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Imaging Modalities for Locating Impacted Maxillary Canines: A Critical Literature Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author MMCB was responsible for the research design, methodological execution, manuscript interpretation, writing, and revision. Author UBDS contributed to the research design, methodological execution, data acquisition, analysis, and manuscript writing. Authors LMK and FWGC performed a critical review of the manuscript content. Author DMDP conducted a critical review and suggested content modifications. Author DSDM provided guidance, contributed to the research design, and assisted with methodological planning. All authors read and approved the final version of the manuscript.

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ABSTRACT

Aims: To do an integrative review of the literature on the types of imaging exams used to determine the position of the impacted maxillary canines (IMC), with emphasis on the analysis of panoramic radiographs (PR) and cone-beam computed tomography (CBCT).
Methodology: A search was carried out on the Web of Science, PubMed, Scopus and VHL databases, which resulted in 395 articles; 42 duplicates were removed, totalizing 353 articles. After reading the titles and abstracts, 281 were excluded for not meeting the eligibility criteria. 56 articles were selected for full reading, and 5 articles were included for data synthesis.
Results: The authors used PR, CBCT, periapical and occlusal radiographs, which were evaluated by orthodontists, surgeons and radiologists. Different assessments were identified regarding the position of the canine and the presence of root resorption, depending on the imaging examination.
Conclusion: The possibility of identifying root resorption with PR is controversial among authors; CBCT images were considered a more accurate examination method compared to two-dimensional images.

Keywords: Cone-beam computed tomography; impacted tooth; orthodontists; panoramic radiography; planning techniques.

1. INTRODUCTION

The correction of alignment and levelling of impacted and displaced maxillary canine teeth (IMC) represents a significant challenge for orthodontists. The orthodontic realignment of these canines is recognised as one of the most complex procedures due to its multifactorial nature, with both local and genetic factors influencing the treatment performed (Ali-Turaihi et al., 2020; Grande et al., 2006). Some aspects of the IMC to be evaluated include how horizontally it overlaps the adjacent incisor, the vertical height of the crown, the angulation in relation to the midline and the position of the root apex in the horizontal plane (Counihan et al., 2013). These characteristics are directly related to the complexity of the treatment and can influence the time of traction. An integrated approach to clinical and imaging factors is essential for indicating and defining treatment (Borges et al., 2025).

The decision-making regarding the handling of patients with IMC requires a deep understanding of the position of these teeth and their interaction with the other teeth in the arch. Obtaining comprehensive information is, therefore, possible through imaging exams (Christell et al., 2018).

The panoramic radiographic (PR) technique is a standard imaging method, frequently performed due to its availability in dental offices and clinics (Ali-Turaihi et al., 2020), low cost and low radiation rate, which allows the detection of impaction of upper canines by allowing a complete and two-dimensional view of the oral and maxillofacial complex and the impacted teeth in terms of position, angulation and orientation in relation to the adjacent teeth (Baidas et al., 2022).

In addition to PR, orthodontists can identify the position of IMC through the obtainment of three-dimensional imaging tests, such as Cone-beam computed tomography (CBCT). With this imaging technique, dentists can also evaluate the IMC, possible damages to the roots of adjacent teeth, and the amount of bone surrounding it in three dimensions. However, the increased cost, time, radiation exposure and medico-legal issues associated with the use of CBCT limit its frequent use (Manne et al., 2012).

The ALARA principles and the SedentexCT guidelines state that CBCT examination should not be used indiscriminately, but rather in selected orthodontic cases in which the conventional radiography does not provide sufficient diagnostic information (European Commission, 2012). Therefore, the use of CBCT should not be routine in orthodontic patients, but justified for specific cases to minimize radiation exposure and benefit the patient (Alqerban et al., 2016). When indicated, CBCT can be used reliably to detect the position of the IMC and its proximity to adjacent teeth with high specificity and sensitivity (Ali-Turaihi et al., 2020).

To this end, the objective was to carry out an integrative review of the literature on the types of imaging exams used in the determination, analysis and verification of the position of the impacted upper canine, with emphasis on the

analysis of Panoramic Radiographs and CBCT.

