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Orthodontically induced root resorption – a literature review

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Keywords

external resorption, cervical resorption, OIIRR, CBCT

Summary

Root resorption in moved teeth is a common undesirable side effect of orthodontic treatment.
This pathology usually affects permanent teeth. Although any part of the root may be involved, the apical or cervical area is usually affected. The formation and development of these changes are a long-term process and depend on various factors. The etiology of resorptive changes associated with orthodontic treatment has been widely discussed by many authors, who proposed numerous classifications. Particularly noteworthy are the works on techniques for the treatment of malocclusion and their potential adverse effects. Modern diagnostic methods allow for an early detection of this pathology and the implementation of appropriate therapeutic measures. These techniques include periapical radiography (paralleling technique) combined with cone-beam computed tomography. Dentists not only notice the need to achieve a beautiful smile, but they also take into account possible root shortening. This process is not fully understood, but realizing its existence is important for planning and implementing both orthodontic and general dental treatment.

Introduction

Orthodontic treatment is often associated with root resorption of the teeth being moved, leading to the loss of hard tissue (dentin, cement and/or alveolar bone). It is a long-term, painless process, which is usually revealed accidentally during a routine X-ray (1-3). The process may be either physiological or pathological. Physiological root resorption occurs in primary dentition as a result of biochemical reaction between permanent tooth follicle and the periodontium of the root of the primary tooth (4). This process begins at the age of about 4-5 years, i.e. 2-4 years before physiological tooth replacement (5).

Pathological resorption usually effects permanent dentition. Several classification systems for tooth resorption, depending on its location, causative factors and stage, may be found in literature. The simplest and the most common classification system used in clinical practice distinguishes external, internal and external-internal tooth resorption (5-7). External resorption may affect the cervical region, the mid or the apical portion of the root, beginning superficially and spreading towards the dentin and dental cavity. The most common factors responsible for external resorption include periapical tissue inflammation, trauma (8), ectopically erupting adjacent tooth (9), tumour invasion, a dentigerous cyst, chronic occlusal trauma and orthodontic treatment (10, 11). Internal root resorption is less common (12). It begins in the dentin and spreads towards the cement (5). The most common causative factors include chronic bacterial pulpitis and local circulatory impairment, which may be caused by an injury (6, 10). A simultaneous occurrence of these two processes is referred to as external-internal or perforating resorption (10).

The relationship between orthodontic treatment and root resorption was first described by Ottolengui in 1914 (13), and radiologically evaluated by Ketcham, who already in the 1920s noticed apical root reduction after orthodontic treatment (14). This way, the author drew the attention of future generations of orthodontists to root resorption, which is a complication of orthodontic treatment, as well as to factors promoting this process. The study presented by Ketcham also aimed to raise doctors' awareness on the need for radiological evaluation both before and after orthodontic treatment (14, 15). The term "orthodontically induced inflammatory root

resorption" (OIIRR) was introduced in terminology and literature by Brezniak and Wasserstein in 2002 (11).

The aim of this paper was to present aetiology, distinctive features and types of orthodontically induced root resorption and the proposed based on the available literature.

A systematic review of literature on orthodontically induced root resorption was performed using the following databases: PubMed/MEDLINE, Polish Medical Bibliography and widely available dental literature. The following keywords were used for creating literature database: external resorption, cervical resorption, root resorption. Both, English- and Polish-language literature was included. Papers published until December 31, 2017 were included in the study. Papers whose authors performed radiological assessment of root resorption during or after orthodontic treatment were included. Articles whose authors focused on other aspects of root resorption were excluded.

Aetiology

Brezniak and Wasserstein drew attention to important radiographic elements that should be analysed by an orthodontist before treatment initiation, such as the shape of roots, the presence of endodontically treated teeth, agenesis, aplasia, ectopy, replanted teeth, bone structure and malocclusions (11, 16). Many authors, e.g. Vlaskalic et al. (17) and Topkara et al. (18), classified aetiological factors into two groups: individual (patient-related) factors, and factors directly associated with orthodontic treatment (tab. 1).

