Original Article

Incisor Root Resorptions Due to Ectopic Maxillary Canines Imaged by Computerized Tomography: A Comparative Study in Extracted Teeth

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Abstract: The purpose of the study was to analyze the ability of computerized tomography (CT) scanning to discriminate maxillary incisor root resorptions caused by ectopically erupting canines. Seventeen maxillary incisors were radiographed in vivo by CT scanning. Contiguous transverse CT scans with a slice thickness of 2 mm were exposed perpendicular to the long axis of the lateral incisors and through the crown of the adjacent, ectopically positioned maxillary canine. Each scan was analyzed and the resorptions on the roots of the laterals were graded according to the maximum depth of the cavity. After the lateral incisors were extracted they were clinically inspected, photographed in different light settings and views, and probed at the contact area between the laterals and the canines. The assessment of the extent of resorption in 4 stages on the CT images compared with the in vitro observations of the extracted roots showed a high degree of agreement for the extent of loss of root substance for all teeth. We conclude that CT scanning performed with good technique accurately reveals tooth root resorption. The presence and influence of the inherent artifacts of tooth root resorption on CT scans are discussed. (*Angle Orthod* 2000; 70:276–283.)

Key Words: Children, Computerized tomography; Incisor; Tooth abnormalities; Cuspid, Tooth eruption; Ectopic; Tooth root resorption; Maxilla

INTRODUCTION

The risks associated with the eruption of maxillary canines makes careful supervision and early diagnosis of disturbances important.[1,2] For most children, the supervision can safely be limited to clinical procedures (ie, digital palpation) but in 7% to 10% of patients the clinical investigation must be supplemented with radiological studies to identify suspected eruption disturbances and possible complications.[2–4]

Resorptions on adjacent teeth after eruption of maxillary canines are rare in the population of children as a whole, but when they occur, they may lead to extractions, time-consuming and expensive orthodontic treatment, or both.[2] Early detection and grading of the extent of resorption has a major impact on the therapeutic approach and may reduce the number of late (severe) complications.[2,5]

Conventional periapical radiography is usually the first choice for imaging of suspected eruption disturbances, but is an inaccurate method for diagnosing root resorption.[2,4,6] The major shortcoming of conventional radiography for the assessment of incisor roots adjacent to impacted canines, located buccally or palatally to the incisor roots, is the overlapping of all structures on the film. This problem makes it difficult to distinguish a particular detail, especially when structures differ only slightly in density. In buccally or lingually positioned canines, for example, resorption on laterals may even reach the pulp with no evidence seen on the films.[4,10] In an earlier study of children with ectopic eruption of maxillary canines, we found twice as many resorbed incisors when using conventional polytomography, and altogether 12.5% of the ectopic maxillary canines caused resorption on adjacent incisors.[4,6] The inherent lack of sharpness on conventional tomographic images and the fact that conventional tomography does not eliminate all unwanted structures from adjacent areas makes the assessment of resorbed teeth unreliable and may lead to misinterpretations.

Computerized tomography (CT) is an imaging method that has proved to be superior to other radiographic meth-

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FIGURE 1. Contiguous transversal CT scans through the upper alveolar process. Slice thickness 2 mm. Beam direction perpendicular to the long axis of the maxillary lateral incisors. The mesial limbus of the ectopically positioned canine 13 is in contact with 12 and the normally erupting 23 is tangential to 22. The 22 partly lacks the alveolar lamina but the root contour is intact (a–c). Extensive root resorption in 12. The radiolucence in cut (b) represents resorptions within the upper part of the cut, the partial volume effect (arrow); cut (c) shows an extensive loss of root substance but the pulp-lining is still unbroken (arrow); (d) the resorptions almost reach the pulp of 12; (e) the apices of the laterals are intact, but 12 is displaced lingually (arrow). Resorptions, grade *moderate.* (f–h) Photographs of the extracted 12 (f) and 22 (g,h) above. An extensive, irregular resorption cavity within the root of 12 (arrows). The resorptions almost reach the pulp, but the pulp is covered by a thick layer of hard dentine (f). On the center and the coronal part of the distal root surface of 22, the cementum is resorbed but the dentine is intact (g,h, arrows).

ods in visualizing bone tissue. Computed tomography overcomes the limitations of conventional radiographic methods, has proved to be a useful method for diagnosing the positions and complications of ectopically erupting teeth, and has been used with increased frequency since 1988.[7–10] However, the accuracy of CT scanning when imaging tooth root resorption is not well known. Artifacts eg, beam hardening effects, linear and nonlinear partial volume effects, edge gradient effects, and metal artifacts may affect on the diagnostic reliability.[11,12] It may be especially difficult to image the hard tissues of the teeth. The choice of imaging algorithm, filter, quality of X-rays, window settings, slice thickness, and condition of the machine are other factors which may influence the image and the diagnostic accuracy.

