Predisposing factors for severe incisor root resorption associated with impacted maxillary canines

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Introduction: Severe incisor root resorption (SIRR) associated with impacted maxillary canines is rare but has important implications. Early diagnosis and treatment are imperative. In this investigation, we aimed to identify predisposing factors for impacted canine-linked SIRR. Methods: Clinical and radiographic data of 55 consecutive patients (77 canines) with SIRR of 96 incisors were compared with data from 57 consecutive control subjects (72 canines). The studied variables were age, sex, position of the impacted canine, size of the dental follicle, and incidence of anomalous lateral incisors. Results: Lateral incisors were more often affected than central incisors, and bilateral SIRR was common. When each variable was examined separately, SIRR was significantly associated with female sex, severely mesiodistally displaced and vertically positioned canines in the middle third of the adjacent incisor root, dental follicles wider than 2 mm, and normal lateral incisors. The multivariate statistical analysis showed that the risk for SIRR was significantly higher in female subjects (4.2 times) with enlarged dental follicles (8.3 times) and normal lateral incisors. Conclusions: SIRR should be carefully screened in female patients with enlarged dental follicles and normal lateral incisors. A greater degree of canine displacement might also be associated with SIRR. (Am J Orthod Dentofacial Orthop 2015;147:52-60)

Early studies with plain film radiography indicated that canine-related incisor root resorption occurs in approximately 12% of patients.1 Yet the authors were at pains to point out that with plain film radiography, it was impossible to properly assess the buccolingual aspects of the incisor roots. With the advent of more advanced imaging techniques such as computerized tomography scanning, detectable root resorption was diagnosed in 38% of resorbed lateral incisors and 9% of central incisors.2 Moreover, from the study of Walker et al3 using cone-beam computed tomography (CBCT), detection capability increased to 67% of cases of which 11% were central incisors and 4% were premolars.3,4

Congenitally missing, small, and peg-shaped maxillary lateral incisors are highly correlated with maxillary canine palatal impaction.5 Whereas resorption of maxillary incisor roots is a well-recognized phenomenon that can occur in patients with impacted canines,6-11 these anomalous lateral incisors with reduced size or abnormal shape have been reported to be less at risk to develop severe root resorption, compared with patients with normally shaped and sized lateral incisors.11

Fortunately, severe incisor root resorption (SIRR) associated with impacted maxillary canines is rare, but when it appears, it threatens the long-term survival of the affected teeth. Early diagnosis and treatment are imperative to save the affected tooth.12,13 At present, evidence-based information regarding potential predisposing factors for SIRR is lacking. The aim of this study was to identify predisposing risk factors for SIRR associated with impacted maxillary canines.

MATERIAL AND METHODS

The study group included 55 consecutive patients with impacted maxillary canines and SIRR, and the
control group included 57 consecutive patients with impacted maxillary canines without SIRR from the Department of Orthodontics of the Hebrew University in Jerusalem, Israel, and the Medical University of Warsaw in Poland and from the private practices of 2 authors (S.C. and A.B.).

The inclusion criterion for the study group was SIRR of at least 1 maxillary incisor associated with an adjacent impacted canine in untreated healthy patients. Diagnosis of SIRR was made from the available panoramic and peri-apical radiographs that had been taken earlier with the intention of commencing orthodontic treatment (Fig 1, A and B). For most of the patients (75%) in the study group, CBCT images were also available for examination (Fig 1, C). CBCT was considered superfluous for patients in whom SIRR could be diagnosed on plain films alone. When CBCT was unavailable for a patient, the buccolingual position of the ectopic canine was determined using the routine tube-shift method and confirmed by the treating orthodontist or surgeon during surgical exposure. In the control group, CBCT had been available for all subjects to exclude any signs of root resorption. The radiographs were examined by 2 authors (S.C. and A.B.) using an x-ray viewer with standard light intensity.

The CBCT examinations were performed with an i-CAT scanner (12-bit; Imaging Sciences International, Hatfield, Pa) with the following parameters: 26.9 seconds scan time, 120 kV, 5 mA, field of view size of 13 (height) \(\times\) 16 (diameter) cm, and 0.2-mm voxel. The resultant slice image data were converted to 3-dimensional images in DICOM format, reconstructed by XoranCat software (version 3.1.62; Xoran Technologies, Inc, Ann Arbor, Mich) and imported to be evaluated in i-CATVision (2008 version 1.8.1.10; Imaging Sciences International). The reconstructed image had a 2-mm slice thickness.

