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Diagnostic methods and treatment strategies of impacted maxillary canines: A literature review

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SUMMARY

Objective. This study aims to review main diagnostic methods and different treatment strategies of impacted maxillary canines.

Materials and methods. A computerised systematic search of studies was conducted on PubMed and Cochrane databases. The systematic search was performed using inclusion and exclusion criteria.

Results. 23 publications were identified as relevant to the theme. Nine studies were about the treatment of impacted maxillary canines, and fourteen reviews were about the diagnostic methods of impacted maxillary canines. Seven of these studies analysed samples comprising combined surgical and orthodontic treatment. Two studies were based on a treatment method whereby deciduous maxillary canine was extracted, and maxilla was expanded to avoid the impaction of permanent maxillary canine. Seven studies compared which diagnostic way – a cone-beam computed tomography or conventional radiography – is more accurate. Four studies evaluated only the accuracy of dental panoramic radiograms. Two studies evaluated how accurate the cone-beam computed tomography method is in diagnosing impacted maxillary canines. One study analysed if cephalogram could be useful in early diagnosis of impacted maxillary canines.

Conclusions. Impacted maxillary canines are usually diagnosed by using panoramic imaging or cone-beam computed tomography. Cone-beam computed tomography is the most accurate diagnostic method to identify the localisation of impacted maxillary canines. Palatal expansion can help to avoid the impaction of maxillary canines. Combined surgical and orthodontic treatment is used to treat impacted maxillary canines in permanent dentition.

Key words: maxillary canine; impaction; impacted canine; treatment; diagnostic methods.

INTRODUCTION

Altered tooth eruption is a clinical condition which is characterised by failure of the tooth to emerge in the appropriate position. An eruption disorder may lead to the impaction of the tooth. In turn, tooth impaction is defined as a failed eruption of the permanent tooth with a wholly developed root (1).

The maxillary canines play an important functional and esthetical role in humans. That is the main reason why patients are concerned about having impacted maxillary canines and usually want treatment for this pathology. Modern diagnostic methods and a therapeutic approach combined with precise knowledge of all prognostic implications are necessary for timely diagnosis and appropriate treatment planning.

One of the most frequently impacted teeth after the third molars are the maxillary canines (2). The prevalence of impacted canines ranges from 1 to 2.5 per cent all over the world (2). Accordingly, there are several studies with large patient samples (>1000) that have investigated different diagnostic methods and different treatment strategies for impacted maxillary canines (3-5). The mentioned methods and procedures range from conventional radiography to cone-beam computed tomography, guided force eruption or extraction and orthodontic space closure (3-5).

Although there are different types of studies, case reports and some reviews on this topic, it is still difficult for the clinician to find reliable data regarding the early diagnosis and treatment of impacted maxillary canines. Therefore, this study aims to