2. MATERIALS AND METHODS

2.1 Guiding Question, Research Strategy and Search Theme

This integrative literature review was conducted to answer the following question: “In patients with impacted maxillary canine teeth, what is the effectiveness and importance of using panoramic radiographic examinations and cone-beam tomographic examinations to identify and determine the precise position of the impacted canine?”. The question was developed using the PECOS strategy, in which:

i) population (P): patients with impacted maxillary canines (IMC);
ii) exposition (E): types of imaging tests used to determine the position of the IMC, with emphasis on panoramic radiographs and CBCT;
iii) comparison/control (C): panoramic radiographic examinations compared with CBCT;
iv) outcome (O): results of using these tests to identify and determine the position of the IMC;
v) study design (S): cross-sectional and observational studies.

2.2 Literature Selection, Inclusion and Exclusion Criteria

An integrative review was carried out by two researchers, M.M.C.B. and U.B.S., under the guidance of D.S.M., following the criteria established by Botelho, Cunha and Macedo (2011), correlating the results with the scientific evidence available in the literature.

In order to identify the studies to be included in this review, an electronic search was carried out on PubMed, Web of Science, Scopus databases and on the Virtual Health Library (VHL) using the descriptors “tooth”, “impacted”, “radiography”, “panoramic”, “orthodontics” and “corrective”, present in the Medical Subject Headings (MeSh) platform and Boolean operators “AND” and “OR”.

In the first stage of this review, the titles and abstracts of all articles obtained from the databases were analyzed with the aim of selecting studies to be read in full and removing duplicate articles. The second phase comprised the complete reading of the chosen articles, aiming to obtain a comprehensive understanding of the studies and data to be acquired.

Complete articles were included, without restrictions on language, year and place of publication, as long as they addressed the topic and met the following criteria:

i) original studies, both prospective and retrospective, involving patients with impaction in one or both upper canines;
ii) analysis of tests and diagnostic methods;
iii) orthodontic and surgical treatment strategies;
iv) clear and complete descriptions of materials and methods.

Literature review articles, case reports, abstracts, animal and in vitro studies, as well as studies involving patients with genetic syndromes and severe facial malformations, were excluded from the analysis.

2.3 Analysis and Interpretation of Findings

After analysing the articles, the data obtained was evaluated for the purpose of accurately interpreting the standards and criteria used in the analysis of radiographic images.

3. RESULTS AND DISCUSSION

3.1 Selection of Studies

The search found 395 articles. 42 were duplicates. After reading the titles and abstracts, 281 were excluded for not meeting the eligibility criteria. Finally, 56 articles were selected for full reading, and 5 articles were included for an overview of the data.

Among the studies analysed, the samples consisted of imaging exams that highlighted the presence of IMC and included the recommendation to perform CBCT for a complementary evaluation. The five studies covered in this review analysed a total population of 221 patients. In some studies, the sex of the individuals was not provided (Tsolakis et al., 2017), resulting in a total of n = 127 for female patients and n = 74 for men.

3.2 Description of Studies

Among the five studies incorporated in this review, Haney et al. (2010) included the evaluation of four orthodontists and three dental

surgeons, who compared the differences in diagnoses and treatment planning for IMC using two imaging modalities: PR and CBCT. The results indicated that two-dimensional and three-dimensional IMC images can lead to different diagnoses and treatment plans.

Jung et al. (2012) conducted a study with two oral and maxillofacial radiologists as evaluators, correlating the bucco-palatal position of IMC in PR with CBCT. They analyzed the bucco-palatal position of the canines and the root resorption of the permanent incisors in CBCT, taking into account the mesiodistal position and position in sectors of the canines in PR: the study showed that the bucco-palatal position of the IMS and the resorption of the incisors permanent canines can be predicted using the location of the sector in the PR, buccal impacted canines were seen more frequently in sectors 1, 2, 3 and root resorption of the adjacent incisor in sectors 3, 4 and 5.

Alqerban et al. (2013) compared the impact of using PR (2D) and CBCT (3D) in the planning of the surgical treatment of IMC. Four orthodontists and two dental surgeons conducted the study, concluding that pre-surgical treatment planning for IMC did not present significant differences between PR and CBCT images; however, CBCT evaluation was associated with fewer extractions than evaluation in PR.

