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Risk of Maxillary Canine Impaction in Pediatric Patients with Maxillary Constriction: Retrospective Study on Panoramic Dental Images

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Abstract: The maxillary canine is the second most commonly impacted tooth after the maxillary third molar. Identifying risk factors for impaction is crucial for timely intervention; panoramic radiographs are particularly valuable for screening and identification purposes. This study aims to explore the association between transverse maxillary deficiency with bilateral crossbite, and the risk of maxillary canine impaction. A cross-sectional retrospective study was conducted on records of pediatric patients (7–13 years old) undergoing orthodontic evaluations. Panoramic radiographs were analyzed to assess the risk of canine impaction using the sectorial method, distance from the occlusal plane, and the alpha angle. Results from 48 canines of patients with transverse maxillary deficiency and bilateral crossbite were compared to canines of sex- and age-matched patients without these malocclusions. Statistical analysis was performed by the Shapiro–Wilk test, Levene's test, or a *t*-test. There were no significant differences in high-risk canine impaction between groups when considering sector classification or distance from the occlusal plane. However, the control group showed a significantly higher risk according to the alpha angle ($\geq 25°$). No overall significant difference in risk was observed, suggesting that transverse maxillary deficiency with bilateral crossbite may not increase the risk of maxillary canine impaction.

Keywords: impacted canine; skeletal crossbite; alfa angle

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1. Introduction

Maxillary canines rank as the second most commonly impacted teeth after maxillary third molars [1], with a prevalence ranging between 1% and 5% of the population [1–4]. Several studies have reported a higher incidence in females, with a female to male ratio from 1.3:1 to 3.2:1 [5–13]. The prognosis for an impacted maxillary canine commonly involves a thorough examination of its position, conducted through both clinical and radiographic evaluations. Panoramic radiographs are particularly useful and have a sufficient degree of sensitivity [14], especially since they are routinely performed during orthodontic screening [15]. The established criteria aim at classifying the type of impaction, ultimately informing about the prognosis for eruption and guiding the formulation of treatment plans. One of the most frequently used classifications is the method proposed by Ericson and Kurol. This method categorizes the position of the impacted tooth based on its proximity to adjacent teeth (divided in sectors), the angle between the canine's axis and the midline (α angle), and the distance to the occlusal plane (measured in millimeters).

Figures 1 and 2 are taken from Ericson and Kurol's original paper to better describe the method used.

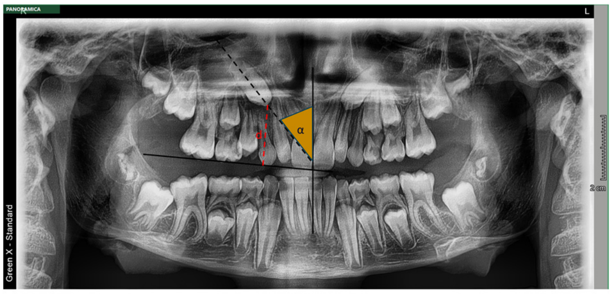

Figure 1. The inclination of the maxillary permanent canine (α) is measured by the internal angle formed by the major axis of the canine and the midline. Distance (d) is the distance to the occlusal plane according to Ericson and Kurol [16].

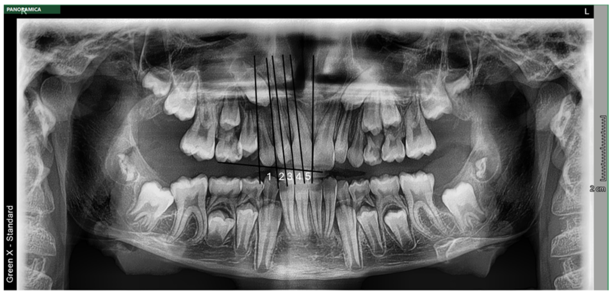

Figure 2. The sectors of the mesiodistal crown position of the maxillary permanent canine (1–5) according to Ericson and Kurol [16].

Accordingly, a more favorable prognosis is expected when the canine is positioned higher in the alveolar process and in closer proximity to the midline. Conversely, an unfavorable prognosis is associated with distally located canines, at a lower level, within the palatal bone, displaying palatal displacement or causing the resorption of adjacent teeth [16].

Understanding potential risk factors for ectopically or nonerupting canines is crucial, as impacted canines can cause resorption of adjacent permanent teeth's roots [17,18].

