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Radiological determination of orthodontic traction prognosis of the maxillary canine impaction

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Radiological determination of orthodontic traction prognosis of the maxillary canine impaction

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ABSTRACT

Aims & Objectives: the objective of this study is to determine the precise radiological location of impacted maxillary canines, with two and three-dimensional technology, and to evaluate the prognosis of traction, based on predefined measurements. This literature review has as its main objective to serve as a clinical guideline, using panoramic radiography, postero-anterior radiography, computed tomography (CT) and the latest technology, such as cone-beam computed tomography (CBCT), to precisely diagnose location of the maxillary canine impaction as well as possible sequelae, as is the case of dental root resorption of adjacent teeth.

Materials & Methods: the theoretical basis of this thesis was based on The PUBMED, SCIENCE DIRECT, COCHRANE DATABASE OF SYSTEMATIC REVIEWS and Library of the Faculty of Medicine of Porto (FMUP). We obtained 96 articles, from which we selected 73, from 1st September 2018 to 1st June 2019. The images used in this work were selected namely from books of radiology and original images of orthodontic cases on the scope of the Master´s degree of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of Oporto University. The keywords used were: *impacted maxillary canine*, *palatally impacted maxillary canine*, *cone beam computed tomography* and *dental anomalies*.

Results & Discussion: the ectopic eruption and impaction of permanent maxillary canines is a frequently encountered clinical problem. Diagnosis is usually based on both clinical and radiographic examinations. Conventional two-dimensional radiographic imaging is the most common modality used clinically as the primary diagnostic radiograph for the location of impacted canines, treatment planning, and evaluation of the treatment result. Panoramic radiography is a standard diagnostic tool in orthodontics for the pre-operative diagnosis of routine cases. The development of cone beam computed tomography for use in dentistry has, to a large degree, removed significant barriers. This technology allows patient's study in three orthogonal planes (sagittal, coronal and axial), improving diagnosis, treatment planning and management not only in orthodontics but in several dentistry areas. The labio-palatal location of the crown and the apex revealed significantly larger labial position with the three-dimensional method and significantly more root resorption was found in CBCT images.

Conclusion: dental impaction of permanent maxillary canines constitutes a quite common problem in the area of orthodontics', clinical practice. It is important to find a correct clinical and radiographic diagnosis for a more adequate orthodontic treatment planning in each case. The panoramic radiography is considered the adequate exam due to its easy interpretation, low cost and low effective radiation. It has the disadvantage of being a two-

dimensional exam, not giving information about the three-dimensional position of the impacted tooth. The CT or CBCT technology provides important additional information such as the labiopalatal position of the tooth and possible root resorptions of the adjacent teeth. According to the studies presented, the CBCT improved detection of resorptions in 50%, when compared with panoramic radiography. When compared to panoramic radiography and CBCT technology, the differences between the two exams are related with the mesiodistal apex position, the labiopalatal cusp position and the assessment of root resorptions in the adjacent teeth.

RESUMO

Objetivo: o objetivo deste estudo é determinar a localização radiológica precisa de caninos permanentes maxilares inclusos com a tecnologia bidimensional e tridimensional e avaliar com bases em medidas pré-definidas o seu prognóstico de tração. Este trabalho de revisão da literatura tem como principal objetivo servir como uma diretriz clínica, usando desde a ortopantomografia, a radiografia postero-anterior, a tomografia computorizada e a mais recente tecnologia, como é o caso do cone-beam computed tomography, para o diagnóstico mais preciso da localização do canino maxilar incluso como possíveis sequelas, como é o caso da reabsorção radicular dentária de dentes adjacentes.

Materiais & Métodos: a base teórica desta dissertação baseou-se na base de dados PUBMED, SCIENCE DIRECT, COCHRANE DATABASE OF SYSTEMATIC REVIEWS e na Biblioteca da Faculdade de Medicina da Universidade do Porto (FMUP). Obteve-se 96 artigos, dos quais foram selecionados 73, de 1 de setembro de 2018 a 1 de junho de 2019. As imagens utilizadas neste trabalho foram selecionadas a partir de livros da especialidade, nomeadamente livros de radiologia e imagens originais de casos ortodônticos do âmbito da consulta de Ortodontia do Mestrado Grau de Cirurgia Ortognática e Ortodontia da Faculdade de Medicina da Universidade do Porto. As palavras-chave utilizadas foram: *impacted maxillary canine*, *palatally impacted maxillary canine*, *cone beam computed tomography* and *dental anomalies*.

Resultados & Discussão: a erupção ectópica e a inclusão de caninos maxilares permanentes é um problema clínico frequentemente encontrado. O diagnóstico é geralmente baseado em exames clínicos e radiográficos. A imagem radiográfica convencional bidimensional é a modalidade mais frequentemente utilizada clinicamente como meio de diagnóstico para a localização dos caninos inclusos, para o planeamento do tratamento e a avaliação do resultado do tratamento. A radiografia panorâmica é uma ferramenta-padrão em ortodontia para o diagnóstico pré-operatório de casos de rotina. O desenvolvimento da tomografia tridimensional para uso em medicina dentária, em grande medida, removeu barreiras significativas no diagnóstico e prognóstico da tração ortodôntica. Esta tecnologia permite o estudo do paciente em três planos ortogonais (sagital, coronal e axial). A localização labio-palatina da coroa e do ápice do canino, bem como as reabsorções radiculares que na radiografia panorâmica não eram percetíveis, são a grande vantagem deste meio de diagnóstico.

Conclusão: a inclusão dentária dos caninos superiores permanentes constitui uma problemática na área da Ortodontia, bastante comum na prática clínica. É importante realizar um diagnóstico clínico e radiográfico minucioso para o planeamento do tratamento

ortodôntico mais adequado em cada caso. A radiografia panorâmica é o exame de eleição devido à sua fácil interpretação, baixo custo e baixa radiação efetiva. Tem como desvantagem ser um exame bidimensional, não fornecendo informações tridimensionais da posição do dente incluso. A tomografia computorizada e a CBCT fornecem informações adicionais importantes, como a posição labio-palatina do dente e possíveis reabsorções radiculares dos dentes adjacentes. De acordo com os estudos apresentados, o uso do CBCT melhorou a deteção de reabsorções em 50%, quando comparada à radiografia panorâmica. Quando comparadas à radiografia panorâmica e à tecnologia CBCT, as principais diferenças entre os dois exames estão relacionadas com a posição do ápice mesio-distal, a posição da cúspide labio-palatina e a avaliação das reabsorções radiculares aos dentes adjacentes.

ABBREVIATIONS AND ACRONYMS

In order to facilitate the reading of the text, the abbreviations used are explained below.

ALARA As Low As Reasonably Achievable

CBCT Cone Beam Computed Tomography

CT Computed Tomography

DPT Dental Panoramic Tomography

MSX1 *Muscle Segment homeobox 1*

PAX9 *Paired axial 9*

2D Two - dimensional

3D Three - dimensional

FMUP Faculdade de Medicina da Universidade do Porto

PA Posteroanterior

INDEX OF FIGURES

TABLE INDEX

INDEX

I- INTRODUCTION

The ectopic eruption and impaction of permanent maxillary canines is a frequently encountered clinical problem[1, 2]. Maxillary canines are the most commonly impacted teeth after the third molars, with a prevalence ranging from approximately 1% to 3% [3-6].

Impaction is defined by the lack of eruption of a tooth into the proper position in the dental arch within the time and physiological limits of the normal eruption process [7, 8]. A canine is defined as impacted if it was unerupted after complete root development, or if the contralateral tooth was erupted for at least six months within complete root formation [9]. Palate impacted canines very seldom erupt spontaneously. Buccally unerupted canines sometimes are orthodontically treated after the age of 13, but in most cases these procedures are performed on younger patients. It is difficult to verify that those labially unerupted teeth could not erupt spontaneously in a labial ectopic position. The limit between labial impaction and labial ectopic eruption is not determined. For this purpose, it would be prudent to distinguish between labial unerupted and palate impacted canines [10] .

The long developmental path of the maxillary canine was described by *Moyers et al*. in 1976, as “The maxillary cuspid follows a more difficult and tortuous path of eruption than any other tooth. At age of 3 it is high in the maxilla, with its crowns directed mesially and somewhat lingually. It moves towards the occlusal plane, gradually uprighting itself until it seems to strike the distal aspect of the root of the lateral incisor. It then seems to be to a more vertical position; however, it often erupts into the oral cavity with a marked mesial inclination” [11, 12] .

According to *The French Society of Stomatology, Maxillofacial Surgery and Oral Surgery* (2015), an impacted canine is defined as a "retained tooth in the maxillary or mandibular arch beyond the date of eruption, surrounded by its peri-coronary sac and without communication with the oral cavity”. An ectopic canine is an immature canine not present on the arcade at the age when it should have erupted, and can be included by having completed its root edification. Dental impaction can be described as a simple delay or stop of a tooth eruption at the level of the dental arch during the standard period of growth. It can also be in general described as a failure of the spontaneous rash with bone inclusion of the tooth whose eruption is stopped by local mechanical obstruction or by the position of adjacent teeth. Sometimes, the tooth loses its eruptive potential even in the absence of physical obstacle: it is the so-called "primary" inclusion as opposed to "secondary" inclusion linked to an obstacle [13] .

The diagnosis and treatment of this problem usually requires the expertise and cooperation of the general dentist, the pediatric dentist, the oral surgeon, and the periodontist, as well as the orthodontist [8, 11, 12, 14] .

I.i - Epidemiology

Ericson and Kurol (1986) estimated the incidence of impaction of permanent maxillary canines of the orthodontic population at 1-2%. With respect to gender, impactions are twice as common in females (1.17%) as in males (0.51%) [2, 9, 15]. One of the hypotheses for this discrepancy is that the left palatal blade, especially in females, takes longer to reach the midline, during the formation of the fetus. Of all the patients with maxillary impacted canine diagnosis, it is estimated that 8% have bilateral impactions, and approximately one-third of impacted maxillary canines are located labially, and two-thirds are located palatal and unilaterally (92%). The incidence of mandibular canines impacted is only of 0.35%, much less frequent than maxillary impactions [2, 11, 15-18].

According to the *Jacoby's* study (1983), 85% of palatally impacted canines had sufficient space for the eruption in the dental arch, while 83% of labially unerupted canines had not sufficient space for the eruption in the dental arch. This study shows that, in most cases, it is not the lack of space in the dental arch that determines the non-eruption of the permanent canine [10] .

I.ii – Etiology

The etiology of impacted canines is unclear and seems to be multifactorial. Primary etiological causes include space deficiency, disturbances in tooth eruption sequence, trauma, retention of primary canine, premature root closure, rotation of buds, as well as localized pathological lesions [11, 12, 18].

Moyers in 1963 study, described the general etiology of the impacted teeth:" Although there are hereditary patterns leading to impacted teeth, the etiologic factors of most concern are prolonged retention of primary teeth, localized pathologic lesions and shortening of the arch-length. This tooth (the maxillary cuspid) may be simply impacted, as sometimes happens when the primary cuspid fails to resorb, or it may be impacted ectopically" [10, 12].

Two main theories have been proposed to explain the occurrence of palatally displaced maxillary canines: the "guidance theory" and the "genetic theory" [12, 16, 18-20] . The "guidance theory", reported by *Becker et al.* in 1981, proposes that the distal aspect of the lateral incisor is the guidance for canine eruption. It was found that palatally impacted canines were very closely associated with spaced dentitions and lateral incisors that are peg-shaped, of small mesiodistal width or congenitally absent [19]. Nearly half of the cases of

palatal impactions that were examined were associated with anomalous lateral incisor. The nonexistence of maxillary lateral incisor and variation in the root size of the tooth, as well as - the variation in the timing of its root formation, have been implicated as important etiologic factors associated with canine impaction. It seems that the presence of the lateral incisor root with the right length, formed at the right time, is an important variable demanded to guide the mesially erupting canine in a more favorable distal and incisal direction [10, 19, 21, 22].

