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Maxillary Incisor Root Resorption Induced by Ectopic Canines Part 1: Prevalence Rates and Longevity Outcomes

Abstract: Root resorption of maxillary incisors as a result of impacted maxillary canines is a sequelae of canine ectopia that has been reported in the literature in terms of case reports and retrospective case series. However, to our knowledge there has been no work done that consolidates the available information on the subject, particularly since the advent of improved imaging techniques with higher rates of detection of maxillary incisor root resorption. This paper aims to review the prevalence rates of maxillary incisor root resorption induced by impacted maxillary canines, as well as to discuss the diagnosis and prognosis of teeth affected by this phenomenon.

Clinical Relevance: Maxillary incisor root resorption induced by ectopic maxillary canines is an issue which may be encountered by all dental specialties; however, the awareness of each stage of management is frequently unknown by clinicians. This paper aims to increase awareness and provide a reference point for appropriate management.

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The failure of eruption of the maxillary canine at its appropriate site within its normal period of eruption has led to a high volume of literature reporting on the aetiology, diagnosis and management of ectopic canines.[1] The significance of palatally impacted canines has also been acknowledged by the Royal College of Surgeons (Eng) in the form of a national treatment guideline.[2]

The prevalence of canine impaction has frequently been quoted in literature as second only to third molars, occurring from 0.8% to 3.3% in varying population bases.[1,3,4,5] Impaction of the maxillary canine can lead to root resorption of the maxillary central or lateral incisor. The resorption can occur as either a physiological or pathological activity of the cementoclasts, which results in loss of cementum and/or dentine.[6] External root resorption of the maxillary incisors is usually discovered by chance and, once clinically diagnosed, may already be at an advanced stage, thereby limiting the treatment options.

Method

The search strategy for undertaking this review followed guidelines from the National Health Service (NHS) Centre for Reviews and Dissemination (2011). A computerized search was performed using the Medline database (Entrez PubMed) and the Cochrane Library electronic databases. Non electronic journals were also hand searched. The terms used in the search were

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'canine, tooth, root, impaction, ectopic, incisors, root resorption, radiographs and Cone Beam Computerized Tomography'.

Prevalence

The prevalence of root resorption of permanent maxillary incisors due to ectopic canines has been quoted as ranging widely depending on the diagnostic imaging technique used. Plain film radiography has been less accurate at detecting resorption as a result of the two-dimensional view obtained, whereas Computed Tomography (CT) has revolutionized detection rates due to its increased accuracy. CT-based studies have reported rates of incisor resorption from ectopic canines to be as high as 48% in children aged between 9 and 15 years, whereas plain film radiographs have reported detection rates of 12%.[7,8] A three-dimensional (3D) investigation method of CT scanning has shown the prevalence of lateral incisor root resorption to range between 7.7% and 66.7% and the prevalence of central incisor resorption to range between 2% and 23%.[4,7,8,9,10,11,12] There is also a large discrepancy in reported figures from each author. For example, Walker *et al* (2005) report a rate of lateral incisor resorption of 66.7% in a study which examined a relatively small sample of 19 patients with 27 impactions.[4] The classification used noted the presence or absence of resorption using precise 3D volumetric imaging systems that recorded the smallest resorption microcavities induced by the proximity of the impacted canine.[3] This degree of diagnostic accuracy cannot be replicated by 2-dimensional imaging. Another factor contributing to the discrepancy in reported figures is the sample size used. A low figure of 7.7% reported by Strbac *et al* (2013) was based on 440 patients with 557 impacted canines using low-dose dental computed tomography. This compares with the 19 patients in the Walker *et al* (2005) study.[4,12]

Resorption caused by palatally ectopic canines has been reported to commence rarely after 14 years of age and studies have found the female to male ratio to vary between 2:1, 3:1, 4:1 and 10:1.[1,13] It is difficult to draw comparative figures on the prevalence of resorption of maxillary incisors owing to the varied radiographic imaging techniques reported in the literature; these have included plain film radiographs, CT and Cone Beam Computerized Tomography (CBCT). Further factors to account for the wide range of figures relating to prevalence include the differing size and age of population study groups, varied methods of reporting, the classification used and the general lack of standardization of reporting methodology.

