

Risk factors of root resorption after orthodontic treatment

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SUMMARY

External apical root resorption is an iatrogenic consequence of orthodontic treatment, although it may also occur in the absence of orthodontic treatment. Root resorption causes root shortening and breaks the integrity of teeth arch and this is very important for successful orthodontic treatment. Orthodontics is probably the only dental specialty that actually uses the inflammatory process as a means of solving functional and aesthetic problems. They should know the risk factors of root resorption and do everything to reduce the occurrence of root resorption.

The aim of our review is to find, classify and estimate factors, that can initiate and induce root resorption during orthodontic treatment. The articles from 2002 to 2007 in English related to the topic were identified. Twenty four articles were selected for data collection.

The severity and degree of root resorption associated with orthodontic treatment are multifactorial, involving host and environmental factors. The review shows that root resorption is significantly correlated with treatment duration, fixed appliance treatment, tooth structure, individual susceptibility, type of orthodontic tooth movement.

Key words: root resorption, external resorption, apical root resorption, orthodontic treatment.

INTRODUCTION

Orthodontically induced inflammatory root resorption is one of complications induced by orthodontic treatment however sometimes it is diagnosed to patients that haven't undergone orthodontic treatment. This root resorption differs from other kinds of resorption [1, 2]. This is a sterile, local inflammatory process, which is complicated and has all characteristic inflammatory symptoms [3]. Trauma, infectious inflammation of periapical tissues and periodontal diseases – these are some of etiological factors that may induce root resorption or root shortening [1]. Usually asymptomatic course is characteristic to root resorption process until destruction of solid dental structure thus early detection is possible just during radiological examination [3]. Root apex as well as lateral surfaces of the root can resorb however just apical root resorption can be shown by means of radiological examination. Usually orthodontic treatment doesn't

cause clinically significant root resorption however microscopic changes appear on the teeth roots, which are difficult to detect in radiological images. Root resorption induces root shortening and weakening of teeth arch and this is very important for successful orthodontic treatment [4]. Root resorption is considered as clinically important when 1-2 mm (1/4) of the root length is lost [5] (Fig. 1).

Severe root resorption during orthodontic treatment (more than ¼ of the root length, >5 mm) occurs very rarely, just in 1-5 % of patients [6]. Analysis and assessment of factors inducing root resorption would simplify timely diagnosis of root resorption and would help avoiding complications impacted by it. Knowing risk factors for root resorption would help the orthodontist to assess a patient upon planning orthodontic treatment and to choose the best method for treatment.

DEGREES OF SEVERITY OF ROOT RESORPTION

There are three degrees of severity of root resorption distinguished:

1. Cementum or surface resorption, occurring together with remodelling, when only outer cementum

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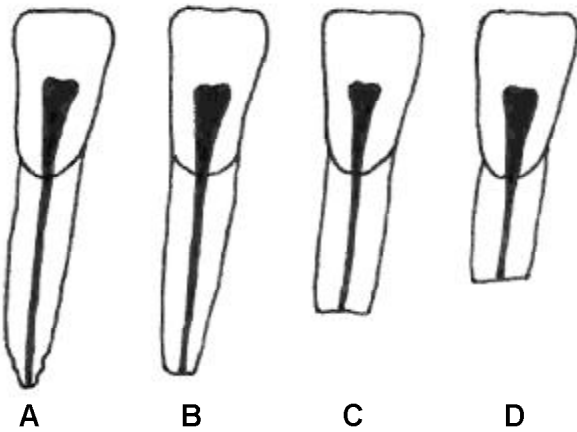


Fig. 1. The degree of root resorption

- A. Irregular root contour
- B. Apical root resorption is less than 2mm
- C. Apical root resorption is from 2mm to 1/3 of the initial root length
- D. Apical root resorption is more than 1/3 of the initial root length

layer is resorbed, which regenerates or remodels later. This process is similar to trabecular bone remodeling [2].

2. Dentin resorption with repair (deep resorption), when cementum and outer dentin layer are resorbed; resorption is irreversible because only cementum regenerates. Tooth root form after this resorption and remodelling may stay the same or altered [2].

3. Surrounding apical root resorption, when hard apical root tissues fully resorb and root shortening is observed. Root apical tissues under cementum are lost, root tissues do not regenerate. Repair of outer surface occurs in the cementum layer. Later sharp tooth edges may be gradually leveled [2].