The “genetic theory” designates the anomalous eruption of the permanent maxillary canine as a result of a developmental disorder of the dental lamina. This theory shows multiple evidential categories for the genetic origin of palatally impacted canines, such as familial and bilateral occurrence and sex differences. Other relevant reciprocal dental associations such as the ectopic eruption of first molars, infraocclusion of primary molars, aplasia of premolars and the one third molar, can be associated with an anomalous eruption. *Baccetti* (1988)[23] perceived a relationship between canine impaction and other dental anomalies. The author also stated that transcription factors such as MSX1 “the MSX1 gene have a role for making a protein that regulates the activity of other gene”. It is considered that a deletion of the MSX1 gene disrupts the development of oral structures in an early stage, leading to missing teeth and other dental abnormalities. A loss of the MSX1 gene might cause an opening in the roof of the mouth (cleft palate) and/or a split in the upper lip (cleft lip). The author also refers the PAX9 gene, present a significant role during the fetal development (this gene is a member of the paired box (PAX) family of transcription factors). Members of this gene family typically contain a paired box domain, an octapeptide, and a paired-type homeodomain. Mice lacking this gene exhibit impaired development of organs, musculature and the skeleton, including absent and abnormally developed teeth, and neonatal lethality. Mutations in the human gene, associated with selective tooth agenesis, may have a role in palatal canine displacement [23-26].

Other factors documented in the multifactorial etiology for impacted canines involve: (a) the presence of supernumeraries; (b) tooth sizes-arch length discrepancies; (c) odontomas; (d) pathological lesions, eg cysts or neoplastic lesions;(e) delayed exfoliation of the deciduous canine (although this is thought to be an indicator rather than a cause of displacement); (f) early trauma to the maxilla; (g) cleft lip and palate; (h) ankyloses; displacement of crypt; (i) long path of eruption; (j) presence of specific syndromes, e.g. cleidocranial dysplasia and (k) idiopathic conditions with unknown etiology. This multifactorial etiology may justify why canine impactions occur when other dental relationships are normal, or in circumstances in which lateral incisors are congenitally

missing when more than sufficient space is available for eruption of the impacted tooth [11, 16, 18, 23, 26-28].

A case of the Master of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of the University of Oporto (FMUP). A male patient at the age of 13, with the tooth 13 and 14 impacted, due to the existence of an odontoma. It was removed as well as that of the tooth 14. The traction of the13 was performed.

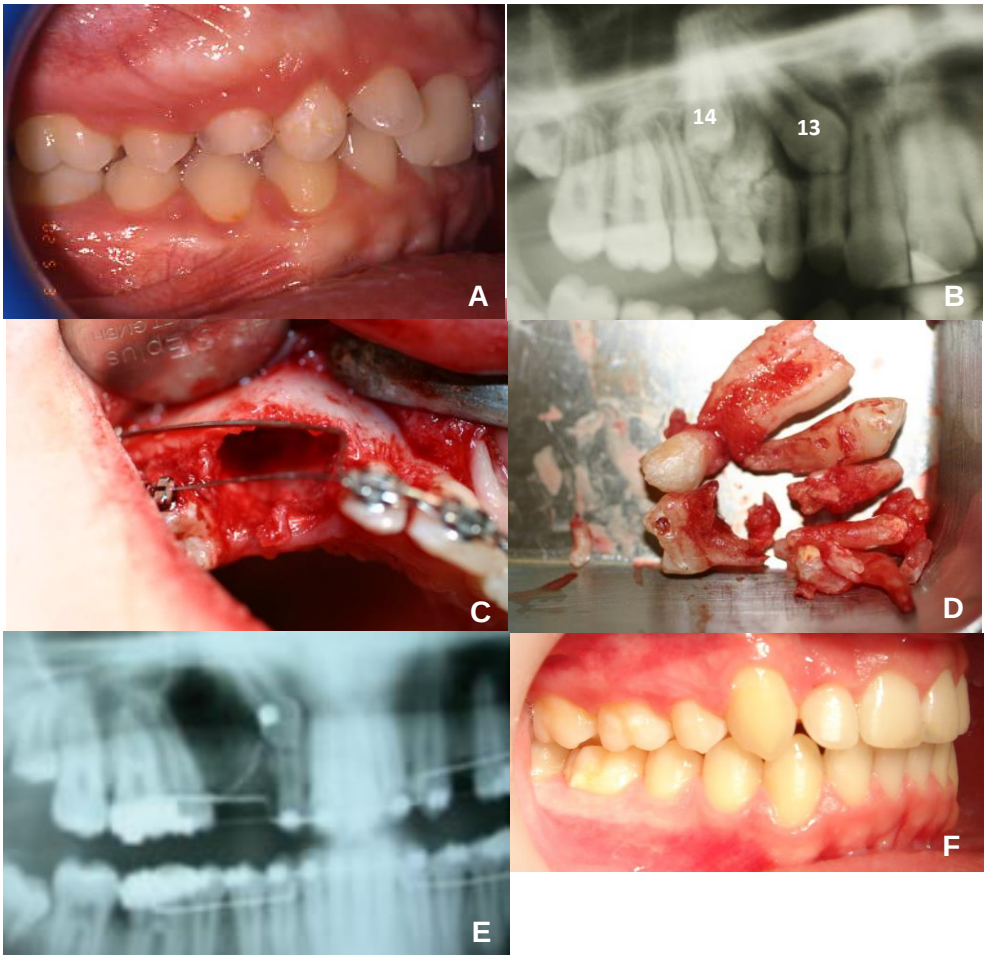

Figure 1: A male patient of FMUP with 13 impacted and odontoma. A) Right intra-oral view; B) Radiographic view, where are visible the odontoma, 14 and 13 impacted; C) and D) removal surgery of odontoma and the teeth 14; F) traction of the teeth 13 and F) final result of the treatment.

I.iii - Sequelae of maxillary canine impaction

Impacted canines usually are asymptomatic for the patient. Consequently, a patient usually is unaware of the occurrence of impacted canines. General dentists and orthodontists find most of these impacted teeth during initial radiographic examinations[29]. Potential sequelae of impacted canines include (a) cyst formation, (b) internal resorption of the impacted tooth, (c) external resorption of impacted adjacent teeth, (d) ankyloses, (e) infection and (f) migration of the neighbouring teeth with loss of arch length. Resorption and

its pathology are more apparent in females older than 14 years, and in cases where the angulation of the canine to the midline is of more than 25º [11, 26, 28, 30].

The reported incidence of resorption depends upon the imaging technique applied in the radiographic diagnosis. A common problem in orthodontics is the miscalculation of the extent of resorption associated with unerupted teeth, especially in maxillary canines. Resorption is not always identified on plain radiographs due to superimposition of the incisor roots and the crown of the impacted canine's obscuring morphology. Cone Beam Computed Tomography (CBCT) decreases potential difficulties with magnification and superimposition, which make diagnosis and location with conventional radiography challenging [8, 11, 14, 26, 28, 31].

I.iv - Diagnosis and location of impacted canines

Diagnosis is usually based on both clinical and radiographic examinations. The location of impacted teeth is important to assess the need of surgical or orthodontic approach. The precise determination of the relation of the impacted tooth to the adjacent teeth and relevant structures is imperative to be avoided during treatment [11].

1. **Clinical.** Any one or a combination of the following signs may be present: a) delayed eruption at least one of the permanent canines after 14 years of age; b) prolonged retention of a primary canine; c) elevation of the soft tissue of the palatal or labial mucosa (depending on the canine location); d) distal migration of the lateral incisors with or without a midline shift; e) absence of a normal labial canine bulge, in other words, either inability to locate canine position through intraoral palpation of the alveolar process or the presence of an asymmetry in the canine bulge [11, 32].

   According to *Ericson and Kurol* (1986), the absence of the "canine bulge" at earlier ages should not be considered as indicative of canine impaction. In their evaluation of 505 schoolchildren between 10 and 12 years of age, they found that 29% of the children had nonpalpable canines at the age of 10, but only 5% at 11 years, whereas at later ages only 3% had nonpalpable canines. Therefore, for an accurate diagnosis, clinical examination should be supplemented with a radiographic evaluation [11, 15].

   If disturbances in the eruption are clinically suspected, the assistant dental practitioner must perform a radiographic examination on the patient. A radiographic examination is indicated in the canine region if: a) asymmetry is present between the right and left sides, concerning the possibility of palpating the canines buccally, or if there is any other marked difference in eruption between the two sides; b) the canines are not palpable in their normal sites on dental arch in spite of advanced general

occlusal development and root formation; c) the maxillary lateral incisor was late erupted or proinclined [1].

2. **Radiographic evaluation.** Several radiographic exposures, including occlusal films, panoramic views, and lateral cephalograms, can help in evaluating the position of the canines. Radiographic examination is performed stepwise as follows:
    - When disturbances in eruption are suspected, an indispensable examination is made comprising two or three intraoral periapical films of each canine. Periapical films are supplemented with a vertex axial projection with the x-rays parallel to the roots of the central incisors of the region. Further, an orthopantomogram of the jaws is used to present a survey of the dental situation in the jaws. Lateral head films are used in those cases needing extensive orthodontic treatment [1, 14].

    2.1 Periapical films. A single periapical film (figure 2)[33] provides the clinician with a two-dimensional representation of the dentition, relating the canine to the neighboring teeth both mesiodistally and superoinferiorly. Until recently, conventional two-dimensional (2D) radiographic imaging was the most common modality used clinically as the primary radiographic diagnosis for the location of impacted canines, treatment planning, and evaluation of the treatment result [11, 32, 34].

Figure 2: Periapical radiography shows the impacted canine, located near to the roots of the lateral incisor and the first premolar [33].

2.1.1 The Tube-shift technique: The examination to locate the position of an impacted canine usually involves taking two different radiographs and using the principle of parallax. The shift in the tube head position can either be in the horizontal plane or the vertical plane. Some studies have shown that the horizontal parallax technique is more reliable than vertical parallax in what concerns locating unerupted canines. The basic principle of this technique deals with the foreshortening and

elongation of the film images [11, 32, 35, 36]. Charles Clark introduced the Clark´s rule in 1910 [37]. Two periapical films are taken of the same area, with the horizontal angulation of the cone changed when the second film is taken, with the same vertical angulation. If the tooth in question moves in the same direction as the tube head, it is lingually positioned. If its moves in the opposite direction, it is situated close to the source of radiation and therefore is buccally located. [11, 32, 38, 39].

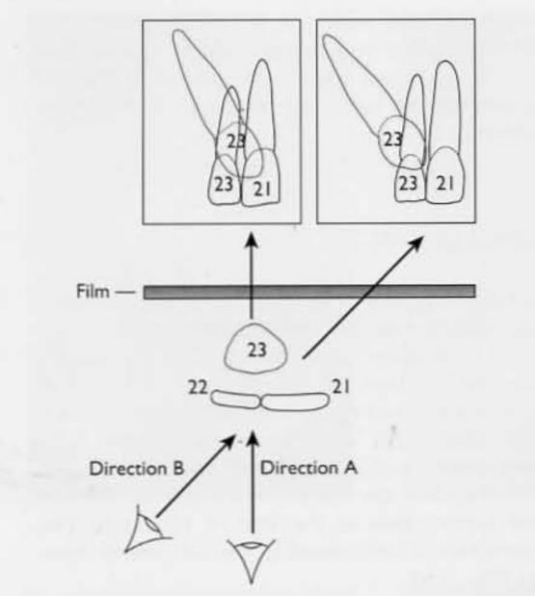

Figure 3: A diagrammatic representation of the tube-shift technique adapted by Becker (1998) [39].