The aim of this study was to analyze the character and clinical appearance of root resorptions on maxillary lateral incisors caused by ectopically erupting maxillary canines, and to compare the morphological appearance of extracted laterals with CT images obtained prior to extraction.

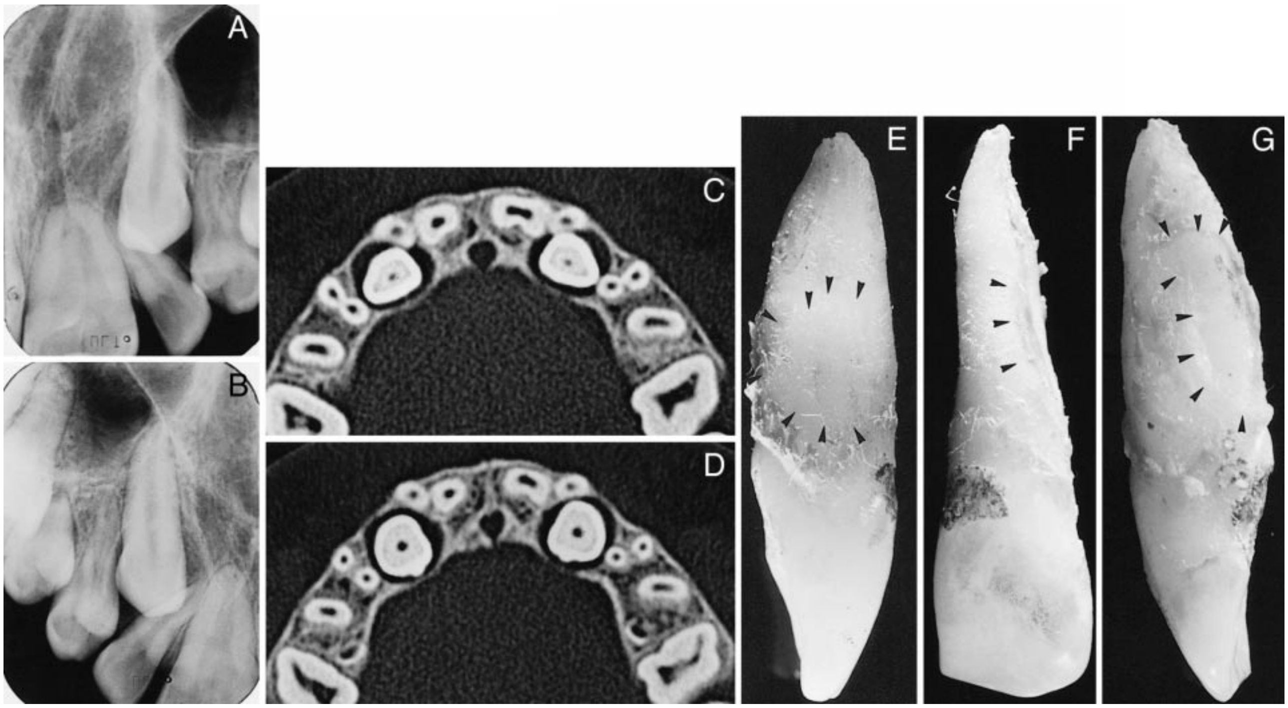

FIGURE 2. (a,b) Intraoral periapical films of ectopically erupting maxillary canines. The root contours of 12 and 22 are unbroken, with no sign of resorption. The lamina dura of 22 is not seen. (c,d) CT scans illustrating distolingually positioned facets on the roots of the laterals indicating resorption, grade *slight.* (e–g) Photographs of the extracted laterals 12 (e) and 22 (f,g) showing shallow resorptions with smooth surfaces and loss of cementum around the resorptions (arrows).

MATERIALS AND METHODS

A Siemens Somatome Plus CT scanner was used with 512 × 512 matrix size. The pixel spacing was 0.19 × 0.19 mm, corresponding to approximately 0.3 mm spatial resolution in the slice plane.[11] A bone algorithm for the middle ear (ultra-high) was applied and the window setting was 3.000 HU-units, the center value 750–800 and the exposure parameters 100 kV and mAs 340. The reconstruction of the objects on the screen and film images was based on processed (computerized) raw data.

