The therapy of the impacted canine

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ABSTRACT

Material: Our clinical research was based on findings from 129 orthodontic patients (79 female, 50 male) between 10.9 and 46.1 years of age who had 171 impacted canines.

Methods: The canines, according to their radiographic position in the orthopantomogram (OPG) at the onset of treatment, were grouped into 7 categories (Grade I-VII) and were treated orthodontically and surgically over a period of 18 years by the first author (S.I.K.). The diagnosis of the impacted canines was based mainly on the study of the OPG, and the clinical evaluation, which included the intraoral palpation and the meticulous observation of the characteristics of the anatomical structures (crown and root) of the adjacent teeth. The diagnosis of the impacted canine, the early treatment of the ectopically erupting or impacted canine, the side effect of the loss of the lateral incisor, the surgical procedures that we performed, according to the location and the severity of the canine impaction, several important orthodontic considerations and the ankylosis of the impacted canine a priori or during its traction are discussed in this clinical study.

Results: Forty-one canines erupted spontaneously after space gaining, and the other 130 were treated surgically with an open (66 cases) or a closed (64 cases) exposure technique. Finally, 167 canines out of 171 were moved into the dental arch to a proper position. Four ankylosed canines and 3 proximal lateral incisors were extracted. These side effects were mainly associated with a traditional closed surgical exposure technique.

Conclusions: We finally concluded that we should perform an open surgical technique in the cases of palatal impaction and a closed surgical technique in specific cases of labial impaction. If the proper uncovering technique is chosen for each case, is performed in time and skeletal anchorage is used during the canine traction, where necessary, severe root resorption of the lateral incisor and ankylosis of the impacted canine can be avoided during its traction and the eruption process can be simplified, resulting in a predictable and non-time-consuming outcome in most cases.

INTRODUCTION

The maxillary permanent canine comes second in frequency of impaction, after the third molar, with a prevalence of approximately 1.5% of the population. Chu et al.[1] reported a maxillary canine impaction prevalence of 0.8%, Dachi and Howell[2] give for the same tooth, a prevalence of 0.92%, whereas Ericson and Kurol,[3] and Thilander and Myrberg,[4] reported a prevalence of 1.7% and 2.2% respectively. The above-mentioned percentages depended on the mean age of the population examined in each study: the higher the mean age of the examined population, the smaller the percentage of impaction of the maxillary canine. The prevalence of mandibular canine impaction fluctuates between 0.07%[1] and 1.29%.[5]

In 1949 Dewel[6] writes about the upper canine: "Of all teeth it has the longest period of development, the deepest area of development and the most devious course to travel from its point of origin to full occlusion. ...Although it starts to calcify almost as early as the first molar and the central incisor, it takes nearly twice as long to achieve complete eruption, which makes it susceptible for much longer to environmental influences, whether favorable or unfavorable". Independently of these developmental considerations, the most common causes for canine impactions are localized, as Bishara[7] states in his review and as reported by other authors.[8-15] Such causes include: the long path of eruption, tooth size-arch-length discrepancies, abnormal position of the tooth bud, prolonged retention or early loss of the deciduous canine, trauma, presence of an alveolar cleft, ankylosis of the deciduous or permanent canine, cystic or neoplasmatic formation or dilacerations of the root and supernumerary teeth. Root deviation of the first premolar could also be an aetiological factor of maxillary canine displacement.[16] An association between palatal canine impaction and microdontia of the lateral incisors has also been reported.[9-11,13,14] This type of impaction occurs more frequently in patients who present horizontal growth characteristics, wide maxillary arches[10,11] and Class II division 2 malocclusion.[11] In these conditions the canine is free to "dive" into the bone and to become palatally impacted.[14] The labial canine impaction in the maxilla occurs more frequently in patients with an arch-length deficiency and vertical growth characteristics.[10,11] The congenitally missing maxillary lateral incisor and the variation in the root size of the tooth, as well as variation in the timing of its root formation, have been implicated as important aetiological factors associated with maxillary canine impaction.[8-14,17]

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MATERIAL

Our clinical research was based on findings of 129 orthodontic patients (79 female, 50 male), who presented 171 impacted canines. The patients' ages at the beginning of therapy ranged between 10.9 and 46.1 years.The canines were considered impacted when their roots were fully developed but the teeth were still covered with bone or mucosa. In total, 161 (94.2%) were found in the maxilla and 10 (5.8%) in the mandible. Thirty-seven of the impacted canines in the maxilla were found in labial (23%) and 124 in palatal (77%) malposition, while in the mandible 7 impacted canines were found in labial and 3 in lingual malposition.

All the patients were treated orthodontically and surgically over a period of 18 years by the first author.

AETIOLOGICAL CONSIDERATIONS

Microdontia of one or both lateral incisors in the maxilla was ascertained in 22 patients (17.1%) with simultaneous palatal impaction of 27 canines. The microdontia of the lateral incisor was considered to be the main aetiological factor for the palatal impaction of these canines. Aplasia of one or both lateral incisors in the maxilla was found in 4 more patients, and in 2 other patients aplasia of one and microdontia of the other lateral incisor, were also considered to be the principal aetiological factors for the palatal impaction of 8 more canines. Of the 124 palatally impacted canines, 35 (28.2%) were associated with the presence of microdontia or aplasia of lateral incisor/s, this being the main cause of their impaction. Of a total of 103 patients, who presented upper

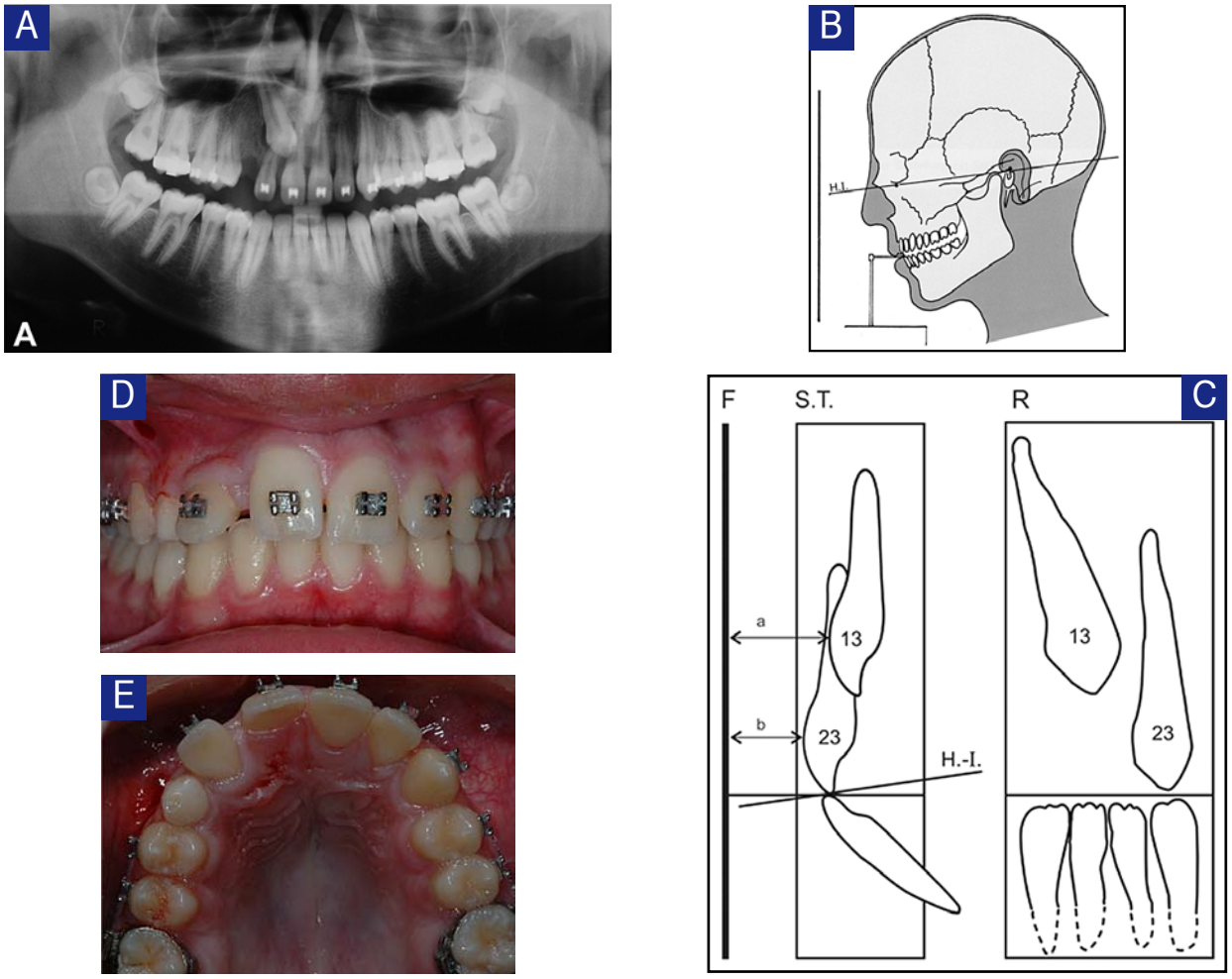

Fig 1. A, OPG of a 15-year-old male patient with an upper right labially impacted canine; B, Schematically, the improper placement of the head in the horizontal plane (head inclined to a ventral inflexion) is shown. The vertical dimension of the anterior teeth is particularly influenced by the head inclination. The length of the upper anterior teeth, which is measured in the radiograph, is increased, while the radiographic length of the lower anterior teeth is reduced.[29] C, Schematically, the positioning of the upper canines and the lower incisors, their relationship to the film, to the section thickness and to the result of their images (F: Film, S.T.: Section Thickness, R: Result, H.I.: Head Inclination, a and b: distances of the upper right (13) and left (23) permanent canines corresponding to the film); Section Thickness or Slice Thickness: means the thickness of the section that is in sharp focus on a tomogram. D, Observe the labial crown-torque of the upper right lateral incisor. E, The palatal bud in the region of the upper right lateral incisor was created by the palatal inclination of its root and not by the impacted canine on this side. The labial crown-torque of the upper right lateral incisor and the palatal inclination of the crown of the upper right central incisor are meaningful clinical observations.

