<td>OP2 (nc = 62)</td>
<td>9 (14.5)</td>
<td>53 (85.5)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18 (nc = 80)</td>
<td>4 (5)</td>
<td>76 (95)</td>
</tr>
<tr>
<td>≥ 18 (nc = 39)</td>
<td>7 (17.9)</td>
<td>32 (82.1)</td>
</tr>
<tr>
<td>Grade of impaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsevere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I-V, nc = 102)</td>
<td>6 (5.9)</td>
<td>96 (94.1)</td>
</tr>
<tr>
<td>Severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(II-V, nc = 14)</td>
<td>5 (35.7)</td>
<td>9 (64.3)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (nc = 44)</td>
<td>2 (4.5)</td>
<td>42 (95.5)</td>
</tr>
<tr>
<td>Female (nc = 75)</td>
<td>9 (12)</td>
<td>66 (88)</td>
</tr>
<tr>
<td>Location of impaction in the maxilla*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labial (nc = 12)</td>
<td>1 (8.3)</td>
<td>11 (91.7)</td>
</tr>
<tr>
<td>Palatal (nc = 102)</td>
<td>9 (8.8)</td>
<td>93 (91.2)</td>
</tr>
</tbody>
</table>

*One case of ankylosis was diagnosed in the mandible.
Table III. Crude and adjusted odds ratios (OR) and 95% confidence intervals (CIs) from logistic regression for the effect of surgical exposure technique, age, grade of impaction, sex, and location of impaction in the maxilla on canine ankylosis

<table>
<thead>
<tr>
<th>Category</th>
<th><strong>Univariable model</strong></th>
<th><strong>Multivariable model</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>OR</strong></td>
<td><strong>95% CI for OR</strong></td>
</tr>
<tr>
<td>Surgical exposure technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP1 Referent</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>OP2</td>
<td>4.59</td>
<td>0.93-22.46</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per unit</td>
<td>1.01</td>
<td>1.04-1.02</td>
</tr>
<tr>
<td>Grade of impaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsevere (I-VI) Referent</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Severe (VI)</td>
<td>9.13</td>
<td>2.28-36.52</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Referent</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2.89</td>
<td>0.60-14.10</td>
</tr>
<tr>
<td>Location of impaction in the maxilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labial Referent</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Palatal</td>
<td>1.40</td>
<td>0.27-7.24</td>
</tr>
</tbody>
</table>

**OP1**, Open surgical procedure; **OP2**, closed surgical procedure.

Fig 5. A, Orthopantomogram of a 41-year-old woman with a palatally impacted maxillary right canine (grade VI); B and C, open surgical exposure procedure; D, appropriate force vector during canine traction; E, orthopantomogram of the same patient 1½ years after the initiation of treatment. A first reexposure procedure had already been performed, but there had been no response to the orthodontic traction. An a priori ankylosis was present. F and G, With the cone-beam computed tomography images, external and internal resorption of the impacted canine's crown was diagnosed. “Tunnels” through the enamel and dentin connected the 2 entities. H, Second open reexposure procedure; fine instruments were used to remove the inflammatory tissue on the labial surface of the impacted canine's crown. I, The force vector did not change; J, the arrow indicates the area affected by ankylosis on the labial surface of the tooth; K, the resorptive area on the labial surface of the pulp chamber and the gutta percha filling of the root canal are shown; L, final result.
Additionally, evidence of an association between the severity of impaction, based on the categorization developed during this study, and the appearance of ankylosis was found. Finally, rapid palatal expansion appears to be associated with automatic eruption of the impacted canines.

The choice of the surgical exposure technique (open or closed) was independent of age and the grade of impaction. The relatively large sample size of our study and cases in which rapid palatal expansion was performed also allowed us to consider this space-gaining technique in relation to canine impaction. Our study was in accordance with previous studies that have also indicated that the higher the mean age of the examined population, the smaller the percentage of impaction of maxillary canines.22,23 This means that, as age increases, the percentage of automatic eruption also increases. Rapid palatal expansion, usually performed in young patients, was used in our study as the main technique to gain space in all cases that met the criteria. Rapid palatal expansion affects the whole maxilla in contrast to other space-gaining techniques such as premolar extraction therapy and local space gaining with an opening spring. In this case, the use of a control group would be of great importance, but it would be unethical to wait to see whether the impacted canine spontaneously erupts.

