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Is mild dental invagination a risk factor for apical root resorption in orthodontic patients?

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SUMMARY The purpose of this retrospective study was to assess if dental invagination is a risk factor for root resorption during orthodontic treatment. The sample consisted of 91 patients (32 males, 59 females) with a mean age of 13.1 years (range 9.3–32.1 years) with complete orthodontic records, including periapical radiographs of the maxillary incisors before and after treatment. Forty-nine patients had at least one maxillary incisor invaginated, whilst the remaining 42 patients were free of dental invaginations. Variables recorded for each patient included gender, age, Angle classification, extraction or non-extraction therapy, ANB angle, overjet, overbite, trauma, habits, agenesis, tooth exfoliation, treatment duration, Class II elastics, body-build, general factors, impacted canines, and root form deviation. Crown and root length of the maxillary incisors were measured on pre- and post-treatment long cone periapical radiographs corrected for image distortion. The percentage of root shortening and root length loss in millimetres was then calculated.

Most of the invaginated teeth were minor type 1. Statistical analysis revealed no significant difference in the severity of apical root resorption between invaginated and non-invaginated incisors in patients without dental invaginations, nor was the extent of dental invagination related to the severity of apical root resorption. However, invaginated teeth had malformed roots more often than non-invaginated teeth.

Dental invagination, and particularly type 1, cannot be considered a risk factor for apical root resorption during orthodontic tooth movement.

Introduction

Dental invagination is the most prevalent (26.1 per cent) dental anomaly in orthodontic patients (Thongudomporn and Freer, 1998a). The maxillary lateral incisors are most often affected, followed by the maxillary central incisors. Affected teeth show a deep infolding of enamel and dentine, starting from the foramen caecum, or the incisal edge, and extending deep into the root. The pathogenesis of invaginations is unknown and probably multifactorial (Ruprecht *et al.*, 1987). The anomaly can be the result of an active proliferation of an area of the enamel organ with infolding into the dental papilla, or displacement of part of the enamel organ into the papilla as a result of abnormal pressure from surrounding tissues (Soames and Southam, 1998). It can also derive from relative retardation in growth of a portion of the enamel organ (Kronfeld, 1934).

Dental anomalies, such as invagination, have been claimed to be one of the predisposing factors for root resorption during orthodontic treatment (Kjær, 1995; Thongudomporn and Freer, 1998b). The importance of neuroectodermal deviation from normal development has been stressed in these studies. On the other hand, Lee *et al.* (1999) found that individual dental anomalies such as invaginations are not risk factors for orthodontic root resorption. A later report by Ferrer (2002) support that result. Moreover, regression analysis of various risk factors considering orthodontic root resorption has revealed a negative relationship for dental invagination (Mavragani *et al.*, 2000). The latter study, however, was not primarily designed for the investigation of this question. Furthermore, the definition of dental invagination and the study design vary considerably between the above-mentioned investigations.

It seems that there is no general agreement concerning the role of dental invagination as a risk factor for orthodontic apical root resorption. Therefore, it was considered appropriate to investigate the association between this specific dental anomaly and root shortening during orthodontic treatment. The purpose of this study was to test the hypothesis that dental invagination is a risk factor for orthodontic apical root resorption.

Subjects and methods

The study was retrospective in design. The sample consisted of 91 patients who had completed orthodontic treatment in The Postgraduate Clinic, Department of Orthodontics and Facial Orthopedics, University of Bergen. The patients were treated with a straightwire edgewise technique with 0.018-inch slot brackets (New Bergen Technique brackets, 3M Unitek, Dyna-Lock™, California, USA). Orthodontic records, including periapical radiographs of the maxillary incisors, taken with the long cone parallelling technique (Eggen, 1973), before and after treatment, were available. For each patient, several pre-treatment variables considering individual, dentition, and treatment characteristics were recorded (Table 1).