canine impaction, 18 patients (17.5%) presented palatally displaced canines on both sides of the maxilla.
One odontoma was the main cause of the labial impaction of one upper canine.
In three other cases, the mesial-palatal drifting of the second premolar was considered to be the main cause of the palatal impaction of three canines. In all three cases there was delayed shedding of the deciduous second molars. After the extraction of the primary second molar, the second premolars erupted at an accelerated rate in a better position in the arch, as if the obstacle to their eruption had been eliminated.
Three other cases presented ankylosis and delayed shedding of the deciduous canine, which could have caused the palatal impaction of the corresponding permanent canine. Persistence of the deciduous canine was found in 124 (72.5%) out of the total 171 cases.
In four other cases, labial (in 3 cases) and palatal (1 case) impaction of the upper canine and simultaneous transposition18-27 was diagnosed. In two of these cases (labial impaction) a maxillary canine-lateral incisor transposition (Mx.C.I2) was found and in the third case (palatal impaction) a maxillary canine-first premolar transposition (Mx.C.P1) was noticed. In one case in the mandible, labial impaction of the lower left canine was diagnosed in combination with Mn.C.I2 transposition. A pseudotransposition was observed in four other cases in the maxilla. According to Peck S. and Peck L.,[22] "the type of pseudotransposition in maxilla is usually characterized by a maxillary canine crown visibly erupted mesiofacially relative to the lateral incisor, but on x-ray analysis, the crown of the canine is clearly seen as only tipped forward with its root apex still distal to the lateral incisor; this is not a transposition at all, and it should be classified simply as a case of ectopic eruption of the maxillary canine tooth".

METHODS

Categorization (Grade of impaction)

In order to have specific criteria concerning the severity of the impaction, the impacted canines were grouped into 7 categories (GR I – GR VII), according to their radiographic position in the orthopantomogram (OPG) at the onset of treatment.[28]

Diagnosis of impaction

From the study of the OPG, the accurate location of the crown of the impacted canine was evaluated, before its surgical exposure, but it was more specifically located with the help of clinical examination. This included the intraoral palpation and the meticulous observation of the characteristics of the anatomical structures (crown and root) of the adjacent teeth (premolars, deciduous canine, permanent incisors) and especially those of the lateral incisors (Fig 1).
If we observe only the OPG in the case of Figure 1, A, we will find that the head of the patient, during the exposure, in relation to the median-sagittal plane, was placed in the proper position[29] (Fig 2, A and B) and, as a result, we can roughly compare distance measurements between the right and left side. The mesiodistal width of the crown of the upper right canine is greater in comparison to the same width of the crown of the upper left canine. Due to this measurement we can conclude that the crown of the upper right canine is placed more palatally in comparison to the crown of the other maxillary canine. The distance between the crown of the canine and the film was greater on the right side (a>b, Fig 1, C). This information in combination with the clinical examination (Fig 1,D and E) leads to the conclusion that the crown of the upper right canine is positioned between the labial side of the palatally dislocated root of the upper right lateral incisor and a part of the palatal side of the labially dislocated root of the upper right central incisor.
A CBCT was only performed in the severe cases of impacted canines in which the eruption of the impacted canine after its surgical exposure was severely impeded by the location of its crown, by ankylosis of the impacted canine or by an improper direction of orthodontic traction.[28]

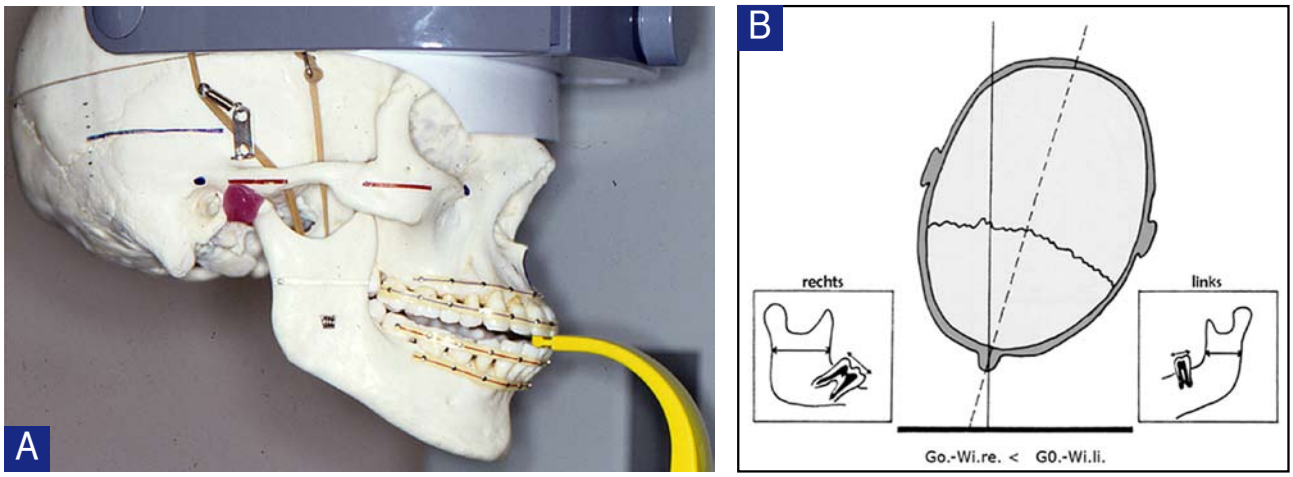

Fig 2. A, Proper positioning of the head in the cephalostat of the panoramic apparatus in the median-sagittal plane; B, Schematically, the effect of the improper placement of the head in the median-sagittal plane is shown, as well as the asymmetric radiographic results regarding the anatomical structures of the right and left side of the mandible.[29] Reproduced with permission from Quintessence Publishing.

THERAPY

EARLY TREATMENT

Palatally erupting permanent canines - extraction of maxillary deciduous canines

The referral of the patients for extraction of the maxillary deciduous canines was the only therapeutic measure, when palatally erupting permanent canines were diagnosed (Fig 3). Therefore, all these cases were excluded from our clinical study.

Extraction of deciduous molars

Delayed shedding of deciduous molars, regardless of its cause, could lead to a change in the premolars' path of eruption. Subsequently, the developing canine could also be pushed and dislocated into an abnormal position by the dislocated premolars.

Severe lack of space for the eruption of maxillary permanent canines

In cases of severe lack of space for the natural eruption of the permanent canine, we used the rapid palatal expansion (RPE) technique to gain enough space for the accommodation of the permanent canine in the dental arch and to prevent, early enough, the progressive root resorption of the permanent lateral incisors. In total, we used the RPE in 57 cases (35.4%) out of 161 impacted canines in maxilla.

In a few cases, Pendulum-type appliances[30,31] were used, during the mixed dentition stage, to gain space in the sagittal direction and to allow for the natural eruption of the ectopically erupting canines.

In 12 cases of severe lack of space the extraction of the four first premolars, alone or in combination with RPE, was considered necessary.

Transposition of the permanent canine

In the cases of transposition, an auxiliary attachment was bonded onto the impacted tooth during its surgical exposure. With its help it was possible to move the tooth before its artificial, "orthodontic" emergence to a better position close to its proper position in the dental arch, in order to achieve its final alignment (Fig 4).

SURGICAL EXPOSURE TECHNIQUES

There are numerous surgical procedures6,32-50 to expose an impacted canine and to bring it to its proper position in the dental arch. Generally, there is the open exposure technique, which allows natural eruption of the impacted canine and the closed exposure technique with placement of an auxiliary attachment. Orthodontic traction is subsequently performed on the attachment to move the impacted canine.

Labial Impaction

Labial impaction especially of the maxillary, but also of the mandibular canine, could mainly be the result of the following situations: (a) lack of space for its eruption because of maxillary dental midline shifting, often in micrognathic maxillas, (b) ectopic migration of the canine with its crown over the root of the lateral incisor, or even more mesially (grade of impaction GR VII),[28] or over the root of the first premolar, or even more distally (grade of impaction GR VII),[28] (c) disturbance of its natural eruption because of delayed shedding of the deciduous canine and (d) the tooth bud of the canine in a severely vertically displaced position (grade of impaction GR VI),[28] (e) cleft lip and palate cases.

Fig 3. A, OPG of a 9-year-old male patient, who was referred for the extraction of his deciduous canines in maxilla, as the only therapeutic orthodontic means for his palatally erupting permanent canines; B, Intraoral photograph of the same patient; C, Intraoral photograph of the same patient 1½ years later.