Eight girls and 4 boys, with ectopically positioned upper maxillary canines diagnosed on intra-oral films were scanned by contiguous transverse CT with a slice thickness of 2 mm. The scans were perpendicular to the long axis of the lateral maxillary incisors (Figure 1). About 8 to 10 scans were obtained from the cervical area of the root up to the apex in each patient. A Siemens laser camera documented the scans. The region of interest was studied initially on the monitor using different zoom factors and scan by scan along the root and finally on the films. The enlargement of the object on the film was ×1.5, and we used 6 images on the film in order to get optimal resolution.

In all cases, 1 or 2 maxillary lateral incisors were extracted after CT scanning because of resorption or other reasons associated with the orthodontic treatment plan. A total of 17 permanent upper laterals were extracted 1 to 2 months after CT scanning and they constituted the ''control'' material for analyzing the accuracy of the resorptions on the scans.

The images of the teeth on the CT scans were analyzed and reported continuously to the submitter as part of the daily diagnostic work at the radiology department. The subject material was collected during 6 years and consisted of extracted maxillary lateral incisors from a larger sample of boys and girls being investigated by the CT technique for risks associated with ectopic eruption of the maxillary canines.[13] The radiological interpretation of the CT scans was performed 1 to 6 years before the in vitro inspections of the extracted teeth. The extracted maxillary lateral incisors were stored in formalin until the teeth were clinically analyzed.

The extracted teeth were inspected clinically using a magnifying glass and photographed in different light settings and views. The photos were duplicated and enlarged 2×. The root surfaces of the extracted teeth were probed to determine the extent of the injury and the hardness of the dentine in the contact area between the crown of the ectopic canine and the extracted tooth. The in vitro inspections (probing and assessment of the root surfaces) were done on 1 occasion by 1 investigator who did not have access to the radiology reports. The resorptions were graded in 4 categories clinically and radiologically:

1. *No* resorption—intact root surfaces, except for loss of cementum (Figure 1).