The sample comprised two groups according to the presence or absence of invaginations of the maxillary incisors. The dental invagination (I) group consisted of 49 patients who had at least one invaginated maxillary incisor. The non-invagination (NI) group consisted of 42 patients whose maxillary incisors had no sign of invagination (Table 2).

Dental invagination was determined on pre- and/or post-treatment periapical radiographs following the classification by Oehlers (1957). According to this classification, type 1 invagination, the mild form, is confined within the crown and does not extend beyond the level of the cementoenamel junction, type 2 invagination invades into the root, but remains confined within it as a blind sac, whereas the more severe type 3 invagination penetrates through the root and expands apically (Figure 1). After exclusion of 37 teeth due to unsatisfactory radiographs, 328 teeth were examined (Table 3). The method of root and crown measurement and the calculation of apical root resorption in millimetres and percentage of root shortening have been described in detail previously (Mavragani *et al.*, 2000).

Error of the method

All measurements were performed by one examiner (JA). The reproducibility of the measurements was assessed by statistically analysing the difference between double measurements by the same examiner. Thirty teeth from the radiographs of 30 patients were randomly selected for the second measurement 2 weeks after the first measurement. The systematic error was estimated separately for crown and root with the paired *t*-test between double measurements, and the measurement error (τ) separately for crown and roots was calculated by the formula:

$$\tau = \sqrt{\frac{\sum D^2}{2N}}$$

where D is the difference between first and second measurements and N is the number of double measurements (Dahlberg, 1940).

No significant systematic errors were found and the measurement errors (τ) were within acceptable limits. Furthermore, duplicate determinations of dental invagination showed 93.33 per cent agreement. The accuracy of assessment of dental invagination was considered acceptable.

Statistical analysis

In order to assess the difference of the recorded variables between the two groups, a two-sample *t*-test was performed for quantitative variables and a chi-square test was applied to determine the association between qualitative variables.

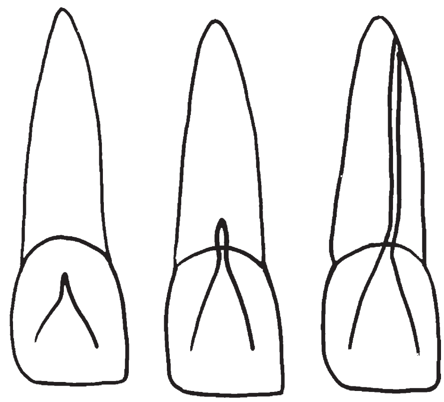
The two-sample *t*-test was used to detect any difference in the root length reduction in millimetres and percentage between

Table 1 Variables recorded and units of measurement.

Variables	Unit
Pre-treatment patient characteristics	
1. Gender	Male/Female
2. Age at start of treatment with fixed appliances	Years
3. General factors (allergies, hormonal imbalances)	Yes/No
4. Habits (lip-tongue dysfunction, finger-sucking, atypical swallowing pattern, nail-biting)	Yes/No
5. Trauma (separately for 12, 11, 21, 22)	Yes/No
6. Late tooth exfoliation	Yes/No
7. Body-build	Normal/Light/Heavy
Analysis of dentition	
8. Agenesis	Yes/No
9. Impacted canine (separately for 13, 23)	Yes/No
10. Root form deviation (Levander and Malmgren, 1998; Mavragani *et al.*, 2000; separately for 12, 11, 21, 22)	Yes/No
11. Overjet	mm
12. Overbite	mm
13. Angle classification	Class I, II, III
14. ANB angle	Degrees
Treatment variables	
15. Orthodontic technique	Standard/Straightwire edgewise
16. Extraction or non-extraction therapy	Ex./Non-ex.
17. Treatment duration	Months
18. Contraction duration	Months
19. Class II elastic duration	Months

Table 2 Gender and age distribution of the sample in the invagination (I) and non-invagination (NI) groups.