2.1.3 Occlusal films: these films (figure 4)[33] also help to determinate the buccolingual position of the impacted canine in conjunction with periapical films, provided that the image of the impacted canine is not superimposed on the other teeth [11, 32].

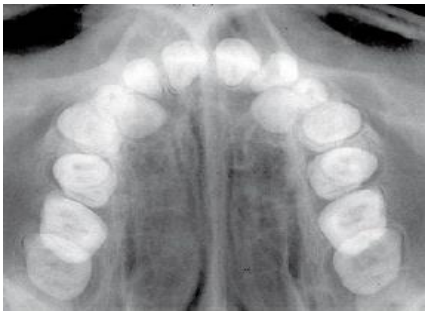

Figure 4: Occlusal view (vertex) shows that the maxillary canine is located near to the lateral incisor and first premolar roots [33].

2.2 Extraoral films: frontal and lateral cephalograms can seldom be of aid in determining the position of impacted canines, particularly concerning other facial structures, especially the maxillary sinus and the floor of the nose. Dental Panoramic radiography (DPT) is a standard diagnostic auxiliary in orthodontics for the pre-operative diagnosis of routine cases, as shown in figure 5 [11, 32].

Figure 5: Two-dimensional panoramic radiograph of a 28-year-old male, patient of Master Course in Orthognathic Surgery and Orthodontics at the Faculty of Medicine of the Oporto University, with an impacted maxillary right canine with no sign of resorption of the right maxillary lateral incisor. The deciduous canine teeth still in the dental arch.

2.2.1 Computed Tomographic (CT): corrected treatment planning requires accurate diagnosis and location of the impacted canine on adjacent structures. Assessing root reabsorption and changes in root surface morphology usually require three-dimensional (3D) information. Many authors have therefore recommended the use of CT in such cases, since it overcomes the limitations of conventional radiography and increases the detection rate of root reabsorption by 50 per cent [3, 4, 6, 34]. CT technology is not a routinely accepted as a diagnostic modality for impacted cupids due to concerns regarding radiation dose, cost, and availability [3, 6, 34, 40, 41].

2.2.2 Cone Beam Computed Tomographic (CBCT): in comparison to panoramic radiographs, CBCT manages to get an improved location of impacted teeth, recognizes relevant structural oral pathology, and has a high capability and reliability in detecting root reabsorption by reducing the overlap of dental structures. Besides, CBCT has lowered the cost and radiation dose compared with CT, by reducing the cone shaped X-ray beam, the scanner size, and the scanning time [8, 16, 34, 42]. According to the ALARA (As Low As Reasonably Achievable) principles and

Sedentex CT guidelines, that CBCT scan should not be used indiscriminately; however, it might be used in selected orthodontic cases in which conventional radiographs cannot provide satisfactory diagnostic information [16, 34, 43, 44].

Radiographic examination	Effective radiation dose (µSv)	Equivalent background radiation (days)	Risk of fatal cancer (per million)
DPT	3-38	0.5-5	0.2-1-9
Cephalometric lateral skull	2-5.6	0.3-0.45	0.34
Upper standard occlusal	8	1.2	0.4
Bitewing/periapical	0.3-2.2	0.15-0.27	0.02-0.6
Conventional CT scan (maxilla)	100-3000	15-455	8-242
Conventional CT scan (mandible)	350-1200	53-182	18-88
Chest	14	3	2
CBCT (small volume)[a]	10-67	4-10	
CBCT (large volume)[a]	30-1100	10-42	

Table 1: Radiographs used in orthodontics and equivalence[45]. Values are based upon Radiation Protection 136, (2004). European Guidelines on Radiation Protection in Dental Radiology. The Safe Use of Radiographs in Dental Practice European Commission. It should be emphasized that these only represent a guide and are regularly updated as new recommendations are made, particularly with regard to tissue weighting factors in the calculation of effective doses. CBCT, cone-beam CT; CT, computerized tomography; DPT, dental panoramic tomography [44, 45] a) Cone-beam CT data is based upon Pauwels *et al.*(2012) [46].

The dental practitioner is responsible for justifying the exposure of patient to ionizing radiation, and this should be based upon a defined clinical need. Each view carries an estimated effective dose of radiation, as can be seen in the table1. The fundamental principle, however, is that radiographs should be taken when clinically indicated [45].

I.v - Treatment

The radiographic examination should be carried out initially to confirm the position of the unerupted canine. Patient and parent counselling on the various options is essential [11, 32, 35, 47].

1. **Interceptive treatment by extraction of the primary canine.** In particularly selected cases, where the ectopic permanent canine is not severely displaced, there is some evidence that interceptive extraction of the adjacent primary canine can result in an improvement in the position of an ectopic permanent canine.
    - The patient should be aged between 10-13, with better results reported in the absence of crowding.

- The need to space maintain, or even create additional space, requires consideration.
- If radiographic exanimation reveals no improvement in the ectopic canine position 12 months after extraction of the primary canine, alternative treatment options should be considered [17, 47-49].

2. Surgical exposure and orthodontic alignment.

- The case is not considered to be suitable for interceptive extraction of the primary canine.
- The patient should be willing to wear fixed orthodontic appliances, motivated and have adequate dental hygiene.
- The degree of malposition of the ectopic canine should not be so great that orthodontic alignment becomes impractical (e.g. close proximity to the midline, above the apices of the adjacent teeth, horizontal angulation).
- The likelihood of success decreases with age in adults [11, 50, 51].

3. Surgical removal of the palatally ectopic permanent canine.

- This treatment option should be considered if the patient declines active treatment and is satisfied with their dental appearance.
- Surgical removal of the ectopic canine should be considered if there is radiographic evidence of early root resorption of the adjacent incisor teeth (but exposure and alignment of the ectopic canine are usually indicated in cases where severe root resorption of an incisor tooth has occurred necessitating the extraction of the incisor).
- The best results are achieved if there is good contact between the lateral incisor and first premolar or the patient is willing to undergo orthodontic treatment to replace the first premolar for the canine.
- The possible risk of damaging the roots or the neurovascular supply of adjacent teeth during the act of surgical removing the impacted canine should be assessed and discussed with the patient [1, 11, 32, 35].

4. Transplantation.

- Transplantation is not normally considered unless other possible active (or interceptive) treatment has failed or is felt to be inappropriate.

- This treatment option can be considered if the patient is unwilling to wear orthodontic appliances or the degree of malposition is too great for orthodontic alignment to be practical.
- There prognosis should be good for the canine tooth to be transplanted with no evidence of ankylosis. The best results are achieved if the ectopic canine can be removed with minimal trauma and before closure of the apex.
- Depending on the stage of root formation (i.e. > ¾ root formed), the transplanted canine may require root canal therapy to be commenced within 10 days following transplantation [22, 32, 52, 53].

5. No active treatment/leave and observe.

- The patient does not want treatment or is happy with their dental appearance.
- There should be no evidence of root resorption of adjacent teeth or other pathology.
- Ideally, there should be good contact between the lateral incisor and first premolar or the primary canine should have a good prognosis.
- Severely displaced palatally ectopic canines with no evidence of pathology may be left *in-situ*, particularly if the canine is remote from the dentition. If the ectopic canine is left *in-situ*, then, as with any unerupted tooth, the practitioner providing continuing care for the patient should carry out a careful clinical examination of the patient on a regular basis to ensure the unerupted canine does not represent a risk to the patient's well-being. No guidance currently exists as to how frequently radiographic checks should be carried out [22, 32, 35].

I.vi- Objective

The objective of this review is to determine the location of impacted maxillary canines radiologically with the 2D and 3D technology and to evaluate the prognosis of traction. Furthermore, this literature review has as main objective to serve as a clinical guideline, using panoramic radiography, postero-anterior radiography, computed tomography (CT) and the latest technology, such as cone-beam computed tomography (CBCT), to diagnose a more precise location of maxillary canine impaction as well as possible sequelae, as is the case of dental root resorption of adjacent teeth.

The introduction of 3D technology as the cone beam computed tomography makes the diagnosis of possible sequelae of impaction cleat, such as the resorption of adjacent teeth, in particular the maxillary lateral incisor.

II- MATERIAL AND METHODS

The theoretical basis of this thesis was based on The PUBMED, SCIENCE DIRECT, COCHRANE DATABASE OF SYSTEMATIC REVIEWS and Library of the Faculty of Medicine of Oporto (FMUP). We obtained 96 articles, from which we selected 73, from 1st September 2018 to 1st June 2019, having the title, the abstract, the clinical studies, diagnosis prediction explanation and originality and scientific contribution on maxillary canines as criteria, excluding all the articles that did not correspond in their entirety to the inclusion criteria. The articles used in this work were written in English and French, and also book in Portuguese language was used. The images used in this work were selected namely from books of radiology and original images of orthodontic cases on the scope of the Master´s degree of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of Oporto University. All the documentation of clinical cases exposed in this study had informed consent of the patients, or their legal representatives in the case of being minors, for the dissemination of photographs and radiographs made in the Stomatology Service of the Hospital Center of São João, Oporto, in the context of Orthodontics and Orthognathic Surgery. The keywords used were: *impacted maxillary canine*, *palatally impacted maxillary canine*, *cone beam computed tomography* and *dental anomalies*.

III- RESULTS/ DISCUSSION

The conventional 2D radiographic imaging is the most clinically used modality as the primary diagnostic radiograph for the location of impacted canines, treatment planning, and evaluation of the treatment result [34]. Panoramic radiography is a standard diagnostic tool in orthodontics for the pre-operative diagnosis of routine cases. The diagnostic precision and efficacy for locating impacted canines and adjacent structures can be underrated due to insufficiencies, such as distortion projection errors, blurred images, and complex maxillofacial structures that are projected into a 2D plane, thus increasing the risk of misinterpretation [14, 34, 54].

Proper treatment planning demands accurate diagnosis and location of impacted canine concerning adjacent structures [3, 4, 6, 34]. CBCT solves this problem, improving detection of reabsorption by 50%, eliminating potential difficulties with magnification and superimposition, which makes interpretation and location with conventional radiography challenging [28, 55] .

Becker et al. (2010) study described the reasons for failure of orthodontic treatment for impacted maxillary canines, besides the 2D and 3D radiological diagnosis. The reasons for failure must consider many factors, which can be roughly divided into 3 groups, as follow:

1. Patient- dependent factors: abnormal morphology of the impacted tooth, age, pathology of the impacted, grossly ectopic tooth, resorption of the root of an adjacent tooth, and lack of compliance (eg. missed appointments, inadequate oral hygiene).
2. Orthodontist-dependent factors: mistaken positional diagnosis and inappropriate directional force, missed diagnosis of resorption of the root of an adjacent tooth, poor anchorage, inefficient appliance, and inadequate torque.
3. Surgeon-dependent factors: mistaken positional diagnosis, exposure on the wrong side, or rummaging exposure; injury to the impacted tooth; injury to an adjacent tooth; soft-tissue damage; and surgery without orthodontic planning.

The results of this study concluded that failure in this type of treatment is too frequent due to inappropriate positional diagnosis. What happens is, that traction will be applied in the wrong direction; ankylosis might have afflicted the impacted tooth either a priori or as the result of the earlier surgical or orthodontic maneuvers and a lack of appreciation of the considerable anchorage requirements of the case [56] .

III.i- 2D Radiographic Evaluation and Prevention of Impaction (Interceptive treatment)

If canine impaction is recognized, extraction of the maxillary deciduous canine may, in some cases, allow the impacted canine to erupt in the correct position[47]. The extraction of a deciduous canine, in the late mixed dentition stage, as an interceptive treatment to prevent canine impaction has been supported based on the hypothesis that the persistence of the primary tooth would represent a mechanical obstacle for the emergence of the permanent tooth [57]. In Class I non-crowded cases, where the permanent maxillary canine is impacted or erupting buccally or palatally, the preventive approach of choice is the extraction of the deciduous canine, in what concerns patients from 10-13 years old [47].