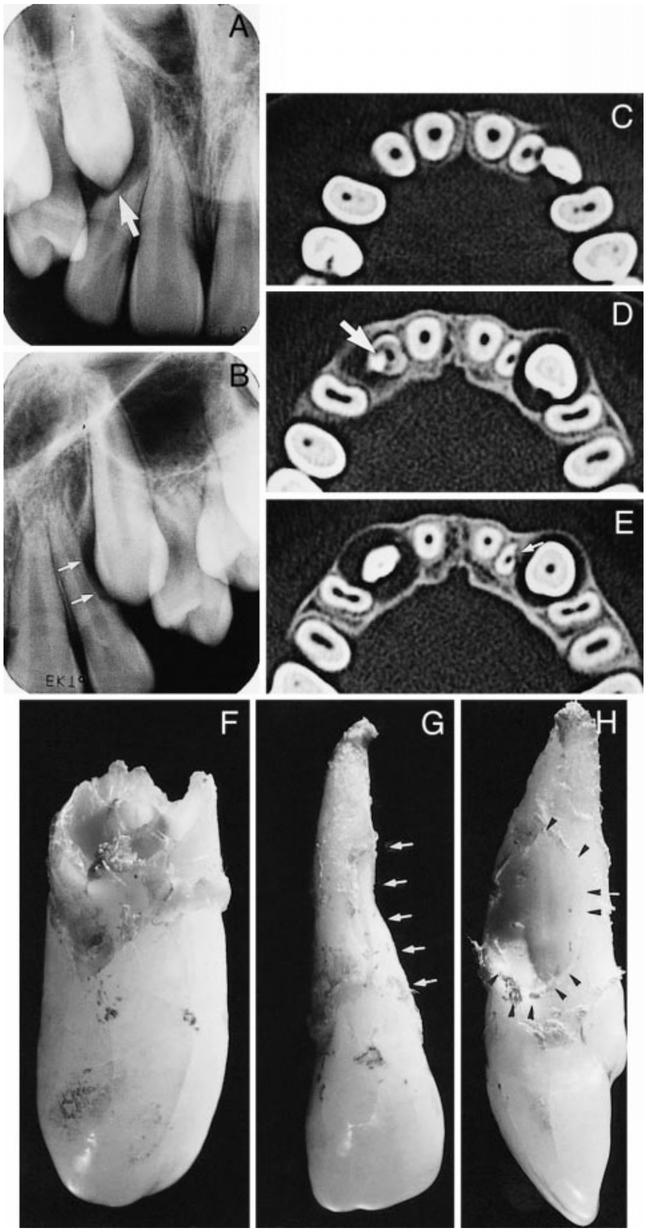

FIGURE 3. (a,b) Intraoral periapical films of erupting upper maxillary canines. Extensive apical resorption on the rooth of 12 and distally on the root of 22 (arrows). (c) CT scans showing the canine 23 in contact with 22. Note the radiolucent zone in the dentine at the contact point and compare with the extracted 22 (g,h). The loss of dentine looks more severe on the scan than in the photo. The radiolucence is a combination of resorption and artifacts. (d) The cut through 12 illustrates the buccal cusp of 13 in 12 (arrows) and widespread radiolucences within the root of 12. The appearance is mainly a consequence of the irregular surface of the resorbed root (cf. 3 f) and the level and thickness of the cut. The 12 shows resorption, grade *severe.* Between the resorbed, outer boundary distally of the root of 22 and the pulp, there is a thin, intact dentine distance with reduced opacity. Resorption, grade *moderate.* (e) The apex of 12 is gone. The root of 22 shows a facet and repair of the periodontal space and lamina dura of the alveolus as well (arrows). The prominent part of the crown of 23 has passed the area. The cut level is 6 mm above (3d). (f–h) Photographs of the extracted laterals 12 (f) and 22 (g,h) illustrating the extent of resorptions (arrows) and the appearances of the resorbed surfaces, which are irregular and smooth, respectively. The areas of resorptions hard on probing.

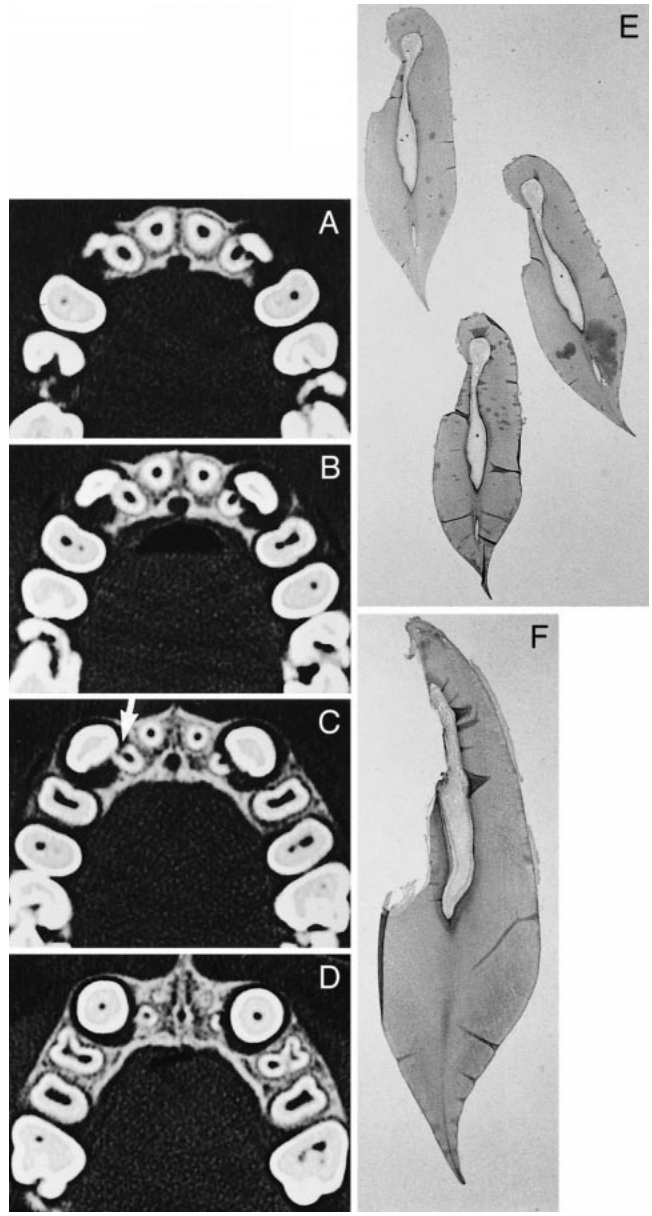

FIGURE 4. (a–d) CT scans perpendicular to the long axis of the roots of 12 and 22. In 12 there is a dentine wall between the canine and the pulp (c), arrow); in 22 the resorption reaches the pulp. The resorptions are seen in the contact areas between the canines and laterals. (e,f) Histological cuts through the area of resorptions; (e) 12, (f) 22. The extent of the resorptions shown histologically corresponds well with the radiological images.