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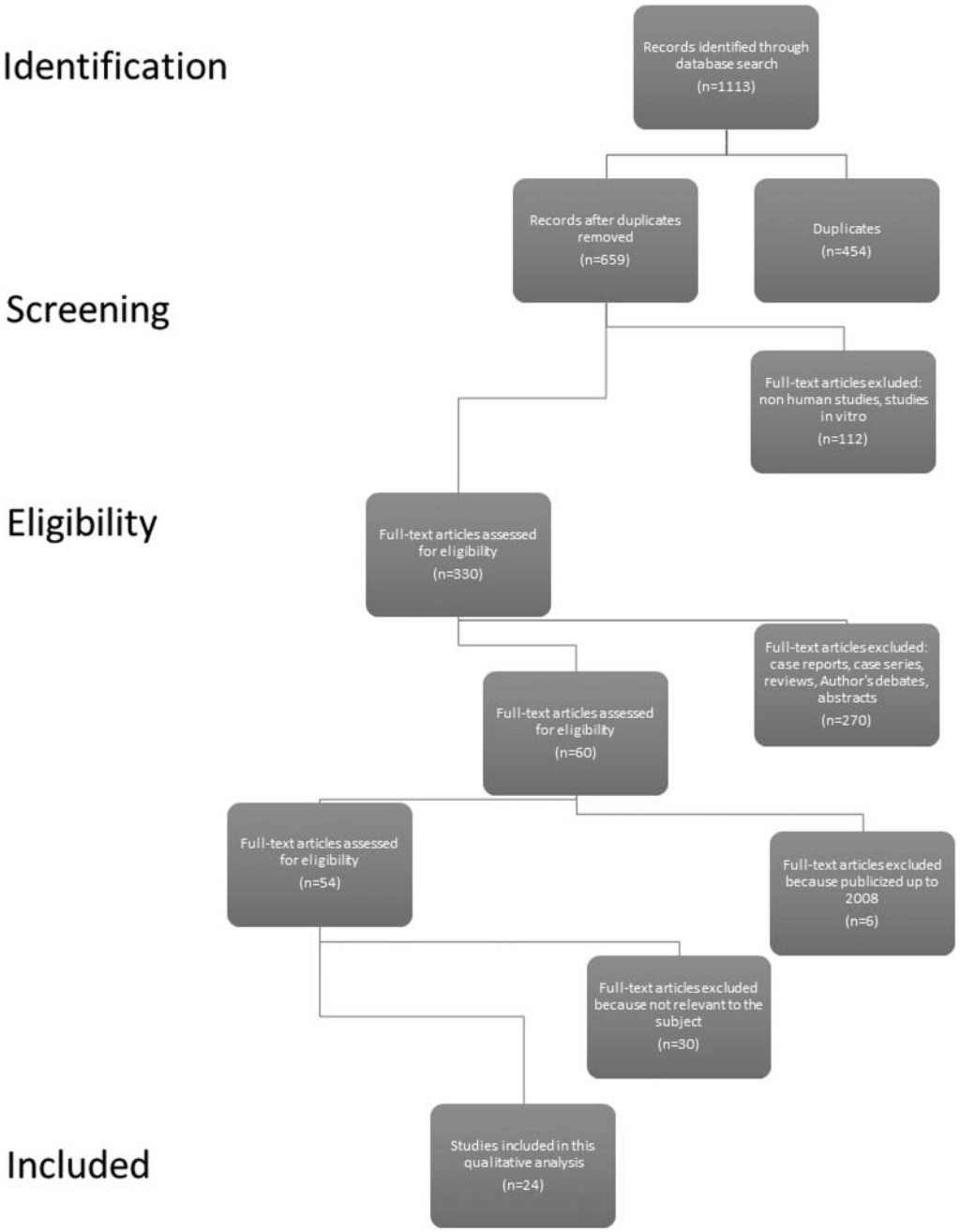

Fig. Diagram of the literature search strategy

review main diagnostic methods and different treatment strategies of impacted maxillary canines (6, 7). A combination of the results of all studies conducted to date will allow to gather evidence regarding the advantages and disadvantages of certain clinical approaches (6, 7).

MATERIALS AND METHODS

A computerised systematic search of studies published up to December 2018 was conducted without language restrictions (Appendix), in the following databases: Cochrane Central Register of Controlled Trials (issue 1, 2018) and Medline (via PubMed).

The criteria of inclusion and exclusion for this literature review were based on the type of study and publication year (see Table 1 and Figure). Literature reviews (n=39), systematic reviews (n=7), case reports (n=175), abstracts (n=68), animal studies (n=19), and in vitro studies (n=9) were excluded. Studies that were published before 2008 were excluded, too (as they are mostly discussed in older literature reviews). The reference lists of the chosen articles were examined and related references were investigated. Studies were selected independently. From the materials chosen, the investigator extracted data that answered

Table 1. The criteria for study selection

Inclusion criteria	Exclusion criteria
Studies with diagnostic tests and diagnostic methods	Reviews
Studies with orthodontic and surgical treatment strategies	Case reports, abstracts
Studies which included explicit descriptions of material and methods	Studies on animals and in vitro studies
Prospective and retrospective original studies on the human	Summary articles
Studies that included patients with impacted on or two maxillary canines	Studies on patients with genetic syndromes and severe facial malformations
Publication date since 2008	Publicised up to 2008

the clinical research questions. A customised data extraction form was developed, which included the following items: author's name and year of publication, study design, diagnostic method or treatment strategy, and conclusion of the study. The Newcastle-Ottawa scale (NOS) was applied to assess the quality of the reviewed articles (8). Studies were considered of low quality if they received between and three stars, of medium quality between four and six stars, and high quality between seven and nine stars.