The etiology of maxillary canine impaction is recognized as multifactorial and is still debated. The established etiological factors include morphological anomalies of the adjacent upper lateral incisor [1–3,10,19–23], reduced mesiodistal width of maxillary teeth [24,25], eruptive space deficiency [26], genetic predisposition [8,27,28], congenitally missing teeth [8,21], mesial bony displacement of upper first premolar [29], arch length deficiency [13,30], an inadequate space for eruption of the permanent tooth [31,32], and transverse maxillary discrepancy [33]. Notably, contradictory findings arise regarding the potential correlation between transverse discrepancies and maxillary canine impaction. Some studies suggested an association between impacted maxillary canine and either an increased [32] or decreased [13,34–36] intermolar maxillary width calculated on dental casts, when compared to controls without tooth impaction. Conversely, other studies have not found any association between intermolar maxillary width and canine impaction, whether the measurements were taken from dental casts or through cone beam computed tomography (CBCT) [23,30,33,37,38]. Yet, some of these studies identified an association with anterior skeletal and dental deficiencies [23,33,38].

Given the conflicting findings in the existing literature, the aim of this study was to further investigate the potential association between transverse maxillary deficiency, with bilateral crossbite, and the risk of maxillary canine impaction. It was hypothesized that children with transverse maxillary deficiency and bilateral crossbite would exhibit a higher risk of maxillary canine impaction compared to those without such discrepancy. If this hypothesis were confirmed, early interceptive interventions could be recommended to mitigate the risk of maxillary canine impaction, reducing the complexity and potential complications of treating impacted teeth [9]. Therefore, this study seeks to contribute to the existing knowledge and provide insights that may influence clinical practices and treatment strategies for patients at a high-risk of maxillary canine impaction.

2. Materials and Methods

2.1. Study Design

This observational retrospective study was reviewed and approved by the Ethics Committee of the A. Gemelli IRCCS University Polyclinic Foundation (Protocol No. 0004079/23 of 8 February 2023).

2.2. Sample Size Calculation

Based on the available literature [39], a normal distribution of the main variable (the absolute difference in alpha angle of the canine) was hypothesized. A standard deviation of 13° was estimated. A minimum of 26 canines was required for each group, when the true value of the absolute difference in the alpha angle between the test and control groups was 10°, with alpha error set at 0.05 and statistical power at 80%.

2.3. Study Participants

A retrospective chart review was conducted using records of consecutive patients evaluated for orthodontic needs at the Orthodontic Department of the A. Gemelli IRCCS Polyclinic Foundation from April 2019 to November 2023. Two groups were identified based on the following inclusion criteria: the study group consisted of children, aged 7 to 13 years (since this age generally allows deciduous teeth to still be present in the dental arch), diagnosed with skeletal transverse maxillary deficiency at both canines and molars, bilateral skeletal crossbite, and with deciduous maxillary canines present in the dental arch. The control group consisted of age- and sex-matched children without maxillary deficiency or posterior skeletal crossbite. All patients were evaluated by a specialist orthodontist. The exclusion criteria included patients with a history of orthodontic treatment, genetic anomalies, syndromic and/or craniofacial conditions, cleft lip and/or palate, traumatic injuries to the face or permanent incisors, and agenesis of permanent maxillary lateral incisors or congenitally missing teeth (excluding third molars).

2.4. Data Collection

Clinical archival records were reviewed to collect demographic variables of biological sex (male, female) and age (years). The diagnoses of maxillary constriction and bilateral posterior crossbite were obtained upon agreement of three orthodontists by combining clinical examination, analysis of intraoral photographs, and digital dental casts. The clinical examination consisted of the evaluation of symmetry and shape of the palatal vault, the buccal corridor width of the patients during smiling, and the canine and molar transverse relationship with the opposing dental arch [40]. Next, the analysis of dental casts involved the evaluation of dental arch symmetry, tooth inclination through Curve of Wilson and Curve of Monson, and transverse relationship with the two dental casts in occlusion [40]. Finally, the intraoral photographs were taken following a standardized protocol, as suggested somewhere else [41]. The patients were instructed to sit upright and to look straight to a reference point, with their Frankfurt plane being parallel to the floor and the mouth closed in maximum intercuspation. The same digital camera (D7000, Nikon, Japan) with the focus point centered on the incisal edge of the upper central incisors, was utilized to take photographs to all the included participants. From the intraoral photographs, the maxillary skeletal discrepancy and posterior crossbite were evaluated based on the buccal corridor width, the transverse posterior relationship between upper and lower molars and canines, and the difference between the upper and lower Wala Ridge distances [41]. The panoramic radiographs of corresponding patients were reviewed. To maximize internal validity and minimize inconsistencies related to variations in image acquisition protocols, machine calibration, and system specifications, only images acquired from the same orthopantomograph were selected. All panoramic radiographs analyzed were taken by the same operator using the Vatech® PaX-i 2D (Vatech®, Hwaseon, Republic of Korea) machine, with the equipment parameters at 10 mA, 80 kV, and an exposure time of 10.1 s.