2. *Slight* resorption—up to half of the dentine thickness to the pulp (Figure 2).
3. *Moderate* resorption—half way to the pulp or more; the pulp is covered with dentine (Figures 1f, 3g and 4e).
4. *Severe* resorption—the pulp is exposed (Figures 3f through 7b).

The probing result was graded as *hard* or *soft* surface and as *smooth* or *irregular* (Figures 2e and 3f).

Four of the extracted lateral maxillary incisors were his-

TABLE 1. Clinical Findings in 17 Extracted Upper Lateral Incisors Adjacent to Ectopic Permanent Canines

Grade of Resorption	Number of Teeth	Root Surfaces			
		Smooth	Irregular	Hard	Soft[a]
None	1	1		1	
Slight	3	3		3	
Moderate	4	2	2	4	
Severe	9		9	8	1

[a] Like probing ''resistant'' caries.

tologically processed after the clinical assessments. After fixation in 10% formalin, the teeth were decalcified with 10% triflourioacetic acid, dehydrated by dipping the specimens in alcohol and embedded in paraffin, sectioned longitudinally and stained with HTX-eosin according to the method of van Giesen and Mallory. Sections were taken at 4 representative levels, 2 of which were through the pulp.

A nonparametric Fisher's exact test was used for the statistical analysis.

RESULTS

The results of the clinical in vitro investigations are shown in Table 1 and a comparison between the clinical findings on the extracted lateral incisors and the radiological in vivo findings on the CT scans of the same subjects are shown in Table 2.

Resorptions were diagnosed clinically on 16 of the 17 extracted teeth. The resorption varied within the laterals and were mainly of a serious character with an exposed pulp where the resorption cavity was deepest (Table 1, Figures 3 through 7). In all individuals except 2 (Figures 1 and 2), there were at least unilateral resorptions into the pulp on the roots of the maxillary laterals. At probing, the dentine in the contact areas between the roots of the laterals and the canines was hard except for 1 root with atypical extensive resorption (Figure 6) and the inspection showed smooth or irregular dentine surfaces (Table 1, Figures 1 through 7). When the resorption was deep, the irregularity of the dentine surfaces increased, and was most evident when the resorptions included the apical area (Figures 3 and 5).