MECHANISM OF ROOT RESORPTION

Mechanism of root resorption is not completely explored. According to Brudvik and Rygh, inflammatory root resorption induced by orthodontic treatment is a part of process of elimination of hyaline zone [2]. It is considered that occurrence of root resorption can be induced by the strong force through orthodontic treatment and hyalinisation of periodontal ligaments induced by increased activity of cementoclasts and osteoclasts [4]. During tooth movement, areas of compression (where osteoclasts are in action inducing bone resorption) and areas of tension (where osteoblasts are active inducing bone deposition) are formed. Thus a tooth moves towards the side of bone resorption. An imbalance between bone resorption and deposition, losing protective characteristics of cemen-

tum may contribute to the cementoclasts/osteoclasts resorbing areas of the root [5]. When hyaline zone forms, tooth movement will stop. Upon regeneration of periodontal ligament, hyaline zone is removed by mononucleus cells similar to macrophages and by multinucleus gigantic cells and a tooth starts to move again. During removal of hyaline zone an outer tooth root surface consisting of the layer of cementoblasts may be damaged, exposing the underlying highly dense mineralized cementum. It is possible that a force occurring during orthodontic treatment may directly damage outer root surface. Tooth root surface under the hyaline zone resorbes just after a few days, when a repair process is already happening in the periphery. On the grounds of the literature data it can be stated that the resorption process is completed after removal of the hyaline zone, and/or when orthodontic force decreases [2, 5].

RISK FACTORS FOR ROOT RESORPTION

There are a lot of factors that can initiate and induce root resorption during orthodontic treatment. All these factors can be distributed to biological, mechanical and combined biological and mechanical factors and other circumstances.

I. Biological factors

Individual susceptibility is a main factor determining root resorption, which can manifest in both milk-teeth and permanent teeth [7]. Historically, there has been appreciable variability among orthodontic patients in susceptibility to root resorption, which may be due to a systemic or innate predisposition to occurrence of resorption. It is supposed that in case of increased susceptibility to root resorption, severe root resorption may occur without any evident reason [3].

Genetics. Predisposition to root resorption may be autosomal dominant, autosomal recessive, or hereditary determined by a few genes. It is supposed that, genetic predisposition is very important to occurrence of root resorption [7]. Genetic factors account for at least 50 % of the variation in root resorption [3].

Systemic factors. Owman-Moll and Kurol have established that allergic patients are in the group of increased risk for root resorption [1]. On the grounds of researches it was established that lack of estrogens may induce quick orthodontic tooth movement, and calcitonin inhibits activity of odontoclasts [3]. Conditions like asthma also appear to indicate a greater risk for a large amount of apical root resorption [8].

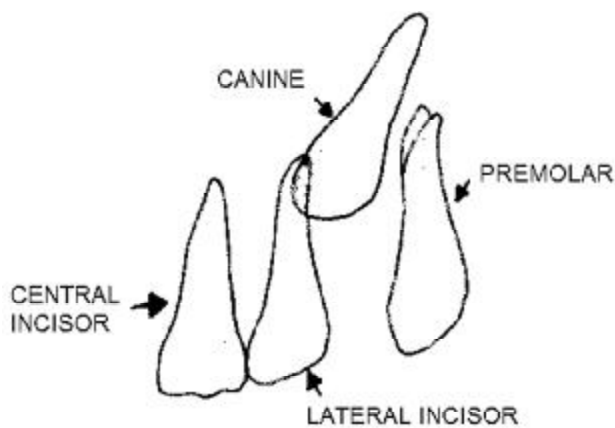


Fig. 2. Erupting canine teeth may induce root resorption of the lateral incisors and first premolars

Nutrition. Becks has shown that root resorption occurred in the animals lacking calcium and vitamin D in their foods [7].

Chronological age. Periodontal membrane becomes narrower and less vascularized, aplastic, alveolar bone becomes denser, less vascularized and aplastic, and cementum becomes wider with age. Through these changes adults show higher susceptibility to root resorption [7]. When a patient is older than 11 years, risk for root resorption increases [4, 9].

Dental age. Rosenberg has stated that teeth with incomplete root formation undergo less root resorption than those with completely formed roots. It is stated that incompletely formed roots reach their normal root length [7]. Naphtali Brezniak et al. have stated that if tooth roots are not completely formed in the beginning of orthodontic treatment, they are further developing during treatment, however remain shorter [1]. Linge and Linge have established that orthodontically treated teeth lose averagely 0,5 mm of the root length [7].

Sex. No significant relationship between sex and root resorption was found by performed studies [7].

Ethnic group. Root resorption more rarely occurs in Asians than in white, Caucasian or Hispanic patients [10, 3].

Root resorption prior to orthodontic treatment. Root resorption that existed prior to orthodontic treatment increases risk for root resorption during orthodontic treatment [7].

