ORIGINAL ARTICLE

Long-term follow-up of severely resorbed maxillary incisors after resolution of an etiologically associated impacted canine

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Background: Resorption of maxillary incisor roots because of an impacted canine is a well-recognized phenomenon that occurs in a surprisingly high proportion of patientts with impacted canines. In this retrospective study, we studied a sample of patients in whom the resorption was particularly severe. **Methods:** The sample consisted of 11 patients (age, 11.8 ± 1.2 years) with 20 severely resorbed maxillary incisors. The amount of resorption was measured at the outset (T1), when the impacted canine was distanced from the incisor root area (T2), at the completion of the orthodontic treatment (T3), and at a follow-up appointment at least 1 year posttreatment (T4). **Results:** A 17.2% increase in the crown/root ratio occurred due to aggressive continued resorption between T1 and T2. The resorption rate reduced to an almost insignificant level, despite continued and often appreciable orthodontic movement of the resorbed teeth from T2 to T3. **Conclusions:** Patients with impacted canines should be screened for resorption and the impacted tooth treated as soon as possible. The resorption process can be halted and the affected tooth moved orthodontically without further risk of resorption. In the long term, with early treatment, even severely resorbed teeth do not suffer from increased mobility or discoloration and might not require splinting. (Am J Orthod Dentofacial Orthop 2005;127:650-4)

Before computerized tomography (CT) scanning became widely available, root resorption of lateral incisors adjacent to an impacted maxillary canine was estimated to occur in approximately 12% of patients, as determined by plane radiographic imaging supplemented by polytomography, when necessary.[1] This conformed with the "standard of care" current in 1987. This figure was considered alarming at the time. Nevertheless, it was recognized that plane radiographic imaging was probably understating the extent of existing resorption processes and missing many smaller ones.[1,2] Traditional radiography cannot image a surface of the roots of teeth that lie in the buccolingual plane—specifically, the surface facing the crown of a palatally impacted canine tooth.

However, with the advent of CT and its availability for diagnostic dental procedures, a repetition of the earlier study reported root resorption associated with ectopic canines in a much larger proportion of the patients. The improved imaging that is achievable with CT resulted in the detection of root resorption in 38% of lateral incisors and 9% of central incisors.[3]

In the routine orthodontic treatment of uncomplicated malocclusions, shortening of the roots of the teeth by resorption occurs frequently, and this has been studied and reported widely in the literature over the past 2 decades. Among the findings most consistently recorded has been that the process almost never progresses after orthodontic forces are discontinued.[4,5] In contrast, a review of the literature shows that very little has been written about maxillary incisor root resorption in association with an adjacent ectopic canine and the long-term survival of those maxillary incisors.

In some reports, the ectopic canine or the severely resorbed incisors have been extracted on the assumption that the teeth have a poor long-term prognosis.[6-8] In these patients, definitive alternative treatment has been recommended either in the form of substitution of the canine or with the artificial rehabilitation of the tooth with conventional prosthodontics or an implant-borne restoration.[7-11]

Anecdotal evidence from clinical observation of these patients indicates that extraction or orthodontic distancing of the impacted canine seems to arrest the resorptive process without the need for root canal

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therapy if the tooth's vitality has been maintained.[6-8,10-14] It seems that, in some situations, these teeth can survive for several years if the resorption has not been too extensive.[15] Sasakura et al[16] studied 11 patients with ectopic canines. Of the 22 resorbed maxillary incisors, only 8 remained in place without treatment at the end of the study. However, no observation or follow-up was made, and there was no comment on their expected survival. The few cases in the literature with long-term follow-ups have indicated an optimistic prognosis even for severely resorbed incisors.[11,14]

In the absence of evidence-based information, this retrospective study was performed to evaluate the progress of the resorption process in severely resorbed maxillary incisors, caused by and after the orthodontic resolution of the associated impacted canines.

MATERIAL AND METHODS

The inclusion criteria for the sample were severe resorption of at least 1 maxillary incisor, in close association with an impacted canine, in which neither the canine nor the affected incisor was extracted as part of the treatment plan, and a minimum follow-up period of 12 months after the completion of treatment. In this study, root resorption was defined according to Levander and Malmgren[5]; teeth that had lost more than one third of their original root length were described as having suffered extreme resorption (group IV). Their study was specifically aimed at root resorption, secondary to routine orthodontic movement, which is characterized by a fairly uniform shortening of the root. In contrast, our study describes root resorption caused by an adjacent impacted tooth; the pattern differs insofar as the resorption is largely oblique, rather than horizontal.[2] Our inclusion criteria of the affected incisor required that the length of the longest part of the resorbed root was not more than two thirds of its expected length. When the resorption pattern was oblique, patients in which the resorption could be identified to extend from the apex to beyond the apical third of the root were included in the sample.

