European Journal of Orthodontics 30 (2008) 346–351
doi:10.1093/ejo/cjn010

A possible association between early apical resorption of primary teeth and ectodermal characteristics of the permanent dentition

M. L. B. Bille, M. J. Kvetny and I. Kjær
Department of Orthodontics, School of Dentistry, University of Copenhagen, Denmark

SUMMARY The hypothesis of this study is that children with unexpected early apical resorption of the primary teeth are also predisposed to resorption in the permanent dentition. Accordingly, the aim was to perform a longitudinal study focussing on the permanent teeth in children with unexpected early apical resorption in the primary dentition.

Panoramic radiographs of 12 children (7 boys and 5 girls) aged 6 years 4 months to 8 years 9 months with unexpected early apical resorption of primary teeth were identified from a dental archive of 588 patients. After written request, follow-up radiographs were obtained (2–15 year interval between early and follow-up radiographs). The radiographs were examined in order to verify the abnormal resorption pattern of the primary teeth and dental deviations in the permanent teeth, known to predispose for root resorption (i.e. invaginations, narrow crowns, abrupt root deflections, slender roots, short roots, taurodontia, agenesis, deviant pattern of eruption).

Primary dentition: Two phenotypically different resorption groups were identified: group I, eight patients (resorption of the roots only), and group II, four patients (resorption of root and crown). Permanent dentition: In all 12 children, dental deviations in the permanent dentition were observed. Additionally, idiopathic external apical resorption of the permanent teeth was seen in three children, two of whom had received orthodontic treatment.

Introduction

During orthodontic treatment, root resorption can be a complication. It is generally agreed that a tendency to root resorption is dependent on treatment factors and the patient's individual susceptibility (Brezniak and Wasserstein, 1993; Hartsfield *et al.*, 2004). Previous research has revealed that dentitions exhibiting certain morphological characteristics are predisposed to root resorption during orthodontic treatment (Kjær, 1995; Levander and Malmgren, 1988; Thongudomporn and Freer, 1998; Nishioka *et al.*, 2006). In other studies, this association between resorption tendency and dental morphology was not observed (Lee *et al.*, 1999; Kook *et al.*, 2003; Mavragani *et al.*, 2006).

A link has been demonstrated between resorption of the permanent teeth during orthodontic treatment and deviant resorption of primary teeth due to ectopic eruption of a permanent tooth and atypical external collum resorption (Kjær, 1995).

Kjær (1995) also showed a relationship between root resorption during orthodontic treatment and certain morphological characteristics and dental anomalies in the permanent dentition, such as invaginations, narrow crowns, short roots, slender roots, pipette-shaped roots, abrupt root deflections, taurodontia, agenesis, and ectopia.

Additionally, an association was seen between root resorption and anterior open bites as well as between root resorption and condylar changes such as flattening of the cranial contour of the mandibular condyle (Kjær, 1995).

The normal correlation between maturity stages of the permanent teeth and resorption stages of the corresponding primary teeth has been described by Haavikko (1973). Two abnormal apical resorption patterns in the primary dentitions have recently been described in 14 children (Bille *et al.*, 2007). The abnormal resorption pattern was designated 'unexpected early apical resorption', and the subjects were divided into two groups according to phenotype. Group I was characterized by resorption of the roots only and group II by resorption of the entire root complex and partial resorption of the crown (Bille *et al.*, 2007). The resorption pattern of group II was designated as teeth with a 'shell appearance'.

In the present study, it was hypothesized that this recently described unexpected early apical resorption of the primary teeth observed in the presence of permanent successors also predisposes to root resorption of the permanent teeth during orthodontic treatment. The aim therefore was to determine whether children with unexpected early apical root resorption of the primary teeth in the later stage of dental development had deviations in the permanent dentition previously shown to be connected with root resorption (Kjær, 1995).

Material

Dental pantomograms of the early mixed dentitions for evaluating mainly the primary dentition

Dental pantomograms of 12 children (7 boys and 5 girls, aged from 6 years 4 months to 8 years 9 months) in the early mixed dentition were identified in an archive of dental radiographs. The archive consisted of radiographic material from 588 patients forwarded since 1995 from Danish municipal clinics to the Department of Orthodontics, Copenhagen School of Dentistry, for diagnostic guidance and treatment planning.