Habits, such as bruxism, nail biting, tongue thrust associated with open bite and increased tongue pressure are related to increased root resorption [7, 3].

Anomalies of position and the number of teeth. Supposedly, hypodontia increases risk of root resorption [1]. Impacted teeth may also induce occurrence

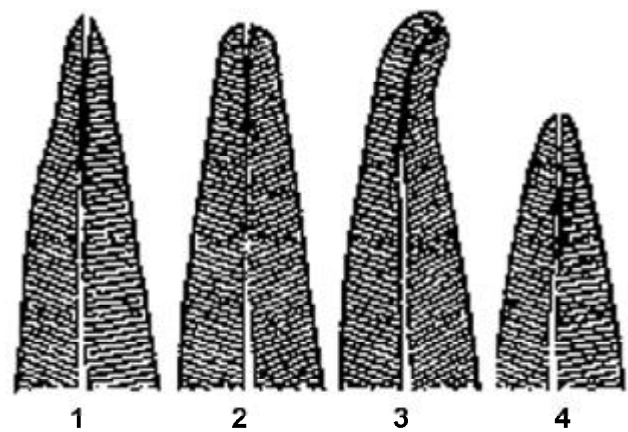


Fig. 3. Root forms

- 1 – pipette-shaped root;
- 2 – blunt root;
- 3 – dilacerated root;
- 4 – short root.

of root resorption. Third molars are the most commonly impacted teeth, which may cause root resorption of the second molar through the cutting of the third molar, which lacks the place in the tooth arch [11]. Maxillary canines are the second most commonly impacted teeth; they can induce root resorption of the incisors and first premolars [12] (Fig. 2). It is recommended annual palpation of the canine regions, dental radiographs before 10 years of age and early extraction of deciduous canines [13].

Tooth structure. Root resorption most often occurs in the apical part of the root, because forces are concentrated at the root apex because orthodontic tooth movement is never entirely translatory and the fulcrum is usually occlusal to the apical part of the root; periodontal ligaments are situated in different directions in the apical part of the tooth root; the apical third of the root is covered with cellular cementum, whereas the coronary third is covered by non-cellular cementum. Active cellular cementum depends on blood circulation; thus periapical cementum is more friable and easily injured in the case of trauma [3].

Levander and Malmgren divide root forms to (Fig. 3): normal, short, blunt, dilacerated and pipette-shaped [6].

Most authors have shown that roots with abnormal shape have a higher susceptibility to root resorption. According to the data of Sameshima and Sinclair, normal and blunt tooth roots are resorbing the least [6]. Pipette-shaped roots are the most susceptible root form to root resorption [7]. Short roots have a greater risk for root resorption than average length roots [4]. It was found that small roots resorb almost twice more than other root forms [6]. There are controversial data about initial length of the tooth

root and the amount of tooth root resorption. There is an opinion that longer roots are more likely to be resorbed than shorter ones because longer roots are displaced farther for equal torque [9]. Tooth with longer roots need stronger forces to be moved and that the actual displacement of the root apex is greater during tipping or torquing movements [3, 14]. It was established that a normal root form of central incisors and wide roots are preventive factors of these teeth roots, decreasing risk of root resorption [15]. Slightly increased root resorption is characteristic for the tooth with narrower roots [14].

Dental trauma may cause root resorption to the teeth without orthodontic treatment. Orthodontically moved traumatized teeth with previous root resorption are more sensitive to further loss of root material [7]. The teeth can be treated orthodontically three months after the tooth transplantation or replantation. According to the research data, a completely assimilated transplanted tooth reacts to orthodontic force as a normal tooth [1].

For endodontically treated teeth increased and more often root resorption is characteristic during the orthodontic treatment. The hypothesis was raised that endodontically treated teeth are more resistant to root resorption because of increased hardness and density of dentin [7, 6]. Qualitative endodontic treatment of teeth is very important. When the root canal filling reaches the root apex, resorption doesn't start however in case of a shorter filling a part without the filling resorbs [6].

Alveolar bone density on root resorption is assessed controversially. A part of the studies has established that the denser is alveolar bone, the more root resorption occur during the orthodontic treatment. According to Reitan, strong continuous force affecting alveolar bone of less density causes the same root resorption as a mild continuous force affecting alveolar bone of higher density. It is more difficult to resorb with orthodontic pressure than bundle bone. Wainwright has stated that bone density determines tooth movement rate but has no relation to the extent of the root resorption [7]. Cementum is harder than alveolar bone and more mineralized, more fibres of periodontal ligaments are inserted into cementum than in alveolar bone, thus osteoclasts have less possibility to injure the cementum layer and induce root resorption [16].