Traditionally, root resorption has been described elsewhere as horizontal shortening of the root.\(^{14}\) The pattern is different for SIRR associated with impacted maxillary canines, where the resorption is mostly oblique rather than horizontal (Fig 2). Root resorption was measured on the radiographs, and it was considered severe when it affected more than a third of the length of the root, but not specifically its apical part (Fig 3). The exclusion criteria for the sample were root resorption of maxillary incisors less than one third of their expected root length, root resorption secondary to trauma or pulp pathology, or the presence of cysts and other pathologies.

The numbers of involved central vs lateral incisors, and unilateral vs bilateral cases, were recorded.

The associations between SIRR and the following variables were evaluated: (1) age; (2) sex; (3) buccolingual location: palatally, buccally, or in the line of the arch; (4) mesiodistal location: sector\(^7\) (Fig 4, A); (5) angulation to the midline\(^{14,15}\) (Fig 4, B); (6) overlap of the adjacent incisor\(^{14,15}\) (Fig 4, C); (7) vertical crown height relative to the adjacent incisor root: apical, middle, or coronal\(^16\) (Fig 4, D); (8) maximum width of the

![Fig 1. A 14-year-old boy with severely resorbed maxillary right lateral incisor associated with canine impaction: A, panoramic view; B, periapical view; C, transaxial and 3-dimensional CBCT views.](image-url)
Study group included 22 patients (20 girls, 2 boys) with bilateral impacted canines, and the control group included 15 bilateral subjects (12 female, 3 male). In the study group among the bilateral impacted canine patients, 3 (13.6%) had unilateral SIRR. The control group was older than the study group (14.2 ± 4.7 vs 12.0 ± 1.4 years) because of the presence of 3 adults (>20 years old).

A markedly elevated prevalence of SIRR was associated with maxillary canine impaction in female subjects (83.6% in the study group vs 54.4% in the control group) compared with male subjects (16.4% in the study group vs 45.6% in the control group; \( P < 0.001 \); Fig 5). When studied in isolation, the risk of female patients having SIRR was 4.2 times higher than in males.

In both groups, the prevalence of palatally impacted canines was higher than that of buccally impacted canines by a ratio just under 2:1 (Fig 6). No statistically significant differences were seen between the study and control groups.

In the study group, most canines (64.9%) were located close to the midline, mainly in sector 5 (35%) and sector 4 (29.9%) (Fig 7). In the control group, only a small percentage of the canines were seen in sector 5 (13.9%), with larger percentages in sectors 3 (33.3%) and 2 (20.8%). The differences between the distributions of canines were almost statistically significant \( (P = 0.06) \). When studied separately, the risk of SIRR in association with canines positioned in sector 5 was 5.5 and 3.5 times higher than for canines positioned in sectors 2 and 3, respectively.
In the study group, 68.8% of the impacted canines were angulated $\geq 31^\circ$ (grade 3), 20.8% of the canines were between $16^\circ$ and $30^\circ$ (grade 2), and 10.4% of the canines were between $0^\circ$ and $15^\circ$ (grade 1) (Fig 8). In contrast, in the control group, only 40.3% of the canines were grade 3, 36.1% were grade 2, and 23.6% were grade 1. The increased prevalence of severely angulated maxillary canines (grade 3) in association with SIRR was statistically significant in comparison with the controls ($P = 0.02$). When this factor was studied in isolation, the risk of SIRR associated with a canine in sector 3 was about 3 times more than the risk for SIRR in canines in sectors 1 and 2.

The overlap of the adjacent incisor root was more toward the more extreme end of the grading in the SIRR group, with 64.9% of impacted maxillary canines exhibiting complete overlap of the adjacent root or beyond (grade 4) compared with 26.4% in the control group (Fig 9). Only 14.3% of the canines showed no or less than half root horizontal overlap (grade 1) in the study group, compared with 45.8% in the control group, and the differences were highly statistically significant ($P = 0.001$). When studied separately, the risks of SIRR in canines graded 4 were 17.8, 5.8, and 3 times more than in canines graded 1, 2, and 3, respectively.

In the vertical plane, more than half (62.3%) of the impacted maxillary canines in the SIRR-affected group were located in the middle third of the adjacent incisor root (Fig 10). Apically positioned crowns of involved maxillary canines comprised 15.6%, and coronally positioned crowns, 22.1% of the total. The differences in the vertical location were highly statistically significant ($P = 0.001$). The pattern was different in the control group, with a much higher incidence of coronally positioned crowns (43.1%) and smaller incidences of middle

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**Table I.** Distribution of SIRR according to the maxillary incisors (N = 55 patients)