The criterion for identifying radiographs for the present study was the occurrence of a subjective estimate of unexpected early apical resorption of several primary teeth in regions with a permanent successor. In no case could the early resorption of several primary teeth be explained by caries, apical infection, or ectopic eruption of the permanent successor.

Follow-up radiographs for evaluating the permanent dentition

After a written request, follow-up radiographs were obtained (Table 1). These follow-up radiographs were taken 2–15 years after the radiographs of the early mixed dentition. Two of the 12 children had received orthodontic treatment during the follow-up period.

Method

The radiographs were examined by two independent observers in order to verify the abnormal resorption pattern of the primary teeth and to divide the material into group I (abnormal root resorption only) and group II (abnormal root and crown resorption). Only radiographs with agreement between the observers were included. In the permanent dentition, dental deviations known to predispose for root resorption were registered, i.e. invaginations, narrow crowns, screwdriver-shape, abrupt root deflections, slender roots, short roots, taurodontia, agenesis, and deviant pattern of eruption (Kjær, 1995).

Invagination was defined as teeth with radiographically distinct enamel notching (a distinct cingulum dentis) according to Kjær (1995). A crown was defined as narrow when the diameter of the crown was no wider than the collum of the root. A root was defined as short if the root had the same size or appeared shorter than the crown, and a tooth was defined as taurodontic if the part of the tooth between the enamel dentine junction and the furcation was enlarged (Shaw, 1928).

Additionally, deviations from the normal eruption pattern of permanent teeth were noted, and resorption of permanent teeth was registered.

Results

Primary teeth

Two phenotypically different groups of resorption were identified according to Bille *et al.* (2007). Eight children (four boys and four girls) belonged to group I (Figure 1) and four children (three boys and one girl) to group II (Figure 2).

Morphological characteristics of the permanent teeth

Dental deviations of the permanent teeth previously described by Kjær (1995) as associated with to root resorption during orthodontic treatment were seen in all 12 patients with unexpected early resorption of the primary teeth.

The following morphological characteristics and dental anomalies were seen in the subjects: invaginations in five (Figure 1), a narrow crown of the maxillary central or lateral incisors in one (not shown), abrupt root deflection of a maxillary incisor in one (Figure 3), slender or tapered roots in six (Figure 3), short roots in three (Figures 1 and 3), taurodontia in six (Figures 2 and 3), and agenesis in three (Figures 1 and 2). Pipette-shaped teeth were not registered.

Additional findings

Deviant eruption pattern of the permanent teeth. Premature eruption of lower incisors was presumed in two subjects. Resorption of a neighbouring primary tooth during eruption of a permanent tooth was seen in six subjects, with resorption of a primary maxillary canine during eruption of a permanent maxillary lateral incisor as the most common type of deviant eruption pattern (Figure 1).

Resorption of permanent teeth. Resorption of the permanent teeth was seen in four subjects. These resorptions were as follows: ongoing idiopathic external apical resorption of the mandibular first molars with the most pronounced resorption of the distal roots, seen in one patient who had not received orthodontic treatment (Figure 4); one case of internal crown resorption of a permanent molar; external apical resorption of molars, incisors, and lower canines, seen in two subjects who had received orthodontic treatment (Figure 5).

The distribution of dental deviations between the groups and genders is listed in Table 1.

Discussion

This longitudinal study examined the morphology of the permanent teeth on the radiographs of a sample of patients with unexpected early apical resorption of the primary teeth.

