EDITORIAL

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Orthodontic Implants and the Risk of Root Injury – a Literature Review

Implanty ortodontyczne a ryzyko uszkodzenia korzenia – przegląd piśmiennictwa

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Abstract

Currently, orthodontic implants are more and more popular among orthodontists, since they provide maximum extradental anchorage. Interradicular spaces are often the optimal site for orthodontic screw implantation due to favorable direction of the force vectors and easy insertion through attached gingiva. However, interradicular placement of orthodontic implants affords injury risk of either periodontal ligaments or the dental root. Proximity of the orthodontic implant and the root or direct root contact may induce external root resorption. Necrosis, ankylosis or root fracture are serious possible complications following root injury. Moreover, proximity of the orthodontic implant and the root is a risk factor of failure of the screw. Thorough radiological evaluation, application of decreased dose of local anesthesia, manual implant insertion as well as proper implant angulation to the dental axes in maxilla (30°–40°) and in mandible (10°–20°) all evidently decrease the risk of root injury during insertion (**Dent. Med. Probl. 2010, 47, 4, 395–400**).

Key words: ankylosis, orthodontic implants, resorption, anchorage.

Streszczenie

Implanty ortodontyczne cieszą się coraz większym zainteresowaniem lekarzy ortodontów, gdyż zapewniają maksymalne pozazębowe zakotwienie. Ze względu na korzystny przebieg wektorów sił oraz łatwość wprowadzania implantów przez dziąsło właściwe, przestrzenie międzykorzeniowe stają się często miejscami z wyboru do implantacji śrub ortodontycznych. Jednak podczas wprowadzania implantów w przestrzenie międzykorzeniowe istnieje ryzyko uszkodzenia korzeni zębów. Bliska odległość implantu i korzenia lub jego kontakt z korzeniem może doprowadzić do rozwoju zewnętrznej resorpcji korzenia. Poważnym potencjalnym powikłaniem uszkodzenia korzenia może być utrata żywotności zęba, ankyloza lub złamanie korzenia. Ponadto bliska odległość między wszczepem a korzeniem zęba jest czynnikiem ryzyka utraty stabilności śruby. Dokładna ocena radiologiczna, stosowanie zmniejszonej dawki znieczulenia powierzchniowego, manualne wprowadzanie śrub oraz zmiana kąta wprowadzenia implantów z prostopadłego w stosunku do długiej osi zębów na 30°–40° w szczęce, 10°–20° w żuchwie, wyraźnie zmniejszają ryzyko uszkodzenia korzeni podczas implantacji (**Dent. Med. Probl. 2010, 47, 4, 395–400**).

Słowa kluczowe: ankyloza, implanty ortodontyczne, resorpcja, zakotwienie.

Supporting maximum anchorage is often crucial in orthodontic treatment. Numerous methods used to improve anchorage not only do not provide maximum anchorage, resulting in unfavorable teeth movement, but moreover: require patient's compliance exceeding oral hygiene rules. Various skeletally-anchored mechanisms have been developed in order to eliminate necessity of patient's active cooperation. Melsen et al. used 0.012 inch stainless steel surgical ligature wire fixed in a canal drilled in the superior portion of the infrazygomatic crest. Roberts et al. (acc. 1) used dental implants placed in the retromolar region to help reinforce anchorage in the premolar area to close first molar extraction site in the mandible by mesializing second and third molar. They proved that there was no loss of osseointegration, despite the applied force [1]. Sugawara and Umemori used surgical osteosynthesis plates. Single osteosynthesis screws were also used, however – due to large size – only in limited cases (acc. 2). Eventually, miniimplants introduced by Kanomi [3] and Costa et al. [4] designed especially for orthodontic treatment, due to their diameter (1.2 mm) and design (bracket-like head of implant) popularized use of skeletal anchorage in orthodontic treatment. The diameters and lengths of nowadays used orthodontic implants vary: from 1.2 to 2 mm and from 6 to 10 mm respectively.