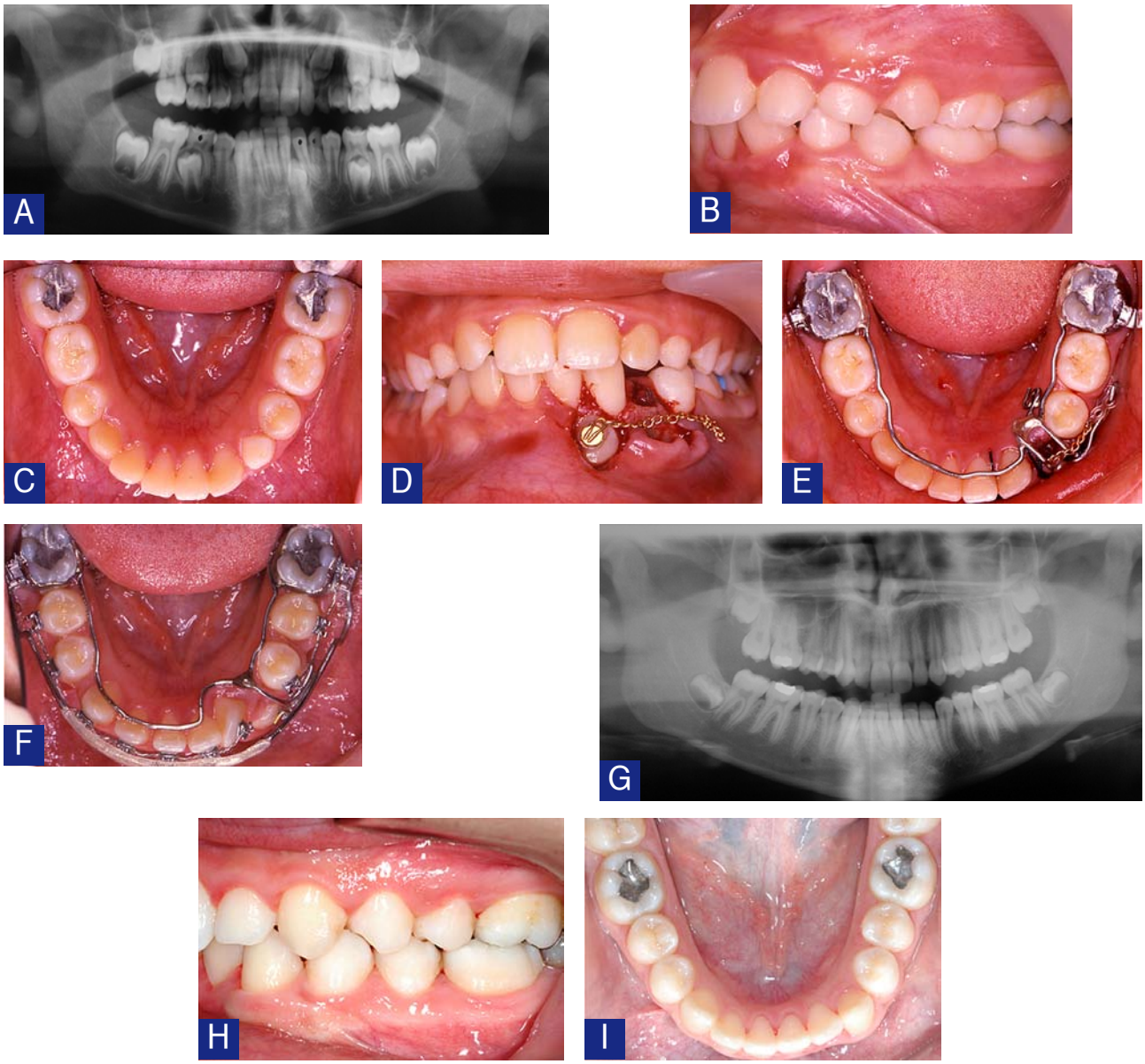

Fig 4. A, OPG of a 10-year-old female patient; her lower left deciduous canine is in the arch and the corresponding permanent canine is impacted, transposed and located between the lower left lateral and central incisors (Mn.C.I2). B, Occlusion of the left side of the same patient; C, Impaction and transposition of the lower left permanent canine; D, Closed surgical exposure and attachment placement; E and F, Orthodontic traction of the transposed lower left permanent canine; G, Final OPG; H and I, Final result after appliance removal.

The first thing we did in the (a) cases was to create sufficient space in the dental arch and to wait. It was a question of time. In most of these cases the canine erupted in a short time, without any surgical intervention, because the "obstacle" (lack of space) was eliminated and mainly because of the inherent eruptive ability of the tooth to come in occlusion. In the (b) cases we used a closed surgical technique (3 cases) as described in Figure 4 and an open surgical technique (1 case). In the (c) cases we removed the deciduous canine, created sufficient space for the impacted canine in the arch and waited. If the canine's crown was located close to the occlusal plane, the emergence of the impacted tooth was a question of time. But if the crown of the impacted canine was located in the middle or the apical third of the incisors a closed surgical procedure was performed. A full-thickness mucoperiosteal flap had to be raised to expose the cortical plate. After that, the bone from the canine's crown had to be removed carefully, not from the whole crown, but only from a small area, which was adequate for the bonding of an attaching device (Fig 5D). The flap was repositioned and sutured in its original position. After one week we removed the sutures and we began with the orthodontic traction using light forces. The same technique was also performed in the (d) severe cases (grade of impaction GR IV-VI), as also seen in Figure 5D.

Palatal Impaction

After local anesthesia an incision was performed as far as

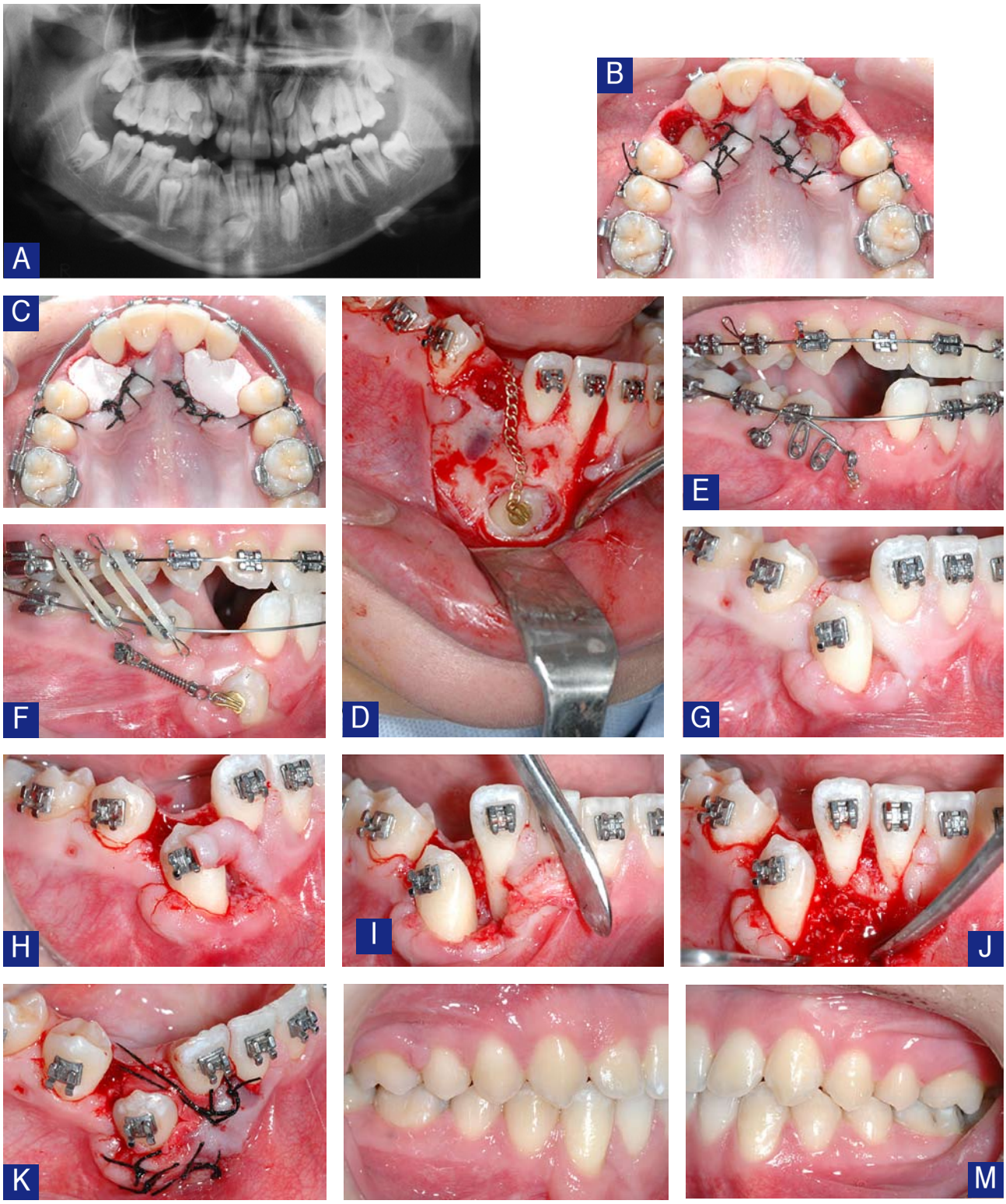

Fig 5. A, OPG of a 15-year-old female patient; all four permanent canines are impacted. B and C, Open surgical exposure of the palatally impacted canines; D, Closed surgical exposure of the lower right permanent canine; E and F, The use of skeletal anchorage in this case was not only essential for the anchorage unit itself, but it played the role of the main determinant of the traction vector. In this case a traction vector of horizontal direction was essential for the first stages of the impacted canine's traction. G,H,I, J and K, Covering the recession area via "guided tissue regeneration"; L and M, Posttreatment intraoral photographs.