RESULTS

The article selection process is shown in the diagram (Figure). The electronic database search found 1113 articles. Duplicates were identified and excluded, following which 659 items were screened. After screening, 330 materials were selected for full article review. When inclusion and exclusion criteria were applied, 23 publications were identified as relevant to the theme and included in this qualitative analysis. There were 9 studies of the treatment of impacted maxillary canines, 2 studies were retrospective, 5 were prospective and 2 were evaluation. Moreover, there were 14 studies on the diagnostic methods of impacted maxillary canines, 8 studies were retrospective, 5 were prospective, and 1 was a diagnostic cross-over study.

Seven of these studies analysed samples comprising combined surgical and orthodontic treatment: open eruption and closed eruption techniques (9-15). These studies tried to investigate the advantages and disadvantages of these two methods. The patients studied in the reviews had at least one

Table 2. Summary of data of the treatment of impacted maxillary canines

Year	Author	Study design	Journal	Open eruption technique	Closed eruption technique	Maxilla expansion	The conclusion of the study
2017	Silva AC	Retrospective	Journal of applied oral science	-	+	-	The traction of impacted maxillary canines had minimal effect on root length and buccal and palatal bone loss.
2014	Lempesi E	Retrospective cohort	European Journal of Orthodontics	+	+	-	Both treatment methods are suitable; open eruption technique is a faster method; no significant difference in posttreatment periodontal status and adjacent teeth.
2013	Bensaha T	Evaluation	International Journal of Oral and Maxillofacial Surgery	+	-	-	No tissue necrosis; no bleeding; brackets can be placed during the same visit.
2013	Koutzoglou SI	Prospective clinical	American Journal of Orthodontics and Dentofacial Orthopaedics	+ (3.5% chance of ankylosis)	+ (14.5% chance of ankylosis)	+ (no chance of ankylosis)	Surgical exposure can induce ankyloses; evidence between surgical exposure technique and ankyloses was found; the use of early palatal expansion can induce automatic eruption of impacted maxillary canine.
2013	Parkin NA	Multicentre, randomised controlled trial	American Journal of Orthodontics and Dentofacial Orthopaedics	+	+	-	Open- and closed eruption techniques compared; no significant difference in periodontal health was found after treatment.
2013	Smailiene D	Prospective	Medicina	+	+	-	No significant difference when using open- or closed eruption technique.
2012	Brusveen EM	Evaluation	American Journal of Orthodontics and Dentofacial Orthopaedics	-	-	+	An impacted maxillary canine does not seem to be a risk factor for apical root resorption after orthodontic treatment.
2012	Kocsis A	Prospective	Journal of Orofacial Orthopaedics	+	-	-	Mini screw anchorage should be taken into consideration when extrusion of impacted maxillary canines is planned.
2011	Baccetti T	Prospective	European Journal of Orthodontics	-	-	+	Trans palatal arch therapy can be equally effective as rapid maxilla expansion or a combination of these two methods.