	Males	Females	All	Mean age (years)	Range (years)	SE
I group	19	30	49	13.1	9.9–25.2	0.3
NI group	13	29	42	13.1	9.3–32.1	0.5
All	32	59	91	13.1	9.3–32.1	0.3



Type 1 **Type 2** **Type 3**

Figure 1 Graphic illustration of the three types of invagination according to Oehlers (1957).

invaginated teeth in the I group and the teeth in NI group, for each examined tooth (12, 11, 21, 22) separately. Additionally, root length loss of non-invaginated teeth in group I was compared with the teeth in the NI group by the Mann–Whitney test.

To investigate any relationship between the amount of apical root resorption and severity of invagination, a Kruskal–Wallis test was performed by comparing root length reduction of the non-invaginated, type 1, and type 2 invaginated teeth, in group I.

Additionally, frequency distribution of variable 'root form deviation' was compared between only the invaginated teeth from the I group and the teeth in the NI group. For that purpose, a chi-square test was used for each tooth.

Statistical analyses were carried out using the Minitab software package (Minitab Data Analysis Software, State College, Philadelphia, USA).

Results

The majority of the invaginated teeth showed the minor form of invagination (type 1). No severe (type 3) invagination was found in the sample. Type 2 invagination was present only in eight lateral incisors (Table 3).

The two groups were well matched considering all variables recorded, except for root form deviation. This variable was significantly more common in the I group than in the NI group, for teeth 12 (P = 0.01) and 22 (P = 0.03; Figure 2). When only the invaginated teeth from the I group were compared with the teeth in the NI group, the difference was significant for three of the maxillary incisors (Table 4).

Table 3 Distribution of teeth in the invagination (I) and non-invagination (NI) groups according to the presence and type of invagination according to the classification of Oehlers (1957).

Teeth	I group					NI group
	No invagination	Type 1	Type 2	Type 3	Total	
12	11	27	4	0	42	33
11	18	30	0	0	48	39
21	17	31	0	0	48	38
22	9	31	4	0	44	36
Total	55	119	8	0	182	146

The comparison of apical root resorption in percentage of root shortening and millimetres between invaginated teeth in the I group and teeth in the NI group did not reveal any significant difference. The mean values for apical root resorption varied between 0.46–1.22 mm for invaginated teeth and 0.50–1.00 mm for non-invaginated teeth; however, negative values for root resorption, indicating root lengthening, occurred among all teeth in both groups (Table 5, Figures 2–4).

Non-parametric comparison of apical root resorption between non-invaginated teeth in the I group and teeth in the NI group did not show any difference at the 5 per cent level of significance. However, for tooth 11, non-invaginated teeth in the I group had a tendency for more severe apical resorption compared with the NI group (Table 6).

The Kruskal–Wallis test showed no significant variation in percentage of root shortening among non-invaginated, type 1 and 2 invaginated teeth within the I group. For tooth 11, non-invaginated teeth showed a trend for a higher resorption value than type 1 invaginated teeth. The median values for root resorption for tooth 22 were not significantly reduced from non-invaginated to type 2 invaginated teeth (Table 7).

Discussion

Oehlers' (1957) classification according to the severity of dental invagination was easy to apply and reproduce. One drawback of the analysis, which derives from its nature, was that it could not be performed blind. During the radiographic analysis the examiner was inevitably aware of the existence and type of invagination. The comparison of root resorption of non-invaginated teeth between the I and NI groups was performed in order to evaluate potential differences in unknown factors, for which the groups had not been tested. No such differences revealed.

The mean values for apical root resorption were slightly lower than in a previous study (Mavragani *et al.*, 2000). The present sample comprised both extraction and non-extraction subject and all types of malocclusion, whereas the previous study only included Class II division 1 patients treated with

Table 4 Comparison of frequency distribution of root form deviation between the non-invagination (NI) and invagination (I) groups, as well as between the NI group and invaginated teeth only from the I group.