Using rapid palatal expansion in a group of patients younger (7.6-9.6 years) than our group (11.5-23.6 years) with palatally dislocated canines, Baccetti et al24 drew similar conclusions regarding automatic canine eruption.

The effect of age on the success rate and duration of treatment of palatally impacted canines has also been studied by Becker and Chaushu.25

In the cases of ankylosis-related resorption, fibrous connective tissue, and inappropriate direction of traction presented in Table IV, there was movement of the impacted tooth between the start of traction and the diagnosis of ankylosis. This was not so in the a priori cases. Nevertheless, even in these cases, if, after a proper diagnosis with cone-beam computed tomography, the surgeon can remove the ankylosed tissue from the crown of the canine without damaging the anatomic parts of adjacent teeth, then the orthodontist can move the tooth into its proper position (Fig 5). Mobilization of the tooth with forceps in this form of ankylosis was not necessary.

In our opinion, 3 main causes could result in trauma to the periodontal ligament or the cementum of the cervical root of the impacted tooth and lead to ankylosis-related resorption: (1) the low-speed bur during exposure, (2) chemical trauma26 to the periodontal ligament from the 35% phosphoric acid, and (3) trauma to the periodontal ligament in the cervical region because of the direction or magnitude of the orthodontic force. In these cases, during reexposure, the ankylosed teeth were mobilized with forceps, and orthodontic traction began immediately. In 2 of 3 cases, we noticed the same side effect of ankylosis after some weeks.

With regard to the a priori (Figs 1 and 5) and fibrous connective tissue (Fig 6) cases as well as the case shown in Figure 7, the role of the dental follicle must be studied further. In the dental follicle, stem cells are available; they are pluripotent and capable of differentiating into other cell types.27,28 These cells could create ankylosed cavities in the crowns of the impacted teeth.

The orthodontist should obtain all available information from both traditional diagnostic means (orthopantomogram and lateral cephalogram, for which almost all of our patients are referred) and meticulous clinical examinations, and not thoughtlessly refer the patient for a cone-beam computed tomogram that, although providing additional diagnostic and therapeutic benefits, exposes the patient to higher levels of radiation.29-31

Fig 6. A, A bonded attachment with fused tissue was removed after reexposure of an impacted maxillary canine that had been ankylosed for months after a closed surgical exposure; B, the histologic examination of the fused tissue showed edematous fibrous connective tissue with mild chronic inflammatory infiltration of the substrate and irregular calcified deposits (diffuse calcification). CD, Calcified deposits; F, fibroblasts; L, lymphocytes.
The categorization of our impacted canines on panoramic radiographs (grades I-VII) was based on anatomic structures and not on the angulations and linear measurements that many authors have included in their studies. Our method can be used in both the maxilla and the mandible, and its main advantage is that it is virtually unaffected if the patient’s head is incorrectly positioned in the cephalostat during exposure. The improper positioning of the patient’s head, especially in the horizontal or median-sagittal plane during orthopantomogram exposure, might affect the angular and linear measurements as well as the categorization of the impaction based on those measurements.

The estimation of the anatomic position of the impacted canines was accurately determined in most cases.