Ericson et Kurol (1988) examined the effect of extraction of the deciduous canine on 46 palatally erupting ectopic maxillary canines in 35 individuals aged 10-13. They discovered that, in 78% of palatally erupting ectopic canines, the eruption paths normalized within 12 months after extraction of the deciduous canine. In 64% of these cases, improved positions were noted after only six months, and in 36% the position improved after 12 months. Inclusion criteria specified that normal space conditions were present and no incisor root resorptions were found in this study[17].

Leonardi et al. in 2004 in a prospective randomized clinical trial of 46 subjects with 62 palatally displaced canines evaluated the effectiveness of extraction of the primary canines, alone and in association with the use of a cervical pull headgear. The sample was divided into three groups: (1) a group that underwent the extraction of the deciduous canine only; (2) a group that received the use of a cervical pull headgear, and (3) an untreated control group. Panoramic radiographs were evaluated in two times: (T1) initial treatment and (T2) after 18 months. These authors proposed combining the tooth extraction with the use of cervical pull headgear in order to increase arch length, such as distalization of the buccal segments of the upper arch. The extraction of the primary canine as an interceptive treatment measure to prevent palatal canine displacement had a success rate of 50%, which was not significantly higher than the success rate in untreated controls. On the other hand, the prevalence rate of successful eruption of the canine in subjects treated by headgear in addition to primary canine extraction was 80%, which is more than three times greater than a percentage of spontaneous eruption of the canine in untreated subjects [58].

Baccetti et al. in 2008 examined at interceptive treatment of palatally impacted canines in 75 subjects with 92 maxillary canines, randomly assigned to three groups: extraction of the primary canine only; extraction of the primary and cervical-pull headgear; and an untreated control group. Panoramic radiographs were evaluated at the initial time, and 18 months later. They revealed that removal of the deciduous canine alone showed correction

of palatal displacement in 65,2% of cases, which was significantly higher than that in the untreated controls (36%). The additional use of a headgear resulted in successful eruption in 87,5% of subjects [(59)]. In a later study, *Baccetti et al.* in 2009 showed that the use of a rapid maxillary expander as an early interceptive approach is useful for increasing the rate of eruption of impacted canines. A sample of 60 subjects in the early mixed dentition with palatally displaced canines diagnosed on posteroanterior radiographs was enrolled in the trial. Their age range at the first observation was 7.6 to 9.6 years. The 60 subjects were randomly allocated to the treatment group (35 subjects) or the no-treatment group (25 subjects). The treatment group was treated with a banded rapid maxillary expander; after expansion, all patients were retained with the expander in place for six months. In the treatment group, 65,7% erupted successfully compared to only 13,6% in the control group. The success of interceptive treatment depends on the degree of impaction, age at diagnosis and canine position [(60)].

*Sigler et al. (*2011) investigated the effect of rapid maxillary expansion and transpalatal arch therapy, combined with deciduous canine extraction on the eruption rate of palatally displaced canines, in the late mixed dentition. 70 subjects were enrolled with previous displaced maxillary canine diagnosis, based on panoramic radiographs. The treatment group with 40 subjects underwent rapid maxillary expansion, followed by transpalatal arch therapy and extraction of the deciduous canines. The control group with 30 subjects received no orthodontic treatment. The age of the subjects ranged from 9,5 to 13,0 years old at the start of the treatment. Rapid maxillary expansion followed by transpalatal arch therapy with extraction of the deciduous canines in late mixed dentition patients was significantly more effective at inducing successful eruption of displaced maxillary canines (80%) than with no treatment (28%). In this study it is confirmed that several dental anomalies are significantly associated with palatally displaced canines and are valuable as early risk indicators, such as: small lateral incisors, infraocclusion of deciduous molars, and distally displaced erupting mandibular second premolars [(61)].

Ericson and Kurol (1988) *ana*lyzed the effect of extraction of the primary canine palatally erupting ectopic maxillary canines. In this study, 46 impacted permanent palatally maxillary canines were collected in 21 girls and 14 boys, from 10-13 years old. After the clinical analysis, the complementary radiographic analysis consisted of a panoramic radiograph and periapical radiographs, and a total of forty-six impacted canines were analyzed. The authors concluded (figure 6) that, if the canine overlapped the lateral incisor by more than half of the lateral root, only 64% were normalized, compared to 91% when the overlap was less than half the lateral root [(17)] .

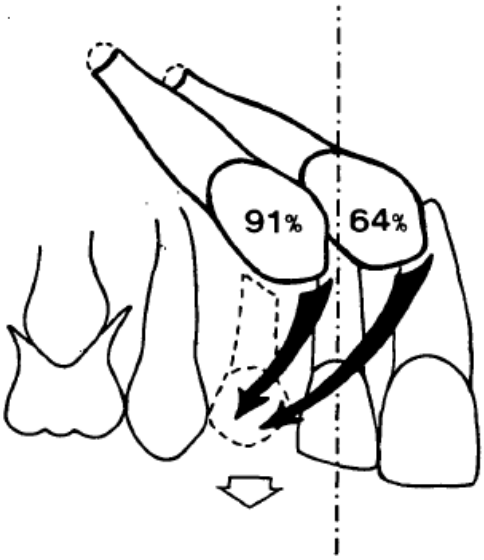

Figure 6: Schematic illustration of the normalization of the maxillary permanent canine at the control 18 months after extraction of the primary canines. The figures indicate the rate of success for the permanent canine positions at the start of treatment, mesial and distal to the midline of the lateral incisor in the orthopantomogram, adapted by *Ericson and Kurol* (1988) [17].

Lindauer et al. (1992) carried out a retrospective study; they compared panoramic radiographs taken at an early stage of dental development of two groups of patients. One group consisted of 28 patients (15 girls and 13 boys) all with either unilateral or bilateral palatally impacted canines and currently with permanent dentition. This impaction group had 41 canine palatally impactions: 26 were bilateral; eight, right unilateral; and seven, left unilateral. No patients in the impaction group had any extraction or orthodontic treatment before the diagnosis of impacted teeth. The mean age of the patients at the time of the earlier panoramic radiographs was 12 ±1 years, at late mixed dentition. The second group of 28 chronologically and dentally age-matched control patients was composed of 11 girls and 17 boys, whose 56 canines had erupted normally. None of the patients had extractions or orthodontic treatment before the eruption of the permanent canines. The average age of the control group patients at the time of their earlier mixed-dentition panoramic radiographs was 11 years, 8 months ± 19 months. In this study, it was shown that 78% of impacted canines exhibited overlapping with the lateral incisor during the radiographic evaluation at the mixed dentition period. In contrast, they found overlapping in only 4% of the 71 control canines that did not develop impaction, concluding that such relations detected in panoramic radiographs during the mixed dentition period constitute a prognostic sign of canine impaction [9].

Fernandez et al. (1998), in a retrospective study of 554 maxillary canines, in children between 4 and 12 years old, studied the eruption pattern, in terms of its panoramic radiograph records. When the lateral incisor is not yet fully developed, panoramic radiographs show 67% overlapping of the canine and lateral incisor. In contrast, when lateral incisor development is complete, only 11% of the subjects show some degree of

overlapping. According to the authors, the overlapping of the canine and lateral incisor can be considered as a sign of early canine displacement after the incisor has completed its root development [62].

III.ii- Guidelines for the Assessment of the Impacted Maxillary Canine in 2D

III.ii.i – Panoramic radiography

Panoramic radiography is the standard diagnostic method in orthodontics, with low radiation doses, provides an overview of the situation in both jaws, the temporomandibular joints and adjacent structures [63] .

The prognostic factors have been investigated by *Stivaros et al.* (2000) and *Pitt et al.* (2006) [64, 65]. The *Stivaros et al.'s* investigation aimed to evaluate which radiographic factors influenced the orthodontists' decision whether to expose or remove an impacted maxillary permanent canine, using retrospective, cross-sectional design. The sample consisted of all radiographic records of patients referred to the Orthodontic Department at Manchester University Dental Hospital, with impacted maxillary permanent canines along two years (n=44). The following canine position measurements were made from the panoramic radiography taking four aspects into consideration: angulation to the midline; vertical height; overlap of the adjacent incisor; position of canine root apex anteroposteriorly [64].

Power et al. (1993) analyzed the factors contributing to a successful outcome. Thirty-nine consecutive patients of mean age 11.2 years (standard deviation 1.43), with 47 palatally displaced canines were included in the research. The cases were examined clinically and radiographically for a maximum period of 2 years following deciduous canine removal. The primary canines were extracted, and the permanent canines were followed up clinically and radiographically for a maximum period of 2 years. The permanent canines were allocated to sub-groups according to the outcome of the treatment, thus:

Group 1 Successful (*S*) - those canines which showed a complete recovery of the eruptive pathway and obtained an acceptable bucco-palatal position within the dental arch without orthodontic traction.

Group 2 Improved (*I*) - those canines which demonstrated some improvement in position, but which required exposure and traction for full alignment.

Group 3 Unsuccessful (*U*) – those canines which showed no improvement in position, or which continued to deteriorate.

The three sub-groups were analyzed by reference to the position of the permanent canine at the time of the deciduous extraction [66].

Twenty-nine (62 per cent) of the 47 ectopic canines accomplished a normal eruptive position, and nine (19 per cent) showed some improvement in eruptive position [66].

- **Canine angulation to the midline**

  A midline was constructed as shown in figures 7 and 8, and a second line drawn through the canine root apex canine tip. The results of the study about the canine angulation to the midline are presented in the table 2 and 3. The angle between the two lines gave the impacted canine angulation to the midline that was grouped as [64-66]:

  Grade1: 0-15°

  Grade 2: 16-30°

  Grade 3: ≥ 31° [64, 66]

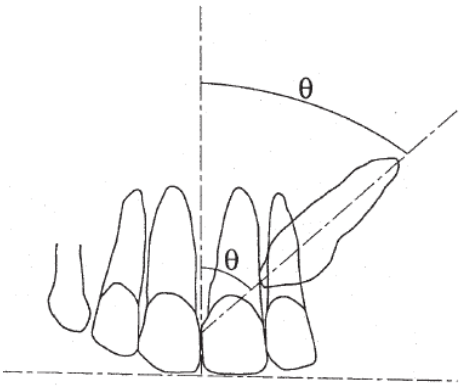

Figure 7: The angulation of the canine to the midline, adapted by *Stivaros et al. article* (2000) [63].

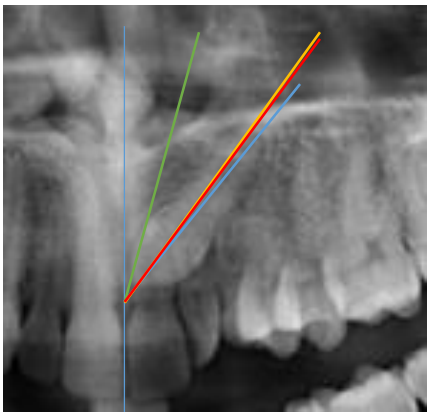

Figure 8: Angulation of the canine: two-dimensional panoramic radiograph of a 17-year-old female patient of FMUP, with an impacted maxillary left canine. The angulation of the canine with the midline is around 32°.

	Angulation (degrees)					
GROUP	0-15		16-30		31+	
	n	%	*n*	%	*n*	%
S	13	45	13	45	3	10
I	1	11	6	66	2	23
U	1	11	5	55	3	34

Table 2: *n* is the number of cases as a function of the group and angulation. % is the percentage of each group [65].