<table>
<thead>
<tr>
<th>Resorbed maxillary incisor</th>
<th>Right lateral</th>
<th>Right central</th>
<th>Left central</th>
<th>Left lateral</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of teeth (%)</td>
<td>40 (41.6%)</td>
<td>18 (18.8%)</td>
<td>9 (9.4%)</td>
<td>29 (30.2%)</td>
<td>96 (100%)</td>
</tr>
</tbody>
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**Fig 4.** Schematic illustration of the projection of the canine in the panoramic image: A, canine position in sectors 1 through 5 (the most mesial contour of the crown is taken); B, canine angulation to the midline (grade 1, $0^\circ$-$15^\circ$; grade 2, $16^\circ$-$30^\circ$; grade 3, $\geq 31^\circ$); C, canine overlap of the adjacent incisor root (grade 1, no horizontal overlap; grade 2, less than half of the root width; grade 3, more than half, but less than the whole root width; grade 4, complete overlap of root width or more); D, vertical canine crown height (apical, middle, coronal).
and apical canines (11.1%) compared with the SIRR group \((P = 0.05)\). When this factor was studied in isolation, the risk of SIRR was 2.7 times higher for a canine in the middle third than for a canine positioned coronally.

The dental follicle was graded 4 \((\geq 3 \text{ mm})\) in 19.5% of the canines in the SIRR group (Fig 11). Grade 4 dental follicles were not observed in any control subject. The differences were statistically significant \((P = 0.03)\). Grades 3 and 4 dental follicles \((\geq 2 \text{ mm})\) were found in 41.6% of the patients in the study group compared with 8.3% of the subjects in the control group.

The patients with congenital absence of the lateral incisor, but whose central incisor was the affected tooth, were combined with subjects with anomalous lateral incisors (Fig 12). In the study group, 20.0% of the lateral incisors were anomalous (congenitally missing and peg-shaped), compared with 42.1% in the control group. Significantly, 31.6% of the lateral incisors in the control group were small, whereas no small lateral incisors with SIRR were found. Because of the total absence of small lateral incisors, all
anomalous lateral incisors were grouped together for the statistical analysis. The risk of SIRR for a normal lateral incisor was 5.8 times greater than for an anomalous lateral incisor.

The multivariate analysis considered all 9 parameters together (Table II). The “buccolingual position” variable took into account only buccal and palatal canines because of the small number of “in line of the arch” canines. Similarly, the anomalous lateral incisors were grouped together compared with the normal lateral incisors because of the lack of small incisors in the SIRR group.

The analysis showed that only 3 factors significantly discriminated between the groups: sex, dental follicle size, and anomalous lateral incisors. More specifically, female subjects had a 4.2 times higher risk for SIRR than did males; dental follicles wider than 2 mm increased the risk by 8.3 compared with normal dental follicles; and lateral incisors of normal shape and size increased the risk for SIRR by 5.8 compared with anomalous lateral incisors.

**DISCUSSION**

The etiologic factors underlying root resorption caused by the neighboring erupting tooth are still unknown. Some authors suggested that the erupting tooth exerts physical pressure. Others postulated that the pressure is caused by the dental follicle and not by the tooth per se. The fact that maxillary lateral incisors are more affected by SIRR than central incisors, reported in this study and also in previous studies, partially supports these theories, which are based on the closer intimacy of the canine to the lateral incisor than to the central incisor.

But why the roots resorb in one patient and are intact in another patient, in whom the canine is identically situated, remains an enigma.

Our study points toward a multifactorial etiology including both general systemic factors (sex) and local factors (aberrant position of the canine, follicle size, anomalous incisors).

Incisor root resorption associated with impacted maxillary canines has been reported to occur more in female patients, but the number of affected persons in that study was inadequate to draw valid conclusions. Lai et al noted that female subjects seem to be more affected than males, but their results did not reach statistical significance. Other authors found no differences...
with regard to sex. However, none of these investigations restricted their samples to severe cases, which comprised only 11, 21, 20, 20, 20, 20, 21, and 21 teeth within larger samples. Thus, severe resorption was largely unrepresented, in contrast to our study (96 teeth). Furthermore, their definition of “severe” or “resorption through the pulp” included subjects whose resorption was limited to the root apex. If the inclusion criteria of our study had been applied, their samples would have been further reduced. It is imperative to note that canine-related resorption of incisor roots does not generally shorten the roots in a horizontal manner but, rather, causes oblique resorption, which is usually found on the palatal or the labial aspect, depending on the location of the impacted canine.

To the best of our knowledge, this study includes the largest sample of patients with severe root resorption linked to impacted canines in the literature. The results show a definite predilection for SIRR in female subjects (5:1 ratio, female to male) compared with the control group (almost a 1:1 ratio). These results regarding the distribution of the sexes in the control group support previous findings from a random population of the same ethnicity living in the same general area. However, in other previous studies, impacted canines were more frequently found in female subjects than in males; therefore, it may be claimed that the apparent predilection of root resorption in females merely reflects this imbalance. In studies of orthodontic patient samples, the ratios of impacted canines in females to males were 2.3:1 in an American sample, 2.5:1 in an Israeli sample, and 3:1 in each of Welsh, American, and Italian orthodontic samples.