Based on these criteria, a sample of 11 patients, aged 11.8 $\pm$ 1.2 years, with 20 consecutively diagnosed, severely resorbed, maxillary incisors (7 central and 13 lateral incisors) was assembled, with follow-ups of 1 to 23 years after treatment for resolution of the associated impacted canine. Twelve canines were palatally impacted, 2 were buccally impacted, and 2 were in the line of the arch.

Orthodontic treatment was performed in 10 patients without extractions; in the remaining patient, the extraction of both maxillary central incisors was due to complications after severe trauma. For this patient, the lateral incisors were moved into the place of the central incisors, even though 1 lateral incisor suffered from severe root resorption. Extensive orthodontic movement of these teeth was involved.

Assessments were made at 4 stages of treatment—pretreatment (T1), after resolution of the impaction (T2), after overall orthodontic treatment (T3), and at a minimum of 1 year follow-up (T4).

The survival rate of the resorbed incisors was calculated as the number of surviving teeth at T4, divided by the number of resorbed teeth at T1 and expressed as a percentage. Tooth mobility and discoloration were assessed clinically at T4 in 9 patients (18 teeth). Two patients had relocated abroad and could not return for clinical examinations, although their radiographs were available. Tooth mobility was assessed by using Miller's index,[17] and discoloration was assessed relative to the adjacent teeth.

Periapical radiographs were available for all patients at the various stages, and these were supplemented with panoramic views at least at the outset and the posttreatment follow-up. Complete radiographic records were available for all patients at T1, T3, and T4, but, at T2, the records were unavailable in 5 patients (5 teeth).

Crown length was measured from incisal edge to the cementoenamel junction, and the root length from the cementoenamel junction to the most apical limit of the visible root; both were measured to the nearest 0.1 mm and parallel to the long axis of the tooth. The crown/root ratio was defined as crown length divided by root length. The use of crown/root ratio was considered preferable to a direct measurement of the root on the radiograph to overcome possible vertical distortion, due to a lack of standardization in radiographic technique.[18]

A qualitative assessment of the radiographic appearance of the lamina dura and the integrity of the periodontal ligament (PDL) and the alveolar bone of the periapical area was performed. The films were also used to assess pulpal status, obliteration, periapical pathology, or root canal therapy.

STATISTICAL ANALYSIS

The differences in crown/root ratios measured at each specific stage were examined with the Student *t* test for paired variables (2-tailed) at the 0.05 significance level.

Error of method was assessed by repeating all radiographic measurements a week later. When both periapical and panoramic views were available, a double determination of the crown/root ratio was made to check the compatibility of the 2 radiographic methods.

Table I. Description of sample

Patient	*Sex/age*	*Impacted canine location*	*Incisor no. (FDI)*	*T1*	*T2*	*T3*	*T4*
1	F/11	Palatal	12	0.76	0.85	0.88	1.03
			11	0.92	1.1	1.1	1.09
		Palatal	21	0.81	1.06	1.08	1.09
			22	0.65	0.79	0.87	0.89
2	F/11.5	Palatal	12	0.92	1.11	1.13	1.14
3	F/13	Palatal	12	0.99		1	1.02
4	F/11	Palatal	12	0.52		0.59	0.60
5	F/10	Line of arch	11	1.53		1.63	1.64
6	F/14	Palatal	11	0.95	1.15	1.15	1.16
		Palatal	21	0.84	1	1.02	1.03
7	F/11.5	Palatal	12	0.78	1.16	1.2	1.2
		Buccal	22	0.78	1.12	1.4	1.4
8	F/11	Palatal	12	0.71	0.87	1.04	1.04
			11	1.06	1.13	1.29	1.29
		Palatal	21	0.9	0.91	0.9	0.9
			22	0.52	0.61	0.59	0.59
9	F/13.5	Palatal	12	0.75	0.9	0.91	0.93
		Buccal	22	0.91	1.1	1.2	1.2
10	F/12	Line of arch	22	1.37		1.39	1.39
11	F/11.54	Palatal	22	0.7		0.84	0.84
		Mean		0.87	0.99	1.06	1.07
		SD		0.27	0.19	0.28	0.22

Pearson correlation coefficients were computed as a measure of reliability between the repeated measurements. All measurements were found to be highly reliable for replication (crown/root ratios measured a week apart, r = 0.997 [$P < .001$], crown/root ratios in periapical and panoramic views, r = 0.96 [$P < .001$]).