Individual factors include genetic factors (17-20), race (20), the group of teeth affected by resorption, root shape (2), type of malocclusion (18, 20), general diseases such as asthma and allergies (2), as well as previous damage of dental structure, e.g. cervical resorption induced by general factors: Paget's disease (osteitis deformans), tuberous sclerosis complex, ectodermal dysplasia (21-23) and dental trauma (24).

The following orthodontic factors have been distinguished by authors: age (25, 26), type of appliance (removable or fixed), treatment duration, forces used, elastics and treatment mechanics (2, 25, 27) (tab. 1). OIIRR is less common in patents aged about 11 years (± 1), which is due to higher biological tolerance – undeveloped roots are protected by predentin and a wider layer of cementoid (25, 28, 29). Maxillary resorption usually affects lateral and central incisors, as well as canines, while the highest risk of mandibular resorption is reported for canines, central and lateral incisors, respectively (24, 30-33). The shape of the root is also important: roots with features of dilacerations, bottle-shaped or pointed roots are resorbed more often compared to normal-shaped roots, while short and wide roots are less likely to be resorbed compared to long and narrow ones (25, 29, 34). The duration of orthodontic treatment is another predisposing factor. Root resorption is very rarely detected in patients treated for 1.5 years. The risk of advanced root resorption is increased in patients treated for more than 2-3 years. The risk is reduced in patients with a 2-3-month interval after a 6-month therapy, followed by continued active treatment (18, 29). The risk of root resorption is also associated with malocclusions, with the highest prevalence seen in patients with an open bite (30). Various forces are applied during orthodontic treatment, depending on the chosen treatment approach. The use of large alternating forces and significant tooth shifting predispose to resorption (30, 32). Long-term use of class 2 elastics also increases the risk of resorption. The mechanics used during treatment is another aspect of orthodontic therapy. Intrusive mechanics combined with anterior retraction is associated with higher resorption compared to retraction alone (27, 32, 33). Intrusive mechanics causes more resorption than non-intrusive treatment (35). Another factor predisposing to OIIRR is the type of appliance used during treatment – fixed appliances increase the risk of resorption compared to removable appliances due to the continuity of forces applied (20, 34). The type of dentition is the last analysed aspect; Fiore et al. found that root resorption also affects primary teeth included in fixed appliance, but at sites untypical for physiological resorption (36). Furthermore, genes (TNFRSF11A, IL-1beta gene) and salivary biomarkers which may be assayed in orthodontically treated patients diagnosed with apical root resorption have been identified (tab. 2).

Tab. 1. Aetiological factors in OIIRR

Individual factors	Orthodontic factors
– Genetic factors	– Age at treatment onset
– Race	– Type of appliance
– Group of teeth	– Treatment duration
– Root shape	– Forces used
– Malocclusion	– Elastics
– Systemic diseases	– Treatment mechanics
– Dental trauma	

Pathomechanism

Damage to the cementoblast layer and cementoid, which is susceptible to the destroying effects of osteoclasts, is the main cause of root resorption. An imbalance occurs between the apositioning effects of cementoblasts and the repositioning effects of osteoclasts. The surrounding alveolar bone is also involved. Pathological resorption occurs only in the presence of a stimulating factor, such as an orthodontic force. Absence of stimulation factor inhibits the process and enables osteoblasts to restore the lost tissue (37, 38).

Tab. 2. Individual and orthodontic aetiological factors in OIIRR

Feature	Predisposing factors
Age	over 11 years of age
Group of teeth (consecutively from the most vulnerable to OIRR)	maxillary: lateral and central incisors, canines mandibular: canines, central and lateral incisors
Root shape	root deceleration, bottle-shaped root or pointed root
Treatment duration	more than 2-3 years
Type of malocclusion	an open bite
Forces	high alternating forces, large tooth shifts, class 2 elastics
Treatment mechanics	intrusive mechanics combined with anterior retraction
Type of appliance	fixed

Classifications

Orthodontically induced resorptive processes are classified based on histological (pathomorphological) stage, location, the extent of hard apical tissue loss or the depth of the defect. OIIRR usually affects the apical or the paracervical portion of the root. Histologically, three stages of OIIRR have been proposed (11, 39): superficial cemental resorption with remodelling. External cemental layers are resorbed and then regenerated. The process resembles trabecular bone remodelling, deep cemental and dentinal resorption with tissue repair. Root cement and external dentin layers are involved. The tissue is usually repaired with cementum material. This process may alter the shape of the root from its original form or restore the original shape, circumferential apical root resorption. All hard tissues of the root apex are involved, leading to root shortening.