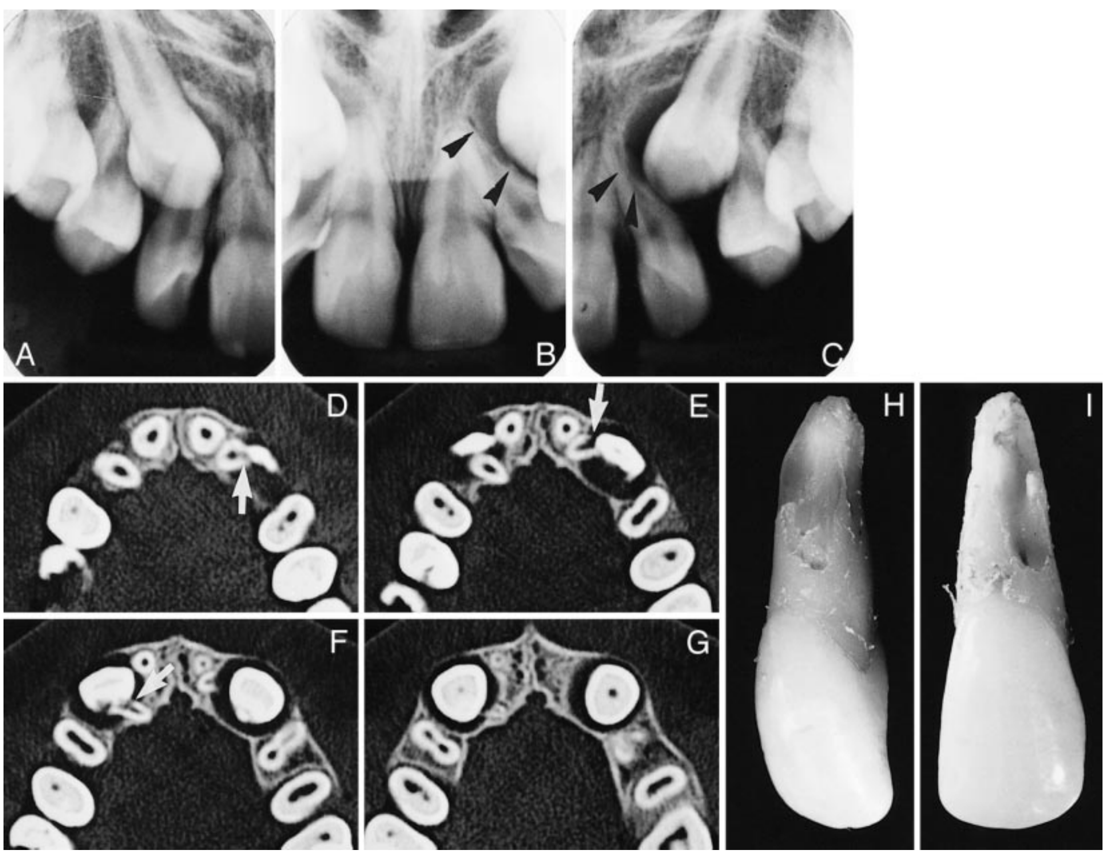

FIGURE 5. (a–c) Intra-oral periapical radiographs of ectopically erupting 13 (a) and 23 (c). No resorption is seen on the root of 12. On 22 there are resorptions (b, c, arrows), but the pulpal wall seems to be intact. (d–g) Cuts in different transversal, parallel planes show resorptions on the roots of 12 and 22. The mesial dense limbus of the crown of 13 creates resorptions on 12 and an artifact in the image of the root of 12 as well as giving an impression of resorption to the pulp (f, arrow). The root surface of 22 is extensively resorbed and no dentine wall to the pulp is seen (e, arrow). (h–i) Photographs of the extracted 12 (h) and 22 (i) showing irregular resorptions close to the pulp (12) and (22) to the pulp, respectively.

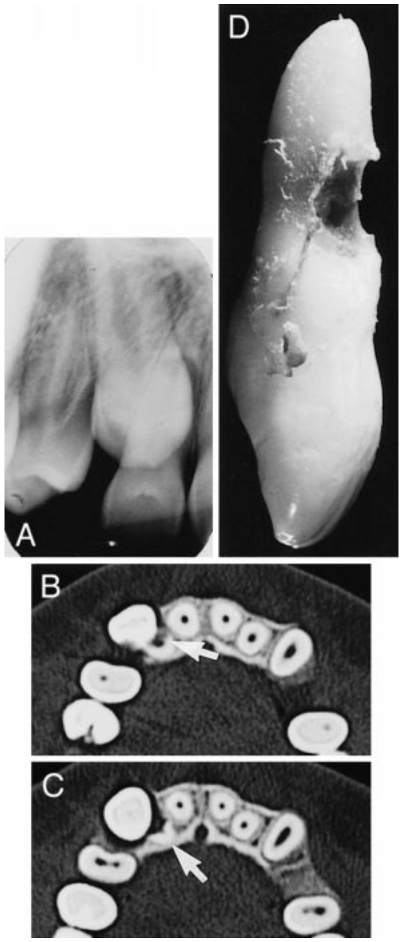

FIGURE 6. (a) Intra-oral, periapical film of 12 with a buccally erupting 13. The film shows an intact root contour and no resorption on 12 is visible, contrary to what is shown in (b), (c) and (b) CT scan showing buccally close contact between the mesial limbus and the lingual cusp of 13, and the root of 12. Dentine loss into the pulp of the lateral incisor at the contact zone. The radiolucency in 12 is a combination of true resorptions and artifacts, mainly partial volume effects (arrow), due to the thickness and orientation of the cut. (c) CT scan 2 mm above (b) and in the middle of the defect showing resorptions to the pulp (arrow). (d) Photograph of the deeply resorbed cavity into the pulp with irregular, partly soft resorption surfaces on probing.

TABLE 2. Agreement Between the Assessment of Grading Resorptions (Maximal Depth) on 17 Lateral Incisors Clinically After Extraction and on *In Vivo* Computerized Tomography (CT) Images

Assessment of Resorption				
Grading from Clinical Inspection	Grading from CT Scans			
	None	Slight	Moderate	Severe
None	1			
Slight		3		
Moderate			3	1
Severe				9

Comparison of the assessment of the clinical in vitro examination and the in vivo radiological registrations scan by scan showed a high agreement between the 2 methods concerning the extent and grading of the resorptions (Table 2, Figures 1 through 7).

