Predictive Factors and Ideal Timing for Spontaneous Eruption of Displaced Canine after Primary Canine Extraction: A Literature Review

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Abstract

The extraction of the primary canine in mixed dentition is an interceptive procedure to reduce the incidence of palatally displaced canines. The aim of this study is to evaluate the predictive factors and the ideal timing for spontaneous eruption of the palatally displaced canine after primary canine extraction.

The literature search was conducted using the PubMed and Scopus databases. The PICOS criteria were used to select studies.

To ensure the effectiveness of primary canine extraction in promoting the spontaneous eruption of the permanent canine, the following factors should be considered: biological variables (with higher probability of success if extraction is performed between 10 and 11 years old), radiological parameters (α angle between 20° and 30° and sectors 2 and 3 concerning the segmentation method of Ericson and Kurol; stage of dental development: before complete eruption of mandibular canine of same side as maxillary canine and primary canine root resorption more than half or oblique) and clinical parameters (crowding reduces spontaneous eruption of maxillary canine).

The extraction of the primary canine is an effective interceptive measure for facilitating the eruption of palatally impacted canines. Ideal timing and favorable predictive factors can influence the success of this interceptive treatment.

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Introduction

Tooth impaction refers to the position of a tooth within the bone after the expected time of eruption[1,2]. Early diagnosis and interceptive treatment can promote the eruption of palatally displaced maxillary canines (PDC), avoiding possible impaction[3,4]. Indeed, the presence of an impacted maxillary canine represents a need for orthodontic treatment[5].

After the third upper molar, the maxillary canine is the most commonly impacted tooth, with a prevalence of 1-3%[6]. The upper jaw is affected 10 times more than the lower jaw and the female sex has an incidence 3 times higher than the male[4,7]. Canine impaction has been found on the palate in 85% of the cases and to the buccal surface in 15%[8].

Two main theories have been proposed to explain palatal impaction of maxillary canines: the "guidance" theory and the "genetic" theory. According to the guidance theory, proposed by Becker et al. in the 1980s, canine impaction is caused by structural abnormalities of the lateral incisor (microdontic or conoid incisors), agenesis or asynchrony in the transition from the mixed dentition to the permanent dentition, as the roots of these elements act as guides for the eruption of the canine[9-11]. In the mid-1990s, Peck et al. proposed the genetic theory, suggesting that palatal canine impaction is a hereditary trait[12,13]. This theory is supported by sereveral evidences, including the association of palatally impacted canine with other inherited dental anomalies, such as agenesis, microdontic teeth, supernumerary teeth, ectopic eruption of teeth

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and transpositions[14,15]. Studies involving monozygotic twins and more recent studies using a whole exome sequencing (WES) approach on selected members of a family with maxillary canine eruption abnormalities have shown further support for the genetic theory[16-18].

The radiographic diagnosis, which follows the clinical assessment, includes orthopantomography as the first examination of choice. Orthopantomography provides an overview and allows various measurements to be made for an early diagnosis of inclusion in mixed dentition[19]. Measurements can be divided into angular (the α angle formed between the long axis of the tooth and the interincisal midline), sectoral (Ericson and Kurol's overlapping sector identifies the position of the canine with respect to 5 sectors, delimited by the straight lines: tangent to the distal and mesial surfaces of the deciduous canine, axis of the lateral incisor, straight line tangent to its mesial surface, axis of the central incisor and straight line tangent to its mesial surface[20,21]; Lindauer's method, in which three lines, distal, central, and mesial, are drawn, tangent to the root and crown contour of the permanent lateral incisor in order to create four vertical sectors; the overlap of the canine on the lateral incisor assesses the position of the canine in relation to the root of the lateral incisor and its long axis[22]) and millimetric (the distance d between the cusp of the canine and the occlusal plane, delimited by a line passing from the incisal edge of the central incisor and the occlusal surface of the first permanent molar).