Angulation Degrees	Successful (%)	Improved (%)	Unsuccessful (%)
0-15	86	7	7
16-30	54	25	21
31+	37,5	25	37,5

Table 3: Angulation to the mid-sagittal plane (θ) [65].

A definite trend emerged, which demonstrated that the chance of a successful return of the canine to a normal eruptive pathway decreased if the original canine angulation exceeded 31 degrees. The angulation appeared to exert less influence on the chance of resolution than the degree of overlap. Two out of the three cases which were successful and had an angulation over 31 degrees also had missing lateral incisors and no overlap to the central (the canines were both from the same patient). In conclusion, the angulation of the canine to the mid-sagittal plane was found to reduce the likelihood of improvement if this exceeded 31 degrees, but it is important to note that it depends on other factors [28, 65, 66].

- **Vertical Canine Crown Height**

The crown height was graded relative to the adjacent maxillary incisor (figures 9 and 10). The more apical the position of the crown, the weaker the prognosis for alignment. From the level of the cemento-enamel junction to less than halfway up the root of the lateral incisor, it would indicate a good prognosis; more than halfway up the root but less than the full-length, it root length would indicate average prognosis; and above the full length of root, it would have poor prognosis [28, 64, 66].

Grade1: Below the level of the cemento-enamel junction (CEJ).

Grade 2: Above the CEJ, but less than half way up the root.

Grade 3: More than half way up the root, but less than the full root length.

Grade 4: Above the full length of the root [64, 66].

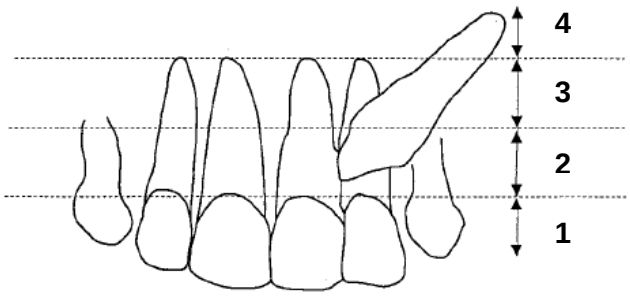

Figure 9: The height of the canine vertically, adapted by *Stivaros et al. article* (2000) [63].

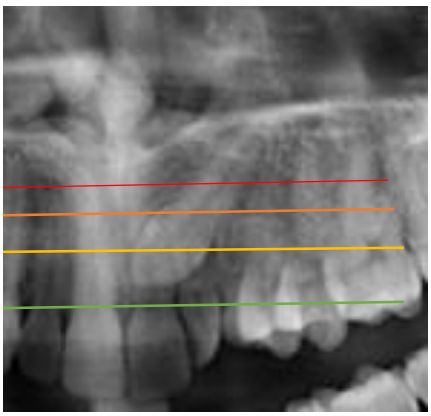

Figure 10: Vertical canine crown height: two-dimensional panoramic radiograph of a 17-year-old female patient of FMUP, with an impacted maxillary left canine. The position of the crown is the middle of grade 2 and 3.

- **Canine overlap of the adjacent incisor root**

The amount of canine crown horizontally overlaps the adjacent incisor (figures 11 and 12). The closer the canine lies to the midline, the weaker the prognosis for alignment. No horizontal overlap of the adjacent incisor indicates good prognosis; overlap up to half the root width suggests average prognosis; and complete overlap indicates poor prognosis. The results are presented in the table 4 and 5. [28, 64-66]

Grade 1: No horizontal overlap.

Grade 2: Less than half the root width.

Grade 3: More than half, but less than the whole root width.

Grade 4: Complete overlap of root width or more [64, 66].

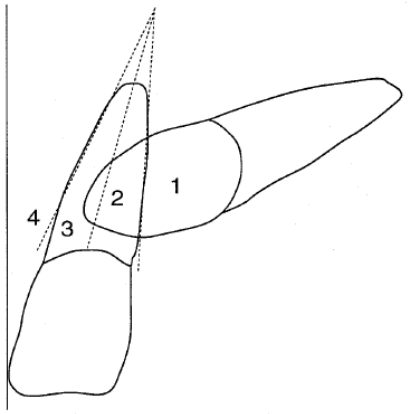

Figure 11: Canine overlap to the adjacent incisor, adapted by *Stivaros et al. article* (2000) [63].

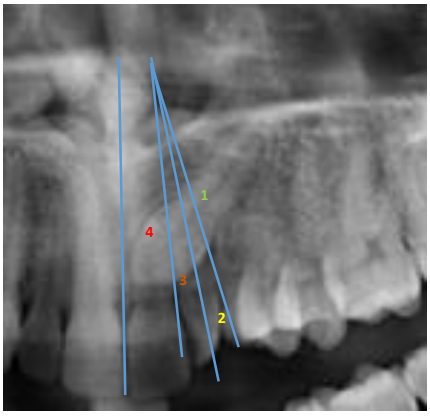

Figure 12: Canine overlap of the adjacent incisor root: two-dimensional panoramic radiograph of a 17-year-old female patient of FMUP, with an impacted maxillary left canine.

In *Power et al* 's (1993) investigation the degree of overlap was shown to be the most important single factor determining whether success was achieved or not [66].

	STAGE							
	1		2		3		4	
GROUP	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
S	8	28	16	55	4	14	1	3
I	0	0	3	33	4	45	2	22
U	0	0	3	33	1	11	5	56

Table 4: n is the number of cases as a function of the group and stage. % is the percentage of each group [65].

Overlap Stage	Successful (%)	Improved (%)	Unsuccessful (%)
1	100	0	0
2	73	13.5	13.5
3	44	44	12
4	12	25	63

Table 5: Overlap to nearest incisor measured in stages [65].

- **Position of Canine Root Apex Antero-posteriorally**

  The position of the canine root apex in the horizontal plane is showed in (figures 13 and 14). If the canine apex is located above the normal canine position, prognosis for alignment is good; if the apex is above the first premolar region, the prognosis is average, and if it is above the second premolar, the prognosis is poor [28, 64].

  The canine root apex was judged as being either:

  Grade 1: Above the region of the canine position.

  Grade 2: Above the upper first premolar region.

  Grade 3: Above the upper second premolar region [64].

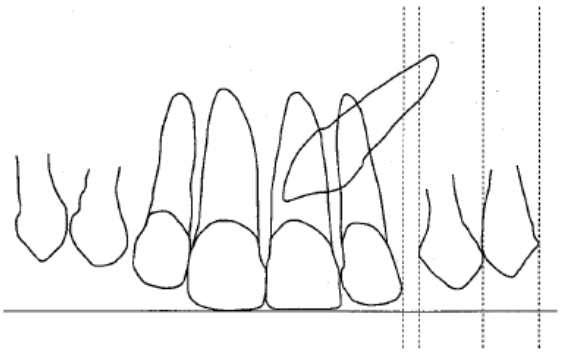

Figure 13: The position of the canine root apex horizontally, adapted by *Stivaros et al. article* (2000) [63].

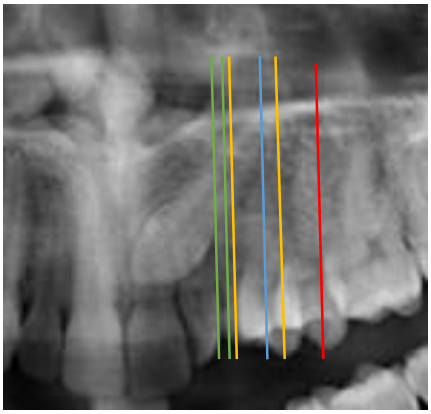

Figure 14: Position of canine root apex antero-posteriorally: two-dimensional panoramic radiograph of a 17-year-old female patient of FMUP, with an impacted maxillary left canine. In this case, the canine is above the upper first premolar position.

As an example, a case of the Master of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of the University of Oporto is presented. A 16- year-old female patient presents tooth 13 (permanent right maxillary canine) impacted and ectopic tooth 33 (permanent left mandibular canine). We had access to a panoramic radiograph made in

2011, in which no interceptive treatment was carried out in this situation. The position of the right permanent maxillary canine worsened, leading to its impaction. It does not present the deciduous canine in the dental arch. It was decided to open spaces without extractions with brackets with CCO prescription, and tooth 13 was traced to the dental arch. The traction prognosis was poor according to *Stivaros et al.* article (2000), but the traction was carried out successfully.

- **Initial panoramic radiography in 2011**

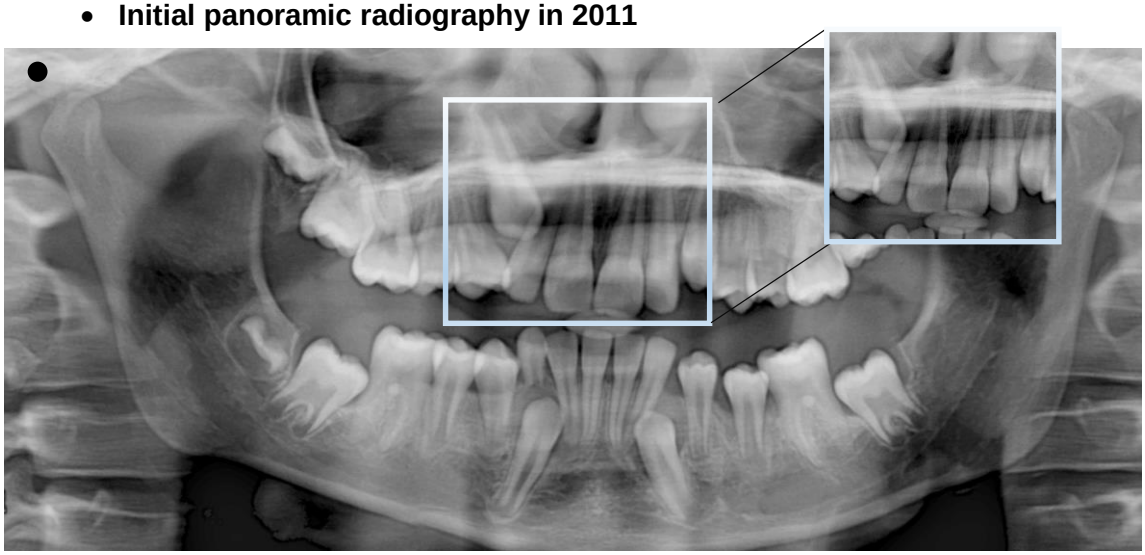

Figure 15: Initial panoramic radiograph with right canine impacted and deciduous right canine absence, in 2011. No interceptive treatment was performed.