Table 1 summarizes the prevalence of the resorption of maxillary central and lateral incisors from impacted canines in the literature and classifies the findings according to the imaging technique used. As before, this table reflects the widely ranging figures quoted in the literature and the consequent difficulty in agreeing a smaller range of the prevalence of maxillary incisor resorption.

Aetiology

The aetiology of maxillary incisor resorption from an ectopic canine is said to be caused by inherent pressure due to migration of the displaced, erupting canine combined with physical contact between the root of the incisors and prominences on the canine crown.[8,17] This can occur as a result of both palatal and buccal canines.[10,18] Other suggested factors identified with minimal evidence include genetics (heredity or developmental insufficiencies of immature roots and their susceptibility to

Author	% Max incisor resorption determined using plain film	% Max incisor resorption determined using CT	% Slight resorption	% Moderate resorption	% Severe resorption
Hitchin, 1956[14]	5.6%				
Thilander and Jakobsson, 1968[15]	0.3%				
Howard, 1972[16]	13.5%				
Ericson and Kurol, 1987[3]	12.5%				
Ericson and Kurol, 2000[7]		*38% +9%	*12% +3%	*3% +2%	*23% +4%
Walker *et al*, 2005[4] (classified as Y or N)		*66.7% +11.1%			
Bjerklin and Ericson, 2006[9]		50%			
Liu *et al*, 2008[10]		*27.2% +23.4%	*15.5% +8.1%	*6.3% +9.6%	*5.3% +5.7%
Cernochova *et al*, 2011[11]		*12.6% +2.1%			Only severe analysed
Oberoi, 2011[5]		*59.6%	*35.7%	*14.2%	*4%
Strbac *et al*, 2013[12]		*7.7% +2%	*3.1% +0.9%	*1.3% +0.4%	*3.8% +0.7%

Table 1. Occurrence of resorption.[4,5,9,10,11,12,14,15,16,19,20] Key: * Refers to lateral incisors; + Refers to central incisors

resorptive enzymes), trauma to the primary or secondary incisor adjacent to the canine and parafunctional or destructive occlusal habits.[18,19] Pressure from an enlarged follicle is not generally thought to be a factor.[20]

The reasons for the high susceptibility of lateral incisors compared to central incisors include the conical-shaped root, a high rate of abnormal root morphology of the lateral incisor and dental anomalies, for example dens invaginatus, that may result in an aberrant root apex morphology and thereby make it more prone to being resorbed.[21] There may be an increased susceptibility to resorption during the lateral incisor developing stage as it develops after the maxillary central incisor. Other factors that may contribute to greater resorption of maxillary lateral incisors may be related to the deep location of the apex of the lateral incisor root in the palate where impacted canines can develop.[21] The greatest risk to the lateral incisors may be due to the medial inclination of the ectopically erupting canine, particularly when it is overlapping more than 50% of the lateral incisor crown and when there is an impacted canine with a well-developed root.[3,7]

Degree of root resorption

The severity of root resorption is dependent on the time of discovery as well as factors such as location of teeth and tooth morphology.[11,22] Incisors with short roots are likely to resorb to a greater degree.[11,22] Another factor affecting the severity of resorption is the percentage area of overlap of the incisor by the impacted canine. It has been reported that severe root resorption occurs more frequently when the impacted canine is positioned buccally, less frequently for those within the dental arch and least often for a palatal position of the canine crown.[11,22] Studies consistently show higher rates of resorption of lateral incisors compared to centrals, which is reflective of the proximity of the lateral root to the erupting canine. For example, lateral incisor resorption with pulpal involvement is quoted at 12.6% compared to 2.1% of central.[11] Other studies involving 156 ectopic canines have reported severe resorption in 22.8% of lateral incisors and 3.8% of central incisors, respectively.[7] Furthermore, the most severe root resorption occurred in the apical third or apical and middle third of the root.[7,11]