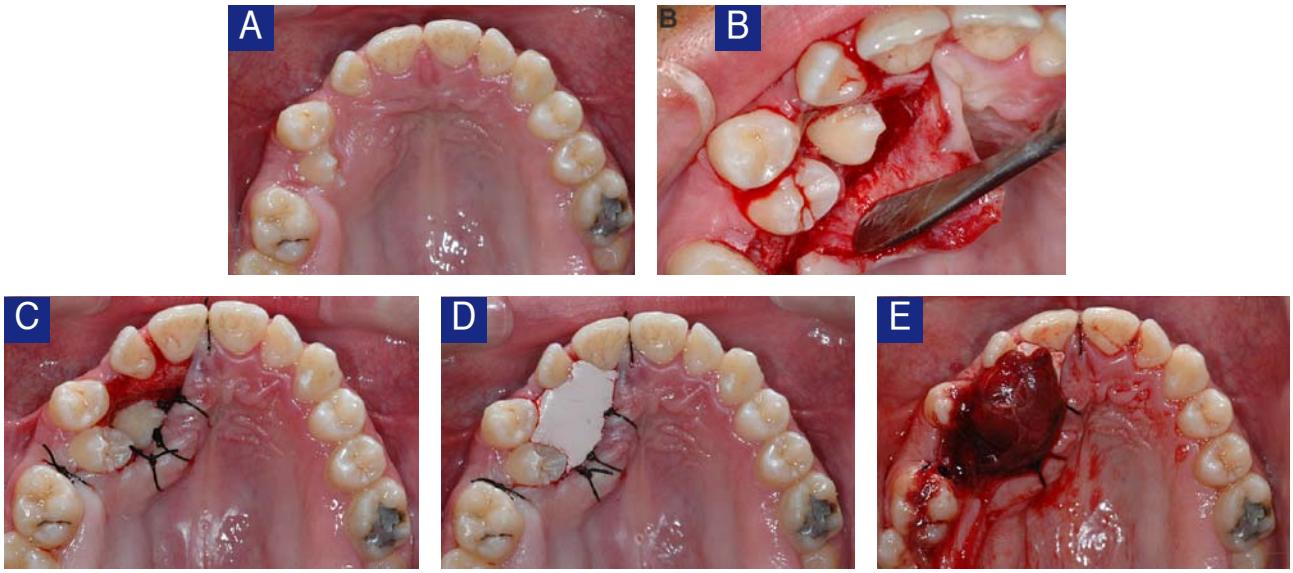

Fig 6. A, Upper dental arch of a 17-year-old male patient who presents the upper right second premolar and the upper right permanent canine palatally dislocated; B, Elevation of the flap; C, Before the flap was repositioned apically, part of which covered the occlusal surface of the second premolar which was intraoperatively cut and removed. D, Surgical dressing in place; E, The patient came to the surgery because of a haematoma in the flap area the same day. The haemorrage originated from the region of the flap, where a part was cut and removed.

the cortical bone following the palatal contour of the teeth, in most of the cases from the mesial aspect of the central incisor up to the distal aspect of the first premolar. Then, the full-thickness mucoperiosteal flap was raised to such an extent, 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 (CEJ) as well as part of the follicular tissue from its socket. The bone tissue was respected and only as much as needed was removed. The CEJ area as well as other anatomical structures, such as the roots of the adjacent incisors, were not disturbed. Then, in the closed procedure cases, 35% phosphoric acid in gel form was applied for 10 seconds to prepare the enamel surface, 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.

In the open procedure cases, the full-thickness flap was repositioned apically and was sutured (Fig 5, B). Finally, the tooth and the operative area were covered with a eugenol-free surgical dressing (Coe-Pak; GC America, Alsip, Ill - Fig 5, C) for wound protection and short-term patient comfort. The dressing was positioned carefully, and placed 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 usually removed a week after the operation. After partial eruption, an auxiliary attachment was bonded onto the crown, and orthodontic traction was initiated.

In cases of deep infraosseous impacted canine, a new surgical dressing was positioned for a second time one week after exposure. After the final removal of the dressing, the patient was strictly advised to clean the exposed tooth properly. Under these circumstances, in routine cases, the eruption of the tooth was not disturbed by the hard palatal mucosa or any inflammatory tissue around the exposed crown of the impacted canine. In a few cases of deep infraosseous impacted canines, and especially in older patients, the palatal mucosa tended to recover the exposed tooth, in spite of the use of surgical dressing, before the bonding of an attaching device. The excision of the palatal mucosa was necessary in these cases. For the excisional procedures and the gingivectomies, we have routinely used the electrotom for the last 18 years. The palatal mucosa is certainly a tenacious soft tissue, which greatly resists being perforated by teeth, such as an impacted canine, and particularly when its root is completely formed, its inherent eruptive ability diminished and the patient is no longer young, which results in decreased tissue metabolism. In these cases two or three uses of surgical dressing, changed weekly, were adequate and the use of the electrotom was rare, especially in cases in which the patient maintained proper hygiene of the exposed canine.

Impaction in the middle of the alveolar ridge

When the crown of the impacted canine was located in the middle of the alveolar ridge (absence of the canine bulge palatally or labially), space in the arch was created prior to uncovering the impacted canine. If the tooth did not erupt spontaneously, the exposure was performed on the side

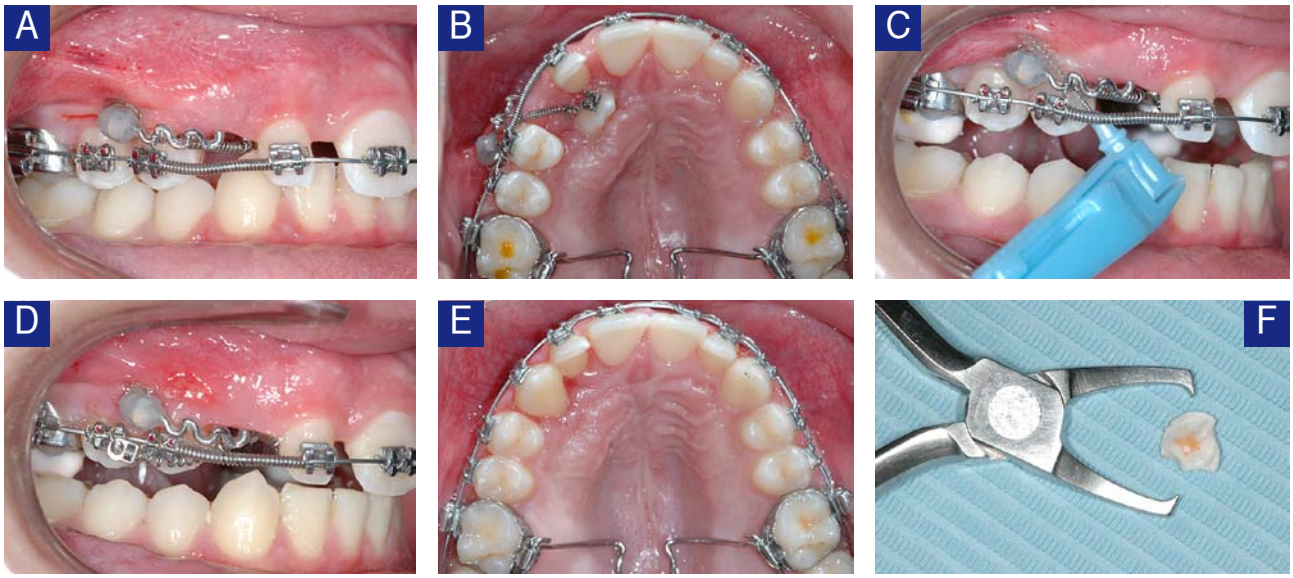

Fig 7. A, Orthodontic traction of the palatally impacted upper right permanent canine in a 13-year-old male patient with the use of skeletal anchorage; notice the deep bite. B, Sodium fluoride paste is carefully applied only in the grooves of the occlusal surface of the upper first molars as a preventive means for caries immediately before the placement of the glass-ionomer cement bite-planes. C, The fixed bite-planes allow the exposed canine to move labially. Proper hygiene through interdental brushes plays a significant role in the prevention of gingival inflammation around the mini-implant and the other orthodontic devices. D, Two complications of the mini-implant use, appeared one week after its placement: a) the aphthous ulceration mesial to the head of the mini-implant and b) the migration of the mini-implant (displacement within the bone - compare with Fig 7, A). E, Two months after the initiation of orthodontic movement, the exposed canine reached a relatively good position in the dental arch and the fixed bite-planes were removed. Notice that the sodium-fluoride paste remained uninfluenced by the glass-ionomer cement and protected the grooves of the occlusal surface of the first molars from caries. F, The glass-ionomer cement is easily removed with bracket-removal-pliers because of the layer of the sodium-fluoride paste.