- **Intra-oral photos in 2018**

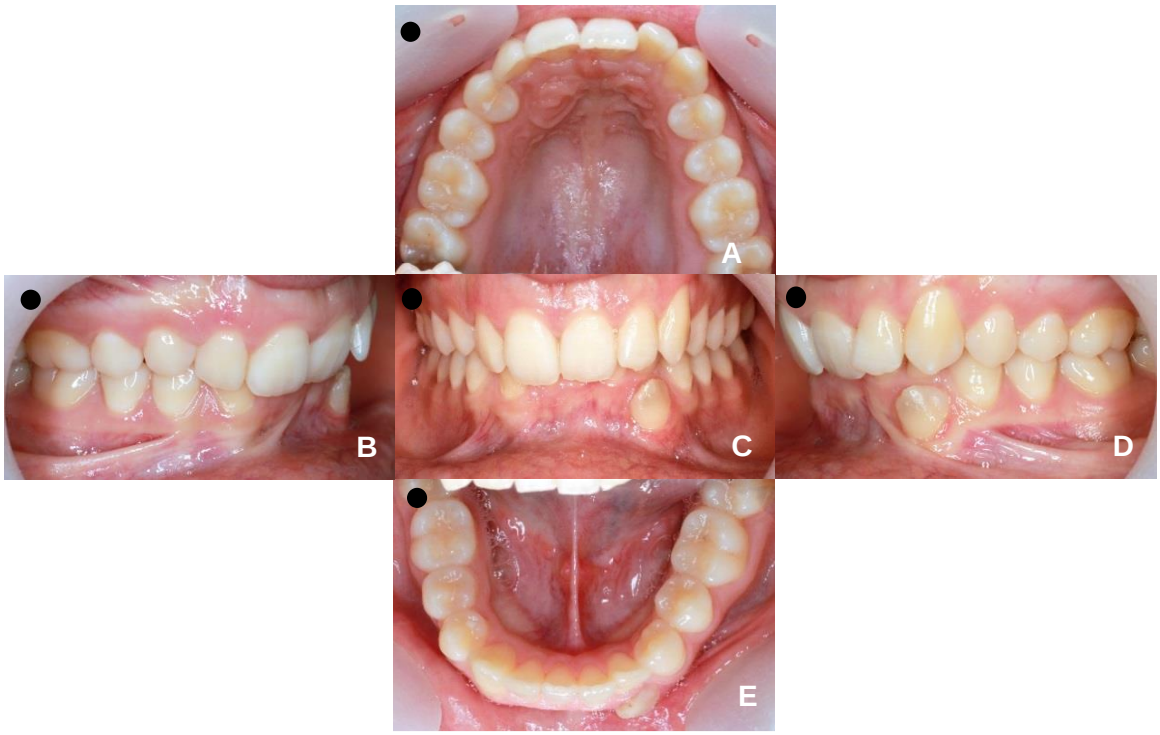

Figure 16: Initial intra-oral photos: A) upper view, B) right view, C) frontal view, D) left view and E) lower view,

- **Panoramic radiograph**

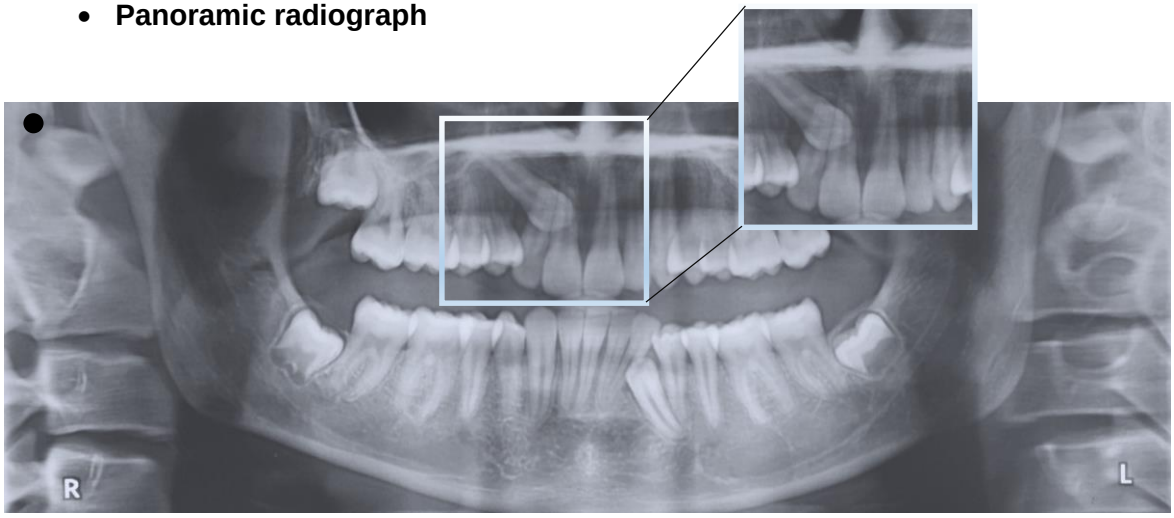

Figure 17: Initial panoramic radiograph with right canine impacted and deciduous right canine absence.

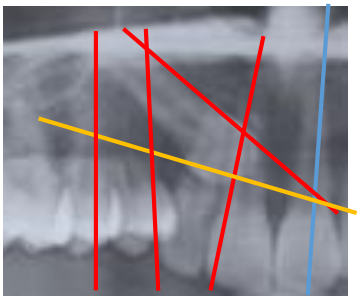

Figure 18: Close up panoramic radiograph of 1st quadrant. Poor prognostic of traction, according to the *Stivaros et al*. (2000) article [63].

- **Orthodontic traction surgery of 13**

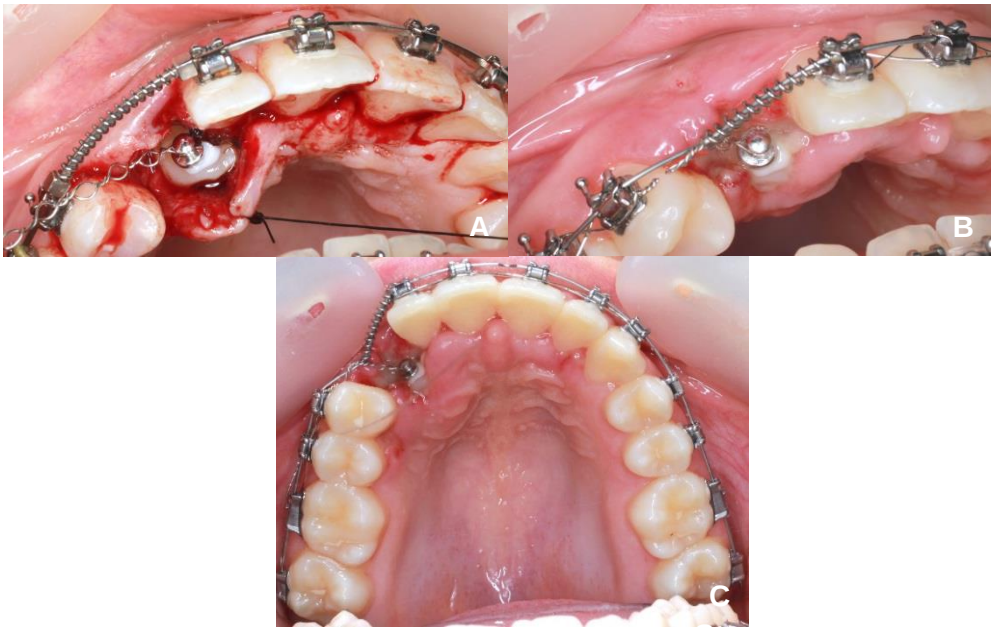

Figure 19: Orthodontic traction surgery of 13. Ensure distal vector of traction using an open spring-coil.

- **Final treatment**

Figure 20: Final intra-oral photos: A) upper view with the permanent right maxillary canine in the dental arch, B) right view, C) frontal view, D) left view and E) lower view.

- **Final panoramic radiograph**

Figure 21: Final panoramic radiograph.

Another case from the Master Degree Orthognathic Surgery and Orthodontics of the Faculty of Medicine of the University of Oporto is presented. A 20- year-old male patient

presented tooth 23 (permanent left maxillary canine) impacted, as well as the deciduous in the dental arch. When the upper fixed orthodontic appliance was placed, the deciduous canine was removed. After 5 months, without any intervention, the canine erupted spontaneously.

- **Initial panoramic radiograph**

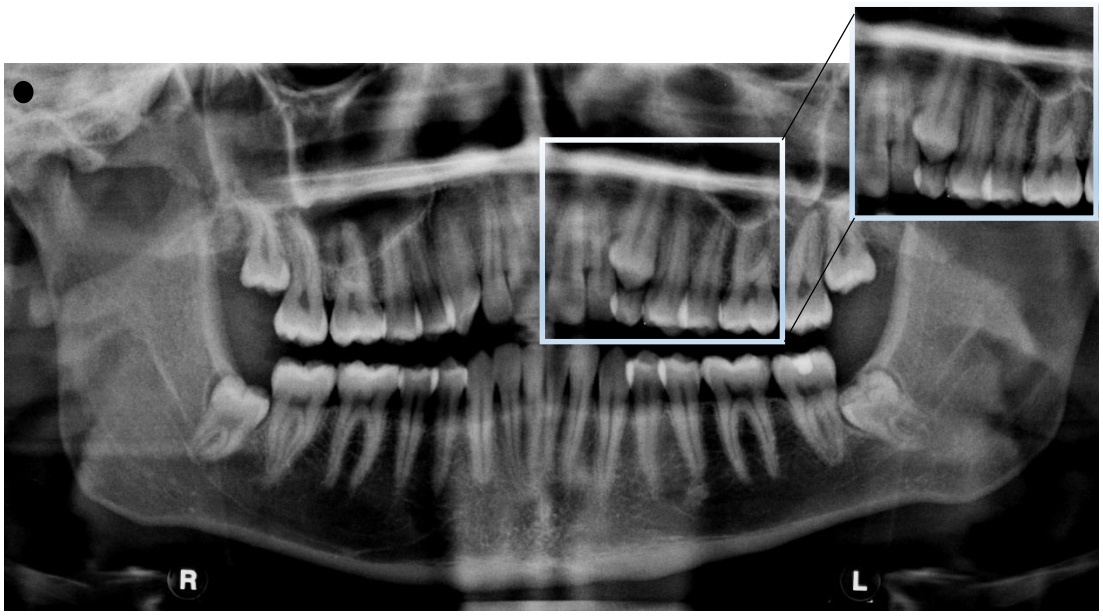

Figure 22: Initial panoramic radiograph with left canine impacted and deciduous left canine in the dental arch.

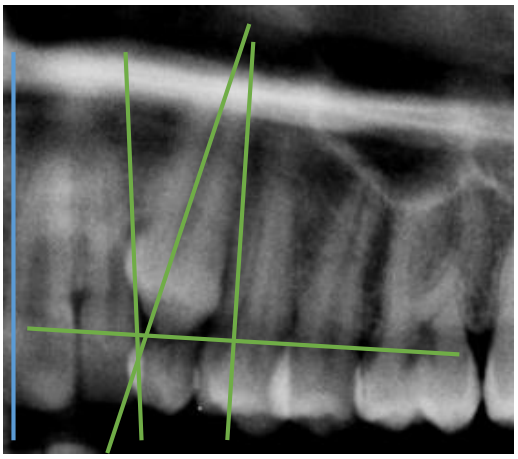

Figure 23: Close up panoramic radiograph of 2nd quadrant. Good prognostic of traction, according to the *Stivaros et al*. (2000) article [63].

- **Intra-oral photos before the treatment**

Figure 24: Initial intra-oral photos: A) upper view, B) right view, C) frontal view, D) left view with the deciduous canine and E) lower view

- **Intra-oral photos at the beginning of the treatment**

Figure 25: Intra-oral photos at the beginning of the treatment. The deciduous canine was removed. A) frontal view, B) upper view and C) left view.

- **Intra-oral photos after 7 months**

Figure 26: Intra-oral photos after 7 months. A) frontal view, B) upper view and C) left view.

- **Final traction intra-oral photos**

Figure 27: Intra-oral photos after the traction of 23. A) frontal view, B) upper view and C) left view.

- **Final traction panoramic radiograph**

Figure 28: Final traction panoramic radiograph.

III.ii.ii – Posteroanterior cephalograms radiography

Posteroanterior (PA) cephalograms radiograph has been suggested as another option to detected early canine impaction [67]. *Sambataro et al.* (2004) suggested that the posteroanterior cephalograms technique is a useful tool to identify the spatial position of the canine in the early mixed dentition period. In this study PA cephalograms of 43 subjects (22 males and 21 females) with different types of malocclusions in the mixed dentition were taken and analyzed at the time of first observation (mean age 8 years and 5 ± 9 months). Stepwise variable range on the measurements at the time of first observation identified two predictive variables on PA cephalograms, i.e., the distance between the center of the canine crown and the midsagittal plane (A3cc to Cg Vertical) and the distance between the jugal process and the midsagittal plane (J to Cg Vertical) (Figure 29 and 30). All subjects were reevaluated at the mean age of 14.3 years. Two predictive measurements were selected, i.e., the distance from the center of the crown of the permanent maxillary canine to the

midsagittal plane and the transverse width of the maxilla on the same side of the evaluated canine. The closer the canine crowns to the midsagittal plane and the larger the posterior portion of the hemimaxilla, the higher the probability of canine impaction [67].