Lateral radiographs may also be useful to assess predictive factors of maxillary canine impaction for the presence of some head and neck skeletal anomalies or variants. Indeed, it is widely documented in the literature that two anomalies associated with impaction of the maxillary canine are Ponticulus Posticus and the bridge of the sella turcica[23-25].

Cone-beam computed tomography (CBCT) represents an advanced diagnostic tool for impaction; CBCT can identify and locate the position of impacted canines accurately and is useful for an evaluation of the resorption of the adjacent teeth[26].

The treatment of the impacted canine aims at repositioning the element in the arch, because of the importance of canines from a functional and aesthetic point of view. The orthodontic-surgical treatment should also consider the periodontal health of the impacted tooth in order to select the least invasive surgical technique[27-30].

Recent technologies have allowed minimally invasive approach to solve the impaction of palatal canines using computer-guided orthodontic miniscrews, reducing the biomechanical side effects associated with conventional treatment and the risk of damaging adjacent anatomical structures, increasing the effectiveness of treatment[31-33].

Considering the potential risks and complications associated with surgical exposure and orthodontic traction of PDC, any interceptive approach that could help mitigate these problems would be desirable.

The extraction of the primary canine in mixed dentition as an interceptive procedure to reduce the incidence of palatally displaced canines was first proposed in the 1930s[34]. The purpose of the extraction is to facilitate the removal of mechanical obstacles or inflammatory factors, reducing bone resistance and facilitating the normal eruptive path of the maxillary canine.
The aim of this study, following a literature review, is to evaluate the predictive factors and ideal timing for the spontaneous eruption of PDCs after primary canine extraction.

Materials and methods

In accordance with PRISMA guidelines, the literature search was mapped across 2 databases: PubMed (The National Library of Medicine MEDLINE,Med) and Scopus. PICOS criteria were used to select studies:

- Patient: patients in mixed dentition;
- Intervention: primary canine extraction;
- Control/Comparison: cases where deciduous canine extraction was unsuccessful;
- Outcomes: factors influencing treatment success;
- Study design: randomized controlled trials, prospective studies and retrospective studies.

The search strategy made use of Boolean operators with several keywords and as follows: (canine or cuspid) AND (maxillary or palatal) AND (impacted or unerupted or retained or ectopic or displaced) AND (interceptive or extraction or removal) AND (deciduous or primary). Studies published between 1974 and 2023 were included in the present review.

Inclusion criteria include:
• Randomized clinical trials, retrospective and prospective studies that evaluated factors influencing eruption of PDC;
• Patients in mixed dentition;
• Presence of unilateral or bilateral palatally impacted maxillary canine;
• Absence of previous orthodontic treatment;
• Absence of craniofacial syndromes or labiapalatoschisis.

Exclusion criteria include:
• Reviews, case reports, letters to editors and publishers and animal studies;
• Studies that used other interceptive treatments associated with primary canine extraction.

We searched for studies with patients in the mixed dentition presenting unilateral or bilateral PDCs and no restrictions regarding racial background or gender. No restrictions were imposed on the language or date of publication. Two reviewers (GP and RG) independently and in duplicate reviewed the title, keywords and abstract of the reports identified by the electronic search.

Results

A total of 360 articles were found using the keywords (200 on PubMed and 160 on Scopus). 122 articles were excluded after detection of duplicates and 164 for title screening. The remaining articles were evaluated by reading the abstracts and 54 were excluded, leading to a complete reading of 20 articles. Among these, only 4 articles satisfied all the inclusion and exclusion criteria, while the others were excluded because there were no post-treatment evaluations or they proposed other interceptive treatments associated with the extraction. Table 1 shows the study design and Table 2 summarizes their characteristics and what they evaluated.

All analyzed variables were divided into three categories:
1. Biological: sex and age;
2. Radiographic: the position of the permanent canine and dental development, on orthopantomography and intraoral radiographs;
3. Clinical: crowding.