(palatally or labially) from which less bone tissue had to be removed. If this occurred on the labial side, a closed exposure technique was the case and an open exposure was performed, if the bone was removed palatally. Elevation of the full-thickness mucoperiosteal flap labially and palatally was rarely needed (2 cases) in order to control this.

Postoperative bleeding

This side effect was experienced in 3 cases of palatally impacted canines, in which an open surgical technique was performed. In one case, two vertical sections of the original full-thickness flap were performed and in two other cases a full-thickness part of the flap was cut and removed, in such a manner, so that the impacted tooth could erupt unimpeded (Fig 6).

ORTHODONTIC CONSIDERATIONS

Mini-implants

The orthodontic means that have been used to bring the impacted tooth into the arch were also adapted, during this period of 18 years, to the new technological methods of our profession. The use of skeletal anchorage by mini-implants and temporary anchorage device (TAD) systems gave us the ability to avoid anchorage-loss during canine traction.

Fixed bite-planes of glass-ionomer cement

When the palatally impacted canine had partially erupted after its open surgical exposure, a bracket was bonded onto its crown and the tooth was moved labially by orthodontic traction. In deep bite cases, the labial movement of the canine was severely hindered by the occlusion. In such cases, to raise the bite, fixed bite-planes of glass-ionomer cement placed on the occlusal surface of the deciduous molars or first permanent molars in upper or lower jaw were used (Fig 7).

ANKYLOSIS

Eleven canines of the 130 that were treated surgically had ankylosis, either a priori or during orthodontic traction. The percentages of ankylosis were 3% (2 out of 66 cases) in the open technique and 14% (9 out of 64 cases) in the closed technique. The issue of ankylosis in relation to the impaction of canine has been discussed.[28]

RESULTS

Forty-one canines erupted spontaneously after space gaining, and the other 130 were treated surgically with an open (66 cases) or a closed (64 cases) exposure technique. Finally, 167 canines out of 171 were moved into the dental arch to a proper position. Four ankylosed canines and 3 proximal lateral incisors were extracted. These side effects were mainly associated with a traditional closed surgical exposure technique.[28]

DISCUSSION

Material

The size of our sample is considered satisfactory enough to obtain a clear overview of the therapy of the impacted canine, in comparison with other clinical studies, in which similar issues were addressed.[34-53] Additionally, the entire material for this clinical study came from the private practice of the first author and all the impacted canines were orthodontically and surgically treated by him. In this way, every patient, in any stage of the orthodontic or surgical therapy was examined by the same clinician, who, thus, directly had full control and information about the outcome of every treatment modality.

Diagnosis

When the information, (which can be gained by the study of OPG and lateral cephalogram, for which every patient is normally referred, before the undertaking of their orthodontic therapy), is exhausted and the clinical examination, which includes the intraoral palpation and the meticulous observation of the characteristics of the anatomical structures (crown and root) of the adjacent teeth (premolars, deciduous canines, permanent incisors) and especially of the lateral incisors is performed, the estimation of the anatomical position of the impacted canine could be accurately determined in the majority of cases. Similarly, Gavel and Dermaut,[54,55] evaluating whether panoramic tomograms and cephalograms, which are routinely used in orthodontic practice, could provide adequate information to locate an impacted canine, concluded: "By analysis and evaluation of both dental panoramic tomograms and cephalograms the estimation of real position of the canine could be accurately determined". The orthodontist could also rely on the "Buccal Object Rule" (BOR).[56]

CBCT (Cone Beam Computed Tomography) images are perceived to be more useful than traditional radiographs for the evaluation of the canine's impaction[57] and might change the recommended treatment plan in approximately 25% of these cases.[58] "The increased precision in the localization of the impacted canines and the improved estimation of the space conditions in the arch obtained with CBCT result in a difference in diagnosis and treatment planning towards a more clinically orientated approach".[59] "However, no patient outcome efficacy studies have been conducted, and CBCT is recommended only when the information cannot be obtained adequately by lower dose conventional radiography".[60,61]

Other x-rays or more invasive diagnostic means, like CT or CBCT, must only be used in complex cases such as: neoplasmatic or cystic formations, cleft lip and palate cases, other craniofacial structural anomalies, multiple impactions with obviously unclear panoramic radiographic findings and in some cases of extremely dislocated canines, where the accurate location of the impacted canine and its relationship to other anatomical structures, such as the sinus or the roots of the adjacent teeth, are necessary for the surgical exposure and the treatment plan.[62]

CT39,53,63-65 or CBCT[58,62,66-68] images provide accurate data, which could be lost during traditional radiographic analysis, such as the accurate extent of root resorption. However, it has to be noted, that from a radiation-protection point of view, conventional images still deliver the lowest doses to patients.[60,69] Therefore, when 3-dimensional imaging is required in orthodontic practice, a cone beam computed tomography (CBCT) should be preferred over a CT image.[62,69]

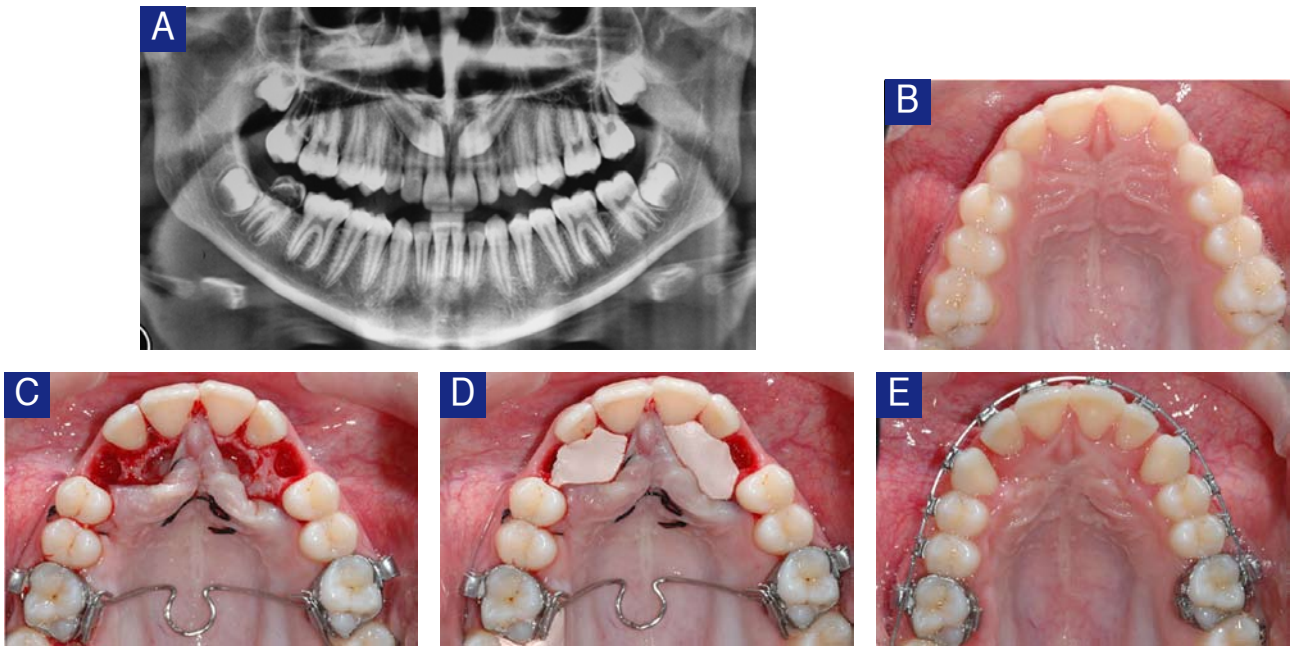

Fig 8. A, OPG of a 16-year-old female patient; the maxillary permanent canines are palatally impacted. B, Occlusal view of the maxilla at the onset of treatment; C, Open surgical exposure and use of a vertical mattress suture; D, Surgical dressing in place; E, Ten months after exposure, the impacted canine reached a relatively good position in the dental arch.

We consider that with the actual data and diagnostic means, which are available today, in simple cases, such as those of canine impaction, we must bear in mind that CT or CBCT examinations expose the patient to so much additional radiation, increase the costs of therapy and damage the environment generally effects, which can not be justified by the additional diagnostic information they provide. More invasive diagnostic means, such as CT or CBCT, should only be used for the accurate diagnosis in complex cases, such as those mentioned above.