To further evaluate the concordance between the CT and in vitro assessments of the resorptions on the lateral incisors, a statistical analysis was performed. The observations presented in Table 2 were classified into 2 groups: the laterals with severe injuries (10) at the clinical evaluation of the injury and the others (7). Fisher's exact test showed a high level of agreement between the CT method and the clinical in vitro evaluation of the teeth, $P < .0004$. The sensitivity of the CT scanning was calculated to 1 and the specificity to 0.875.

The clinical appearance of the root surfaces varied from a smooth contact area to rawness and irregularity. The more pronounced the irregularities were, the deeper were the resorption cavities. The irregularities appeared in the scans as radiolucent zones within the dentine, sometimes difficult to separate from possible artifacts (Figures 3 through 5). Especially close to a thick limbus or lingual cusp of the canine, the border area of the dentine of the root adjacent to the canine crown appeared radiolucent (Figures 4 and 5).

Probing of the cavity surfaces showed no relationship with the radiographic appearance of the scan images. Even in roots with a thin, radiolucent dentine distance between the pulp and the cavity, the demarcating wall was hard except in 1 case (Figure 6). When a dentine distance to the pulp was seen on the scan image, the pulp lining was always unbroken on clinical inspection (Figures 1, 3, and 4).

DISCUSSION

The purpose of this study was to analyze the discrimination of maxillary incisor root resorptions by CT scanning by relating the radiographic images in the in vivo situation to the clinical findings on later extracted teeth. To our knowledge, no similar comparative studies have been published. However, comparisons between conventional radiologic techniques and CT show that CT yields more detailed information than conventional radiography (eg, root resorption on lateral incisors caused by adjacent, aberrant maxillary canines, the location of the root injury, and the position of the canine).[7,9,10,14,15] Moreover, Preen et al[8] investigated 2 patients with resorptions on maxillary lateral incisor roots and stated that CT permitted exact determination of the extent of the lesion by differentiating between superficial resorption and resorption extending to the pulpal canal; however, they offered no objective evidence to support these findings.

This study shows that CT scanning of maxillary lateral incisors may reliably reveal resorption on the root adjacent to an ectopically erupting maxillary canine provided accurate radiological procedures are used (Figures 1 through 7). The comparisons between the clinical in vitro registrations