Correlation between malocclusion and tooth root resorption was assessed. According to the data of studies performed by VanderAhe there is no relation between root resorption and malocclusion. Naphtali Brezniak et al. have stated that dental and skeletal malocclusion induce occurrence of root resorption.

No one orthodontic malocclusion is immune to root resorption [1]. Upon studying tooth root resorption occurring during treatment of Angle II class orthodontic malocclusion, it was established severe (≥ 2 mm) maxillary incisor root resorption in 12,4% of children [17]. According to the research data of Kaley and Phillips, the patients with Angle III class orthodontic malocclusion experience increased root resorption [9].

Relationship between the change in overjet and severity of root resorption was observed. The greater the overjet during the orthodontic treatment, the greater the root resorption for maxillary anterior teeth, because greater tooth movement is necessary in order to decrease overjet [9,10]. Malocclusion in vertical plane do not influence occurrence of increased root resorption. Increased overbite may correlate with more root resorption of maxillary lateral incisors [10]. It was established that the deeper is overbite, the greater is root resorption of a maxillary permanent first molar distal root and maxillary incisor [3].

Specific tooth vulnerability to root resorption.

Some teeth are more susceptible to root resorption, other – less. According to the research data teeth of the maxillary teeth are more sensitive to root resorption than the mandibular teeth [4, 7, 10] and anterior teeth are more susceptible to root resorption relative to posterior teeth [18]. Maxillary incisors are the teeth most affected by root resorption, because the degree of root resorption is correlated with the distance of the apex of an incisor moves and the length of time of the orthodontic treatment [19]. Other researches have shown that root resorption is more common in mandibular incisors [7]. The most resorbed tooth in the lower arch is the canine; they are followed by lateral and central incisors [10]. Root resorption of molars and premolars is very low (less than 1mm) [7, 10, 20]. The most resorbed teeth are the maxillary lateral, maxillary central, lower incisors, maxillary canine, distal root of the first molar, lower second premolar and maxillary second premolar [7, 10, 15, 16, 20].

II. Mechanical factors

Orthodontic appliances. Comparing root resorption resulting from removable and fixed appliances, it was established that root resorption more often is induced by treating it with fixed appliances. Stuteville has stated that forces caused by removable appliances are more harmful to the roots [7]. Ilana Brin has studied influence of treatment methods of class Angle II orthodontic malocclusion on teeth roots. The results showed that root resorption was diagnosed more rarely in children who have undergone 2-phase orthodontic treatment first of all

with functional removable appliance and later with fixed appliance, than in children, who have undergone orthodontic treatment with fixed orthodontic appliances only [17]. While assessing the influence of metal and aesthetic brackets on root resorption, it was diagnosed more often in patients treated with aesthetic brackets. This is because treatment with aesthetic brackets lasts longer [6]. Application of an additional upper utility arch for intrusion of maxillary incisors induces root resorption of maxillary central incisors more often than by treating with straight arch [21]. Intermaxillary elastics: greater root resorption is found on the side of tooth arch where elastics were used. Use of Class III elastics increases root resorption of first mandibular molars distal root [7]. Some researches have established that use of intermaxillary Class II elastics and type of orthodontic arch does not have any influence on occurrence of root resorption [22].

Influence of tooth extraction on root resorption is valued controversially. McFadden and VonderAhe failed to find any differences between root resorption in patients treated with or without extraction [7]. Higher root resorption rates (0,43 mm) were established in patients with several extracted teeth than in those, who haven't undergone tooth extraction (0,31 mm) [4]. Root resorption develops more often after extraction of four first premolars if compared to the patients with non-extracted teeth or with extracted of just maxillary first premolars [7].

Type of orthodontic tooth movement. Any orthodontic tooth movement may induce root resorption. Most often root resorption was established after orthodontic intrusion (anchoring of a tooth into an alveolar bone). According to Reitan, the force that distributes along the root during bodily movement is less than the one, which concentrates at the root apex resulting from tipping. Bodily movement induces less risk for root resorption than tooth tipping [7]. Other researchers state that tooth tipping induces less root resorption than bodily movement. Root resorption occurs in cervical and apical part of the root during tipping movement. Middle part of the root is resorbing during bodily tooth movement; this happens because of the shape of periodontal space, which is the thinnest in the middle part of the root [23]. Comparing root resorption after application of the same magnitude continuous intrusion and extrusion forces it was established that teeth intrusion causes four times more root resorption than extrusion. Deep and extensive resorption areas, situated near the root apex foramen can be observed in the apical part of the intruded tooth root. Superficial and limited resorption cavities

around the root apex foramen is characteristic for extruded teeth [24].