Currently, orthodontic implants are more and more popular among orthodontists, since they provide maximum extradental anchorage. By virtue of their relatively small size, in comparison with dental implants, rather low price, easy implantation and removal, possibility of immediate loading and technically unlimited number of intraoral locations, orthodontic implants are more frequently used not only in complex orthodontic treatment, but also in minor tooth-movement in pre- prosthetic treatment [5, 6].

The implantation site depends on the orthodontic treatment plan and specified desired tooth-movement which cannot arrest. Quantity and quality of available bone, sinus morphology, anatomy of soft tissues and the nerve and vessels topography are among the other factors to be considered prior to choosing implantation sites [7]. They are numerous: eg. alveolar bone, midpalatal suture, area below anterior nasal spine and retromolar region. However, the interradicular space is biomechanically advantageous in terms of mutual relationship of implanted screw and the centre of tooth-resistance. Kanomi and Costa et al. [3, 4] implanted micro- (1.2 mm in diameter) and miniscrews (2.0 mm in diameter) into the basal bone, below the roots apices in order minimize risk of root damage. Since so positioned screws neighbored vestibular vault, vertical vector of the applied force prevailed, subsequently limiting retraction of anterior teeth or protraction of posterior ones. To overcome such drawbacks, Park [8–10] suggested insertion of the microscrews (1.2 mm in diameter) into the alveolar bone between the roots of the posterior teeth to increase the horizontal component of the applied force, that subsequently was used for retraction of anterior teeth. Interradicular spaces are often the optimal site for orthodontic screw implantation due to favorable direction of the force vectors and easy insertion through attached gingiva.

Literature supports no evidence concerning minimal distance between the screws and the dental roots securing either periodontal health as well as the screw stability. Basing on the possible implant displacement, Liou et al. [11] suggest 2 mm distance between the implant and the root as a "safe zone". Insertion of an implant 1.2 mm in diameter would require 5.2 mm interradicular space (2 mm + 1.2 mm + 2 mm), unavailable in majority of locations in alveolar bone, therefore following such guidelines could limit the application of orthodontic implants. Pioggio et al. [12] reported that – considering the width of the periodontal ligament is approximately 0.25 mm – a minimum clearance of 1 mm of alveolar bone around the implant should be sufficient for periodontal health and the stability of implant. These imprecise and contradictory data indicate that although insertion of the screws into interradicular spaces is optimal for the direction of applied force vectors, it involves risk of root damage: one of the main reasons refraining clinicians from use orthodontic screws. Cho et al. [13] who evaluated the influence of the clinician's experience on the possibility of root damage support such concern. They reported statistically significant difference in the incidence of root damage depending on the experience of the clinicians: the root contact was observed in 13.5% of cases in the group of specialists with over two years experience in surgical implantation procedures, and such as 21.3% cases in the inexperienced group.

Changes on the Root Surface After Contact with Orthodontic Implant

Interradicular placement of orthodontic implants thus affords injury risk of either periodontal ligaments or the dental root. The risk of root contact and damage results from narrow interradicular spaces, anatomic variation of interradicular areas and iatrogenic surgical implantation procedure [12, 14]. Bone-stress accompanying screw insertion can initiate inflammatory reaction around implant that can lead to bone damage. The inflammation around the dental root can afterwards induce external root resorption. Necrosis subsequent to the root perforation and screw contact with the root pulp, ankylosis or root fracture are serious possible complications following root injury. Superficial injury of the root, no contact with its pulp, is not likely necrotic for the tooth itself. Kang et al. [5] described consequences of root damage after contact with an implant. They reported that the pattern of the periodontal tissue repair differs depending on either range of the damage or the types of cells recruited for healing. The tooth-supporting tissues can regenerate when the damage is mild and the healing cells originate from the periodontal ligaments. However, root resorption can occur if the damage is severe and cells are recruited from the marrow; then, bone formation and ankylosis may occur. In animal study, Lee et al. [15] analyzed histological reaction of the root surfaces depending on their relation to the implants. They reported that the risk of external root resorption increased when the distance between the root and the implant diminished to less than 0.6 mm; moreover, bone resorption was observed between the implant and the root. In cases of periodontal ligament-invasion, no direct root-contact, external root resorption also occurred in most cases. Resorption lacunae developed on the root surface. The resorbed tissue was replaced with secondary cementum thus suggesting healing process initiation by periodontal cells. Probably, the precursor cells differentiated into cementoblasts. It is in accordance with Asscherickx et al. [16], who also described root repair after injury from an implant, this time due to apposition of the secondary cementum. External root resorption always occurred in cases of direct contact between implant and root surface. The most extensive resorption took place around the implant. The authors also reported bone growth towards resorbed root surface and ankylosis between resorbed root and bone. In cases of root perforation, partial root fracture or localized root cracks were observed. Moreover, ankylosis and root resorption on the side opposite the implant insertion were observed. This indicates that pressure exerted on the root during screw insertion can induce root resorption and ankylosis on the opposite side. Since root resorption occurred almost in 100% of cases if the distance of implant to the root was less than 0.6 mm, the authors thus determined the "safe zone" protecting periodontal structures.