Table 3. Summary of data on the diagnostic methods of impacted maxillary canines

Year	Author	Study design	Journal	Cone-beam computed tomography	Extraoral conventional radiography	Intraoral conventional radiography	Conclusions
2016	Alqerban A	Retrospective	Dentomaxillofacial Radiology	-	+	-	Prediction of maxillary canine impaction using a combination of linear and angular measurements in panoramic images is weak.
2015	Alqerban A	Retrospective	American Journal of Orthodontics and Dentofacial Orthopaedics	+	-	-	Prediction of maxillary canine impaction based on cone-beam computed tomography was excellent.
2014	Caroline S Lai	Retrospective	European Journal of Orthodontics	+	+	-	Orthodontists were more likely to diagnose the exact labiopalatal position of impacted maxillary canines when using only panoramic imaging; oral surgeons more often indicated the need for further 3D imaging.
2013	Alqerban A	Prospective	Dentomaxillofacial Radiology	+	+	-	Surgical treatment planning of impacted maxillary canines was not significantly different between panoramic and CBCT images.
2013	An S	Retrospective	Dentomaxillofacial Radiology	-	+	-	Panoramic radiography is not a very reliable method for locating impacted maxillary canines.
2013	Sajnani AK	Retrospective	Journal of Investigative and Clinical Dentistry	-	-	+	The vertical parallax technique demonstrated a higher degree of accuracy (97.7%) and a greater degree of diagnostic capability (98.2%) when compared with the horizontal parallax technique (92.6% and 78.0%).
2012	Hanke S	Retrospective	Journal of Craniomaxillofacial Radiology	+	-	-	CBCT is suitable for exact metric localisation of impacted maxillary canine.
2012	Novak HM	Prospective	Progress in Orthodontics	-	+	-	Cephalogram can be used to diagnose palatal displaced canines in late mixed dentition and help to avoid the final impaction of maxillary canines.
2012	Sajnani AK	Retrospective	American Journal of Orthodontics and Dentofacial Orthopaedics	-	+	-	Diagnosis of maxillary canines' impaction is possible at eight years of age by using geometric measurements on panoramic radiographs.
2012	Wriedt S	Diagnostic cross-over	Journal of Orofacial Orthopaedics	+	+	+	The results of this study are intended to be validated in a clinical trial; in some cases such as resorption of the adjacent teeth is suspected. CBCT is much accurate than panoramic imaging.
2011	Alqerban A	Perspective	European Journal of Orthodontics	+	+	-	CBCT is much accurate diagnostic method than dental panoramic tomography; using CBCT with the maximum data available would help to reduce unnecessary radiation exposure.
2011	Botticelli S	Perspective	European Journal of Orthodontics	+	+	+	The increased precision in the localisation of the impacted maxillary canines and the improved estimation of the space conditions in the arch obtained with CBCT. That resulted in a difference in diagnosis and treatment planning towards a more clinically oriented approach.
2010	Haney E	Prospective	American Journal of Orthodontics and Dentofacial Orthopaedics	+	+	+	2D and 3D images of impacted maxillary canines can produce different diagnoses and treatment plans.
2009	Nagpal A	Retrospective	Journal of Oral Science	-	+	-	The panoramic radiograph cannot be used as a single radiograph for reliable localisation of impacted maxillary canines.

Table 4. Methodological quality assessment for the included clinical studies using the Newcastle-Ottawa Scale *(continued on next page)*

Study	Selection				Comparability	Exposure/outcome			NOS score	Overall assessment
Silva AC	Yes	Consecutive or representative series of cases*	Community controls*	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	6	Medium
Lempesi E	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Bensaha T	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Koutzoglou SI	Yes	Consecutive or representative series of cases*	Community controls*	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	7	High
Parkin NA	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Smailiene D	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Smailiene D	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Brusveen EM	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Kocsis A	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Baccetti T	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Alqerban A	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Alqerban A	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Caroline S Lai	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Alqerban A	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
An S	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Sajnani AK	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Hanke S	Yes	Potential for selection biases or not stated	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	4	Medium

*According to NOS grading scale.

missing permanent maxillary canine. Additionally, two studies were based on a treatment method whereby a deciduous maxillary canine was extracted and maxilla was expanded to avoid the impaction of permanent maxillary canine (16, 17). Seven studies compared which of the diagnostic ways, namely, a cone-beam computed tomography or conventional radiography (panoramic imaging and conventional intraoral radiography), is more accurate (18-24). Four studies evaluated only the accuracy of dental panoramic radiograms (25-28). Two studies assessed how accurate the cone-beam computed tomography method is in diagnosing impacted maxillary canines (29, 30). Only one study analysed if cephalogram could be useful in early diagnosis of impacted maxillary canines (9-31).

Tables 2 and 3 summarise the key data on the diagnostic methods and treatment strategies for impacted maxillary canines from the 23 studies I analysed. Surgical treatment for impacted maxillary canines was more common than accepting early maxilla expansion to avoid maxillary canine impaction. Also, in many analysed articles cone-beam computed tomography was suggested as a much more accurate method for diagnosing the impaction of maxillary canines. Likewise, cone-beam computed tomography was usually recommended as the main diagnostic method for impacted maxillary canines by oral surgeons. Conversely, orthodontists usually preferred conventional radiography to cone-beam computed tomography as a routine diagnostic method (9-31).

