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ORIGINAL ARTICLE

A retrospective study on the influence of maxillary canine impaction on premolar root morphology

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Abstract
Objectives The root morphology of the maxillary first premolar differs from the other premolars by presenting a high incidence of separated roots. This study addressed the spatial conditions during root development as a possible influencing factor. Therefore, maxillary computed tomographic (CT) scans of patients with regularly erupted or impacted permanent canines were evaluated on the root morphology of the premolars.
Methods The following parameters were retrospectively analysed in 250 maxillary CT scans (100 patients with regular erupted permanent canines, 150 patients with at least one impacted permanent canine): sex, status of the canines (erupted/impacted), position of the impacted canines (buccal/palatal; vertically inclined inside/outside the dental arch/horizontally inclined) and root morphology of the premolars.
Results Of the patients, 68 % with at least one impacted canine were female; the canine was impacted palatally in 75.6 % and in a horizontally inclined position in 58.4 %. In patients with an impacted canine, the number of first and second premolars with separated roots was significantly reduced on the ipsilateral as well as on the contralateral side (all p values <0.01).
Conclusions The present study detected an influence of maxillary canine impaction on the root morphology of all premolars, in that impaction and the associated surplus of space resulted in decreased root separation. This supports the hypothesis that root development is at least partly influenced by increased spatial conditions of the dental arch. However, root development can be regarded as a multifactorial event, influenced by space, direct mechanical interferences, as well as genetic predetermination. The retrospective nature of this observational study did not allow for conclusive differentiation between these factors. Alternatively, root separation and the mesial concavity of the first premolar may represent a path for canine eruption similar to the lateral incisor.
Clinical relevance A single-rooted maxillary first premolar might represent an additional risk factor for canine impaction.

Keywords Tooth root morphology · Impacted canine teeth · Bicuspid · Maxilla · Computed tomography

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Introduction

The root morphology of the maxillary first premolar differs from other premolars by presenting a high incidence of separated roots. Between one and three roots are described in the literature [1–3]. Vertucci and Gauguff [3] described the following distribution of root morphologies: 26 % single rooted, 13.5 % with two fused roots, 56.5 % with two separated roots and 4 % with three separated roots. A reason for this unique root morphology may be found in relation to another distinctive anatomical feature of the maxillary first premolar. The mesial sides of the cervical crown and root often feature a

pronounced concavity (Fig. 1). Clinically, this concavity represents a bacterial hideout [4, 5] and causes higher complications rates during periodontal, endodontic and prosthetic treatment [4–7]. It has been described as the "canine fossa" [1] due to the first premolar's and canine's close spatial relationship during tooth eruption and root development (Fig. 2). So far, it has not been investigated if limited space in this area may therefore influence the developing root morphology of the first premolar.

Impaction of the permanent maxillary canine, which is defined as failure to erupt completely or partially to the correct position in the dental arch, may provide more space for unimpaired root development of the premolars. Therefore, the present study hypothesised maxillary canine impaction to be associated with a higher incidence of single-rooted premolars due to increased space within the dental arch during root development. Root morphology of the first and second premolars was assessed in maxillary computed tomographic (CT) scans of patients with regularly erupted or impacted canines. In order to distinguish between a direct mechanical interference between canine and first premolar, and a general increase in space within the dental arch, root morphology of the second premolar and position of the impacted canine were also included in this analysis.

Methods

Patient recruitment

For this retrospective study, maxillary CT scans of 250 patients, who had been to the Bernhard Gottlieb University Clinic of Dentistry (Medical University of Vienna, Vienna, Austria) between 2006 and 2011 were evaluated (EK-Nr. 904/2010). The study population included two groups: 100 patients with two regularly erupted permanent maxillary canines and 150 patients with at least one impacted permanent maxillary canine.

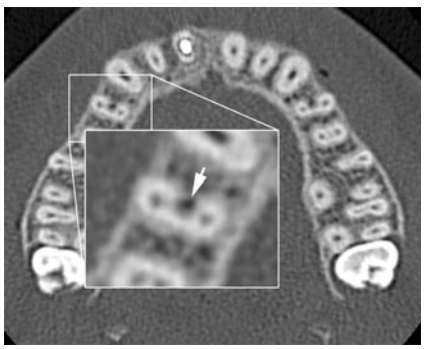

Fig. 1 A maxillary CT scan presenting a pronounced mesial concavity at the right and left first premolar. The right first premolar was magnified and the mesial concavity marked by the *white arrow*