Various studies have used different grading systems to assess the degree of resorption. Methods include scoring the degree of root resorption on a 1–4 scale on the mesial and distal aspects, ranging from a mild irregularity of the root contour up to over a third of the original root length.[23] CT scans using a scale of 0 to 2 have been used to describe the close approximation of roots with normal cross-sectional outline, resorption without involvement of the pulp and finally resorption into the pulpal canal with breakdown of the cemento-dentine line, respectively.[24] Focusing on the vertical plane, some studies have also categorized the distribution of resorption with regard to the location into thirds of the root. The most popular classification was devised by Ericson and Kurol in 2000,[7,19] which utilizes four categories:

1. **No resorption** – Intact root surface where the cementum layer may be lost;
2. **Slight resorption** – Resorption of up to half of the dental thickness to the pulp;
3. **Moderate resorption** – Resorption midway to the pulp or more, the pulp lining being broken;
4. **Severe resorption** – The pulp is exposed by the resorption.

Radiographic diagnosis of resorption of maxillary incisors

Canine ectopia should be suspected if the canine is not palpable in the buccal sulcus by the age of 10–11 years, an asymmetrical eruption pattern is noted, or if bimanual palpation fails to confirm the presence of the canine in a buccal position. Also on clinical examination, malposition may be implied by the position and angulation of adjacent teeth.[2]

Further investigation is warranted only after thorough clinical examination. This may be by imagining to confirm the morphology, position, height, angulation and the presence or absence of associated pathology. Plain film radiography remains the most commonly used diagnostic tool. The vertical and mesio-distal relationship of the unerupted tooth and neighbouring structures is supplied by first line 2-dimensional (2D) radiographic imaging. A combination of 2D imaging allows localization of structures using the parallax technique, a technique first described by Clark in 1910.[25] Horizontal parallax has been shown to be superior to vertical parallax in diagnostic accuracy for the localization of ectopic maxillary canines.[26] Periapical views and dental panoramic tomograms (DPT) (Figures 1, 2 and 4) are the recommended radiographs for horizontal parallax as often a DPT may be required as part of an orthodontic assessment and a periapical radiograph (Figure 2) is usually the non-tomographic image of choice for assessing root morphology.[2] Occlusal views (Figures 3 and 5) and lateral cephalograms are other adjunctive images.

However, extensive research has deemed plain film to be unreliable.[3,27,28] Distortion, magnification and imaging artefacts provide common diagnostic errors.[29] Plain film radiographs provide reduced definition of crown or root form, stage of root development, and number of roots. This is related to the fact that a departure from a linear crown/root relationship is difficult to detect on plain film radiographs when compared to CT. The 3D orientation of the long axis of the tooth in relationship to the root of adjacent teeth is also difficult to reconstruct, with accuracy. However, the addition of views at right angles supplies a reliable view of inclination and orientation. Furthermore, the main shortcoming of conventional 2D imaging for the assessment of incisor roots is the overlapping of structures on the film, particularly when resorption occurs in a vertical direction leaving the root apex intact and therefore appearing normal.[19,29] Details such as the degree of resorption or root shape definition may be difficult to distinguish due to reduced

Figure 1. OPG showing mesial impaction of the UL3 causing gross resorption of the UL1.

definition resulting from slight differentiations of structural densities, and other structures may be included in the field of interest.[19] It has been found that resorption of lateral incisors caused by buccally or lingually positioned canines may even reach the pulp with no evidence on plain films.[3,30]