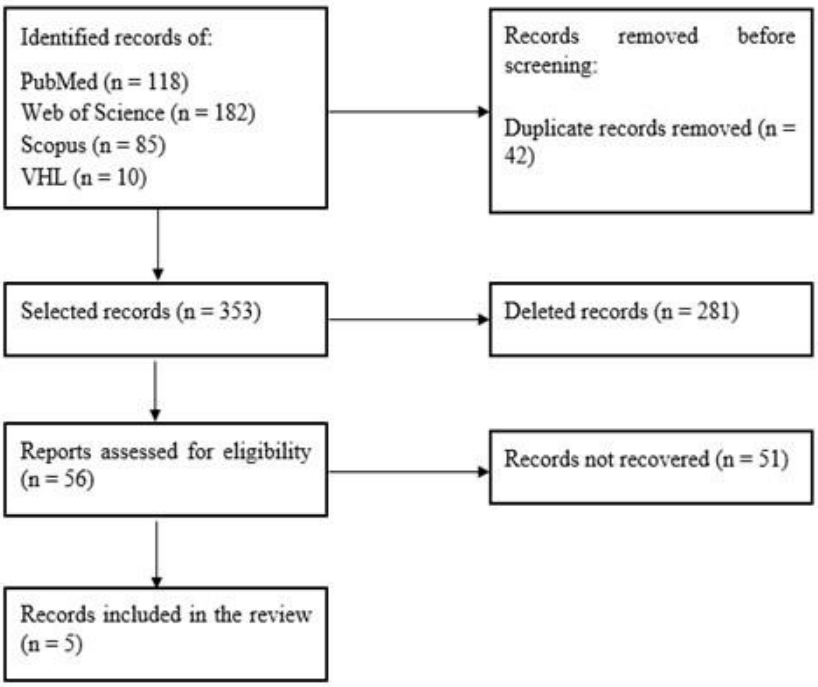

Fig. 1. Article selection flowchart

Table 1. Study Samples

Author/Year	Country	Number of participants (female; male)	Average age/ variation (years)	Number of IMC*
Haney et al. (2010)	USA	18 (12F; 6M)	16,9 / 12,3 to 34,6	25 (6 R; 5 L and 14 bilateral)
Jung et al. (2012)	Republic of Korea	63 (35F; 28M)	18,4 /10 to 56	63 (53 unilateral and 10 bilateral)
Alqerban et al. (2013) Tsolakis et al. (2017)	Belgium Greece	32 (19F; 13M) 20 (NI)	25/ NI NI / 10 to 17	39 (17 R; 22 L) NI
Sosars et al. 2020	Latvia	88 (61F; 27M)	16,8 years /11 to 44	106 IMC (33 L; 35 R and 19 bilateral)

**IMC: impacted maxillary canine; F: female; M: male; L: left; R: right; NI: not informed.*

Tsolakis et al. (2017) evaluated the reliability of radiographic images from conventional techniques compared to the information from the CBCT examination. Three orthodontists acted as evaluators. Conventional radiographic methods proved to be more subjective in terms of diagnosis compared to CBCT images, considered more precise and accurate for locating IMC teeth and root resorption of adjacent teeth.

In Sosars et al. (2020) study, they compared the predictive value of PR and CBCT to estimate the root resorption, the spontaneous eruption of a canine and the time required for orthodontic traction. Despite not informing the evaluators, the conclusion was that only severe root resorption can be predicted with PR, indicating the use of CBCT in cases of IMC.

The studies by Haney et al. (2010), Alqerban et al. (2013) and Tsolakis et al. (2017) were conducted by evaluators with training in orthodontics and/or surgery. On the other hand, the evaluators of Jung et al. (2012) were radiologists. Haney et al. (2010) and Tsolakis et al. (2017) used periapical and occlusal radiographs in association with PR.

The evaluation of radiographic images, in all studies, included the analysis of the position of the IMC tooth and the identification of the presence or absence of root resorption in adjacent teeth. The evaluation was carried out in different angles and sectors, with confirmation by CBCT images:

i) Haney et al. (2010), Alqerbarn et al. (2013), Tsolakis et al. (2017), Sosars et al. (2020) evaluated the position in the axial and sagittal planes;
ii) Alqerbarn et al. (2013); Sosars et al. (2020) in angulations and linear measurements;
iii) Sosars et al. (2020) in angulation;
iv) Jung et al. (2012) in sections.

The studies by Haney et al. (2010), Alqerban et al. (2013), Tsolakis et al. (2017) presented different results for the position of the IMC and for the presence of root resorption. The results of the study by Haney et al. (2010) revealed significant divergences regarding the position of the canine and the presence of root resorption. An important factor highlighted in the study concerns the fact that traditional radiographies required requesting additional images to obtain a more accurate diagnosis. Diagnoses and treatment plans varied considerably for the same patient according to the type of imaging exam used: PR, CBCT, periapical and occlusal radiographs.