2.5. Panoramic Radiograph Analysis

Panoramic radiographs were traced using a 0.003 in matte acetate tracing paper with a fine 0.5 mm HB fine lead pencil. Linear and angular measurements were calculated using a ruler and a goniometer. A single experienced operator was responsible for all measurements. During each calibration procedure, the tracing of each panoramic radiograph was repeated twice. The intra-rater agreement was calculated with the intraclass correlation coefficient (ICC), considering ICC of 1 as perfect agreement, between 0.8 and 1 as excellent agreement, between 0.7 and 0.8 as good agreement, between 0.5 and 0.7 as fair agreement, and below 0.5 as poor agreement [42].

2.6. Radiographic Variables

The collected radiographic variables are as follows:

- Overlapping sectors (Sector I to IV): according to the "sectoral method" (EK/L method) adapted by Ericson and Kurol [16] and modified by Lindauer et al. (EK/L) [43], as described elsewhere [44]. According to three distal, central, and mesial lines drawn tangent to the contour of the root and crown of the adjacent permanent lateral incisor, the following four sectors were identified to locate the canine position. Sector I was located distally to the distal line, thus reflecting the position of the primary canine. Sector II corresponded to the area between the distal and central lines. Sector III identified the area from the central to mesial lines. Lastly, Sector IV was located mesially to the mesial line. Thus, the "sectoral method" was utilized to identify the mesiodistal position of the impacted permanent maxillary canine, based on the location of its cusp tip. Consequently, Sector I and Sector II were classified as "low/moderate risk of inclusion", while Sector III and Sector IV as "high risk of inclusion". This decision was also supported by the study by Warford et al. [45].
- Distance d from the occlusal plane (mm): This was defined as the perpendicular distance from the impacted canine's cusp tip to the occlusal plane [46].
- Angle α (degrees): This indicates the mesial inclination of the crown to the midline and is measured as the angle between the interincisal midline and the long axis of the impacted canine. Angular measurements between 0 and 25° were classified at low-moderate risk of inclusion, while measures $\geq 25°$ were classified at high-risk of inclusion [39].

2.7. Statistical Analysis

The normality of the data distribution was verified using the Shapiro–Wilk test and the Levene's test, confirming the hypothesis of a normal distribution. Demographic data were reported using descriptive statistics as mean $\pm$ standard deviation or median and interquartile range, as appropriate, for continuous variables, and as absolute frequencies and percentages for categorical variables.

The difference in distance d was compared between the two groups with an independent *t*-test. The difference in proportion of high-risk impaction canines was compared between the two groups using chi-square and Fisher's exact test, as appropriate. The measure of association for chi-square and Fisher's exact tests was expressed with Cramer's V, with 1 identifying a perfect relationship. For all analyses, the 2-sides p values were set at $\alpha < 0.05$. All statistical analyses were performed using SPSS software (SPSS Statistics Version 27, IBM, Armonk, NY, USA).

3. Results

A total of 583 patient charts were screened, and 48 patients meeting the inclusion criteria were included in the study. Of these, 24 patients had transverse maxillary deficiency and bilateral crossbite (study group), and 24 were sex- and age-matched controls (control group). The sample consisted of 26 males (54.2%) and 22 females (45.8%), with both groups presenting with a mean age of 9.1 ± 1.4 years. For each patient, both canines were examined, resulting in a total of 48 canines per group (96 canines overall) being analyzed. Intra-rater agreement was calculated as 0.95, which was considered as excellent agreement.

Patient demographics are shown in Table 1.

Table 1. Demographics and comparison between participants in study and control groups.