In the present study, the association between morphological deviations in the permanent teeth known to be of ectodermal origin and unexpected early apical resorption is described. This is the first communication suggesting that there is a connection between unexpected early apical resorption of

Table 1 Overview of the radiographic material of children with unexpected early apical resorption of the primary teeth (early radiographs) and the findings of dental deviations in the permanent teeth in these children (follow-up radiographs)

	Age at radiograph of early mixed denitition	Age at follow-up radiograph	Invaginations	Narrow crowns	Abrupt root deflections	Slender roots or tapered roots	Short roots	Taurodontism	Agenesis	Deviant pattern of eruption	Premature eruption	Resorption of permanent teeth	Figures
Group I boys	6^{11}	8^{11}	—	—	—	—	—	16,26; 46,36	—	—	42,41, 31,32	—	—
	7+	24^{0}	—	—	—	—	—	17,16, 26,27; 46,36,37	15,25; 47,41,31	—		12,11,21, 22; 46,36	—
	8^{1}	11+	—	—	—	11,21; 46,42, 41,31, 32,36	—	16,26	—	—	—	—	—
	8^{2}	17^{5}	12,22	—	—	general	—	—	—	—		17,16,26,27; 47,46,43, 33,36,37	5
Group I girls	6^{4}	10^{0}	12,22	—	—	—	11,21		35	12	—	—	1
	6^{6}	15^{11}	—	—	—	—	—	—	—	12,22		46,36	4
	7^{9}	17^{2}	12,22	—	—	—	45,41, 31,35		—	12,22	—	—	—
	8+	12+	—	—	—	46,36	—	—	—	—	—	47	—
Group II boys	6^{5}	8^{7}	22	—	—	46,36	—	—	—	16,22;36	—	—	—
	7^{2}	11^{5}	—	11,21	—	46,36	—	26	—	—	—	—	—
	8^{9}	12^{5}	—	—	—	—	—	16,26	15,25; 45,35	44,34	42,41, 31,32	—	2
Group II girls	8^{6}	11^{6}	12,11, 21,22	—	21	46,36	15,25; 45,42, 41,31, 35	17,27; 47,37	—	15	—	—	3

Ages for early and follow-up radiographs are given in years and months (+ indicates that the exact number of months is not known). The abnormal resorption pattern of primary teeth is expressed as group I (abnormal resorption of roots only) and group II (abnormal resorption pattern of roots and crowns). Dental deviation in the permanent dentitions are listed according to the actual teeth with invaginations, narrow crowns, abrupt root deflections, slender roots, short roots, taurodontia, agenesis, deviant pattern of eruption, premature eruption, and resorption of permanent teeth. The figures representing the different cases are given in the last column. In all 12 cases, the table demonstrates a close connection between abnormal resorption in the primary dentition and occurrence of dental deviations in the permanent dentition, but it does not reveal whether the different patterns of resorption of primary teeth predispose to special deviations in the permanent dentitions.

Figure 1 Dental pantomogram of a girl aged 6 years 4 months in the early mixed dentition with unexpected early apical resorption. Invaginations of the permanent maxillary lateral incisors, short roots of the permanent maxillary central incisors, and agenesis of the left permanent mandibular second premolar are seen. A follow-up radiograph (not shown) taken 2 years 8 months later confirmed findings of dental deviations seen on the first radiograph, but did not provide any additional findings of dental deviations in the permanent dentition.

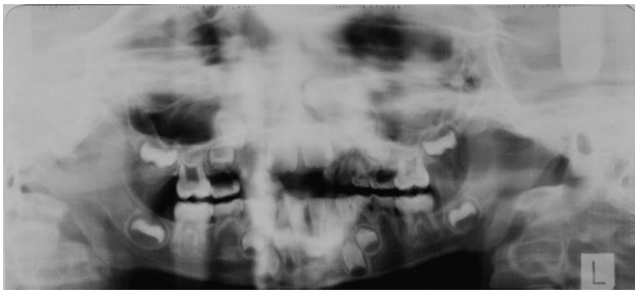

Figure 2 Dental pantomogram of a boy aged 8 years 9 months in the early mixed dentition with unexpected early apical resorption of the entire root complex and partial resorption of the crown of the primary maxillary second molars. Taurodontia is seen in the permanent maxillary first molars and agenesis of all second premolars. A follow-up radiograph (not shown) taken 3 years 8 months later confirmed the findings of dental deviations seen in the first radiograph. Additionally, the mandibular first premolars showed a deviant eruption pattern with resorption of the primary mandibular second molars.

the primary teeth and root resorption tendency of the permanent teeth, but further investigations as well as a longer follow-up period are needed in order to document this association.