The frequent treatment strategy in five studies was surgical exposure with orthodontic traction of impacted maxillary canine (9, 12-15). In these studies, the closed eruption technique was used (9, 12-15) while the open eruption technique was used as a treatment strategy in 4 studies (12-15). The latter four compared open- and closed eruption techniques (12-15). In these studies, no significant difference was found between these two techniques (12-15). Three studies proposed early maxilla expansion to avoid the impaction of maxillary canines (12, 16, 18).

The frequent diagnostic method in two of the analysed studies was cone-beam computed tomography. It was said that this method was very accurate in determining the real position of impacted maxillary canines (20, 25). In six studies, conventional radiography was defined as the routine examination method for diagnosing the impaction of maxillary canines (19, 23, 24, 26, 27, 32). In seven studies, the accuracy between cone-beam computed tomography and conventional radiography was

Table 4. Methodological quality assessment for the included clinical studies using the Newcastle-Ottawa Scale *(continued from previous page)*

Study	Selection				Comparability	Exposure/outcome			NOS score	Overall assessment
Novak HM	No description	Potential for selection biases or not stated	No description	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	4	Medium
Sajnani AK	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Wriedt S	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Same rate for both groups*	6	Medium
Alqerban A	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Botticelli S	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Haney E	Yes	Consecutive or representative series of cases*	Hospital controls	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	5	Medium
Nagpal A	Yes	Consecutive or representative series of cases*	Community controls*	No history of disease (endpoint)*	Study controls for any additional factor*	Secure record*	Yes*	Non-respondents described	6	Medium

*According to NOS grading scale.

discussed when diagnosing impacted maxillary canines (21, 22, 29-31). All of these studies state that cone-beam computed tomography is a more accurate method for diagnosing the impaction of maxillary canines than conventional radiography. This is because cone-beam computed tomography can investigate the location of impacted canine very precisely.

The quality assessment of these 23 articles performed using the NOS: 22 items were rated as medium quality, and 1 piece was ranked as high quality (Table 4).

DISCUSSION

This literature review was performed to summarise data about the diagnostic methods and treatment strategies of impacted maxillary canines. The performed comprehensive search resulted in the selection of 23 articles: ten retrospective, ten prospective, two evaluation, one diagnostic crossover, and one multicentre study. As a result of their methodological heterogeneity, the searched studies were divided into two groups based on their focus: on the diagnostic methods (group I) and on the treatment strategies (group II). All the pertinent details of the included studies were summarised in the tables. The table template drafted for the review did not fit all the studies perfectly since there were differences in the study designs. Nevertheless, the table template helped to maintain consistency and accuracy throughout the review.

Moreover, the current review encountered problems with potential data overall in the studies. Two studies were conducted in the same dental clinic in Hong Kong (*Sajnani et al.*, 2012 and *Sajnani et al.,* 2013) with a possible overlap of patient records included in the analysed databases. However, considering that any meta-analysis was performed combining different study data, both researches were included in this literature review (24, 27). Furthermore, it was not possible to establish, whether there was any overlap between the data in *Smailiene et al,* 2013a and *Smailiene et al,* 2013b studies (14, 15). These two studies were performed at the same time and the same university (2007-2012 The Department of Orthodontics at the Lithuanian University of Health Sciences) (14, 15). Still, both manuscripts were included in this review. Furthermore, it was difficult to determine if there was an overlap between *Alqerban A et al*. (2016) and *Alqerban A et al*. (2015) studies diagnostic methods for recognising impacted maxillary canines (22, 29).

Overall, this literature review aimed to look over the diagnostic methods and various treatment strategies of impacted maxillary canines. There are three main treatment strategies for impacted maxillary canines: no active treatment and monitoring; interceptive treatment, surgical exposure and orthodontic alignment (33). When no teeth are crowding, the impacted maxillary canine can erupt spontaneously, so it is possible to wait and monitor if the tooth is erupting (33). If the impacted canine has no space to explode, it is possible to plan interceptive treatment. At the age of 10 and 13, the deciduous canine can be extracted and induce the spontaneous eruption of impacted maxillary canine (34, 35). The success of interceptive orthodontic treatment depends on the age of the patient at which the impacted canine was discovered (34-36).