Apical root resorption is a process that develops during the active phase of orthodontic treatment and leads to root shortening. Lavender and Malmgren (40) proposed a classification based on the amount of root loss (fig. 1). Cervical resorption is a late complication of orthodontic treatment (41). Heithersay (38) proposed the following classification system distinguishing 4 classes of cervical resorption (fig. 2). The detectability of this process is reduced due to the lack of systematic radiological check-ups for patients at the stage of retention after active orthodontic treatment. Pink colour of the tooth crown is a clinical symptom (38, 41).

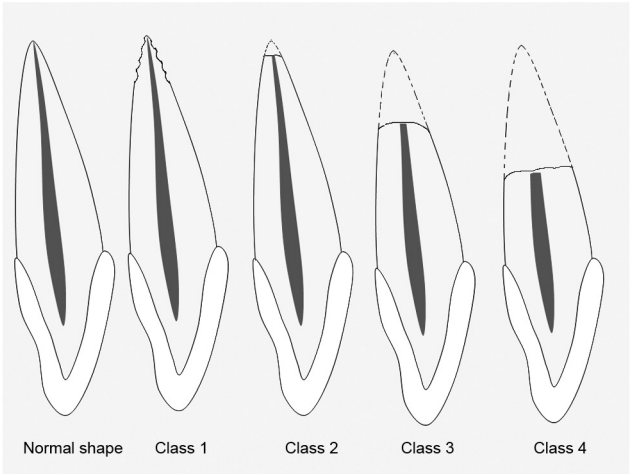

Fig. 1. Classification of external root resorption according to Lavender and Malmgren

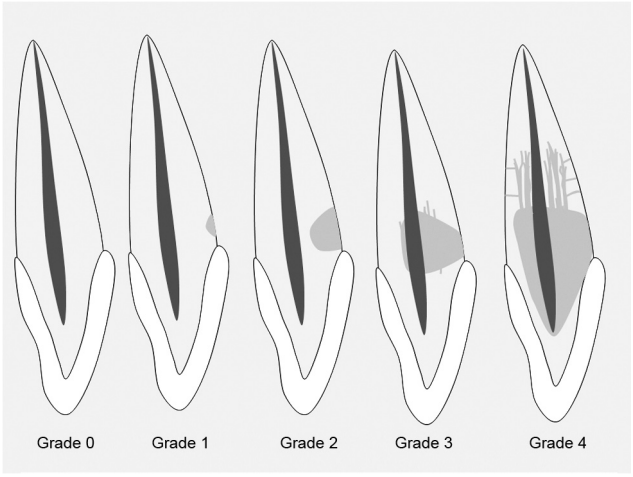

Fig. 2. Cervical resorption classification by Heithersay

Diagnostic methods

Radiological diagnosis is an important component of orthodontic treatment as early detection of root resorption is crucial for further treatment. The highest

diagnostic importance is attributed to cone beam computed tomography (CBCT) (41). A large body of scientific research confirms the efficacy and superiority of CBCT over dental radiographs and panoramic radiographs (3, 34, 42, 43).

The diagnosis of root resorption may be difficult and pose challenge for both the dentist and the orthodontist. Orthodontically induced resorption may affect any part of apical root surface. The commonly used dental radiographs and panoramic radiographs (18) do not allow for a precise assessment as the process may involve both buccal and palatal root surfaces, both of which are difficult or impossible to evaluate in a two-dimensional view. Calculations involving subtraction of the length of the root or the entire tooth before and after treatment are imprecise and may indicate changes (shortening or lengthening), depending on the angle of the X-ray tube or the patient's head (44). Patient's anatomy, operator's skills and the parameters of the apparatus used also affect the accuracy of measurements. Attempts were made by researchers to visualise all root surfaces on radiographs by using projections at different angles (16, 28). Unfortunately, this technique is not reproducible, even for radiographs taken by the right-angle technique, which makes it impossible to perform reliable measurements or precise assessment of resorbed root surface (2, 37). Two-dimensional images enable the detection of only moderate-to-severe resorption. Panoramic radiographs, on the other hand, make it very difficult to precisely assess the stage of resorption due to distortions, which are an inherent element of this technique (44).