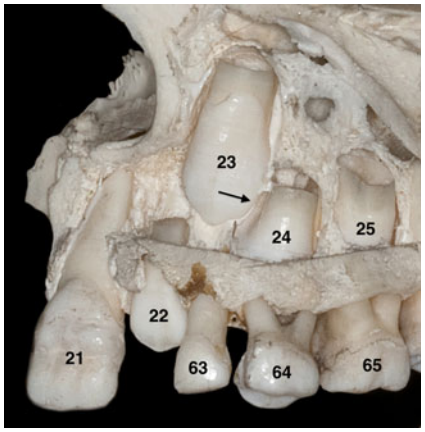

Fig. 2 Position of the permanent canine (23) in the mesial concavity ("canine fossa"; marked by the *black arrow*) of the first premolar (24) during tooth eruption and root development. This figure was thankfully provided by the Dental Museum of Vienna

CT scans were chosen at random and the presence of the permanent canines, first and second premolars was defined as the inclusion criterion. The disparity in the number of patients between control and experimental groups was due to the requirement of subgroup formation (left or right or bilaterally impacted canines) in the latter. The following parameters were assessed: sex, age, status of the canines (erupted/impacted), position of the impacted canines (buccal/palatal; vertically inclined inside/outside the dental arch/horizontally inclined), and root morphologies of the first and second premolars (single root or separated roots and number of roots).

Radiologic examination

CT scans were acquired with a conventional CT scanner (Tomoscan SR-6000, Philips, Eindhoven, the Netherlands). A standard dental CT investigation protocol (1.5 mm slice thickness, 1.0 mm table feed, 120 kV, 75 mA, 2 s scan time, 100–120 mm field of view, high-resolution bone filter) was applied [8]. The CT scans were investigated by two of the authors (GB and MB). Both were trained in CT diagnostics by an experienced oromaxillofacial radiologist (AG). Root separation was diagnosed if clearly present on two consecutive slices. In case of ambiguity, AG was consulted.

Statistical analysis

Descriptive statistics were applied for the distribution of sex, age, root morphology, status and position of impacted canines. The incidence of separated roots of the first and second premolars in patients with impacted or regularly erupted canines was compared with the McNemar test. Differences between buccal and palatal canine

Table 1 Root morphology of the maxillary premolars in the entire study population

	Single root (%)	Two rooted (%)	Three rooted (%)
First right premolar	42.0	54.8	3.2
First left premolar	47.2	50.4	2.4
Second right premolar	86.0	13.6	0.4
Second left premolar	87.6	12.0	0.4

impaction as well as bilateral canine impaction and between different positions of the impacted canines were tested with Fisher's exact test. Statistical analysis was performed using SPSS Version 19.0 (SPSS Inc., Chicago, IL, USA) and p values<0.05 were considered statistically significant.

Results

Patient distribution

Maxillary CT scans of 100 patients with two regular erupted canines (45 male, 55 female; mean age, 30.72; SD, 10.84) and 150 patients with at least one impacted canine (48 male, 102 female; mean age, 21.92; SD, 10.90) were evaluated. Among patients with at least one impacted canine, the right canine was impacted in 49 instances, the left canine in 71 instances and both canines in 30 instances. Located palatally were 74.7 % of the impacted canines on the right side and 76.2 % on the left side. Of the impacted canines on the right side, 56.1 % were horizontally inclined, 25.6 % vertically within the dental arch and 18.3 % vertically outside the dental arch. On the left side, 60.2 % were horizontally inclined, 28.1 % vertically within the dental arch and 11.7 % vertically outside the dental arch.

Root morphology of maxillary premolars in the study population

Root morphology of maxillary premolars in the entire study population is summarised in Table 1. Of the right first premolars, 42 % presented a single root, 54.8 % two roots and 3.2 % three roots. Of the right second premolars, 86 % presented a single root, 13.6 % two roots and 0.4 % three roots. Of the left first premolars, 47.2 % presented a single root, 50.4 % two roots and 2.4 % three roots; and 87.6 % of left second premolars a single root, 12 % two roots and 0.4 % three roots.

Root morphology of maxillary premolars in relation to the status of canine impaction

Cases with a unilaterally impacted right canine showed a significantly lower number of right premolars with separated roots (first premolar, $p<0.001$; second premolar, $p=0.004$): 49 % of right first premolars showed separated roots in case of ipsilateral canine impaction, compared to 73 % in case of regular canine eruption. For the right second premolar, those frequencies were 8.2 and 21 %, respectively (Fig. 3). Similarly, cases with a unilaterally impacted left canine showed a significantly lower number of left premolars with separated roots (first premolar, $p=0.008$; second premolar, $p<0.001$): 40.8 % of left first premolars showed separated roots in case of ipsilateral canine impaction, compared to 71 % in case of regular canine eruption. For the left second premolar, those frequencies were 4.2 and 20 %, respectively (Fig. 3).