The material in the present study was forwarded from different municipal dental clinics in Denmark. Although the radiographs varied in contrast and sharpness, they were considered suitable for the present investigation.

Two independent observers were used in this study in order to control and discuss the subjective evaluation of unexpected early apical resorption and morphological characteristics of permanent teeth. Although a subjective evaluation of tooth morphology on radiographs is not precise, it is a simple method that can easily be applied in dental practice with the purpose of identifying patients with root resorption tendencies.

The findings indicate that it is possible even in the early mixed dentition to identify patients particularly disposed to resorption of the permanent teeth. Very few studies have focussed on connections between resorption in the primary and the permanent dentitions (Kjær, 1995).

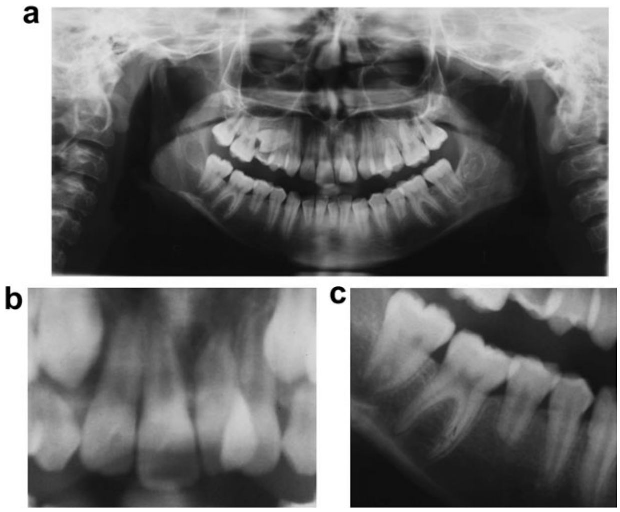

Figure 3 (a) Follow-up radiograph of the permanent dentition in a girl aged 11 years 6 months. Abrupt root deflection of the left maxillary central incisor, slender roots of the mandibular first molars, short roots of the second premolars and mandibular incisors, and taurodontia of the second molars. A deviant resorption pattern of the right primary maxillary second molar is seen. Dental pantomogram (DPT; not shown) of the early mixed dentition showed unexpected early apical resorption of the primary teeth. (b) Enlargement of the DPT of the girl shown in (a). Abrupt root deflection of the left maxillary central incisor is seen in (c). Enlargement of the right mandibular region of the DPT showing taurodontia of the second molar, slender roots of the first molar, and a short root of the second premolar.

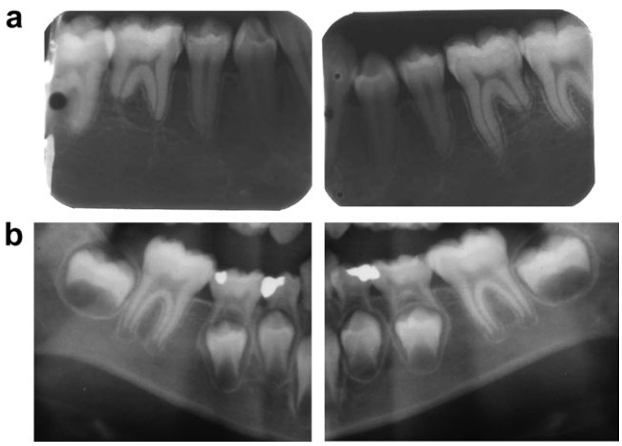

Figure 4 (a) Dental pantomogram (DPT) of the permanent mandibular regions of a girl aged 15 years 11 months showing short roots of the permanent mandibular first molars. The girl had not received orthodontic treatment. (b) For comparison of the mandibular regions (shown in (a)), two segments of the DPT of the early mixed dentition taken 9 years 5 months earlier of the same girl are shown. The root length of the first permanent molar appears longer than shown in (a), and accordingly an unexpected root resorption of the permanent mandibular molars has occurred. Unexpected early apical resorption of primary mandibular molars is also seen in (b).