Furthermore, when a maxillary canine is impacted, usually a combination of surgical and orthodontic treatment is used. When there is a labial impaction, open eruption technique (gingivectomy or apically repositioned flap) is applied (37). Impaction of the mid-alveolus can be treated with open or closed eruption technique (37) while the palatal impacted maxillary canines require closed eruption technique (37). Several studies analysed the impact of surgical exposure on the posttreatment periodontal health of extruded impacted maxillary canine and the adjacent teeth. The reviewed studies suggested no effect of surgical intervention on the periodontal health. Most of the studies compared whether open eruption technique or closed eruption technique damages the periodontal health more (13-15). *Koutzoglou et al. (2013)* identified that surgical exposure of impacted maxillary canines could provoke dental ankylosis. Closed eruption technique induces ankylosis more often (14.5%) than open eruption technique (3.5%) (12). In order to avoid ankylosis of maxillary canine after impaction treatment, early maxilla expansion is suggested as the treatment method of impacted maxillary canine in young patients (12). It is noticed that rapid maxilla expansion can lead to spontaneous impacted maxillary canine eruption (12, 34, 35). However. *Silva et al. (2017)* state that using closed eruption technique as the treatment strategy for impacted maxillary canines can cause buccal and palatal bone loss of extruded maxillary canine and also root resorption of adjacent teeth (9). It is also stated that treatment methods such as open- and closed eruption technique are suitable for the treatment of impacted maxillary canines (14). It is important to mention that the open eruption technique is a faster treatment method than the closed eruption technique (14).

As well as traditional surgical intervention *Bensaha et al. (2013)* offer ultrasonic surgery for impacted maxillary canine treatment (11). The main advantages of ultrasonic surgery are that there is no bleeding, there is no tissue necrosis and brackets can be placed during the same visit (11). Also, the treatment time is shortened. On the other hand. *Baccetti et al. (2011)* suggest using transpalatal arch therapy as a treatment method for impacted maxillary canines (18), which helps to control the movement of maxillary first molars. So the space for permanent maxillary canines is upheld, and spontaneous eruption can be induced (18). Also, transpalatal arch therapy can be used in combination with rapid maxilla expansion (18). This treatment method is suggested to be used in the early mixed dentition to avoid the impaction of maxillary canines (12, 18). Also, mini screws should be taken into consideration when the extrusion of impacted maxillary canines is needed (17, 39, 40). *Roth et al. (2004)* reported a case where impacted maxillary canine was extruded by using a mini screw, was successfully performed (39).

Likewise, it is thought that orthodontic traction of impacted maxillary canines can induce root resorption of the adjacent teeth. However. *Brusveen et al. (2012)* and *Lempesi et al. (2014)* investigated that orthodontic traction of impacted maxillary canines rarely induces the resorption of the roots of adjacent teeth (10, 16). Following the results of previous studies, it can be stated that early maxilla expansion with or without transpalatal arch therapy can help to avoid impaction and lead to conservative orthodontic treatment (12, 18). Also, it is important to mention that surgical exposures rarely induce root resorption of the adjacent teeth or alveolar bone loss (9, 10, 13-16).