Author	Year	Title	Journal name	Types of studies
Bazargani et al.	2014	Effect of interceptive extraction of deciduous canine on palatally displaced maxillary canine: A prospective randomized controlled study	Angle Orthodontist	RCT
Power et al.	1993	An Investigation into the Response of Palatally Displaced Canines to the Removal of Deciduous Canines and an Assessment of Factors Contributing to Favourable Eruption	European Journal of Orthodontics	OPS
Naoumova et al.	2018	The use of panoramic radiographs to decide when interceptive extraction is beneficial in children with palatally displaced canines based on a randomized clinical trial	European Journal of Orthodontics	RCT
Taguchi et al.	2005	A diagnostic proposal to support early treatment of ectopically erupting maxillary canines	Pediatric Dental Journal	ORS

Table 1. Selected studies and types of studies.
RCT: Prospective randomized controlled trial; OPS: Observational prospective study; ORS: Observational retrospective study.

Author and year	Sample	Sample characteristics	Follow-up	Diagnosis	Parameters evaluated
Bazargani et al., 2014	24 patients, 48 PDCs Mean age 11.6 ±1.2 years	Caucasians, bilateral impaction; after randomization one extraction site and one control site	Every six months up to 18 months	Canine bulge absent and orthopanoramics	Age of the patient; linear and angular measurements on orthopanoramics
Power et al., 1993	39 patients, 47 PDCs. Mean age 11.2 ± 1.43 years	Caucasians; after extraction, division into 3 group: success, improved, failure	Up to 2 years	Clinical examination and intraoral radiography	Gender and age; linear and angular measurements on orthopanoramics; clinical features
Naoumova et al.,2018	67 patients, 89 PDCs. 10-13 years	Caucasians; randomly assigned to the extraction group or non extraction group	At 6 months and 12 months	Canine bulge absent and intraoral radiography	Linear and angular measurements on orthopanoramics; clinical features
Taguchi et al., 2005	SG: 64 patients, 68 PDCs; CG: 225 patients	Asians; patients divided into 3 groups in which it was necessary: extraction only, extraction and orthodontic traction, extraction of permanent canine	Not specified	Periapical radiographs and orthopanoramics	Relationship between maxillary canine eruption and mandibular canine eruptive movement classified into different stage

Table 2. Summary of characteristics of selected studies.
PDCs: palatally displaced canines.

Biological parameters:

No statistically significant interactions were found regarding gender[35,36]. However, considering the age of the subjects, Bazargani et al. divided the patients into two sample, a younger group (10-11 years) and an older one (12-14 years), proving that the second group showed no significant improvement in both α angle and distance d[36]. Furthemore the Authors analyzed the loss of space at the extraction site, that it was more pronounced in older patients, with an average decrease of 2.2 mm compare to 0.4 mm in younger patients. Naoumova et al. in 2018 reported that the mean age of subjects with erupted canines after one year (11+/- 0.9 years) was lower than those in which the eruption did not occur (12+/-1.0 years)[37]. The Power et al.

study, divided the participants at the end of the treatment into a successful group, a improvements group and a failure group. The mean ages of these groups (respectively 11.28 years, 11.02 years and 11.06 years), showing no appreciable difference between them[35].

Radiographic parameters:

Regarding radiologic variables evaluated on OPT, the following factors were taken into consideration: the overlap with the lateral incisor, the α angle, the values of the distance d, the degree of resorption of the primary canine and the stage of development of the mandibular canine.

Power et al. found overlap with the closest adjacent incisor to be the most important factor, reporting the following success rates[35]: overlap greater than half of the root (29.5%), less than half of the root (73%), without overlap (100%).