Early treatment

Early treatment of ectopic maxillary canines is called for because of the risk of progressive resorption of the roots of the respective maxillary incisors.[51-53,63,70-74] "Resorption of adjacent incisor roots might occur in nearly 50%, and two thirds of those are in the pulp."[52,53] It is recommended that every new patient, aged 9 to 10, be examined very carefully, bearing in mind the possibility of palatally erupting canines.[53] It has been clearly shown that extraction of primary canines in the upper jaw has a favorable effect on palatally erupting maxillary canines, in most cases, if this extraction treatment is performed in time. The ectopic position and the path of eruption of the maxillary canine should be identified before the age of eleven.[53]

Generally speaking, for every child in the mixed dentition stage, an OPG is recommended.[75] More specifically, the characteristics of the anatomical structures (crown and root) of the incisors and especially these of the lateral incisors after meticulous observation and intraoral palpation, microdontia and/or aplasia of these teeth could be an important reason to refer the patient for an OPG, even if there is no other obvious sign or symptom for the undertaking of orthodontic treatment. If a palatal misplacement of the canine is finally diagnosed, the extraction of the deciduous canines in the upper jaw is recommended. For the labial impaction of the maxillary canines, the lack of space was ascertained as the main aetiological factor,[10,11] while in the cases of palatal impaction the microdontia of the lateral incisor[9-11,13,14] could be discerned to be the more frequent cause and not the lack of space, because, in the majority of these cases, enough space was available. The congenital absence of the lateral incisors is also related to the palatal displacement of the canine.[12,17] In our study, out of 37 canines, which were found in labial impaction in the maxilla, 27 erupted spontaneously after space gaining, which was created by means of RPE and/or orthodontic movement of the adjacent teeth. Without any surgical intervention, only 11 palatally impacted canines from a total of 124 could emerge spontaneously, after orthodontic optimization of the canine space in the upper dental arch. Stellzig et al,10 Al-Nimri[11] and Jacoby[14] described similar findings on the aetiology and characteristics

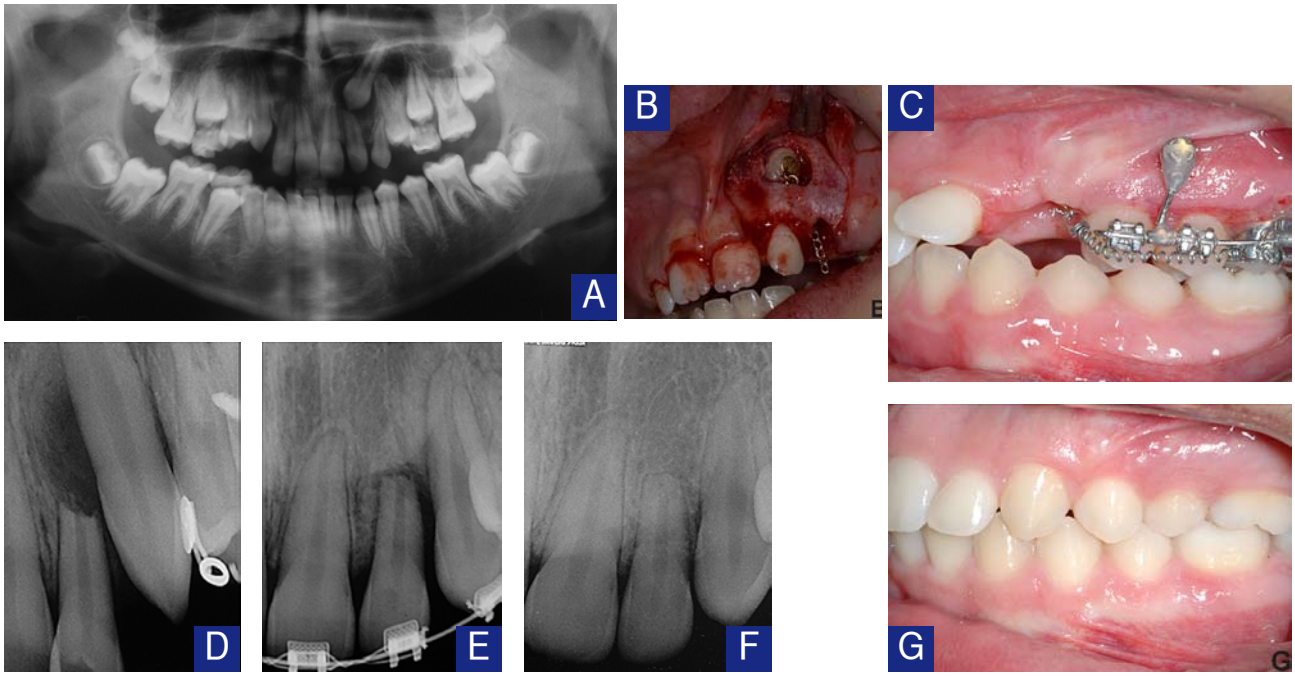

Fig 9. A, OPG of an 11½-year-old female patient with labial impaction of the upper left permanent canine; the resorption of the apical third of the root of the upper left permanent lateral incisor by the dental follicle of the proximal canine is seen. B, Closed surgical exposure procedure; C, The impacted upper left permanent canine was moved orthodontically with the use of skeletal anchorage devices. D and E, Periapical films during active orthodontic therapy showing the reduced bone support of the upper left permanent lateral incisor; F, The original severe root resorption of the lateral incisor did not deteriorate with the orthodontic treatment, and the incisor could remain in the mouth functioning satisfactorily and providing the most natural aesthetic appearance to the patient's anterior teeth. G, Occlusion 1½ years after the end of the active treatment.

of the canine impaction.

Another point to be noted is the increased percentage of the palatally impacted canines in comparison to that of the labially impacted canines as the patients' age advances. Because of that, it could be concluded, that a sufficient number of maxillary canines, which at a young age are labially impacted, will not stay in an infraosseous or submucosal position, but they will emerge into the oral cavity in the future. This happens because of the inherent ability of any tooth to erupt. The palatally dislocated canines do not have the same fate. First, the crown of these canines is very often squeezed against the roots of the upper incisors, and secondly, if the crown of one of those canines finds a path to erupt into the palate, it has to perforate the tenacious palatal mucosa.

The mesial-palatal drifting of the upper first or second premolar by itself or because of delayed shedding of the proximal deciduous maxillary molars as an etiological factor for the palatal impaction of the maxillary canine (3 cases in our study) has not been mentioned in the bibliography. The deviation of the roots of the first premolar (two cases) is mentioned by Chate16 as a possible factor causing palatal impaction of the canine. In this report, in the first case, which is presented by an orthopantomogram and an upper left occlusal radiograph, the mesial-palatal drifting of the upper left second premolar mentioned above in our study, is considered, in our opinion, to be a more probable cause for the palatal impaction of the upper left canine in comparison to the mild root deviation of the upper left first premolar, which is described as the probable cause by the author of this article. Because of that, the clinician must pay attention to all deciduous teeth and to refer the patient not only for the extraction of the deciduous canines a preventive and therapeutic means, especially for the cases of the palatally erupting canines, but in specific circumstances also for the extraction of deciduous molars, as this was already described.

We ascertained the favorable effect of the extraction of the deciduous canines on palatally erupting canines,[70,71] especially when this preventive and therapeutic means is performed in time, in a sufficient number of patients, which were excluded from our clinical study. At this point it is important to emphasize that the first regular appointment to the orthodontist, if there is not any apparent problem, must be at age 7 to 8, when an OPG is also desired.75 Then, the patient should come for an annual routine orthodontic inspection. The orthodontist must bear in mind the case of palatal canine impaction and the preventive means, which have already been described. We also disagree with the recommendation of Williams,[76] who suggests that extraction of the maxillary deciduous canine as early as 8 or 9 years of age will enhance the eruption and self-correction of a labial or intralveolar maxillary canine impaction. As mentioned above, in the cases of labial impaction, the lack of space was ascertained as the main etiological factor. In our opinion, the early extraction of the maxillary deciduous canine will result in a greater lack of space, which will deteriorate the labial impaction of the maxillary canine. Cases of maxillary premolar root resorption because an ectopically erupting canine have also been reported.[77]