Thus, the finding reported here of a 5:1 female-to-male ratio of SIRR indicates an obvious affinity for the condition among female patients, and above their apparent naturally occurring predilection for canine impaction. Although the reasons for this are unknown, it must be assumed that genetic or hormonal etiologic factors, as well as girls’ earlier skeletal growth spurt, earlier eruption of canines, and in general earlier dental development; jaw discrepancies; and root and crown sexual dimorphism might play significant roles.

Patients with bilateral maxillary canine impaction were seen here in considerable numbers (40% in the study group, 26% in the control group); this has been reported elsewhere. However, the fact that 19 of 22 (86.4%) patients exhibited bilateral canine-related SIRR was surprising. This bilateral pattern further supports a more general, systemic etiology, in addition to local factors for SIRR.

The control group of consecutive patients was older than the SIRR group. SIRR will typically be diagnosed and treatment initiated at an earlier age than for a patient with routine canine impaction. Furthermore, a significant proportion of the affected teeth may not survive into adulthood without treatment.

Local factors can be divided into those related to the canine (position and size of the dental follicle) and those related to the size and shape of the affected lateral incisor.

In this study, a majority of the examined SIRR-affected incisors were associated with palatal impaction; this was almost double the number with buccal impaction (Fig 6). However, this is similar to the palatal-to-buccal impaction ratio, as can be seen in the control group and as reported in the literature. Lai et al also found no difference in the prevalence of root resorption between labial and palatal canines.

In contrast, SIRR was associated with severely horizontally displaced impacted canines that were closer to the midline and severely mesially angulated canines, overlapping the lateral incisors. This confirms results published previously. In the vertical plane, the most risk-prone canines were those superimposed on the middle third of the adjacent maxillary incisor root. The fact that the middle third of the maxillary incisor root is most commonly resorbed in association with maxillary canine impaction has already been reported. In their earlier study, using plain film radiography, Ericson and Kurol found that 82% of the lateral incisors were resorbed in the middle third and only 13% apically, with the remainder cervically resorbed. More recent studies with computerized tomography have confirmed that maxillary incisor resorption occurs most commonly in the middle third of the roots.

Our results support the view that pressure from an enlarged dental follicle may increase the risk for root resorption. This finding is in contrast to other studies, which claimed that the existing contact relationship of the impacted maxillary canine with the lateral incisor root is critical. However, our study included only the most severe cases of root resorption, and this could be the reason for the apparent conflict.

In this sample, SIRR was not seen in any of the small lateral incisors. This study is consistent with previous studies, in which anomalous lateral incisors have been reported to be less likely to develop severe root resorption, compared with normally shaped and sized lateral incisors. One may be permitted to speculate that in patients with impacted canines, the normally sized and early developing lateral incisor root obstructs the deviated eruption path of the canine and consequently stands a greater chance of being damaged by resorption. Conversely, shorter or late developing roots of anomalous incisors are...
more easily bypassed and not endangered by the impacted canines. This finding confirms the results of a recent study, in which small lateral incisors were found to be less likely to develop orthodontically related root resorption.36

When all of these factors were examined together in the multivariate analysis model, only 1 general factor (sex) and 2 local factors (enlarged dental follicle and normally sized and shaped lateral incisor) were found to significantly increase the risk of SIRR. However, this might be related to sample size and the number of variables. Future research on larger canine-related SIRR samples might show that the other factors, which were significantly associated when each was studied in isolation, also reach significance in a multivariate model that combines them all.

CONCLUSIONS

1. The etiology of impacted canine-associated SIRR is multifactorial, including both systemic and local factors.
2. The risk for SIRR is increased in female patients with enlarged dental follicles and anomalous lateral incisors.
3. Lateral incisors are affected more than central incisors, and the chance of bilateral occurrence is high.
4. SIRR is found in both palatally and buccally impacted maxillary canines but is associated with the more severely displaced canines, situated in the middle third of the adjacent incisor roots.

Screening for SIRR is recommended for all patients with impacted canines, but especially for female patients with impacted maxillary canines surrounded by enlarged follicles and with normally sized and shaped lateral incisors. When one incisor is diagnosed with SIRR in a bilateral impaction, the contralateral incisor should also be carefully screened. Severely mesially angulated canines positioned over the middle third of the adjacent incisor root should also be treated with suspicion.

This information is of major importance for early diagnosis by the orthodontist, but also for pediatric or general dentists who are frequently the first practitioners to meet the patients, and for surgeons so that they can plan the most appropriate interdisciplinary treatment.

REFERENCES