Cone beam computed tomography is an increasingly used diagnostic method in dentistry. It detects

Tab. 3. Differences between radiological techniques

Dental radiograph	Panoramic radiograph	CBCT
– two-dimensional – an image of a selected area – right-angle-image may be reproducible – imprecise measurement – overlapping structures	– two-dimensional – plain image – overlapping structures – non-reproducible – incorrect measurements due to orthodontic tilting – the image may show elongated or shortened roots	– multidimensional – it is possible to evaluate each surface – reproducible – high image resolution – precise measurements – all root surfaces along with the adjacent tissues are visible – high radiation doses

Fig. 3. Patient after open bite treatment. Short irregularly shaped apices of the roots of the upper incisors are visible

Fig. 4. Patient after intrusive treatment with anterior segment retraction. Irregular root apex of the tooth 12

resorption on all root surfaces owing to the three-dimensional imaging, eliminating structural overlap typical of two-dimensional methods (42). Yi et al. performed a systematic review of available *in vitro* studies, comparing the diagnostic accuracy of CBCT and dental radiographs for detecting resorption, and confirmed significant superiority of CBCT (3) (tab. 3). Clinical cases are shown in figures 3-10.

Conclusions

Orthodontically induced root resorption is a complication that is difficult to avoid. Severe apical resorption affects 1-10% of patients (18, 25), while mild resorption is observed in 48-66% (2). Two-dimensional radiology is prone to significant measurement errors, but radiation doses are lower compared to CBCT. Although CBCT is not a gold standard in the diagnostic

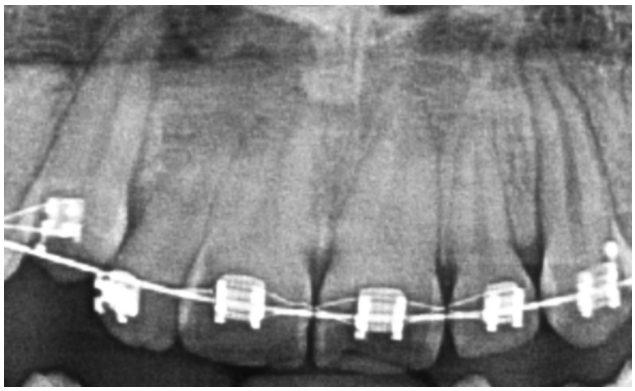

Fig. 5. Patient treated orthodontically for 3 years with anterior segment retraction due to heavy crowding in both arches.

Fig. 6. A fragment of a panoramic radiograph 1.5 years after application of a fixed appliance. The image of the root apex of tooth 12 is ambiguous