Contrastingly, computed tomography (Figure 6) is a sophisticated method of imaging which allows computer-processed x-rays to produce cross-sectional slices, but it is a medium reserved for circumstances where the risk/benefit ratio of increased radiation can be justified. This includes cases of severe impactions, supernumeraries or abnormalities in the shape of teeth when insufficient positional information could jeopardize treatment outcome.[13] The technique has been shown to overcome the limitation of conventional radiographic methods. A 50% increase in detection of incisor resorption by CT compared to that of conventional radiography has been shown and it has also been shown to be superior in the imaging of bone tissue.[3,19] The differences between clarity of crown shape, root shape, crown/root relationship and tooth inclination has been shown to be statistically significant between plain film radiography and CT.[29] However, the accuracy and reliability of CT scanning has also been questioned due to issues such as beam hardening effects and metal artefacts.[31]

Figure 2. Periapical view showing mesial impaction of the UL3 causing gross resorption of the UL1.

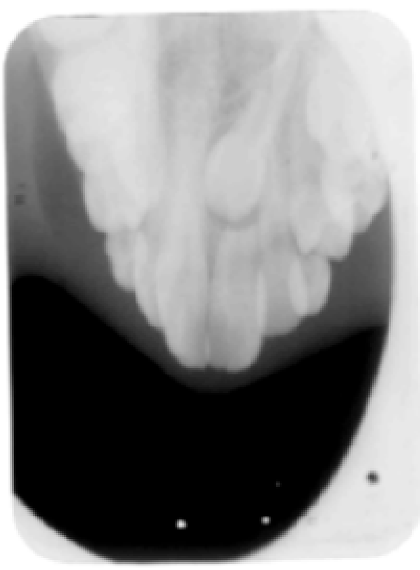

Figure 3. Upper standard occlusal demonstrating resorption of the upper left central incisor root.

Figure 4. OPG showing the impacted upper right canine causing resorption of the upper right lateral incisor root.

Figure 5. Upper standard occlusal showing the impacted upper right canine causing resorption of the upper right lateral incisor root.

Developed in the 1990s, Cone Beam Computerized Tomography (CBCT) provides a 3-dimensional (3D) image therefore, countering some limitations obtained from conventional CT scans and 2D imaging, CBCT has been shown to be more sensitive in detecting extremely small cavities, only giving 5% false negative results in comparison to DPTs (22%) and a 25% false positive diagnosis in resorption compared to 63% with a DPT.[28] The total radiation dosage is reported to be equivalent to 20% of conventional CTs or a full mouth periapical radiographic exposure, with all necessary imaging obtained within 1 minute.[32] The clinician hence has the diagnostic quality of periapicals, panoramic, cephalograms and occlusal radiographs, and a temporomandibular joint (TMJ) series, along with an axial view that cannot be produced by regular radiographic machines, and separate cephalograms for the right and left sides.[33]

The influence on treatment planning through improved localization and diagnosis associated with 3D images has been significant and has led to a more active approach through exposure of the canine and orthodontic traction, particularly relating to the direction of orthodontic traction.[34,35] The 3D approximation of the lateral incisor and canine can aid the surgeon's visualization of the area before a flap is raised, therefore reducing trauma