RESULTS

The mean treatment time for the resolution of the impaction (T1-T2) was 10.7 ± 6.1 months, and the mean overall treatment time was 23.7 ± 8.2 months (T1-T3). The mean follow-up period (T3-T4) was 5.4 ± 8.4 years posttreatment. The survival rate was 100%; none of the involved teeth was lost. Root canal therapy was not required in any patient.

Because most patients had fixed retainers, mobility assessment could not be reliably performed. When a patient had a removable retainer or was not being retained, none of the affected teeth had a mobility rating greater than 1. No teeth showed discoloration.

In most of the patients under treatment, the resorbed incisors underwent significant orthodontic movement after distancing of the impacted canine. This was performed in line with the appropriate demands of the alignment for each patient, while radiographically monitoring for further root shortening. In no patient was it found necessary to stop treatment for this reason.

Table II. Mean crown/root ratio alterations at various monitored stages

Treatment interval	*n*	*Mean difference (%)*	*SD*	*P value*
T1-T2	16	17.2	10.4	.000
T2-T3	16	6.7	8.8	.02
T1-T3	21	19.2	14.8	.0004
T3-T4	21	1.5	3.7	NS

NS, Not significant.

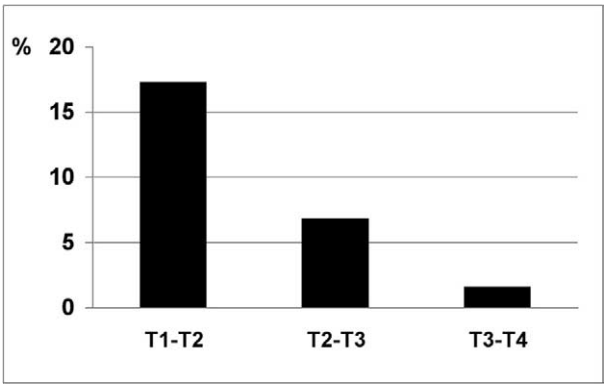

Fig 1. Mean alteration of crown/root ratios in sample of 16 resorbed incisors in which radiographs were available at T2.

Table I describes the subjects in the sample in terms of sex, age, location of impacted canine, which teeth suffered resorption, and the crown/root ratios at the various stages monitored.

Table II illustrates that, between T1 and T2, aggressive root resorption occurred, as indicated by the statistically significant 17% mean increase in the crown/root ratios. At T3, the crown/root ratios compared with T2 showed that deterioration was much reduced (6.7%); this was statistically significant. No further changes in root length were recorded at T4. Figure 1 graphically illustrates these changes in the 16 teeth for which radiographs were available at all examination stages, including T2.

Clinically, the radiographs at T2 showed that the PDL and the lamina dura could not be distinguished in the areas of active resorption of the roots. These areas, previously occupied by the impacted canines, were characterized by a diffuse radiolucency. At T3, a well-defined PDL and lamina dura, and a much improved trabeculation of the periapical area, were consistently observed, and, by T4, the entire radiologic picture showed further maturation toward normalcy (Fig 2), albeit with a severely shortened root stump.

All teeth remained vital, as evidenced by the pro-

Fig 2. Periapical views of patient 7 at different stages of treatment. **A**, T1, severe resorption of left lateral incisor caused by buccally impacted canine; **B**, T2, immediately after resolution of canine impaction, note diffuse radiolucency around severely resorbed lateral incisor root; **C**, T3: reappearance of PDL and lamina dura and normal trabeculation of surrounding bone; **D**, T4: further maturation of periapical tissues.

gressive obliteration of their pulps and intact periapical appearance.