Teeth rotation causes only minor injuries of periodontal tissues especially in single-root teeth. Resorption areas during the tooth rotation appear in the medial root third. Horizontal section of the root shows how prominent root zones might generate pressure areas when single-root tooth rotation is performing. The resorbed areas are consistently located at the boundaries between the buccal and distal surfaces as well as lingual and mesial root surfaces [25].

Orthodontic force leads to micro trauma of periodontal ligaments and activation of inflammation related cells [3]. According to some researches there was no root resorption difference detected while using low and high forces (50 g and 200 g) [1]. However Harry and Sims have established that distribution of resorbed lacunae is directly related to the force magnitude, resorbed lacunae develops more quickly in case of higher forces [7]. According to Schwartz, forces increasing 20-26 g/cm², cause periodontal ischemia, which may lead to root resorption [7]. When orthodontic force decreases to less than 20-26 g/cm², tooth root resorption stops [23]. Optimal force for orthodontic tooth movement but not causing root resorption should be 7-26 g/cm² on root surface area [26]. It was established that intermittent force causes root resorption more rarely than the continuous force because the intermittent force protects from formation of hyalinized areas or it allows reorganization of hyalinized periodontal ligaments and restoration of blood circulation at the time, when forces are not active. Continuous force leaves no time to repair of damaged blood vessels and other periodontal tissues and this may lead to higher level of root resorption [23].

III. Combined biological and mechanical factors

Duration of orthodontic treatment is considered an important factor that may cause root resorption [26]. Many studies show that severity of root resorption is related to duration of orthodontic treatment. Levander and Malmgren have investigated that root resorption after 6 to 9 months of orthodontic treatment was detected in 34% of teeth, meanwhile in the end of orthodontic treatment that lasted 19 months, root resorption increased up to 56% [7, 27]. Goldin has stated that the amount of root resorption during orthodontic treatment is 0,9 mm per year [7]. Results of other studies have shown that root resorption may begin in the early stage of orthodontic treatment; it is especially characteristic to teeth with long, narrow and deviated roots [15].

It was established that duration of treatment with fixed orthodontic appliances was found to contribute to the degree of root resorption. Patients whose orthodontic treatment with fixed appliances lasts longer, experience significantly more grade 2 root resorption. Average treatment length for patients without root resorption is 1.5 years and for the patients with severe root resorption – 2.3 years [20]. Several contemporary studies have found no relation between the length of orthodontic treatment and root resorption [28].

Root resorption detected radiologically during orthodontic treatment. Minor root resorption or an irregular root contour detected 6-9 months from the beginning of orthodontic treatment show that there is a high risk to further root resorption. If root resorption fails to occur after 6-9 months of orthodontic treatment then no severe root resorption will be in the end of the treatment [7].

Root resorption after removal of appliances. Root resorption associated with orthodontic treatment will stop after completion of active orthodontic treatment. Active root resorption lasts approximately about a week after removal of orthodontic appliance afterwards cementum repair lasts 5-6 weeks after removal of orthodontic appliance. Root resorption after removal of orthodontic appliances is mostly related to such causes as occlusal trauma, active retainers or others [7].

IV Other circumstances

Tooth vitality. Tooth vitality and colour doesn't change even at extensive root resorption. Orthodontic movement may cause pulp blood flow disturbances,

vacuolization and, in rare cases, pulp necrosis, however it doesn't relate to root resorption [7].

Alveolar bone loss and tooth stability. Marginal bone loss is more harmful than the equivalent amount of root length loss because of root resorption. Results indicate that 4 mm of root resorption translate into 20% total attachment loss and 3 mm apical root loss equals only 1 mm crestal bone loss [29]. Bone loss leads to decreased stability of a tooth because major part of periodontal fibres is the crestal area if compared to the surface of root apex. About 0,2-0,5 mm of alveolar bone height is lost during orthodontic treatment [7].

CONCLUSIONS

1. Microscopic root resorption is characteristic to all permanent teeth during orthodontic treatment. It is clinically insignificant and radiologically invisible, orthodontic teeth movement couldn't occur without this resorption.

2. Individual susceptibility is the main risk factor for root resorption in orthodontic patients during orthodontic treatment; in case of such susceptibility root resorption can start already in the early stage of orthodontic treatment.

3. It is possible to avoid severe root resorption by doing control x-ray images to all orthodontic patients after 6-9 months of orthodontic treatment. Minor root resorption or an irregular tooth root contour detected during this period show that there is a high risk for further root resorption.

4. Optimal force for orthodontic tooth movement but not causing root resorption should be 7-26 g/cm² on root surface area.

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