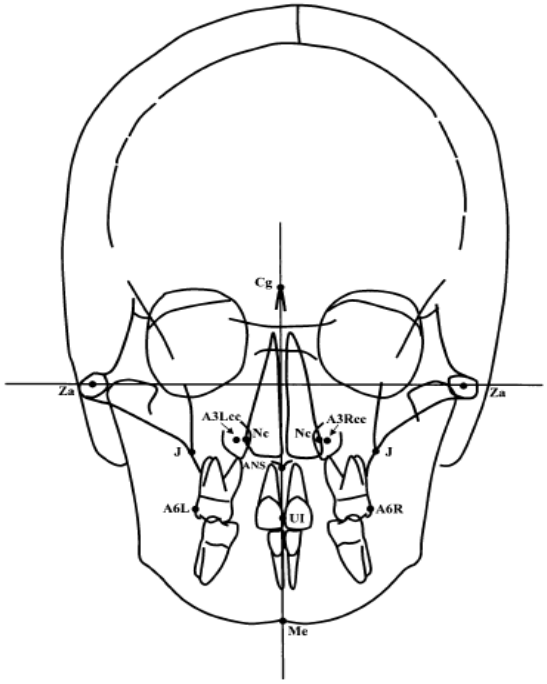

Figure 29: Cephalometric landmarks and reference lines, adapted by *Sambataro et al.* (2004) article [67] .

Figure 30: PA cephalogram, female, 8 years and 7 months. Individual score for upper right canine= 0.628; predicted group: nonimpaction. Individual score for upper left canine= -3.541; predicted group: impaction, adapted by *Sambataro et al.* (2004) article [67].

III.iii- Guidelines for the Assessment of the Impacted Maxillary Canine in 3D

III.iii.i – Computerized Tomography (CT) and Cone-beam computed tomography (CBCT)

Computerized tomography is an imaging method that overcomes the limitations of conventional radiographic methods, and has shown to be a useful method for diagnosing the positions and complications of impacted and ectopically erupting teeth, been used with increased frequency since 1998 [42, 54].

The major limitation of CT is radiation risk which is especially higher in children, and the risk-benefit ratio should be carefully considered for every patient and CT limited, first to the cases where conventional radiography poorly depicts the actual relationships between impacted tooth and the roots of adjacent teeth [3, 6, 54, 68]. However, panoramic radiography has limitations in assessing the labiopalatal position of impacted canines and root resorption of incisors[69].

One case of the Master Degree of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of the University of Oporto is presented as an example. A 16- year-old male patient presents tooth 23 (permanent left maxillary canine) impacted. It does not present the deciduous canine in the dental arch. A panoramic radiograph (figure 31) and a CT (figures 32 and 33) were required to analized the labiopalatal position of the maxillary canine.

Figure 31: Initial panoramic radiograph present the tooth 23 impacted.

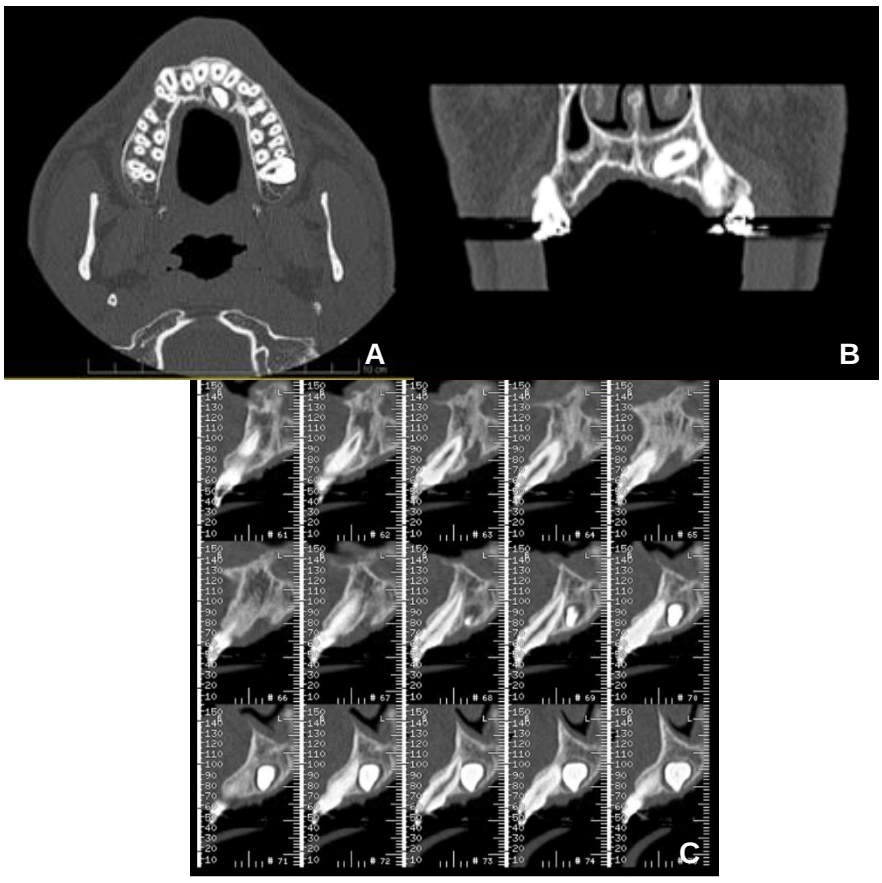

Figure 32: CT images of 23 impacted. A**)** Axial view of the initial CT. The 23 is positioned palatally in relation to the maxillary incisors; B) Coronal view of the initial CT and C) Sagittal view of the initial CT, revealed that the impacted canine in a palatal position.

Figure 33: 3D reconstruction of the maxilla in an axial view. The crown of the impacted canine (23) is in a palatal position, near to the lateral and central incisors.

The development of CBCT for use in dentistry has to a large degree removed these issues as significant barriers. Indeed, there seems to be vast potential for improved diagnostics with immediate use of CBCT. This technology allows patients' study in three orthogonal planes (sagittal, coronal and axial), improving diagnosis, treatment planning and management not only in orthodontics but in several dentistry areas [4, 40, 41, 70].

CBCT images are intrinsically more detailed than traditional x-rays since beam projection is orthogonal; this signifies that the x-ray beams are approximately parallel to one another, and the object is near the sensor. This explains why there is little projection effect and also no magnification. Besides, computer software addresses the projection effect, resulting in undistorted 1:1 measurement. This contrasts with conventional imaging, which always has some projection error because the anatomic regions of interest are at varying distances from the film. For example, panoramic radiographs have an unusual projection error because the main path of the x-ray beam comes from a slightly negative angulation. In this circumstance, the dental provider must account for these imaging artifacts when reading the images. Another likely advantage of the CBCT scan is that the data acquired include information for the entire craniofacial region. Additional views, such as lateral cephalograms, panoramic radiographs, occlusograms, airway evaluation, and volumetric images are available from the original acquisition data. These images can be manipulated with imaging software to aid the dental provider in diagnosis and treatment planning. Costs, efficiency, and benefits of CBCT imaging are favourable because one imaging session can provide many views [71].

Using again as an example the clinical case previously presented on page X, a CBCT (figure 34) was performed as a complementary examination to ascertain the labiopalatal

position, possible root resorptions of the adjacent teeth and dilacerations of the impacted tooth root.

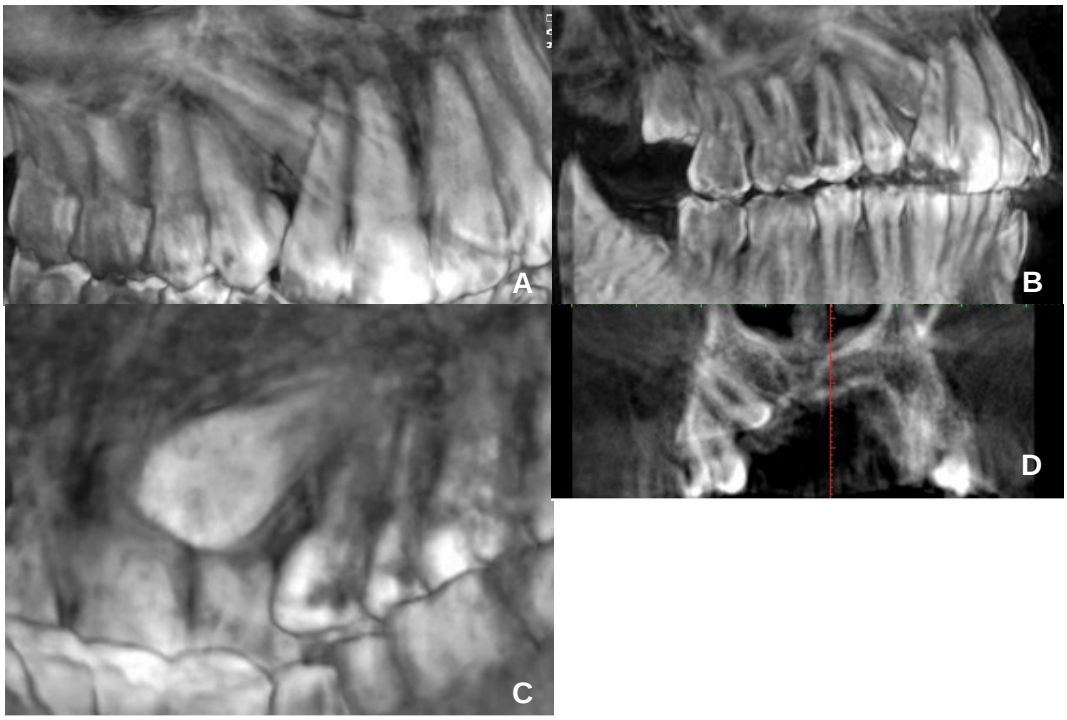

Figure 34: CBCT image. Root resorptions and dilacerations weren't found. A) vestibular view of the 3D reconstruction image, B) position of the apex near to the 2nd premolar, C) crown positioned palatally in relation to the maxillary incisors and D) coronal view.

Another case of the Master Degree of Orthognathic Surgery and Orthodontics of the Faculty of Medicine of the University of Oporto is presented. A 15-year-old female patient, with tooth 13 and 23 impacted. A panoramic radiograph and a CBCT were performed.

Figure 35: Panoramic radiography. 13 and 23 impacted. The canine deciduous are presented in the dental arch.