	Total (N = 48 Children)	**Study Group (N = 24 Children)**	**Control Group (N = 24 Children)**	***p* Value**
Gender (N, %)				
Females	22/48 (45.8)	11/24 (45.8)	11/24 (45.8)	1.000
Males	26/48 (54.2)	13/24 (54.2)	13/24 (54.2)	
Age (mean ± SD)		9.1 ± 1.4	9.1 ± 1.4	1.000

SD: standard deviation.

Sectorial method s. Based on the previously described sector classification, a total of 2.1% of canines in the control group were at high-risk of impaction, while none of the canines in the study group were classified as high-risk. Hence, the study found no statistically significant difference in the presence of high-risk canine impaction between the two groups, according to the sector classification (p = 0.500, Cramer's V = 0.103).

Distance d. The mean distance from the occlusal plane was 16.3 ± 6.0 mm in the study group and 15.4 ± 6.0 mm in the control group, with no statistically significant difference between the two groups (p = 0.879, 95% CI −2.626, 2.251, d = 0.03).

α angle. Based on the α angle and a cut-off of 25°, five canines (10.4%) in the control group were identified as being at high-risk of impaction, while none of the canines in the study group (0.0%) fell into this high-risk category, with a lack of statistically significant difference between the two groups (p = 0.056, Cramer's V = 0.234). Similarly, when observing the mean α angle values between the two groups, which were 10.7° ± 5.3 in the study group and 12.6° ± 7.6 in the control group, the mean values indicated no statistically significant difference between groups (p = 0.174, 95% CI −4.574, 0.839, d = 0.28).

Data of the radiographic parameters examined are presented in Table 2.

Table 2. Comparison between study group vs. control group in selected parameters.

	Study Group (N = 48 Canines)	**Control Group (N = 48 Canines)**	***p* Value**
Sectorial method (N, %)			0.497
Sector I	41/48 (87.5)	39/48 (81.3)	
Sector II	6/48 (12.5)	8/48 (16.7)	
Sector III	0/48 (0.0)	1/8 (2.1)	
Sector IV	0/48 (0.0)	0/48 (0.0)	
Risk of impaction (N, %)	Low risk (100.0) High risk (0.0)	Low risk (97.9) High risk (2.1)	1.000
Distance d (mm)	16.3 ± 6.0	15.4 ± 6.0	0.879
α angle (°, mean ± SD)	10.7° ± 5.3	12.6° ± 7.6	0.174
Risk of impaction (N, %)	Low risk (100.0) High risk (0.0)	Low risk (89.4) High risk (10.4)	0.056

Statistically significant for $p < 0.05$; risk of impaction was identified as high for sectors III and IV and for α angle > 25°.

4. Discussion

The early diagnosis and treatment of canines at high-risk of impaction are essential to providing interceptive treatment and minimizing the risk of more severe complications, such as resorption of adjacent lateral incisors, which can have significant esthetic and functional consequences [47]. Although many studies have been conducted on the possible association between maxillary canine impaction and transverse maxillary contraction, they have led to controversial and contradictory results.

To the best of our knowledge, the present study is the first one to investigate the risk of canine impaction in children with transverse maxillary arch constriction and bilateral crossbite, compared to sex- and age-matched patients with normal maxillary width and absence of crossbite. If an association is present between canine impaction and maxillary width, a clear difference would be observed in the analyzed sample. However, our findings did not reveal any statically significant differences in the risk of maxillary canine impaction between children with transverse maxillary deficiency and bilateral crossbite and those without.

These results contrast with findings from some available studies that indicate a higher risk of canine impaction in the presence of transverse maxillary deficiency [13,36,48–50]. However, a careful review of the results of these studies [36,48–50] highlights that, even in the presence of a statistically significant difference, the clinical significance of such difference is minimal. On average, the difference observed in the maxillary width between subjects with impacted canines and controls accounts for a range between 1.3 and 2.5 mm, which is smaller or similar to the standard deviation reported, thus limiting the clinical utility of their results.

Contradictory findings could also be due to the differences in the considered sample size, which could fail to reveal any statistically significant differences if underpower, in the different sex distribution of the included participants [12,51], and in the radiographic method of measurement collection (i.e., panoramic radiographs vs. CBCT). This latter has been suggested to differ in accuracy in the measurement of canine crown size, [52] angulation to the occlusal plane [52], mesio-distal location of the apex of the impacted canine (i.e., sector location in the present study) [53], and buccal-palatal location of both apex and crown [53]. Notably, this difference in the variable measurement influencing canine impaction according to imaging type (2D vs. 3D) was also found in the subsequent treatment provided to manage such cases. For example, orthodontists evaluating their patients by means of a panoramic radiograph were most likely to adopt a more conservative approach, such as watchful waiting; conversely, those utilizing a 3D radiographic examination were more likely to consider the case as more difficult and favor active intervention [53].