Several authors have shown a relationship between resorption of the permanent teeth and deviant morphology of the permanent teeth (Kjær, 1995; Levander and Malmgren,

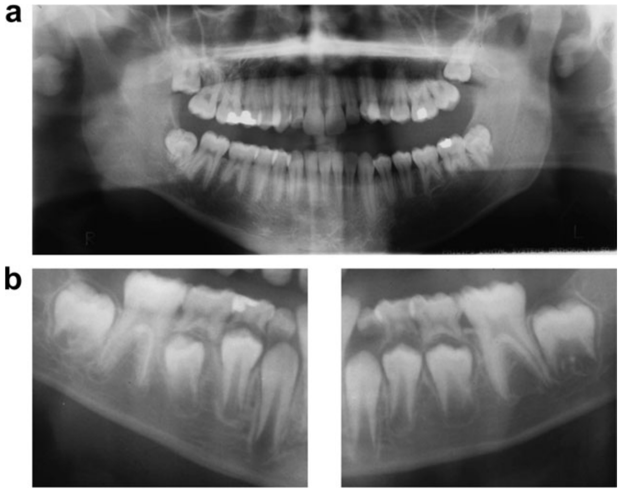

Figure 5 (a) Dental pantomogram (DPT) of the permanent dentition of a boy aged 17 years 5 months with invaginations of the lateral incisors and short roots of mandibular molars. (b) For comparison of the mandibular regions (shown in (a)), two segments of a DPT of the same boy taken 9 years 3 months earlier are shown. Root resorption of the permanent mandibular molars has occurred since the DPT shown in (a) was taken. The patient has received orthodontic treatment. Note less severe early apical resorption of the primary teeth.

1988; Thongudomporn and Freer, 1998; Nishioka *et al.*, 2006), while others did not find an association (Lee *et al.*, 1999; Kook *et al.*, 2003; Mavragani *et al.*, 2006). Such disagreement might be due partly to different study designs as well as varied definitions of the morphological characteristics. For example, Thongudomporn and Freer (1998) did not find a connection between root resorption and taurodontia. In several studies, taurodontia is defined as the size and dimensions of the pulp chamber, which is often clearly visible on the radiographs (Shifman and Chanannel, 1978; Ruprecht *et al.*, 1987). The problem is that the absence of a large pulp chamber does not prove the absence of taurodontia since the size of the pulp chamber in taurodontic teeth as well as in non-taurodontic teeth is gradually reduced with age and influenced by external stimuli. Other definitions of taurodontia exist based on different external measurements.

The main problem with regard to root resorption is that the mechanism initiating and controlling root resorption is not known. Recent studies of tooth resorption and tooth eruption have focussed on the cellular regulation of resorption processes. Especially RANK, RANKL, and OPG have been demonstrated in the roots of human primary teeth undergoing resorption (Lossdörfer *et al.*, 2002) as well as in the permanent crown follicles of rats (Wise *et al.*, 2002).

The present findings indicate that the molecular genetic factors responsible for resorption of the primary tooth roots are the same as those responsible for resorption of the permanent tooth roots at a later stage in development. This link between resorption in the primary and permanent dentition requires further elaboration.

In addition, the relationship between the resorption process and the ectodermal deviation in tooth morphology described in a previous study (Kjær, 1995) needs further elaboration. The connection between resorption and ectodermally derived deviations in morphology can only be understood if the resorption process is also dependent on ectodermal tissue. In a recent study, the epithelial rests of Malassez of ectodermal origin were documented as a continuous cell layer in the periodontal membrane (Becktor *et al.*, 2007). If this ectodermal cell layer influences the resistance of the tooth root against resorption or the susceptibility to resorption, the relationship between morphology and resorption becomes understandable. Future studies will focus on the role of this epithelial cell layer of the periodontium during the resorption process.