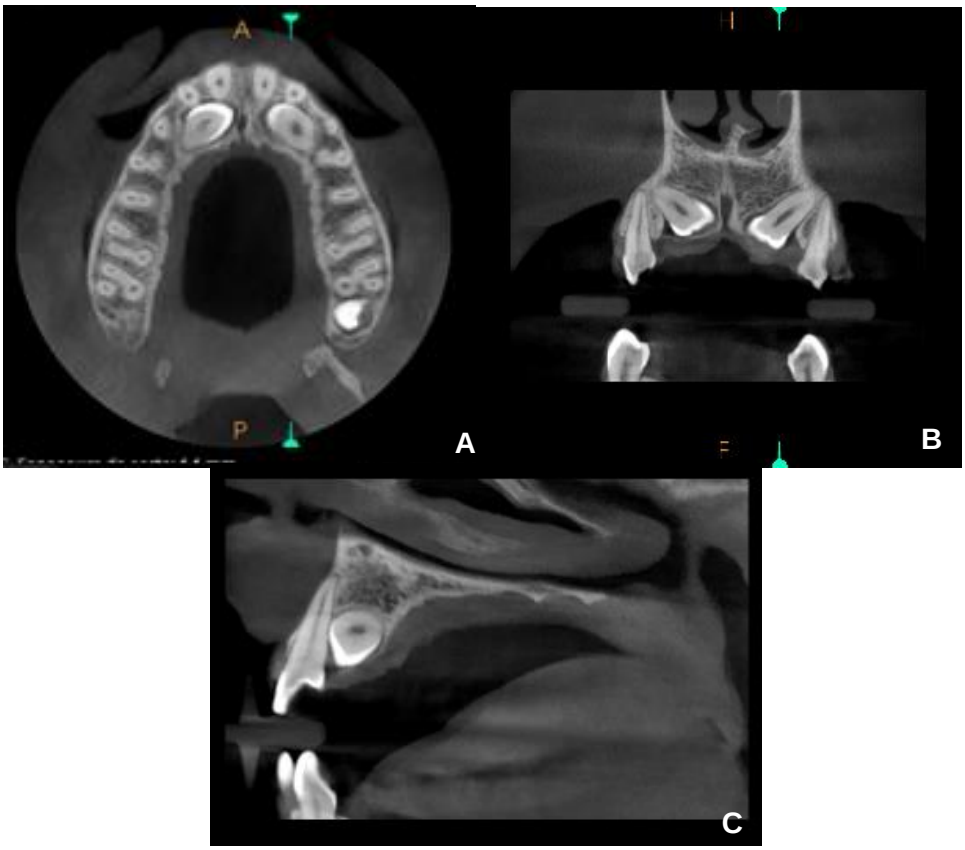

Figure 36: CBCT image. Root resorptions and dilacerations weren't found. A) Axial view of the 3D reconstruction image, 13 and 23 impacted palatally B) Coronal view C) Sagittal view crown positioned palatally in relation to the maxillary incisor.

Pico et al. (2017) compared and concluded in what way the opinion regarding maxillary canine impaction differed when observing a panoramic image compared to the observation of a set of CBCT reconstructions. Twenty patients (10 males e 10 females) with a total of 28 impacted maxillary canines were identified from the database of the Department of Dentistry, Faculty of Medicine, University of Coimbra. For each canine, two different images were available: a panoramic image and a set of CBCT reconstructions. The results of this study indicate that differences between the two exams (2D and 3D modalities) are related not only with the mesiodistal apex position and the labio-palatal cusp position, but also in the assessment of root resorption and with plained with lack of 3D information of the panoramic image, suggesting CBCT examination when these issues are doubtful [(72)] .

Boticcelli et al. (2010) used a comparative study to diagnose differences in the diagnostic information, provided by conventional 2D images (including a panoramic radiograph, lateral cephalograms and periapical radiographs with different projections) and a 3D image (CBCT), for each canine. Twenty- seven patients (17 females and 10 males, mean age 11.8 years), undergoing orthodontic treatment with 39 impacted

maxillary canines were, examined by eight dentists. Findings demonstrated that the inclination measured to the midline did not differ significantly when evaluated using the two methods. The mesiodistal location of the apex was the significant difference found for the two methods. The vertical level of the clinical crown varied significantly with a tendency towards a higher position based on the 2D images. The meaning of overlap with the lateral incisor was congruent for the two methods in 70% of cases; the statistically significant disagreement reflected the larger overlap when evaluated on the 3D images. The labiopalatal location of the crown and the apex revealed significantly larger labial position with the 3D method. Significantly more root resorption was found in 3D images. The difficulty of a case significantly differed at the 95% confidence level, making treatment more difficult, based on 3D treatment [(73)].

Haney et al. (2010), in a prospective study, compared the differences in the diagnosis and treatment planning of impacted maxillary canines between two imaging modalities. Eighteen patients (12 females, 6 males) with impacted maxillary canines were identified in the orthodontic clinic at the School of Dentistry, the University of California at San Francisco. Twenty-five impacted canines were identified; they included seven bilateral impactions. Six canines were unilateral on the right, and five were unilateral on the left. The subjects ranged, and five from 12.3 to 34.6 years (mean, 16.9 ±5.8 years). For each subject, traditional 2D diagnostic radiographs were made, included a panoramic radiograph to evaluate the vertical position, an occlusal x-ray to evaluate the proximity to adjacent teeth, and two periapical radiographs to determine the labio-palatal position. Volumetric images of the maxillary dentition were obtained from a CBCT scan included anterior, posterior, rostral-caudal, caudal-rostral, labial and palatal view. Seven faculty members participated in this study: 4 orthodontists and three oral surgeons. All impacted canines were evaluated in one session. There were differences in the identified location of the impacted cusp tip, depending on the radiographic modality [(40)].

For the mesiodistal tip position, there was 79% agreement percentage between the two methods. The combined methods, traditional 2D radiograph and 3D CBCT volumetric views, had a range of agreement from 43% to 100% for each tooth, based on the seven judges' responses. There was 84% agreement for the labiopalatal position. The combined methods had a range of agreement from 50% to 100% for each tooth. Fifty percent of the teeth had 100% agreement, and 76% had one or no clinician in disagreement. There was 50% agreement when locating the cusp in the vertical position. In the diagnosis of root, there was 64% agreement between the two methods. Twenty-seven percent of the teeth that were planned to be left, recovered, or extracted with the traditional 2D radiographs, were selected for a different treatment when the judges

viewed the 3D CBCT images. The overall for a single tooth was unanimous in 24% ofthe teeth, with a range of agreement from 50% to 100% on the other teeth, but when comparing the responses of 2D with 3D, there was complete agreement on the orthodontic treatment plan in only 36% of the teeth. In this study, not all the results were statistically significant, especially in critical questions like the labiopalatal position of the cuspid tip, which is the most critical question for the surgeon when the tooth is to removed or recovered [40].

Wriedt et al. (2012) carried out a diagnostic cross-over study to evaluate the diagnostic differences using panoramic radiographs (2D) and cone-beam computed tomography (3D), of 21 patients, with a total of 29 impacted maxillary canines (13 left and 16 right). First, the elements of study (photographs, molds) and panoramic radiography were analyzed, two weeks later, the 3D images were analyzed by a total of 26 dentists. The results showed that in 64% of all patients, canine position was assessed concordantly in 2D and 3D images. The lateral incisors and first premolars were also more accurately identified in CBCT than in the panoramic radiographs. Canine root dilaceration was diagnosed in 1.7% of the 2D images and in 6% of the 3D images. In 4.6% of patients, dilacerations were only detected in CBCT. Regarding the therapeutic decision to be taken, almost 52% of the canines led to extraction according to the panoramic radiography findings, and alignment, based on CBCT findings. However, just under 9% of the teeth needed alignment, according to panoramic radiography, and were recommended for extraction based on the CBCT. The examiners concluded that the therapeutic decision depended strictly on the angle of canine inclination (less than 30° inclination, 80% should be aligned; more than 30° inclination, 60% orthodontic traction may be attempted). If root dilaceration was identified in panoramic radiography, impacted canine removal was proposed in 69,2% of the cases. If no canine dilacerations were found, only 13% of the canines were recommended for surgical removal, and 84% for orthodontic alignment [74] .

Lai et al. (2013) analyzed the location of impacted maxillary canines and factors influencing root resorptions of adjacent teeth using cone-beam computed tomography. 113 patients were analyzed, having 134 impacted canines. 69 impacted canines were located palatally, 41 labially and 24 in the middle of the alveolar process. The mean age of the patients was 19 years old (range: 8.7-77.2 years, SD ± 13.65 years). Of all patients, 34.51% were male and 65.49% were female. The resorptions were graded using four clinical and radiological categories, according to the system suggested by *Ericson and Kurol* (2000) [8, 42, 75] :

1. *No* resorption- intact root surfaces, except for loss of cementum.
2. *Slight* resorption- up to half of the dentine thickness to the pulp.
3. *Moderate* resorption- half way to the pulp or more: the pulp is covered with dentine.
4. *Severe* resorption- the pulp is exposed [42] .

Root resorptions were found in 34 lateral incisors (25,37%), 7 central incisors (5,22%), 6 first premolars (4,48%) and 1 second premolar (0,75%). The authors concluded that there was no correlation between the patient's age and prevalence of root resorptions. A statistically significant higher prevalence of root resorption was presented when there was complete root development of the impacted canine with a closed apex, being compared when there was incomplete root development of the canine [8] .

Alqerban et al. (2013), in a prospective study, compared the impact of using 2D panoramic radiographs and 3D cone beam computed tomography for the surgical treatment planning of impacted maxillary canines. In this study there were 32 subjects (19 females and 13 males; mean age 25, standard deviation 14 years), referred for surgical intervention of 39 maxillary impacted canines. Both 2D and 3D pre-operative radiographic diagnostic sets were analyzed by six observers. Root resorption of the lateral incisors was detected more often with CBCT images than with panoramic images (18% vs 11,5%). No significant differences were found for either the type of treatment chosen or the surgical technique. CBCT was associated with fewer canine extractions than panoramic evaluation (13% vs 18%). Pre-surgical treatment planning did not differ significantly between panoramic and CBCT modalities in terms of the type of treatment and surgical technique chosen. CBCT images in comparison with panoramic radiographs, increase the confidence level of the clinician regarding treatment planning and diagnosis [76].

Apostolos et al. (2018) evaluated the reliability of the radiographic images of the main conventional x-ray techniques compared with the information from CBCT. Twenty patients with the range of ages from 10-17 years old, with unilateral or bilateral impaction of the maxillary canines were radiographed by means of periapical x-rays, occlusal x-rays, panoramic x-rays and CBCT scans. Three experienced orthodontists examined all x-rays from each patient. They concluded that the panoramic x-ray is more sensitive for the detection of resorption and tooth position, whereas occlusal and periapical imaging have higher specificity and positive predictive values. Conventional radiographic methods demonstrate a more subjective diagnostic procedure compared with CBCT

images. CBCT images demonstrated to be the most accurate diagnostic method concerning location of impacted canines and root resorption of the adjacent teeth [77].

IV – CONCLUSION

Dental impaction of permanent maxillary canines constitutes a problem in the area of orthodontics, quite common in clinical practice. It is essential to have a correct clinical and radiographic diagnosis for a more adequate orthodontic treatment planning in each case. The initial clinical examination is very important (retention of the deciduous canine after 14 years of age, soft tissue elevation by palatine, vestibular, distal canine migration...) and radiographic examination.

If canine impaction is recognized, extraction of the maxillary deciduous canine allows the impacted canine to erupt. If the canine overlaps the lateral incisor by more than half of the lateral root, 64% normalized, compared to 91% when the overlap is less than a half the lateral root.

The panoramic radiography is the exam of choice due to its easy interpretation, low cost and low effective radiation. It has the disadvantage of being a 2D exam, not giving information about the three-dimensional position of the impacted tooth. The CT and the CBCT technology provide important additional information, such as the labiopalatal position of the tooth and possible root resorptions of the adjacent teeth. However, CT is not considered a routine examination in these cases, due to the dose of radiation used and its cost. The CBCT technology, compared to CT, has lower cost and radiation. The decision as to which diagnostic medium to use should always be taken when clinically supported.

According to the studies presented, the CBCT improved detection of resorptions in 50%, when compared with panoramic radiography. The most significantly differences between the two exams are related with the mesiodistal apex position, the labio-palatal cusp position and the assessment of root resorptions to the adjacent teeth. Panoramic radiography remains the most commonly used diagnostic aid in clinical cases where there is a suspicion of dental impaction of permanent canines.

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