DISCUSSION

In the relatively short time between T1 and T2, the 17.2% increase in the crown/root ratio illustrates the rapidity of resorption.[1,2,16]

Orthodontic tooth movement per se is a known cause of root resorption in the treatment of uncomplicated and routine malocclusions. Thus, the question arises as to whether a cumulative effect can occur with an impacted canine, which might aggravate the long-term prognosis of the involved teeth. Is a canine-resorbed incisor root likely to be resorbed still further as the result of subsequent orthodontic tooth movement after resolution of the canine? Is there justification for the more or less automatic exclusion of these teeth as integral parts of a future scenario for the rehabilitated dentition?

In this study, no teeth were lost in the follow-up period, which ranged between 1 and 23 years. No teeth showed discoloration, despite the degree of obliteration that was evident in some patients.

Despite the relatively long period of subsequent orthodontic treatment (mean, 13 months), during which active forces were applied to the incisors, a very small but statistically significant increase in the crown/root ratio could be detected, once the impacted canine had been distanced from the resorbing root of the incisor (T2-T3). Clinically, this difference was about 1 mm. During the follow-up period after the overall orthodontic treatment (T3-T4), root resorption ceased.

The presence of diffuse radiolucency and the absence of a discernible lamina dura or PDL between T1 and T2 appear to be characteristic of active resorption.[1] Subsequently, when further root shortening had ceased, the clearly defined restoration of these features, with the reappearance of a good bony trabeculation, must be taken as an indication of a cessation of the pathological process.

In light of the aggressiveness of the pathologic resorptive process, while the impacted tooth is near the root of the incisor, the clinician must distance the canine from the resorbing root as early in the treatment as possible, because this will arrest the resorption. From the evidence gathered here, subsequent orthodontic movement does not appear to generate appreciable additional resorption, even when the resorbed tooth needs considerable orthodontic treatment. Accordingly and once the canine impaction has been resolved, there would seem to be little justification for the more or less automatic assumption that severely resorbed incisors should be extracted as part of the patient's long-term overall treatment plan. It is hoped that, with the evidence in this study, the orthodontist will find that a more conservative approach might be the more rational and, certainly, simpler treatment for these patients.[11,14] In this way, such compromise solutions as canine extraction,[7,13] canine-for-incisor substitution (with its attendant restorative implications),[6,7,9,16,19,20] and artificial rehabilitation of the missing tooth (with its attendant implant and prosthodontic aspects)[8,10,16] can be minimized.

The strict inclusion criteria for this study, with the emphasis on severity of root resorption, limited our ability to gather a large group of patients suffering from advanced root resorption due to a related impacted canine, so the sample was inevitably relatively small. Nevertheless, the level of statistical significance of the results was sufficient to draw important conclusions

and, with some caution, to make recommendations to our orthodontic colleagues that might affect treatment decisions in everyday practice.

The sample included 11 patients with 20 consecutively diagnosed, severely resorbed maxillary incisors, due to an associated adjacent impacted canine. All 11 patients were female; in the pool of orthodontic patients from which these were drawn, no males met the inclusion criteria. Additionally, the case reports cited here from the literature,[1,6-10,14,16,19] showed an extremely asymmetric preponderance of affected females. No explanation is offered, but the reader might be tempted to speculate that genetic or hormonal etiologic factors are involved.

CONCLUSIONS

1. Early radiographic monitoring of patients with aberrant canine eruption is needed to detect resorption as early as possible.
2. When resorption of an incisor root occurs as the result of an impacted canine, the process is rapid, and the patient should be treated with urgency.
3. Surgical exposure and orthodontic traction of the canine should be performed as early as possible, even before other stages in the treatment plan, eg, leveling and aligning and space opening, which would normally take precedence.
4. Once the impacted canine has been distanced from the root area, resorption almost always ceases.
5. The resorbed incisor can be subsequently moved orthodontically, with a minimal risk of further resorption, although radiographic monitoring is advised as a precautionary measure.
6. The radiographic reappearance of an intact lamina dura, PDL, and bony trabeculation in the periapical area are signs of cessation of the resorption process.
7. At the 1-year (and longer) posttreatment follow-up, even markedly resorbed teeth are not unduly mobile and might not require permanent splinting.
8. Root canal treatment, as a means of reducing further resorption, is inappropriate.
9. The teeth were not discolored and appeared to have a fairly good long-term prognosis.
10. Patients with the severity discussed here are rare, but there appears to be a much greater prevalence of the condition among females.

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