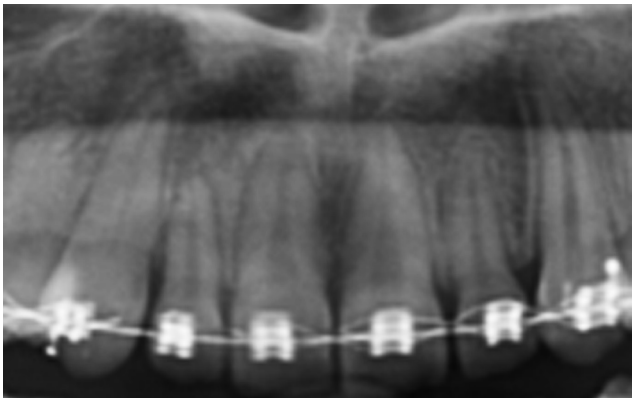

Fig. 7. Normal roots of teeth 12-22

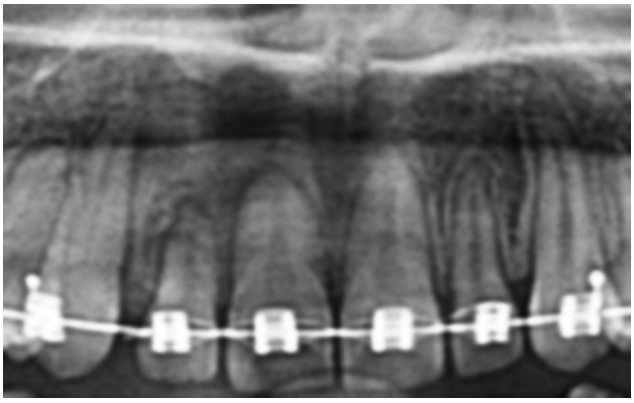

Fig. 8. Diagnostic image obtained 2.5 years after the onset of treatment. Visible, significant changes in the shape and length of roots 12-22

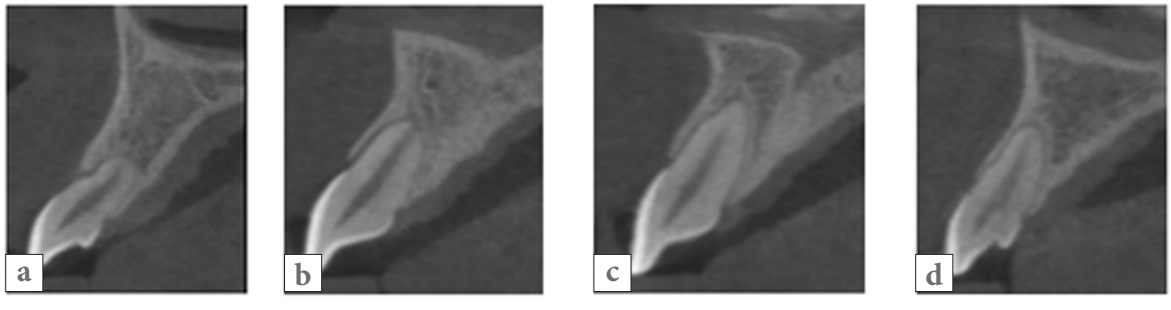

Fig. 9a-d. Diagnostic image obtained 2.5 years after the onset of treatment. Visible, significant changes in the shape and length of roots 12-22

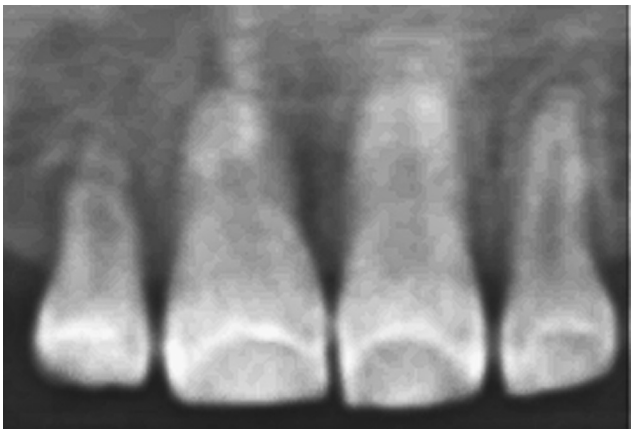

Fig. 10. A section of a pseudo-panoramic radiograph. In comparison with fig. 5, a significant change in the length and the shape of roots 12-22 can be seen

imaging performed before orthodontic treatment, it is the only technique that provides a picture of the entire investigated area. It detects abnormalities and pathologies otherwise undetectable in conventional radiogrammes. Furthermore, it allows assessing the risk during treatment and choosing the best orthodontic treatment plan.

Detection of root resorption is also important before initiating orthodontic or prosthetic treatment in patients with a history of orthodontic treatment as damaged root surface may be important for tooth prognosis. Therefore, full diagnosis including CBCT is of key clinical importance. Many authors emphasise that patients should be informed about potential adverse effects in the form of root resorption before and during orthodontic treatment (2, 39, 41).

Conflict of interest

None

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