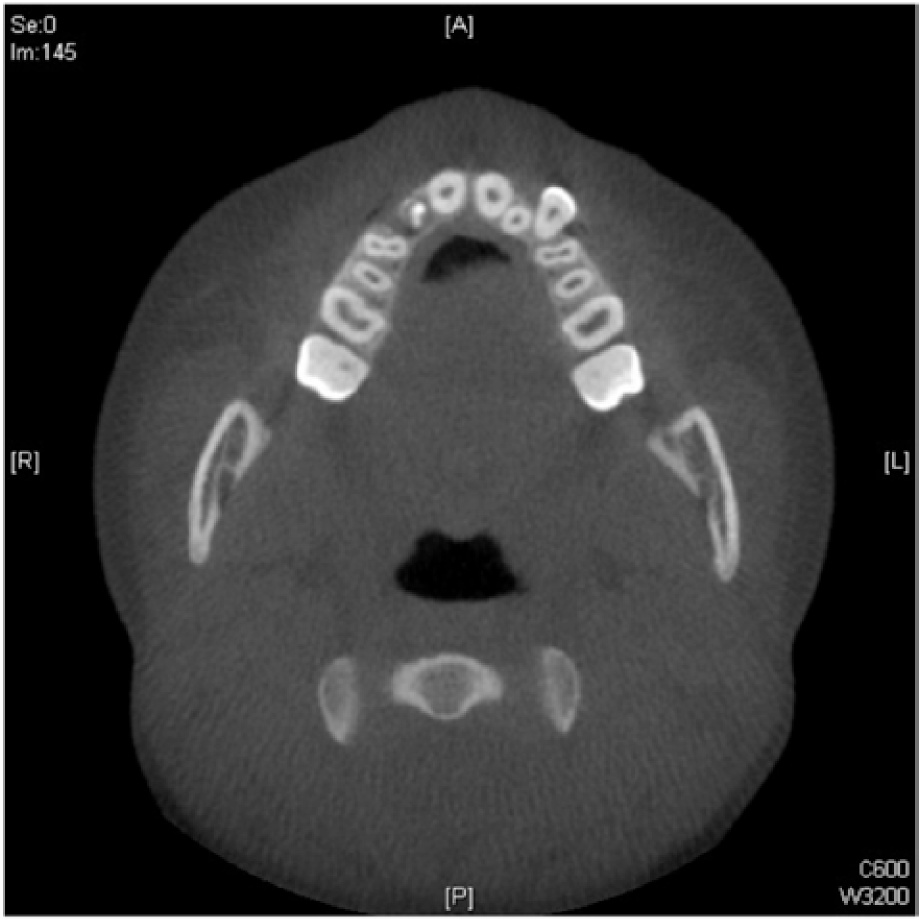

Figure 6. CT scan exhibiting the impacted upper right canine causing resorption of the upper right lateral incisor root.

and improving the periodontal outcome.[36,37] The improvements in the quality of CT have simultaneously increased findings in the incidence of resorption in research. It may be argued that the amount of resorption is more important than the presence of resorption as a small area of root damage can be self-limiting following removal of the offending impacted canine. CT may increase the detection of minor areas of root resorption disproportionately; however, the percentage of serious resorption suggested seems also higher when compared to clinical examination and the incidence of resorption reported by conventional radiography.[27]

New advances in technology are beneficial to the profession. However, it is important to comply with the fundamental guidelines such as the 'As Low As Reasonably Achievable' (ALARA) Principle recommended by The International Commission on Radiological Protection.[38] The three principles of justification, optimization, and dose limitation are followed, hence justifying the risks incurred by radiation exposure to yield sufficient benefit whilst reducing the amount of radiation received. The British Orthodontic Society Guidelines suggest that radiographs should only be justified when the management of the patient is dependent on the information obtained.[39]

According to the guidelines, the use of CBCT is currently only advised in selective cases where conventional radiography is insufficient in supplying satisfactory diagnostic information, such as patients with cleft palate, the assessment of unerupted teeth, identification of root resorption and orthognathic surgical planning.[39] There is more research and evidence required to back a wider use of CBCT in orthodontics, as well as the training of individuals to utilize this tool safely.

Long-term prognosis of the resorbed incisor as a result of impacted canines

A study of 20 teeth followed up for a period of between 1–23 years concluded that, when early radiographic monitoring is undertaken, the resorption process may be arrested with up to a 17.2% increase in crown/root ratio. The incisor can be orthodontically moved without risk of further resorption and treatment should be designed to resolve contact between the teeth as quickly as possible. No mobility or discoloration was noted upon follow-up.[40] Another 2–10 year follow-up study utilizing intra-oral radiographs and CT imaging analysed 24 lateral and 8 central incisors, 11 of which experienced severe resorption which showed pulpal involvement (according to the classification composed by the authors of this paper). No resorbed incisors were lost over the period of the study.[41] These findings were also supported by Bjerklin and Guitirokh who demonstrated a small percentage loss of the affected incisors (4/55 teeth) following maintenance and orthodontic treatment in a 13–28 year follow-up.[42] It was concluded that there is no indication for endodontic treatment to arrest further resorption. A return to normal apical and periodontal health, including well-defined lamina dura, was observed in the study, with improvements of trabeculation of the periapical area with further maturation and smooth edges. Reasons for this were not comprehensively discussed, although comparison of this process was made with that of resorptive processes in orthodontically treated teeth. All subjects expressed a general satisfaction with the aesthetic outcome with the retained incisors, although two were unhappy with the colour. However, where extraction is indicated, lateral incisors with severe root resorption should be extracted in preference to healthy teeth.[42]