Alqerban et al. (2013), in their prospective study to evaluate the impact of using PR and CBCT in the surgical planning of IMC, found that pre- and perioperative assessments were not significantly different between the two imaging modalities. Although the results show higher levels of confidence for treatment plans based on CBCT, surgical planning was the treatment choice after evaluating the canine position, contact situation, resorption and linear measurements, both in tomographic and panoramic examinations. It is important to emphasize that CBCT was associated with fewer extractions of IMC than the panoramic evaluation and the treatment decision in relation to the position of the canine crown in the sagittal and axial planes, contact situation and presence of root resorption of the lateral incisors was significantly different when based on 2D and 3D information, 3D imaging being recommended in 61.5% of impaction cases.

Tsolakis et al. (2017), as well as Haney et al. (2010), used PR, periapical and occlusal radiographs. CBCT was used as the reference standard (gold). During the analysis, divergences and points of agreement were identified when considering the use of CBCT and when evaluating the sensitivity of PR for root resorption (sensitive to the presence) and the location of the IMC (determining where it is not). Regarding periapical and occlusal radiographs, Tsolakis et al. (2017) identified superior predictive value in evaluating root resorption and determining position; thus, these results provide greater confidence and precision in the corresponding diagnoses.

Regarding the identification of root resorption, Jung et al. (2012) carried out evaluations using CBCT and PR, concluding that it is possible to anticipate this condition by identifying specific sectors, as well as by the location of the canine, in PR. Alqerban et al. (2013) showed that root resorption of lateral incisors was detected more frequently in CBCT images than in panoramic images. On the other hand, for Tsolakis et al. (2017), PR demonstrated sensitivity for detecting reabsorption, but it is the periapical radiography that stood out due to its greater specificity. Sosars et al. (2020) identified that measurements obtained from PR were not predictive indicators

of resorption, except in cases of severe resorption. In these, an angulation of the canine in relation to the midline greater than 46° was associated with root resorption with pulp involvement. Therefore, only severe root resorption can be predicted and visualized in PR.

The precise identification of the location and positioning of an impacted tooth is fundamental for the accurate diagnosis and planning of the treatment to be carried out, whether orthodontic, through the application of orthodontic forces or surgical, through extraction (Haney et al., 2010). Among impacted teeth, canines stand out for having a considerable incidence, second only to third molars, due to their prolonged period of development and the presence in areas with longer eruption paths Jung et al., 2012). The treatment of IMC is directly influenced by its location, contact with adjacent teeth (premolars, lateral and central incisors) and the nature and severity of any root lesions (Alqerban et al., 2013), factors that highlight the importance of a thorough analysis and integration through imaging exams.

Table 2. Description of the studies

Author/Year	Objective	Evaluators	Results
Haney et al. (2010)	Compared discrepancies in IMC diagnoses and planning in PR and CBCT.	04 orthodontists and 03 dental surgeons.	2D and 3D IMC imaging can lead to distinct diagnoses and treatment plans.
Jung et al. (2012)	Correlated the position of the IMC in PR with the CBCT, analyzing the bucco-palatal position of the IMC and the RR of the incisors in the CBCT, when considering the mesiodistal position and the position in sectors of the IMC in the PR.	02 oral and maxillofacial radiologists.	The bucco-palatal position of the IMC and the RR of the incisors can be predicted using the location of the sector in the PR. IMC due to vestibular had a higher frequency in sectors 1, 2, 3 and the RR of the adjacent incisor in sectors 3, 4 and 5.
Alqerban et al. (2013)	Compared the impact of using PR and CBCT in planning surgical treatment for IMC.	04 orthodontists e 02 surgeons.	Surgical treatment planning for IMC showed no significant differences between PR and CBCT. CBCT evaluation was associated with fewer canine extractions than PR evaluation.
Tsolakis et al. (2017)	Evaluated the reliability of radiographic images from conventional techniques compared to information from CBCT.	03 orthodontists	Conventional radiographic methods were more subjective in terms of diagnosis compared to CBCT images: precise and accurate for the location of IMC and the RR of adjacent teeth.
Sosars et al. (2020)	Compared the predictive value of PR and CBCT to estimate RR, spontaneous eruption of a canine and the time required for orthodontic traction.	Not clearly informed	Only severe root resorptions can be predicted with PR, indicating the use of CBCT in cases of IMC.