Root form		NI group	I group	P	Invaginated teeth in the I group	P
Tooth 12	Normal	28	24		19	
	Deviations	5	18	0.01	12	0.03
Tooth 11	Normal	34	34		20	
	Deviations	5	14	0.07	10	0.04
Tooth 21	Normal	32	35		21	
	Deviations	6	13	0.21	10	0.13
Tooth 22	Normal	30	27		22	
	Deviations	6	17	0.03	13	0.05

Table 5 Root resorption in percentage (%) of root shortening and in millimetres (mm) for invaginated teeth in the invagination (I) group and in corresponding teeth in the non-invagination (NI) group.

	Invaginated teeth in the I group					NI group					*P*
	n	Mean	SD	Min	Max	*n*	Mean	SD	Min	Max	
Tooth 12											
%	31	7.79	9.35	−11.09	23.93	33	6.05	7.95	−9.30	20.93	0.43
mm		1.22	1.53	−1.73	4.26		0.93	1.27	−1.44	3.48	0.41
Tooth 11											
%	30	2.76	9.54	−15.16	28.69	39	2.30	9.28	−21.28	22.85	0.84
mm		0.48	1.32	−1.72	4.05		0.50	1.58	−3.21	4.28	0.95
Tooth 21											
%	31	2.84	8.85	−20.83	33.49	38	4.08	8.44	−15.83	21.48	0.55
mm		0.46	1.43	−2.67	5.75		0.72	1.40	−2.66	3.96	0.44
Tooth 22											
%	35	5.90	11.10	−15.37	36.50	36	6.30	11.70	−35.66	25.70	0.87
mm		1.10	1.88	−2.26	7.15		1.00	1.74	−5.05	3.69	0.81

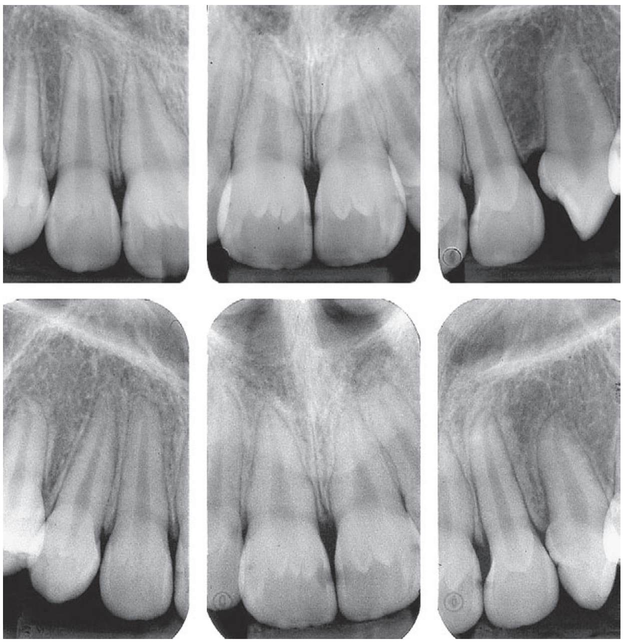


Figure 2 Type 1 invaginated teeth with deviated root form: short, pointed roots of central incisors, curved apices of lateral incisors. Pre- and post-treatment radiographs.