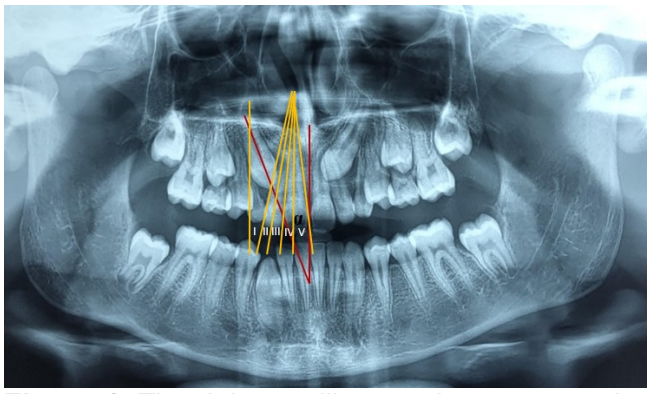

Figure 1. The right maxillary canine presents the positive characteristics for successful interceptive extraction treatment of the corresponding deciduous canine: α angle between 20° and 30° and position in sectors 2 according to the classification of Ericson and Kurol.

Concerning the segmentation method of Ericson and Kurol, Bazargani et al. showed that palatally impacted canines with an initial position in sectors 2-3 had a higher percentage of improvement (79%) than those in sectors 4-5 (20%)[36]. In agreement with these results, Naoumova et al. reported that sector position was a good prognostic indicator, especially when associated with the α angle[37]. Indeed, they demonstrated that an α angle of less than 20° and a position in sector 2 should lead to spontaneous eruption without any intervention after extraction of primary canine (Figure 1), while a canine with an α angle greater than 30° and a position in sector 4, should undergo simultaneous surgical exposure in addition to extraction. An advantageous α angle for interceptive extraction was found to be between 20° and 30°, similar to the study by Power et al. However, an angle greater than 31° had a lower success rate (37.5%) than a smaller angle (67%)[35]. The study by Taguchi et al. reported the mean values of α angles in patients divided into three groups according to the treatment they needed[38]: only extraction of the primary canine (20°), extraction and subsequent orthodontic traction (32.3°), permanent canine extraction (58.3°).

In terms of the values of the distance d, the studies by Power et al. and Taguchi et al. showed no significant importance in influencing treatment success[35,38]. Among the radiographically detectable factors expressing the stage of dental development, Power et al. showed how the degree of resorption of the primary canine can give some indication of the potential for success. The degree of resorption was classified as follows: stage 1 (no resorption), stage 2 (less than half of the root resorbed), stage 3 (more than half of the resorbed root), stage 4 (oblique resorption without apical shortening), stage 5 (oblique resorption and apical shortening). The results showed that in cases with half-root or oblique resorption there was 73% success rate and a 20% improvement, while in the cases with apical shortening the success rate was 100%. Furthermore, in the failure group, 67% had no resorption[35]. The study by Taguchi et al. classified the developmental stage of the permanent mandibular canines into six categories, with stages 0 to 3 defined by the extent of root resorption or exfoliation of the predecessor, and stages 4 and 5 by either in course of eruption or full eruption[38]. In the cases of maxillary canines undergoing simple treatment (extraction of the predecessor and/or exposure of the canine) in half of the cases the mandibular canines are in a stage between 0 and 3. However, in cases requiring orthodontic traction of the maxillary canines, almost 70% were in stage 5 (after full eruption of the mandibular canine) on the same side as the mandibular canine. Out of six cases of an extracted maxillary canine, five mandibular canines were stage 5 and only one was stage 1.

Clinical parameters:

As regards the clinical variables, the study by Power et al. recorded the presence or

absence of crowding, while the other studies did not analyze it or included it among the exclusion criteria. The study showed that 86% of successful cases had no crowding, while in unsuccessful cases, 89% showed crowding. More than half of cases in which only improvement or failure had occurred showed crowding that later justified the extraction of permanent teeth.

Discussion

Extraction of the primary canine in mixed dentition in patients with PDC has been shown to be an effective interceptive therapy, however, following this procedure, not all canines erupt spontaneously. This review evaluated the parameters that may influence the success of this treatment, to identify which cases could benefit from the extraction of the primary canine, and when it should be performed. If an interceptive treatment leads to successful eruption of the PDC, this will prevent the need for a more invasive procedure, bearing in mind the risks and potential complications of surgical exposure and orthodontic traction of PDCs.