Concerning the diagnostic methods of impacted maxillary canines, the following different ways were evaluated: cone-beam computed tomography, extraoral conventional radiography (dental panoramic imaging and cephalometric imaging), and conventional intraoral radiography (horizontal parallax and vertical parallax methods). The most commonly recommended diagnostic method today is a cone-beam computed tomography (20, 21, 28, 31). The accuracy of cone-beam computed tomography method leads to early diagnosis of impacted maxillary canines, so the treatment strategy can be less aggressive. For example, early maxilla expansion can induce spontaneous eruption of permanent maxillary canine. *Novak et al. (2012)* found that cephalogram imaging, which was done in late mixed dentition, can help to recognise palatally displaced canines and to avoid the impaction of maxillary canines by using early treatment strategies (22, 26). Also. *Nagpal et al. (2009)*. *Alqerban et al. (2011)* and *An et al. (2013)* argue that dental panoramic radiography is less accurate than cone-beam computed tomography. When two of these diagnostic methods are used, different treatment plans are composed (23, 29, 32). Also, oral surgeons often prefer cone-beam computed tomography to conventional radiography, while orthodontists usually prefer dental panoramic imaging to CBCT (21). *Alqerban et al. (2016)* remark that predicting the impaction of maxillary canines by using dental panoramic imaging is not always accurate and is not recommended as the main diagnostic method (19). Concerning conventional radiography, it is important to mention that using a vertical parallax method is more accurate (97.7%) compared to horizontal parallax method (92.6%) (24). It is also important to mention that increased precision in diagnosing impacted maxillary canines leads to early diagnosis and treatment planning and even better treatment results (28, 30).

As the reviewed studies show, panoramic imaging can help to predict the impaction of maxillary canines, but CBCT can identify the location of impacted maxillary canine precisely. The radiation can be reduced by performing diagnosing methods accurate at the right time. It is better to take one exact cone-beam CT image than several conventional radiography images to diagnose the impaction of maxillary canines. Also, it is important to mention that the earlier the diagnosis is investigated, the better treatment results can be achieved.

The possible limitations of this literature review include the selection bias, which variably affects all studies. From a therapeutic point of view, the time of the diagnosis plays a significant role in treatment options and prognosis. The earlier the impaction of maxillary canines is found, the less hostile treatment method can be used. Moreover, in order to avoid many surgical interventions, dental panoramic imaging can be used in mixed dentition to predict the possibility of impacted maxillary canines, after which maxilla expansion can be applied. The likelihood of spontaneous eruption decreases with the increase of patients' age. Diagnosing the impaction of maxillary canine in permanent dentition usually leads to surgical interventions such as open- or closed eruption techniques. The risk of complications also increases with the increase in patients' age. Such complications as ankylosis more often occur in older patients after surgical treatment of maxillary impacted canines than in children with mixed dentition after orthodontic treatment.

Finally, there are several conditions that play a significant role in treatment planning: patients' age, the location of impacted teeth as well as patients' preferences and oral hygiene skills. If the oral hygiene skills are poor, the treatment results are also poor. If patients' preferences are not realistic, no treatment should be applied.

Doubtless, the path to the rehabilitation of normal occlusion and good esthetical results is the appropriate timing and precise treatment planning. Each treatment plan should not only treat radiographically diagnosed pathologies but also reflect each patient's needs. It is essential to know how every diagnostic and treatment method works and decide which of them is the most appropriate for that time. Today it is much easier to choose the right time to start the treatment because cone-beam computed tomography is currently the most reliable and informative tool in diagnosing impacted maxillary canines. Therefore, cone-beam computed tomography is the best mode for the precise evaluation of treatment difficulties and clinical strategies (9-32).

CONCLUSIONS

The impacted maxillary canines are usually diagnosed by using panoramic imaging or cone-beam computed tomography.

Cone-beam computed tomography is the most accurate diagnostic method to identify the localisation of impacted maxillary canines.

Early palatal expansion or transpalatal arch therapy can help to avoid the impaction of maxillary canines.

Combined surgical and orthodontic treatment is usually used to treat impacted maxillary canines in permanent dentition.

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Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

APPENDIX

The search strategy

The search strategy on PubMed

((“canine”[All Fields] and “impacted”[All Fields]) or (“cuspid'[All Fields] and “impacted”[All Fields]) or (“canine”[All Fields] and “retained”[All Fields] or “cuspid”[All Fields] and retained”[All Fields])) AND ((“treatment”[All Fields] and “orthodontic”[All Fields] or “surgical”[All Fields] or “conservative”[All Fields]) or (“diagnostic”[All Fields] or “diagnosis”[All Fields])).

The search strategy on Cochrane:

(“Canine” AND “maxillary”) OR (“Cuspid” AND “Maxillary”) OR (“Canine” AND “Upper”) OR (“Cuspid” AND “Maxillary”).

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