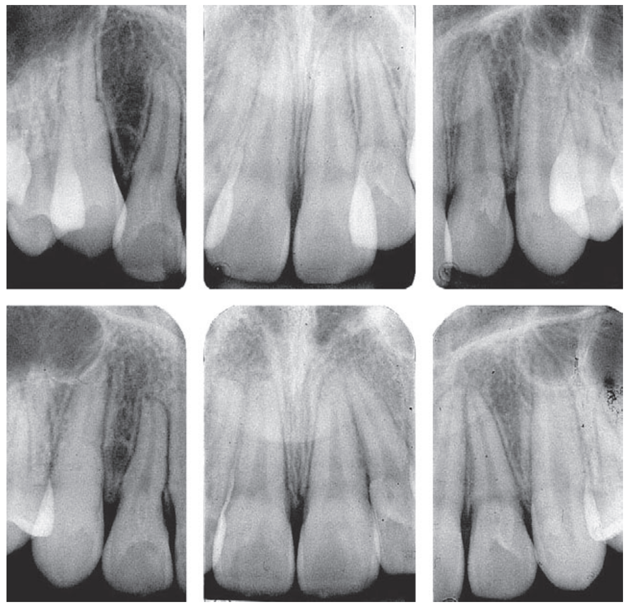


Figure 3 Type 2 invaginated lateral incisors. Pre- and post-treatment radiographs. Root-malformed tooth 12 shows apical resorption after treatment.

extractions. The latter has been considered a risk factor for apical root resorption (Blake *et al.*, 1995). Negative values for apical root resorption, indicating root lengthening, were observed for all groups and teeth examined, indicating that these teeth had immature roots which developed during the course of treatment (Mavragani *et al.*, 2002).

According to the present results, dental invagination cannot be considered a risk factor for orthodontic apical root resorption. Moreover, no significant variation in severity of root resorption was observed in the I group. It should be noted, however, that most of the invaginations were of the minor form (type 1). Type 2 invagination was registered in eight teeth, whereas teeth with type 3 invagination, which occurs rarely, were not present in the sample. Therefore, the results from this study concern the more frequently seen mild dental invaginations, and should be extrapolated with caution. A study including severe cases of dental invagination in relation to orthodontic root resorption would be desirable.

It has been hypothesized that severe type 3 invagination can result in root resorption during orthodontic tooth movement, due to a combined effect of low-grade infection and injury-induced inflammation in the periodontium. However, in a reported case, root resorption was located close to the opening of the invagination canal without severe root length reduction (Fristad and Molven, 1998). Pulpal and periapical pathosis have been related to dental

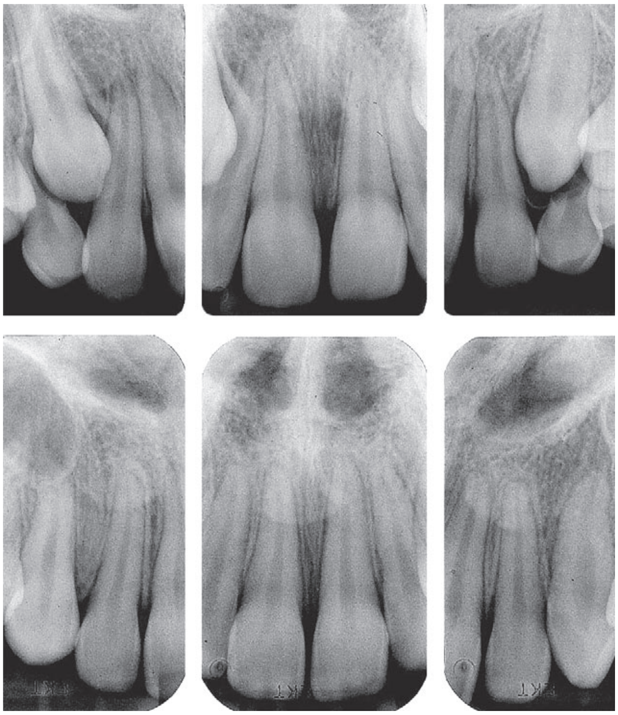


Figure 4 Non-invaginated teeth. Pre- and post-treatment radiographs.

invagination. It has been claimed that spontaneous necrosis of the pulp may occur in teeth with minor invagination, resulting in an apical abscess or dental cyst (Stephens, 1953). On the other hand, Ruprecht *et al.* (1987) found no significant difference in the prevalence of periapical pathosis of pulpal origin in teeth with and without dental invagination.