Table 2 collates the follow-up outcomes of resorbed incisors following orthodontic treatment in various case reports and research papers. It emphasizes the better than expected prognosis of retaining a resorbed incisor in which the resorptive process has arrested following the disimpaction or extraction of the canine. However, it also highlights the limited data available with regard to long-term follow-up of such cases.

Conclusion

This paper discusses the resorption of maxillary central and lateral incisors induced by impacted maxillary canines. It has highlighted the shortcomings of conventional radiographic imaging in the diagnosis of incisal resorption secondary to canine impaction and has reinforced the use of 3D imaging, such as CBCT, as the future of orthodontic diagnostics. There has, however, been strong supportive evidence in the long-term prognosis of the retention of resorbed incisors and orthodontics. Other conclusions drawn from the review of the literature are summarized below:

- The development of ectopic canines

Author	Follow-up	Number of cases and type of resorbed incisors	Normalized/ improved resorption of incisor	Unchanged resorption of incisor	Increased resorption of incisor	Lost
Shellhart *et al*, 1998[43]	2.5 years	2 lateral	0	2	0	0
D'Amico *et al*, 2003[44]	1.1–10.9 years Mean 3.5 years	40 lateral	No information	No information	No information	11
		9 central	No information	No information	No information	0
Becker and Chaushu, 2005[40]	1–23 years Mean 5.4 years	13 lateral	0	13	0	0
		7 central	0	7	0	0
Millberg, 2005[45]	6 years	2 central	0	2	0	0
Falahat *et al*, 2008[41]	2–10 years Mean 3.5 years	24 lateral	13	6	5	0
		8 central	0	6	2	0
Albaker and Wong, 2010[46]	3+ months	2 lateral	0	2	0	0
Bjerklin and Guitirokh, 2011[42]	13–28 years	24 lateral	1	15	5	3 (3 trauma)
		16 central	2	11	2	1 (1 perio)

Table 2. Long-term follow-up outcomes following treatment.[40,41,42,43,44, 45,46]

should be monitored from an early age;

- The aetiology of maxillary incisor resorption from an ectopic maxillary canine is said to be caused by inherent pressure due to migration of the displaced, erupting canine combined with physical contact between the root of the incisors and prominences on the canine crown;[8,17]
- Lateral incisors are most commonly affected by resorption induced by ectopic buccal canines rather than palatal canines; [3,4,5,7,8,10,11,12,13,14,15,16]
- Conventional 2D imaging has been deemed unreliable in detecting the extent of resorption in all cases;[3,27,28]
- 3D imaging, with CBCT in particular, has exhibited promising outcomes for the radiographic detection of resorbed incisors due to impacted canines.[28,32,33,34] CT probably increases the detection of minor areas of root resorption disproportionately; however, the percentage of serious resorption also seems significantly higher compared to clinical experience;[27]
- The process of resorption can be rapid and therefore treatment of the patient must be carried out urgently to move the impacted canine away from the affected tooth;[40]
- Cessation of resorption has been shown to occur following treatment;[40]
- The long-term prognosis following treatment of affected teeth is good.[41,42,43,44,45,46]

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Conflict of interest

The authors have no funding sources or corporate affiliations. There are no commercial associations, current or within the past five years, that might pose a potential, perceived or real conflict of interest.

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