In case of unilateral canine impaction, significant differences in root morphology were also found on the contralateral side: 51 % of left first premolars showed separated roots in case of contralateral canine impaction, compared to 71 % in case of regular canine eruption (Table 2; $p<0.001$). For the left second premolar, those frequencies were 6.1 and 20 %, respectively (Table 2; $p=0.002$). Of the right first

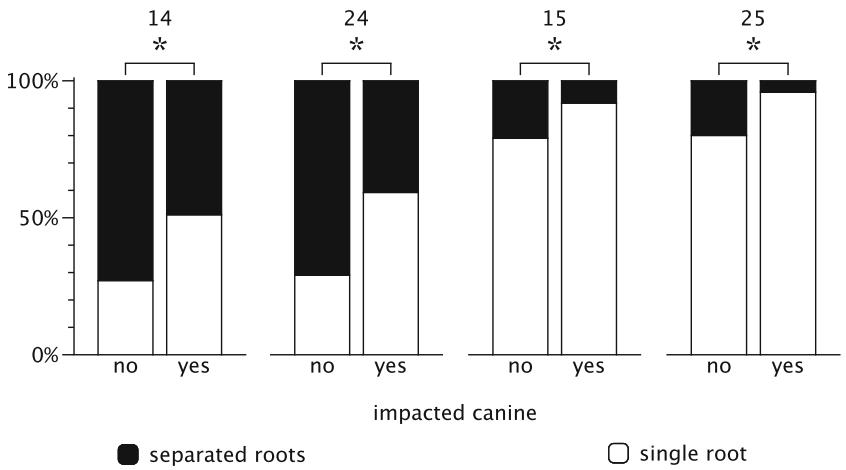

Fig. 3 *Root morphology of the maxillary premolars in relation to the status of the permanent canine.* *In the patients with an impacted canine the incidence of premolars with separated roots was significantly reduced ($p<0.01$)

Table 2 Root morphology of the maxillary left premolars in relation to the status of the permanent right canine

		24	25
Erupted 13	Single root (%)	29.0	80.0
	Separated roots (%)	71.0	20.0
Impacted 13	Single root (%)	49.0	93.9
	Separated roots (%)	51.0	6.1

premolars, 50.7 % showed separated roots in case of contralateral canine impaction compared to 73 % in case of regular canine eruption (Table 3; $p<0.001$). For the right second premolar, those frequencies were 8.5 and 21 %, respectively (Table 3; $p<0.001$).

In cases with two impacted canines, the frequency of separated roots of first premolars decreased markedly: 43.3 % of right first premolars ($p=0.01$) and 33.3 % of left first premolars ($p<0.001$) showed root separation. This tendency was not detected for the second premolars (right, 13.3 %; left, 16.7 %; $p>0.592$).

Root morphology of maxillary premolars in relation to the position of the impacted canine

Differentiating between buccally and palatally impacted canines showed disparities in the incidence of premolar root separation: Buccally impacted canines showed a higher incidence of root separation (right first and second premolar, 55 and 25 %; left first and second premolar, 50 and 12.5 %) than palatally impacted canines (right first and second premolar, 44 and 5.1 %; left first and second premolar, 35 and 3.8 %). This difference was statistically significant for the right second premolar ($p=0.022$), but not for other premolars ($p>0.232$). Impacted canines were further divided into the following three subgroups: vertically inclined within or outside the dental arch and horizontally inclined. The distribution of the root morphology of the first premolars in dependence of these subgroups is presented in Tables 4 and 5. A significant difference was not detected on the left or on the right side (position/inclination of 13 and root morphology of 14: $p=0.0519$; position/inclination of 23 and root morphology of 24: $p=0.111$).

Table 3 Root morphology of the maxillary right premolars in relation to the status of the permanent left canine

		14	15
Erupted 23	Single root (%)	27.0	79.0
	Separated roots (%)	73.0	21.0
Impacted 23	Single root (%)	49.3	91.5
	Separated roots (%)	50.7	8.5

Table 4 Root morphology of the maxillary right first premolar in relation to the position/inclination of the impacted right canine

	Vertically inclined within the dental arch	Vertically inclined outside the dental arch	Horizontally inclined
Single root (%)	28.6	53.3	60.9
Separated roots (%)	71.4	46.7	39.1

Discussion

This study addressed the spatial conditions during root development as a possible influential factor in the root separation of the maxillary premolars by assessing their root morphology in CT scans of patients with regularly erupted or impacted permanent canines.