When differentiating between buccally and palatally displaced canines, many of these studies supported an association between a decreased transverse maxillary width and buccally displaced upper canines [49,50], but not with palatally displaced canines [37,54–56], which could also explain some discrepancies.

The present results are, however, consistent with what was reported by other studies that failed to demonstrate any association with intermolar maxillary width, whether measured on dental casts or through CBCT [23,30,33,37,38].

Most of the available studies identifying factors related to canine impaction were conducted by comparing measurements of skeletal or dental parameters between subjects with already impacted canines and controls [57]. Conversely, the current study utilized a different approach by comparing cases and controls according to the presence of bilateral crossbite and skeletal transverse maxillary deficiency, and not based on the diagnosis of canine impaction. In our study, linear and angular measurements were performed on panoramic radiographs of orthodontic patients of record, as this type of imaging constitutes part of the routine orthodontic screening.

In the presence of maxillary canines at high-risk of impaction, several treatment strategies are suggested to favor a favorable eruption pattern of the permanent tooth, including the extraction of the corresponding canine deciduous tooth between 10 and 13 years of age [58], extraction of concomitant deciduous canine and first molar [39], the use of the cervical pull headgear [59], and rapid palatal expansion (RPE) in early [60] and late mixed dentition [59,61], especially in the presence of space discrepancy.

Strengths and Limitations

The primary limitation of this study is its cross-sectional nature, which does not allow for definite conclusions regarding the future eruption or impaction of the maxillary canines. Indeed, the current study focused on assessing maxillary canines at high-risk of impaction rather than impacted canines. Due to the retrospective chart review design of the present study, it was not possible to calculate the odds ratio of maxillary canine impaction; but it was possible to assess the association between some types of malocclusions, with the presence of a canine with high-risk of impaction. Other dental parameters could have been correlated with high-risk of canine impaction, such as a decreased mesiodistal size of the upper central incisors and first permanent molars [36], class relationship [12], agenesia of other teeth [37,55], skeletal hyperdivergency [48], and intermolar and intercanine widths, as suggested somewhere else. Yet, these parameters were out of the scope of the present study. Future studies are encouraged to better assess these aspects.

Another significant limitation of the present study is the fact that the diagnoses of maxillary deficiency and posterior crossbite were achieved through clinical examination, and analysis of intraoral photographs and dental casts. Despite the inherent limitations and subjectivity of these methods compared to advanced imaging techniques like CBCT, these methods were selected as widely utilized in clinical practice thanks to their practicality, cost–benefit, and non-invasive nature. Prior research has suggested that transverse assessment based on a combination of clinical examination, photographs, and dental casts can provide reliable information, especially when conducted by experienced clinicians [41]. Moreover, the utilization of dental casts for visualization of occlusal relationships remains a valuable tool in diagnosing transverse deficiencies and crossbites [40]. While acknowledging the potential limitations of our approach and that CBCT would have been the best method to assess the maxillary discrepancy, the applicability of the current methods in routine orthodontic practice and the ability to provide adequate diagnostic insights justify their use in the present study. It should also be mentioned that Ericson and Kurol [16] conducted their study on an older sample; therefore, it is possible that some differences may occur.

Despite these limitations, the current study has considerable strengths. The inclusion of a sex- and age-matched control group helped to control for potential confounders related to dentition stage and sex differences. Other strengths are an adequate sample size to draw inferential statistics and the inclusion criteria of participants with presence of deciduous maxillary canine, which has been suggested to significantly influence transverse maxillary width [38]. The use of panoramic radiographs, which are the primary imaging modality for many patients, also ensures that our findings are applicable to routine care practice.

5. Conclusions

Within the limitations of the present study, transverse maxillary deficiency and bilateral crossbite do not appear to increase the risk of canine impaction significantly. Therefore, orthodontists should continue to provide comprehensive screenings to all patients to identify high-risk cases and implement appropriate treatment strategies, regardless of their clinical characteristics.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the A. Gemelli IRCCS University Polyclinic Foundation (Protocol No. 0004079/23 of 8 February 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical reasons.

Conflicts of Interest: The authors declare no conflicts of interest.

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