Conclusions

Two types of unexpected early apical root resorption in the primary teeth were demonstrated in this study. In one type, the root was completely (severely) or partially (less severely) resorbed. The distinction between normal conditions and less severe resorption is difficult to define. In the other type of unexpected primary apical resorption, the root was completely resorbed and the crown partially resorbed. The present research did not comprise sufficient material to decide whether these two different phenotypic patterns of resorption are associated with different types of dental deviations in the permanent dentition. This is a condition that should be examined more closely as it is likely that the genetic causes for the two types of resorption could be different. Any gender differences should also be examined.

Once the different patterns and associations of root resorption are revealed at a macroscopic level, precautions can be taken to avoid resorption during orthodontic treatment and more systematic and goal-orientated research on the aetiology of resorption at a cellular and genetic level can be applied.

Address for correspondence

Professor I. Kjær
Department of Orthodontics
School of Dentistry
University of Copenhagen
20 Nørre Allé
DK 2200 Copenhagen N
Denmark
E-mail: ik@odont.ku.dk

References

Becktor K B, Nolting D, Becktor J, Kjær I 2007 Immunohistochemical localization of epithelial rests of Malassez in human periodontal membrane. European Journal of Orthodontics 29: 350–353

Bille M L B, Nolting D, Kvetny M J, Kjær I 2007 Unexpected apical resorption of primary molars and canines. European Archives of Paediatric Dentistry, 8: 144–149

Brezniak N, Wasserstein A 1993 Root resorption after orthodontic treatment: Parts 1 and 2. Literature review. American Journal of Orthodontics and Dentofacial Orthopedics 103: 62–63, 138–146

Haavikko K 1973 Correlation between the root resorption of deciduous teeth and the formation of the corresponding permanent teeth. Proceedings of the Finnish Dental Society 69: 191–201

Hartsfield J K, Everett E T, Al-Qawasami R A 2004 Genetic factors in external apical root resorption and orthodontic treatment. Critical Reviews in Oral Biology and Medicine 15: 115–122

Kjær I 1995 Morphological characteristics of dentitions developing excessive root resorption during orthodontic treatment. European Journal of Orthodontics 17: 25–34

Kook Y-A, Park S, Sameshima G T 2003 Peg-shaped and small lateral incisors not at higher risk for root resorption. American Journal of Orthodontics and Dentofacial Orthopedics 123: 253–258

Lee R Y, Årtun J, Alonzo T A 1999 Are dental anomalies risk factors for apical root resorption in orthodontic patients? American Journal of Orthodontics and Dentofacial Orthopedics 116: 187–195

Levander E, Malmgren O 1988 Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. European Journal of Orthodontics 10: 30–38

Lossdörfer S, Götz W, Jäger A 2002 Immunohistochemical localization of receptor activator of nuclear factor kappaB (RANK) and its ligand (RANKL) in human deciduous teeth. Calcified Tissue International 71: 45–52

Mavragani M, Apisariyakul J, Brudvik P, Selvig K A 2006 Is mild dental invagination a risk factor for apical root resorption in orthodontic patients? European Journal of Orthodontics 28: 307–312

Nishioka M, Ioi H, Nakata S, Naksima A, Counts A 2006 Root resorption and immune system factors in the Japanese. The Angle Orthodontist 76: 103–108

Ruprecht A, Batniji S, El-Neweihi E 1987 The incidence of taurodontism in dental patients. Oral Surgery, Oral Medicine, and Oral Pathology 63: 743–747

Shaw J C M 1928 Taurodont teeth in South African races. Journal of Anatomy 62: 476–498

Shifman A, Chanannel I 1978 Prevalence of taurodotism found in radiographic dental examination of 1,200 young adult Israeli patients. Community Dentistry and Oral Epidemiology 6: 200–203

Thongudomporn U, Freer T J 1998 Anomalous dental morphology and root resorption during orthodontic treatment: a pilot study. Australian Orthodontic Journal 15: 162–167

Wise G E, Yao S, Zhang Q, Ren Y 2002 Inhibition of osteoclastogenesis by the secretion of osteoprotegerin *in vitro* by rat dental follicle cells and its implications for tooth eruption. Archives of Oral Biology 47: 247–254