The results of the present investigation are in agreement with Lee *et al.* (1999), as well as with similar findings associated with another dental anomaly, i.e. peg-shaped lateral incisors (Kook *et al.*, 2003). The study did not support the findings of Kjær (1995) who concluded that dental invagination was strongly connected to the tendency for orthodontic root resorption. In that study, no relevant classification was used, which could have improved accuracy of the radiographic registration of invagination. Furthermore, Kjær (1995) based her conclusion on the greater frequency of invaginations in patients demonstrating severe root resorption (42 per cent), compared with the normal population (2–25 per cent). However, the incidence of invagination may be generally higher in orthodontic patients than in the normal population. Following similar registration criteria as Kjær (1995), 45 per cent of the maxillary incisors of orthodontic patients were found to be invaginated (Mavragani *et al.*, 2000). In another study the occurrence of dental invaginations in orthodontic patients

Table 6 Root resorption in percentage of root shortening (%) and in millimetres (mm) for non-invaginated teeth in the invagination (I) group and in corresponding teeth in the non-invagination (NI) group.

	Non-invaginated teeth in I group				NI group				*P*
	n	Median	Min	Max	*n*	Median	Min	Max	
Tooth 12									
%	11	7.60	−9.89	34.87	33	4.87	−9.30	20.93	0.97
mm		1.04	−1.53	5.38		0.78	−1.44	3.48	0.85
Tooth 11									
%	18	6.73	−10.56	34.71	39	3.33	−21.28	22.85	0.08
mm		1.04	−1.00	6.34		0.60	−3.21	4.28	0.10
Tooth 21									
%	17	3.10	−12.03	18.77	38	3.81	−15.83	21.48	0.79
mm		0.52	−1.59	3.18		0.72	−2.66	3.96	0.83
Tooth 22									
%	9	6.40	−13.47	26.94	36	5.64	−35.66	25.70	0.57
mm		1.01	−1.97	3.98		0.92	−5.05	3.69	0.70

Table 7 Comparison of apical root length loss (%) in the invagination group.

		No invagination	Type 1 invagination	Type 2 invagination	*P*
Tooth 12	*n*	11	27	4	
	Median	7.60	8.90	8.50	0.96
Tooth 11	*n*	18	30	0	
	Median	6.73	1.82	—	0.07
Tooth 21	*n*	17	31	0	
	Median	3.10	3.20	—	0.44
Tooth 22	*n*	9	31	4	
	Median	6.40	4.40	−0.5	0.65

was found to be 26.1 per cent (Thongudomporn and Freer, 1998a). It could be hypothesized that dental invagination is a genetically distinct morphological tooth abnormality. In a study analysing the inheritance and phenotype of hypodontia and dental anomalies, other abnormalities such as ectopic canines, rotation of premolars and taurodontism, but not invagination, were related to incisor-premolar hypodontia. In fact, the invagination frequency was lower in individuals with hypodontia (Arte *et al.*, 2001).

An interesting finding of the present study was that invaginated teeth more often exhibited deviated root form than non-invaginated teeth. Root malformation has been considered a risk factor for orthodontic apical root resorption. In one study, teeth with blunt or pipette-shaped roots were more resorbed than teeth with a normal root form, whereas the difference was almost significant for teeth with apical bends (Levander and Malmgren, 1988). The association between dental invagination and root malformation could partly explain the positive relationship of dental invagination and apical root resorption reported in other studies (Kjær, 1995; Thongudomporn and Freer, 1998b).

An unexpected observation was a tendency for more severe resorption in the non-invaginated teeth in the invagination group. However, the difference was not significant at the 5 per cent level. A similar trend has been reported earlier (Mavragani *et al.*, 2000). One possible explanation is that invaginated teeth, often with malformed roots, have been delayed in their development. During orthodontic treatment, immature roots seem to be protected from root resorption (Mavragani *et al.*, 2002).

Conclusions

According to the results of this study, dental invagination is not a risk factor for orthodontic apical root resorption. The results are primarily valid for the mild type of invagination, which is more often found among orthodontic patients. Dental invagination may, however, be associated with root malformation.

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