In patients with an impacted canine, the number of first and second premolars with a single root was significantly higher on the ipsilateral as well as on the contralateral side. Based on these results, premolar root development appears to be related to given spatial conditions within the dental arch. In this context, case reports investigated first premolars' root deviation as a possible cause for canine impaction [9–12]. Yet, Chate [10] concluded that it seems more reasonable that canine impaction caused deviation of the developing premolar root than vice versa. In a case report, he presented a developing root deviation over the course of 1 year next to an impacted canine [10]. This theory of a direct mechanical interference of premolar root development is supported by our results. The position of an impacted canine (vertically inclined inside/outside the dental arch/horizontally inclined) tentatively influenced the root morphology of the maxillary first premolar. Vertically inclined, impacted canines within the dental arch seemed to be associated with an increased prevalence of separated roots of the first premolar compared to vertically inclined, impacted canines outside of the dental arch or horizontally inclined, impacted canines. Further, the higher incidence of single-rooted first premolars on the contralateral side as well as the higher incidence of single-rooted second premolars in this

Table 5 Root morphology of the maxillary left first premolars in relation to the position/inclination of the impacted left canine

	Vertically inclined within the dental arch	Vertically inclined outside the dental arch	Horizontally inclined
Single root (%)	48.3	50.0	69.4
Separated roots (%)	51.7	50.0	30.6

study support the hypothesis, that increased spatial conditions due to an impacted canine are an additional confounding factor of maxillary premolars' root separation. Yet, other factors, such as genetic traits, may also predetermine premolar root morphology. Therefore, reverse causality in the presented results should also be considered. Root separation and the mesial concavity of the first premolar may represent a path for regular canine eruption. Similarly, the lateral incisor has been discussed to guide canine eruption and anomalous or missing lateral incisors are associated with a higher prevalence of palatally impacted canines [13–15]. Thus, the higher incidence of impacted canines in patients with single-rooted first premolars may also be due to a consequently impaired eruption.

Besides third molars, maxillary canines are the most commonly impacted teeth [16]. The reported incidence varies between 1 and 2.4 % with a higher prevalence among female subjects, which is supported by our results (68 % female) [13, 15, 17–20]. In most cases, the impacted canine is located palatally [13, 20, 21], which is in accordance with the results of the present study (75.6 % located palatally). The aetiology of canine impaction on the palatal and buccal sides is considered to be different. Buccal canine impaction occurs mainly in the presence of crowding, while palatal canine impaction is associated with a wider maxillary transverse arch dimension, excess space, tooth deviations and a genetic predisposition [13, 19, 22–25]. Differentiating between buccal and palatal canine impaction, the distribution of our results changed slightly. For buccally impacted canines, the incidence of separated roots increased; while for palatally impacted canines, it decreased. As palatal canine impaction is associated with increased space, this further supports our hypothesis. However, due to the limited number of buccally impacted canines (20 right canines and 24 left canines), a definite conclusion in this regard cannot be drawn. Root separation of the first premolars decreased further in case of bilaterally impacted canines. This tendency was not detected for the second premolars, which might also be due to the limited number of bilaterally impacted canines (n=30).

Canine impaction is multifactorial, which often impedes early diagnosis. Early identification of patients at risk for canine impaction allows for appropriate interceptive intervention [20]. Especially for palatally impacted canines, the extraction of the deciduous canine is considered an appropriate treatment after the age of 10 and if the arch is not crowded [20, 24, 26, 27]. So far, a reliable early diagnosis of canine impaction is not possible. Only a combination of various indicators may identify patients at risk. Among those are missing or anomalous lateral incisors, invaginations, crown or root deviations, a horizontal growth pattern, class II division 2 malocclusion, aplasia of third molars, ectopic eruption of the first permanent molars, family history and asymmetry in or lack of palpability of canines [13, 19, 20, 24, 25]. The presence of a single-rooted first premolar may not be a strong indicator; but possibly in combination with other clinical findings, an additional hint to support regular check-ups or early interventions to reduce canine impaction or ectopic eruption. The risks of impacted permanent canines include root resorptions—especially of the lateral incisors—and the requirement of orthodontic treatment [20, 28].

In order to further clarify the causal chain of the present findings, other indicators of limited maxillary space, like retrognathia, palatal width and volume, or the extent of the mesial concavity of the first premolar would be of interest in future studies. In conclusion, patients with at least one impacted permanent maxillary canine showed a significantly increased incidence of single-rooted premolars, when compared to patients with regularly erupted canines. This supports the hypothesis that root development is at least partially influenced by the spatial conditions of the dental arch. Beside limited space and a direct mechanical interference, a genetic predetermination of root morphology was discussed. The retrospective nature of this observational study did not allow for conclusive differentiation between these factors. Further, root separation and the mesial concavity of the first premolar may represent a path for regular canine eruption similar to the lateral incisor and a single-rooted first premolar may therefore represent an additional risk factor for canine impaction.

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