In the literature, the efficacy of interceptive treatment in maxillary canine impaction is a controversial topic and not all studies have shown a benefit from primary canine extraction. In particular, the systematic review by Benson et al. considers the effect of primary canine extraction in patients with PDC, stating that there is no definite evidence that this procedure, either alone or in combination with deciduous molar extraction, can lead to spontaneous eruption of the permanent canine[39]. However, this review takes into consideration patients aged between 9 and 14 years, stating that before the age of 9 it is difficult to diagnose impacted canine, and after 14 years any interceptive treatment is less effective. In our study, however, it was found that in younger patients (under 12 years of age) and before complete eruption of the mandibular canine, a higher success rate is reported. Our study could therefore provide help in identifying with more precision the range of patients who can benefit from an early interception orthodontic intervention to avoid the impaction of the maxillary canine. Other studies in the literature confirm the efficacy of interceptive treatment, in agreement with the results of our study, stating that the prevalence of impacted maxillary canines in a geographical area where interceptive treatment is systematically implemented it is very low[40].

In order for extraction of the deciduous canine to be effective in determining the spontaneous eruption of the permanent canine, the following should be taken into consideration: predictive factors and ideal timing. These characteristics are easily available through a basic orthopantomography and a preliminary clinical evaluation.

With regard to predictive factors, the most important radiographic parameters that assess the position of the palatally displaced canine on orthopantomography, according to Power et Al., are the degree of overlap of the canine on the adiacent incisor (which if greater than half of the root has an unfavourable prognosis) and the α angle (considered unfavourable if greater than 31°)[35]. The authors also suggest that the most important clinical factor for spontaneous eruption is the absence of crowding, not evaluated in other studies because it was often present in the exclusion criteria and not usually associated with palatally displacement of the canine.

The α angle is also defined as a good predictive factor in the randomized controlled study by Naoumova et al. in 2018, especially if associated with the sectoral position of the canine according to Ericson and Kurol. This study found that interceptive extraction is more likely to be successful if there is an α angle of 20-30° and the canine located in sector 2-3. An α angle of less than 20° with the maxillary canine located in sector 2, indicates that the canine may erupt spontaneously[37]. The sectoral position of the canine was also analyzed in the study by Bazargani et al. in 2014, whose results indicate a minor improvement of PDCs located in sectors 4-5 compared to those in sectors 2-3, probably due to the greater distance from the canine extraction site[36]. There are several studies in the literature that take into consideration the significant predictors of impaction of maxillary canines in panoramic radiographs[19,41-43].

The study by Warford et al. shows that the greater probability of inclusion occurs when the canine is located in sectors III and IV, according to Lindauer's method[43].

Regarding the ideal treatment time, both studies by Bazargani et al. and Naoumova et al., emphasise the importance of patient age for the

success of primary canine extraction.

Indeed, both studies reported higher success rates in younger (10-11 years) than in older (12-14 years) patient groups[36,37].

Since chronological age is not always related to the subject's dental development, additional factors should still be considered to identify the ideal time to perform the extraction in order for it to be successful. The following radiographic variables were analyzed in order to identify the ideal timing for the extraction of the deciduous canine: the eruption stage of the mandibular canine and the resorption of the primary canine. The retrospective study by Taguchi et al. on a sample of Japanese children evaluates, in addition to the α angle and the d distance, the relationship between the eruption of the maxillary canines and the eruptive movement of the mandibular canines in order to determine the ideal time to start treatment according to the stage of development of the mandibular canine on the affected side. The authors suggest starting the interceptive treatment before complete eruption of the mandibular canine[38]. According to the resorption of the primary canine, the study by Power et al. revealed increased success rates in cases with resorption greater than half of the root or oblique, especially with apical shortening, and no resorption in the majority of unsuccessful cases[35].

The time when extraction should be performed was also considered in other literature studies. The extraction on patients between 10 and 13 years of age results in an improvement in the position of the permanent canine in 50% of cases already at 6 months and 78% at 12 months. However, before the age of ten years spontaneous correction of potentially displaced canines may occur and extraction is not indicated unless a very early somatic and dental development is found[44]. The extraction of the primary canine as an interceptive treatment should consider additional parameters, such as midline shift and loss of space at the extraction site, which were examined in the studies by Bazargani et al. and Naoumova et al.[36,37].