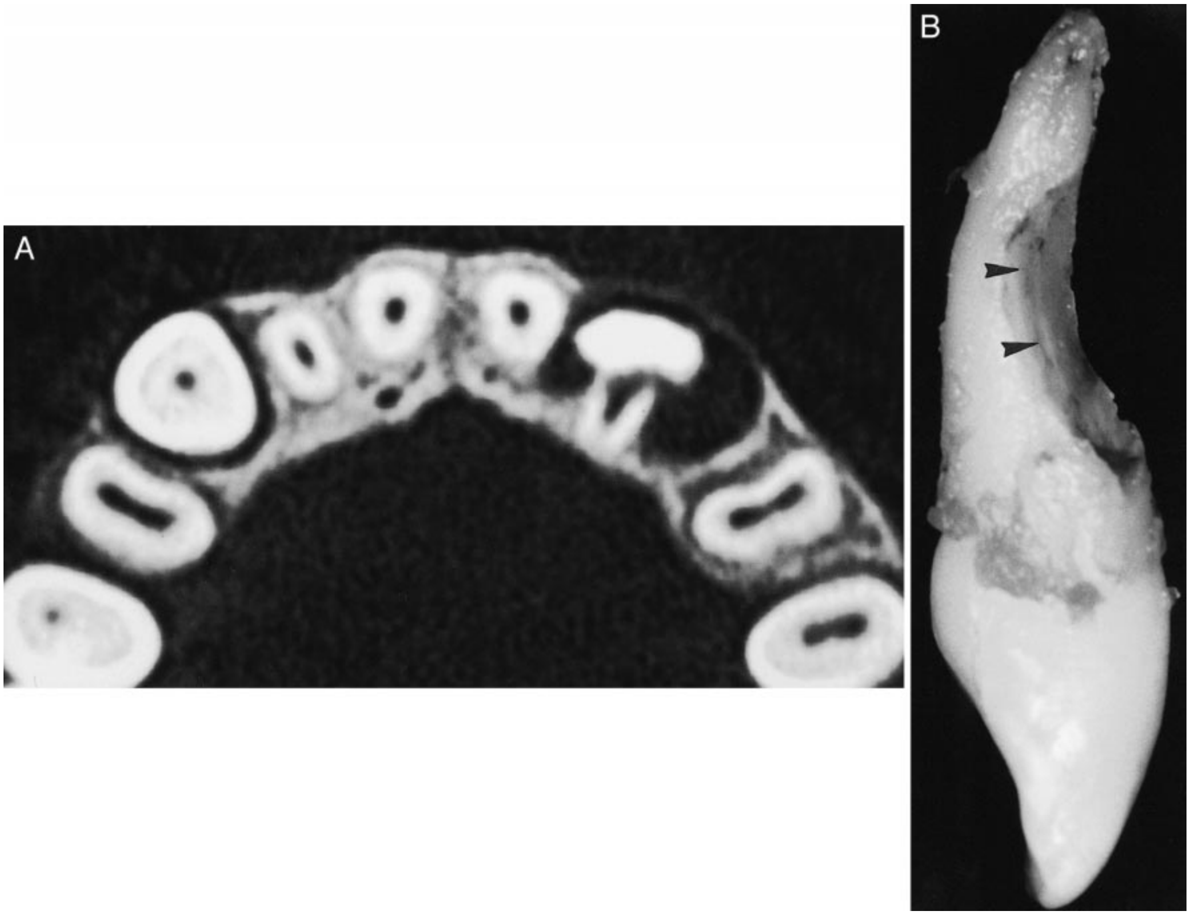

FIGURE 7. (a) CT scan through teeth 22 and 23. The root of 22 is resorbed into the pulp. The lingual cusp of the buccally positioned maxillary canine is in close contact with the root in the cavity. Thirteen in the normal position. (b) Photograph of the extracted 22 showing a deep, concave cavity into the dentine and to the pulp (arrows) adjacent to the place where 23 was situated. The cavity is deepest where the lingual cusp of the maxillary canine was located.

of in vivo resorptions caused by the ectopically positioned canines and the assessment from interpretation of the extent of the resorptions on the CT images showed a high degree of agreement for the extent of loss of root substance, as may be seen from the figures and Table 2 $P < .0004$. The predominance of severe damage in the distribution of the graded resorptions is a result of limitations in performing tooth extraction in the region of interest when lesser-damaged teeth are present. This circumstance may have biased the results somewhat, but even the roots with slight or moderate dentine loss showed good agreement between the clinical grading and the radiological assessment on the CT scans. These observations were confirmed by analyzing the roots in all images, scan by scan, since the depth of the resorptions varied within the resorption cavities (Figures 1 through 5). This explains the small amount of data in Table 2, which compares the clinical and CT assessments based on the maximum depth of root resorption.

Minor differences in the true morphology of the resorbed cavity and the demarcation of the root lining on the CT images may occur because of the limitations in image resolution and the thickness of the CT scans (2 mm thick), but are of no importance to clinical decision-making. We consider the factors of importance for the results are an optimal orientation of the planes of scanning perpendicular to the long axis of the roots of the incisors, a calibrated CT unit, the use of an ultra-high algorithm for bone resolution imaging, reconstruction from the raw data set and adequate zooming, resulting in enhanced detail sharpness.

Most of the CT images showed a radiolucent zone in the dentine at the contact point between the crown of the canine and the root of the lateral incisor, giving an impression of decalcified dentine in the resorption cavity. This phenomenon was most evident where the enamel of the crown of the canine was thick (eg, at the cusps or limbus) and may result in misinterpretation of the image (Figure 5). However, the surfaces were hard on probing and inspection showed healthy dentine. The exact character of this radiolucency in the dentine is not clearly understood, but it may be explained partly by the morphology of the resorbed dentine surface and the slice thickness of the scan in relation to the extent and shape of the defect (eg, Figures 1 and 3), and partly by 1 or more possible co-existing artifacts, some of which are referred to as border effects. The complexity of this phenomenon should be further analyzed in laboratory tests in order to gain a better understanding of imaging procedures and their limitations, aiming to avoid diagnostic failures. However, our findings indicate that a dentine wall between the resorption cavity and the pulp, close to an ectopically positioned canine crown shown on CT scans, probably indicates a clinically unbroken wall. This is true even if there is increased radiolucency in the dentine, making the grading of the resorptions used in the study adequate. The fear that incisor root resorptions adjacent to aberrant maxillary incisors found in CT scans are merely artifacts is rejected by this investigation.

CONCLUSION

This investigation showed that CT scanning is a reliable method of revealing resorptions on maxillary root incisors caused by ectopic eruption of the maxillary canines. The dentine loss is well described. The clinical findings and the CT scans are congruent both in the depth and in the pulpal involvement present.

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