**Table IV.** Ankylosis analysis of our 11 cases presented chronologically

<table>
<thead>
<tr>
<th>Tooth and form of impaction</th>
<th>Surgical exposure</th>
<th>Recexposure</th>
<th>Final outcome</th>
<th>Main cause of ankylosis</th>
<th>Affected area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Crown</td>
</tr>
<tr>
<td>23, palatally</td>
<td>OP2</td>
<td>Closed</td>
<td>Extraction</td>
<td>ARR</td>
<td></td>
</tr>
<tr>
<td>23, palatally</td>
<td>OP2</td>
<td>Closed</td>
<td>Extraction</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>13, palatally</td>
<td>OP2</td>
<td>Closed</td>
<td>Extraction</td>
<td>ARR</td>
<td></td>
</tr>
<tr>
<td>23, palatally</td>
<td>OP2</td>
<td>Closed</td>
<td>Extraction</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>13, palatally</td>
<td>OP2</td>
<td>Open</td>
<td>Success</td>
<td>FCT</td>
<td></td>
</tr>
<tr>
<td>23, palatally</td>
<td>OP2</td>
<td>Open</td>
<td>Success</td>
<td>ARR</td>
<td></td>
</tr>
<tr>
<td>13, labially</td>
<td>OP2</td>
<td>Open</td>
<td>Success</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>23, palatally</td>
<td>OP1</td>
<td>Open</td>
<td>Success</td>
<td>IDT</td>
<td></td>
</tr>
<tr>
<td>43, lingually</td>
<td>OP2</td>
<td>Open</td>
<td>Success</td>
<td>FCT</td>
<td></td>
</tr>
<tr>
<td>13, labially</td>
<td>OP2</td>
<td>Open</td>
<td>Success</td>
<td>FCT</td>
<td></td>
</tr>
<tr>
<td>13, palatally</td>
<td>OP1</td>
<td>Open</td>
<td>Success</td>
<td>AP</td>
<td></td>
</tr>
</tbody>
</table>

23, Maxillary left canine; 13, maxillary right canine; 43, mandibular right canine; OP1, open surgical procedure; OP2, closed surgical procedure; ARR, ankylosis-related resorption; AP, a priori ankylosis; FCT, fibrous connective tissue; IDT, inappropriate direction of traction.

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**Fig 7.** A, Orthopantomogram of an 18-year-old female patient with a palatally impacted maxillary right permanent canine of grade VI and delayed shedding of the maxillary right deciduous canine; B, closed exposure; C, the orthodontic movement of the impacted canine stopped 8½ months after its exposure and its orthodontic traction. An open reexposure procedure was performed. The rest of the impacted canine’s coronal part of the dental follicle and other fibrous connective and inflammatory tissue around the bonded attachment are shown. The impacted canine was ankylosed. D, A large cavity became apparent in the distopalatal aspect of the tooth after removal of the fibrous connective tissue (arrow); E, final result.
from the orthopantomogram, lateral cephalogram, and clinical examination. However, some patients with severe impactions (grades VI and VII) were referred for a cone-beam computed tomography image; this was also done when an a priori ankylosis was suspected (Fig 5).

Study limitations might be associated with the lack of randomization and the small number of ankylosis events. However, the choice of surgical procedure was, in every case, predetermined for the whole period of the study, regardless of age, severity of impaction (grades I-VII), sex, or location of the impaction. Thus, the open procedure was performed on all patients who came at the beginning of the study, the closed procedure on those in the middle, and the open procedure again on those in the last period, except for 3 cases in which the closed procedure was used. Selection bias because of the nonrandomized design is unlikely to have severely influenced the results, since the baseline characteristics between treatment groups were similar; although the interventions changed, the changes did not depend on the cases. The small number of events related to ankylosis is reflected in the low precision of the estimates, and this should be considered when interpreting the results. Performance, observer, and attrition bias are unlikely to have affected the results of this trial, since the outcome was not subjective, and there were no losses to follow up.

The methods of this study in which the investigator performed both surgical and orthodontic procedures might not be a common practice. On the other hand, the inclusion of patients with characteristics commonly treated by orthodontists worldwide, as well as the mainstream treatment approach, could allow us to consider our findings applicable to other settings.

CONCLUSIONS

There is some evidence of an association between surgical exposure technique, age, severity of impaction, and ankylosis. However, these findings should be interpreted with caution because the number of events was small.

Rapid palatal expansion appears to be associated with automatic eruption of impacted canines.

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REFERENCES