IMC: impacted maxillary canine; PR: panoramic radiography; CBCT: cone-beam computed tomography; RR: root resorption; NI: not informed.

As highlighted in the work of Alqerban et al. (2013), imaging exams using two-dimensional techniques, such as periapical, occlusal, cephalometric and panoramic, are fundamental in the diagnosis of cases involving IMC teeth. Among these, periapical and panoramic radiographs stand out.

Periapical radiographs, performed using the Clark technique, demonstrate the precise location of impacted teeth through radiographic views at different horizontal angulations, as proposed by Clark in 1909. Periapical radiographic images are used to evaluate the presence of root resorption; however, buccal and palatal root resorption are difficult to identify, as highlighted by Brusveen et al. (2012).

PRs are used for initial assessment of IMC (Alqerban et al., 2016). The identification through radiographic sectors is adopted to facilitate the understanding and the consequences of the impacted canine in relation to adjacent teeth (Jung et al., 2012). Predictors such as specificity and radiographic sensitivity are evaluated (Tsolakis et al., 2017), formulas are created to assess the probability of root resorption (Alqerban et al., 2016), and angulations of the long axis of the canine with planes and reference lines are considered (Sosars et al., 2020; Guarnieri et al., 2016). All these analyses constitute a series of options for locating the IMC in PR and in situations in which CBCT cannot be used.

The study conducted by Jung et al. (2012) identified IMC in the vestibular position, while the research by Senisik et al. (2019) evaluated methods for locating IMC in PR using predictive approaches. High precision was identified in the location of these teeth when they were in sectors 1 and 5. The association between the location of sectors and the time required for orthodontic traction was also highlighted in the study conducted by Arriola-Guíllen et al. (2019), in which it was observed that the traction time of IMC in sectors 4 and 5 is longer compared to IMC located in sectors 1, 2 and 3. The findings of these studies highlight the importance of considering the specific location of IMC when planning orthodontic interventions through panoramic imaging exams.

The diagnostic accuracy of CBCT has been shown to be superior in relation to PR, for example, in relation to the presence of external root resorption (Christell et al., 2018; Tsolakis et al., 2017; Jung et al., 2012; Alqerban et al., 2013; Sosars et al., 2020). Several studies highlight predictive methods to anticipate the presence of resorption in panoramic exams to justify the request for a CBCT exam (Alqerban et al., 2016; Guarnieri et al., 2016). Furthermore, this approach is also carried out, reserving the indication of this examination in extremely important situations, such as: tooth displaced in a complex position (Schubert; Baumert, 2009); suspicion of proximity of the IMC to adjacent teeth and, consequently, their root resorption (Sosars et al., 2020; Brusveen et al., 2012; Schubert; Baumert, 2009), when conventional radiographs do not provide sufficient information for the preparation and indication of the treatment plan (Ali-Turaihi et al., 2020; Guarnieri et al., 2016).

The two-dimensional IMC images play a basic role in providing the professional with initial information for preliminary diagnoses and presenting treatment plan options regarding them (Haney et al., 2010). However, to make the final decision on which treatment to adopt, it is imperative to resort to three-dimensional imaging exams.

The late diagnosis generally requires surgical exposure of the IMC followed by orthodontic alignment to direct the tooth to its normal position within the dental arch or extraction associated with the dental implant (Litsas; Acar, 2011). Both procedures involve high financial costs and a long treatment time, in addition to the possibility of being associated with an undesirable rupture of the tooth's supporting structures. Thus, early diagnosis and intervention can reduce the complexity of treatment, expenses, time and potential complications (Ali-Turaihi et al., 2020).

In summary, after analysing the articles, a diversity of imaging resources was observed, not only to determine the position of the canine, but also to accurately identify its location and the level of impact for the diagnosis and individualised planning of each case.

4. CONCLUSION

The studies highlighted the subjectivity in diagnoses derived from 2D images, such as PRs, periapical and occlusal, when compared to diagnoses obtained through 3D images from CBCT. Additionally, the articles emphasised tomographic images as a more precise examination method compared to conventional

techniques, highlighting their contribution to a more detailed and reliable analysis of the position and characteristics of the IMC to conclude the treatment strategy.

However, there are research related to ways of analyzing the IMC by specific categories in PR, such as: canine angulation in relation to the midline, position of the apex of the anteroposterior canine root, vertical height of the canine and canine overlap on the root of the adjacent incisor, in order to increase the level of precision of this method.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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