Surgical exposure techniques - loss of lateral incisor

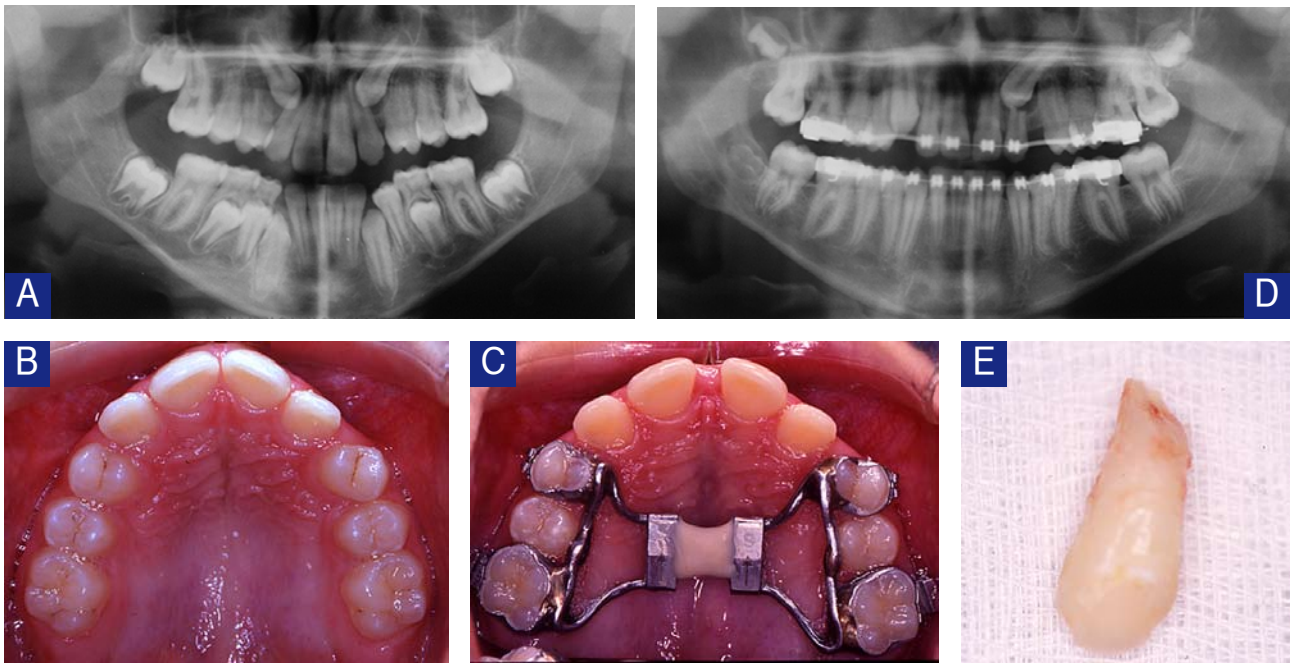

Fig 10. A, OPG of an 11½-year-old male patient with palatally impacted canines; B and C, Gaining space by means of RPE; D, Attachment of the upper lateral incisors to the fixed appliance when gaining space in the sagittal direction; note the severe root resorption of the upper left permanent lateral incisor. The uncooperative patient had not come to his follow-up appointments for over one year after the upper left lateral incisor had been attached to the fixed appliance. E, The lateral incisor with resorbed root after its extraction.

Of the studies mentioned, those of the Italian groups,34,48 which perform a closed surgical procedure (tunnel traction) with outstanding results, stand out.[48] The flap-incisions are performed with great respect for the marginal periodontium and the bone tissue. According to their technique, they perform neat flaps and remove a small amount of bone, which covers the crown of the impacted canine, sufficient only for the bonding of an attachment, which is connected with a metallic chain. In reality they do not expose the crown of the impacted canine in its biggest periphery, but just a small part of it. This technique, apart from using orthophosphoric acid, is the most tissue-respecting exposure technique. On the other hand, the criterion of the sample-selection on the panoramic radiograph (cusp of the impacted tooth more than 17 mm from occlusal plane) in the first study[34] or the use of the a-angle in the second one[48] do not constitute valuable criteria. The improper positioning of the patient's head especially in the horizontal and median-sagittal plane, during exposure for an OPG, may affect the angulations, as well as the linear measurements[28,29] to such a degree that it renders such measurements unreliable for the categorization of the impacted canine. Our method[28] can be used in both, the maxilla and the mandible, and its most important advantage is that it is virtually unaffected by the wrong positioning of the patient's head in the cephalostat during exposure, because it is based just on anatomical characteristics.

In an excellent article of Becker et al[81] the role of the impacted canine traction in two separate stages and in two directions is made very clear.

Another excellent article is that by Kokich.[40] The author describes in a mature and organized way the criteria for the proper surgical exposure technique that the clinician has to perform in labial, intraalveolar or palatal impaction. He gives great attention to the relation of the crown of the impacted canine to the periodontal tissues and to its accurate presurgical location. For the palatal impaction an open exposure technique is particularly recommended,[33,40] which is almost the same as the exposure technique performed by Dewel.[6] In this procedure a part of the full-thickness palatal flap over the impacted canine crown extending as far as the alveolar ridge is completely eliminated. In our opinion, the disadvantages of this technique are the discomfort for the patient and the side effect of possible postoperative bleeding (Fig 6), which nevertheless is rare.

Comparing the exposure techniques, the open and the closed, regarding the need for a second intervention, Pearson et al[82] found that the per centage of reexposure was double for the closed one (30.7% against 15.3% during treatment of 104 patients with palatally impacted canines). The open exposure technique of a palatally impacted canine presents the advantages of fewer reexposures,[82,83] shorter treatment time,[32,40] and improved hygiene during treatment.[45] Consequences for the adjacent teeth, particularly the lateral incisors, seem quite similar in both techniques, according to the study of Schmidt and Kokich.[45]

We began our surgical exposures influenced by the technique introduced by Professor Tränkmann.[84,85] Nevertheless, the rare, but possible side effect of the postoperative bleeding was the reason we began with the closed exposure technique described above. The frequent reexposure sessions, the uncontrolled direction of the orthodontic force, the side effects of the loss of 3 lateral incisors, the ankylosis cases, the 4 successfully treated ankylosed canines (after their open reexposure procedure)[28] and the aggression of the phosphoric acid on the sensitive and unprotected exposed tissues were the most important aspects which finally led us to the open exposure technique.[28]

The sutures, we have been using in recent years for the immobilization of the mucoperiosteal flap after an open exposure, are no longer the simple sutures presented in Figures 5 and 6, but vertical mattress sutures (Fig 8). The most important advantage of this suture is the proper apical immobilization of the flap, especially in the palatally impacted canines cases, which gives the uncovered canine the ability to erupt faster because of the elimination of the obstacle of the palatal mucosa and the attempt of the flap to "unfold" returning to its original position and taking with it the impacted tooth. Between 8 to 20 weeks after exposure, which mainly depends on the grade of impaction,[28] age of patient and hygiene particularly on the exposed tooth, the crown of the palatally impacted canine reaches 3 to 5 mm in length in the oral cavity. After that, an attaching device can be unimpeded and securely bonded onto its crown and the tooth can be moved to its proper position in the dental arch in the optimal direction. We do not wait for the complete eruption of the exposed tooth, to initiate its orthodontic traction, as other researchers,[86] who also use an open exposure technique, do.

Becker and Chaushu[87] note that "palatal canines that are severely vertically displaced in the height of the maxilla, above the incisor apices cannot be treated by an open exposure technique". According to our clinical research and experience we did not ascertain that this conviction is true in the GR VI[28] palatally impacted canines.

It is also of great importance for the lateral incisor to remain apart from the fixed appliance in the cases, in which the contact of the lateral incisor and the dental follicle of the impacted canine or its cusp is too close, because of the risk of further root resorption. Indeed, if the lateral incisor is free, it will be moved to another position in the alveolar ridge pushed by the emerging canine (Fig 9). The main role of the dental follicle is to create the path of tooth eruption,[78-80] destroying any obstacle met in its way. We must not forget the inherent ability of every tooth to erupt, to emerge into the oral cavity, to come into contact with an antagonist, to chew and to accomplish the aim for which it was created. Unfortunately, this is something which is not regarded as significant even by experienced clinicians.[87] In cases of palatal impaction, root resorption of the adjacent lateral incisor does not only occur when the impacted canine is orthodontically moved close to its root, but also in the first stage

("levelling and alignment of the teeth in the maxilla, followed by creating the space in the canine location") of the therapy of the impacted canine before its surgical intervention, as described by the Drs Becker and Chaushu in their treatment protocol.[87] During this stage, the incisors' roots could forcibly be moved against the coronal part of the impacted canine follicle, which could obviously create conditions for further root resorption of the incisors (Fig 10).

According to our clinical research and experience, the lateral or even the central incisor should be incorporated in the fixed appliances, only, when a sufficient part of the crown of the impacted canine is already exposed in the oral cavity. In adults, but in many cases even in adolescents, the open exposure of the palatally impacted canine is our first priority.

In our study, 3 lateral incisors were lost because of extensive root resorption. In one case, that of a 15-year old female patient there was a higher risk factor of root resorption because of "pointed"[88] and short roots at the onset of treatment. Nevertheless, critically thinking, the greatest cause of the loss of the lateral incisors was not the uncooperative patient and the "pointed", short root of the lateral incisor, but the very early fixation of this tooth to the orthodontic appli-