Kadioglu et al. [17] evaluated changes on the surface of the roots of premolars after deliberated contact with orthodontic implants. The premolars were subsequently extracted as a part of the orthodontic treatment. They reported that external root resorption occurred, however only within cementum, without dentin exposure. After 8 weeks of heeling, without contact between the root and the screw, the lesions were completely covered with reorganizing collagen fibers. The results of the cited study suggest that the surface of the root despite the contact with the implant, regenerates promptly and heals almost completely within few weeks.

Andreasen et al. [18] reported that an injured root surface no deeper than 1.0 to 1.5 mm can undergo complete healing. Bae [13] also reported that damaged root surface can experience mild root resorption depending on the size of injury, yet eventually heals to produce healthy periodontal ligaments. Andreasen and Kristerson [19] described healing pattern of the periodontal ligaments. They reported that periodontal ligaments deprivation of 1 to 4 square mm caused temporary ankylosis, which occurred after 2 weeks and disappeared after 8 weeks. Concerning that almost all commercially available orthodontic implants have a diameter of 1 to 2 mm, large root defects are unlikely to occur. Therefore, it is presumed that even if ankylosis arises as the result of root damage, it will only be transient.

Encouraging perspective of healing pattern of the root surface after contact with orthodontic implant raise a question of stability of such controversial implants.

Stability of Implants in Contact with Dental Roots

Proximity of the orthodontic implant and the root is a risk factor of failure of the screw. The literature reports that implants in contact with dental root are more prone to stability loss [5, 20–22]. The force transferred from the tooth can jeopardize the implants' stability, leading to mobility that can eventually cause loss of the implant. Kang et al. [5] studied relationship between implants' stability in cases of root invasion. The premature loss rate of the implants that invaded the roots was 79.2%, on average after 16 days. It is insufficient to provide maximum anchorage in orthodontic treatment. In comparison, the loss rate of screws that did not invade the roots was 8.3%. The reasons for high failure rate of screws in contact with dental roots are unknown, however, it can be assumed that insufficient bone-implant contact does not provide mechanical retention, through which the implants retain their stability. Moreover, during mastication, due to physiologic tooth movement, the implant is repeatedly mobilized, that induces inflammatory reaction in surrounding tissues and can result in loss of implant's stability. According to the presented data, root-invading screws showed high failure rate, but not a rate of 100%. The authors suggest that probably the contact between the implant and the bone surface was sufficient to provide mechanical retention for the stability of implants.

The evidence based instability of implants invading dental roots requires selection of criteria of implantation procedures that minimize the risk of periodontal structures injury.