Regarding unilateral extraction, both studies considered midline shift, measured on plaster models in the study of Bazargani et al. and clinically in that of Naoumova et al. The first study found no midline shift towards the extraction side, concluding that symmetrical extraction of primary canines is not necessary in order to maintain the midline position[36]. In contrast, the study by Naoumova et al. observed upper midline shifts in 17% of cases after unilateral extraction, in disagreement with the previous study, probably due to the different way in which the measurement was assessed[37]. This study also found rotation or displacement at the extraction site in 37% of patients after 6 months, with no further changes during the rest of the observation period. In contrast, in the study by Bazargani et al., the extractive space continued to decrease over the 18-month observation period and, as previously reported, more pronounced in older (12-14 years) than younger (10-11 years) patients[36]. The authors therefore suggest the use of a space maintainer during the observation period, such as the palatal arch, especially when extraction is performed in older patients. Baccetti et al., in a randomized clinical trial in 2008, demonstrated that in all cases of primary canine extraction there is significant mesial movement of the upper first molars, which is minimised by the use of headgear[45]. The use of this device in association with the extraction of the primary canine has shown higher success rates than the extraction alone, but the authors suggest however that this effect could also be obtained with appliances less dependent on patient compliance. Several studies in the literature have evaluated extraction of the primary canine in combination with other interceptive treatments, such as the use of RME, headgear and concomitant extraction of the primary molar[46,47]. However, such studies are not comparable with the present study, as only the effect of primary canine extraction on maxillary canine eruption was evaluated.

A recent randomized controlled trial reports the effect of slow maxillary expansion (SME), primary canine extraction and no intervention on the position of PDCs in patients presenting early mixed dentition[48]. Among the predictive parameters evaluated for the risk of inclusion of the maxillary canine, the most important was the overlapping sector, followed by the angle α; according to the present study, SME appears to be the only treatment capable of improving the overlap area, reducing the need and complexity of subsequent orthodontic treatment.

Also in a recent systematic review of the literature, the different treatment modalities in the mixed dentition were evaluated, in order to evaluate possible improvements in the position of

PDCs[49]. Therefore, the extraction of the primary canine would seem to significantly improve 12 months later the position of PDCs, above all if followed by the use of headgear. In contrast, concomitant primary molar extraction did not show improvement in inclination compared to primary canine extraction alone.

These results contribute to the data presented by previous systematic reviews with respect to the effects of extracting primary canines or other teeth in the spontaneous eruption of PDCs, alone or in combination with other orthodontic procedures. As in our study, the position of the crown of a canine in relation to the midline and the sectorial position of the canine are the most significant factors in treatment outcome prediction.

The main limitation of our study is the heterogeneity in the type and design of the studies (two RCTs, one retrospective and one prospective study). Two studies were conducted in Sweden, one in the UK and one in Japan, with possible differences according to the origin of the subjects. Most of the studies focused on the age of the subject, not necessarily related to dental development, and factors regarding the most favourable canine position for eruption, without indicating when these are valid. Therefore, further randomized clinical trials are needed to evaluate signs of dental development indicating the ideal time for extraction of the primary canine and the effects of an extraction performed at the wrong time.

Conclusions.

The extraction of the primary canine following an early diagnosis is an effective interceptive measure in facilitating the eruption of palatally impacted canine, avoiding complications and more complex treatments. Ideal timing (chronological age between 10 and 11 years) and some favourable predictors (α angle between 20° and 30°; position in sectors 2-3 according to Ericson and Kurol; before the complete eruption of the mandibular canine on the same side; when the root of the corresponding primary canine has a resorption greater than half of it or oblique, especially with apical shortening) could influence the success of such interceptive treatment.

Declaration of Interest

The authors report no conflict of interest.

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