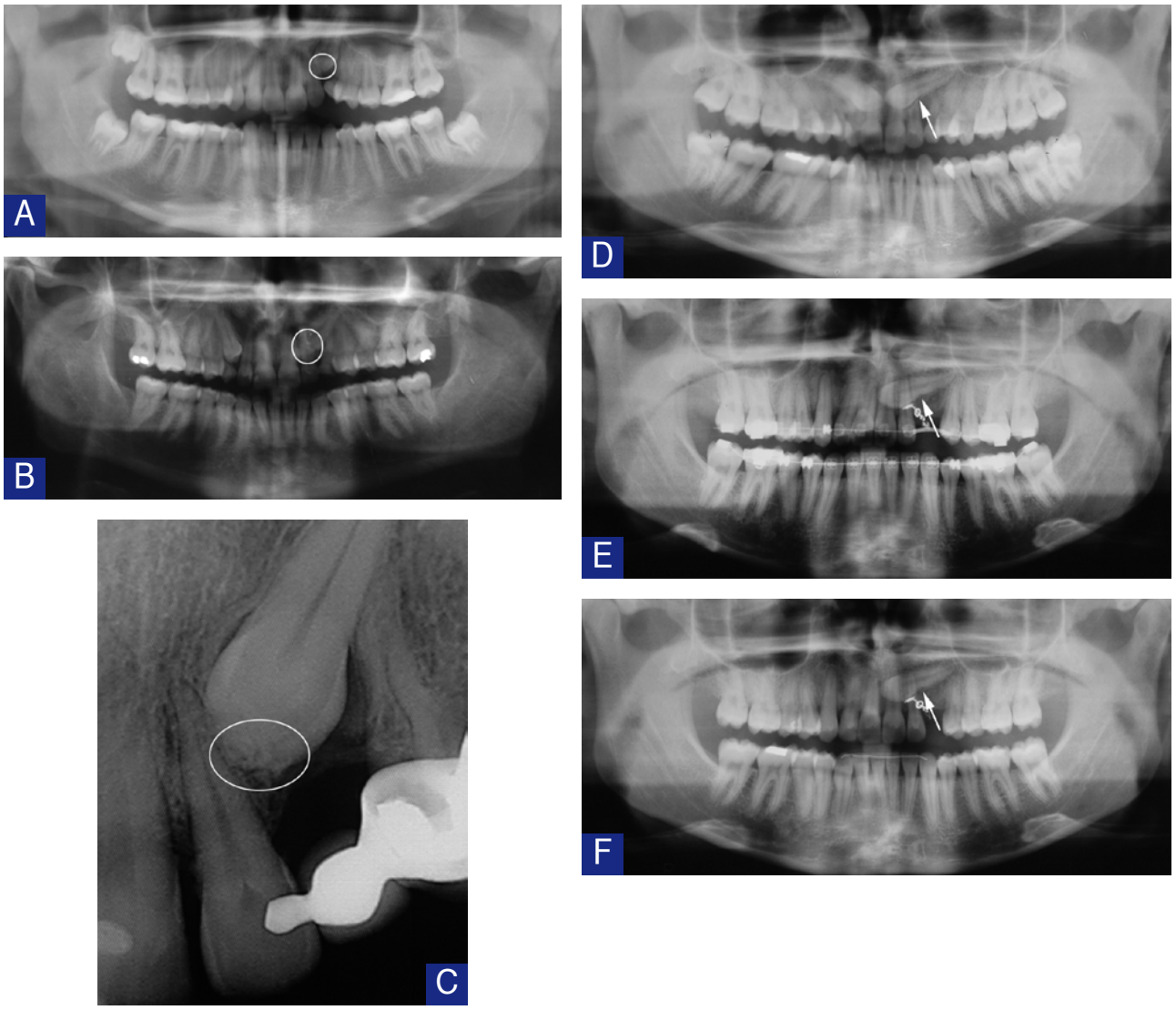

Fig 11. A, OPG of a 15-year-old female patient with an upper left canine palatally impacted and a priori ankylosed; note the ankylosis of the upper left deciduous canine and its effect on the region of the adjacent teeth (upper left permanent lateral incisor and upper left first premolar). B, OPG of a 42-year-old female patient with an upper left canine palatally impacted and a priori ankylosed; C, Periapical film of a 38½-year-old female patient with an upper left canine labially impacted and a priori ankylosed; all three x-rays in Figures A, B and C were taken before initiation of treatment. During therapy of the impacted canines an a priori ankylosis was ascertained in all of them. The white line demarcates the affected areas (external resorption of the canine crown). The discontinuation of the smooth contour of the impacted canine's crown is apparent. D, E and F, OPGs of a 21-year-old female patient with maxillary permanent canines palatally impacted; first OPG before initiation of treatment; Second OPG, two years later, after the upper right permanent canine had been moved into its proper position in the dental arch, while the upper left canine became ankylosed. Third OPG, 1½ years later (end of treatment); the ankylosis-related resorption (trauma-induced external root resorption in its cervical region) became more severe and the tooth was extracted. The arrows show the area of ARR.

ance. Our clinical experience suggests that the sequence of our treatment stages should be: first RPE, where it is necessary and feasible, Pendulum-type appliances, extraction of premolars, other alternatives or combination of these, then open exposure procedure of the impacted canines, and finally the attachment of the incisors to the fixed appliance to gain the rest of the necessary space. When the canine has erupted, there is also no case of improper directional orthodontic traction that drives the canine directly against the incisors' roots.

Among dentitional anomalies, tooth transposition is considered the most difficult to manage clinically.[26] In cases of transposition, if the orthodontic movement of the impacted canine into the dental arch to its original position is planned, the orthodontic/surgical intervention must be performed as early as possible, i.e. before the ectopic canine has erupted into the oral cavity in a transposed position in the dental arch, as it is then extremely difficult to move this tooth orthodontically to its proper position.

The study of D'Amico et al[39] initiates some arguments for discussion as regards its methodology and the early negative consideration of a possible outcome of treatment. In this study, from a total of 83 maxillary impacted canines, 8 canines were extracted (7 palatally and one labially impacted) at the onset of treatment in children, and in 16 more cases, lateral incisors were removed during the orthodontic treatment. "One of the main reasons for the extraction of the canine was, when there was a relatively small or no resorption on the lateral incisor and a bad position of the canine".[51] In the same study, a traditional closed surgical technique was performed for the exposure of the impacted canines. In our opinion, if in the first stages of therapy, an open exposure had been used by the authors, it would most probably not have been necessary to perform, in advance, any canine extraction, and most of the lateral incisors, which were extracted, could also have been saved. Often, teeth remain in the mouth with short resorbed and traumatized roots after a normally delivered orthodontic treatment, because of several risk factors,[88] or an idiopathic root resorption, or after an orthodontic treatment of an impacted canine,[72,89] or in cases of autotransplanted teeth,[90] etc. If the mouth hygiene of the patient is properly performed, these teeth will remain in the mouth perhaps for life. It is not advisable or ethically correct to prejudge the fate of these teeth and especially in the upper anterior region, where both the aesthetic aspect and the function play primary roles. The patient's own six anterior maxillary teeth provide the most natural aesthetic appearance.

Ankylosis

Even eminent researchers[87] on the issue of the impacted canine treatment are unaware of the existence of the different forms of ankylosis, which could affect the crown or the root of the impacted tooth and could lead to failure.[28] The external tooth resorption could affect the crown (a priori ankylosis – probably caused by the dental follicle of the impacted canine and because of its impaction and retention, or ankylosis-related resorption (ARR) during the closed orthodontic traction - probably as a result of chemical trauma to the enamel)[28] and the cervical part of the root of the impacted canine (trauma-induced tooth resorption or ICR, as a form of hyperplastic invasive tooth resorption).[28,91,92] Other causes of failure, which present similar symptoms to the ankylosis of the impacted tooth, could be the fibrous connective tissue (FCT),[28] which can fuse the bonded attachment and its threaded chain or the osseointegration of the wire chain,93 used for the orthodontic traction during a closed traction. In cases of external root resorption, external crown resorption (probably due to chemical trauma of the enamel), fibrous connective tissue, osseointegration of the wire chain and inappropriate direction of traction, there is movement of the impacted tooth between the start of traction and the diagnosis of ankylosis. This is not so in the a priori cases (a priori external crown resorption – Fig 11),[28] when, during exposure procedure, the affected area of the impacted canine's crown is not completely cured. 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 trauma[94] to the periodontal ligament from the 35% phosphoric acid, and (3) trauma to the periodontal ligament in the cervical region due to the direction and/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 the 3 cases of trauma-induced external root resorption in its cervical region (ARR) that we diagnosed, we noticed the same side effect of ankylosis some weeks later (Fig 11).

CONCLUSIONS

1. The characteristics of the anatomical structures of the lateral incisors (crown and root), microdontia and/or aplasia of these teeth, could be an important reason to refer the patient for an OPG in the mixed dentition stage, even if there is no other obvious sign or symptom to justify orthodontic treatment.
2. For the diagnosis of the accurate location of the impacted canine, we drew on all possible information provided by the study of OPG and lateral cephalogram as well as a careful clinical examination, before recommending additional diagnostic means, which expose the patient to unnecessary radiation and involve extra financial cost.
3. We refer the patient for extraction of deciduous canines or molars in time, when necessary, to prevent a possible palatal canine impaction.

4. Skeletal anchorage offers a stable solution to the problem of anchorage-loss during the orthodontic traction of the impacted canine and on the other hand, plays the role of the main determinant of the force vector during orthodontic traction.
5. Before attaching the incisors, and especially the lateral one, to the fixed appliance used for space-gaining, we must ensure that the cusp of the impacted canine is not in close contact with the roots of the incisors. Otherwise, an open surgical exposure of the impacted canine must be performed first.
6. In the transposition cases, very early intervention is needed before the canine has erupted in the transposed position in the dental arch or prior to any resorptive effect on the roots of adjacent teeth.
7. If a closed or open surgical technique has been performed and the impacted canine presents symptoms of ankylosis, the following procedures are suggested after study and reevaluation of the available x-rays and the reaction of the impacted canine to the orthodontic traction up to that point: (a) reexposure of the impacted canine, (b) removal of the bonded attachment (in closed technique) and the soft tissue around the crown of the canine (c) recontouring of the bone socket, in which the canine crown is accommodated (d) surgical luxation, only in cases of external cervical root resorption after treatment of the affected area (e) apically repositioned mucoperiosteal flap, as in the open exposure technique.
8. In all cases of palatally impacted canines, the open exposure technique performed at the appropriate time seems to offer concrete advantages, resulting in an optimal outcome and avoiding most of the possible causal factors of the main side effects of canine ankylosis and the loss of the lateral incisor.
9. If the proper uncovering technique is chosen for each case and skeletal anchorage during the canine traction is used, where necessary, ankylosis of the canine and severe root resorption of lateral incisors can be avoided, and the eruption process can be simplified, resulting in a predictable, stable, aesthetic and non-time-consuming outcome.

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