Safe Implantation in the Interradicular Spaces

Thorough radiological evaluation enables choosing safe implantation sites and is one of the possibilities to decrease the risk of root damage during insertion. Panoramic radiographs and periapical radiographs are used, however in case of atypical shape and deviated form of the dental roots additional radiograms may be required. Park [8] analyzing the CT images, measured interradicular distance in most typical implantation sites. He measured the available interradicular alveolar bone at the level of 5–7 mm apical of the alveolar crest, since the apical portion of the implants is positioned at this level clinically. Moreover, the apical portion of the inserted screw is more prone to contact with roots rather than the coronal portion. In the upper arch, the mean distance between the roots of the second premolar and the first molar was 3.18 mm ± 0.92 mm from the vestibular side, whereas between the roots of the first molar and the second molar was 2.11 mm ± 1.22 mm from the vestibular side, and 4.03 mm ± 0.87 mm from the palatal side. In the lower arch the mean distance between the roots of the canine and first premolar was 2.2 mm ± 0.92 mm, between second premolar and first molar was 3.47 mm ± 1.09 mm, and between first molar and second molar was 4.57 mm ± 1.41 mm, all from the vestibular side. The presented data is in accordance with the results of studies by Poggio et al. [12] and Monnerat et al. [23] who also measured interradicular spaces using CT scans, and enables choice of similar safe insertion sites.

Some authors suggest using individual radiological templates [24, 25], resembling the ones used for dental implant placement. The templates are used to minimize the risk of trauma to the adjacent structures and to determine the exact implantation site.

The other method used to minimize the risk of root trauma is application of decreased dose of local anesthesia in order to anesthetize only the soft tissues. The pain receptors are not therefore blocked, and may react during implant approaching the periodontal ligaments [2].

Manual implant insertion is another method applied to minimize risk of root trauma. The clinician has greater control and precision of implantation when using manual screwdriver. It is possible to sensate changes of resistance during insertion. During penetration of the implant in the spongiosus bone, the resistance remains constant. The sensation of increasing resistance may indicate that the implant invades the dental root. Further implantation is therefore impossible or requires application of greater force [2, 14]. If this occurs, it is recommended to unscrew the implant and change the direction of implantation, after another radiological assessment. Kravitz et al. [14] report that during implantation in the posterior regions in either jaws, there is a tendency to change the angle of implant insertion by inadvertently pulling the screwdriver toward clinicians, increasing the risk of root contact. To avoid it, the clinician may consider using a shorter screwdrivers or slightly push the screwdriver handle away from their bodies after each turn.

To decrease the risk of root invasion by the implant, Park [8] suggests angulated implant placement at 30°–40° in the upper arch and 10°–20° in the lower arch to the long axis of the teeth. It is in accordance with the report of Antoszewska et el. [26] and presented Wroclaw method of implantation. The risk of root invasion decreases due to angular implant placement to the bone surface, instead of perpendicular insertion. In maxilla, due to angular placement of implant 8 mm long, the virtual length of the implant penetration in the horizontal plane is no more than 4 mm (Fig. 1). This allows implantation of longer implants that – in terms of thin cortical bone in the upper arch, providing improper stability – may influence the increased mechanical retention due to contact between longer screw and spongiosus bone [8]. In the lower arch due to angular implantation of

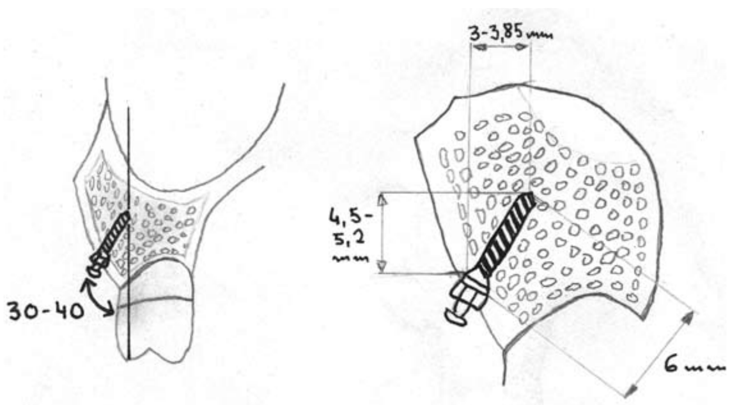

Fig. 1. Angulation of orthodontic implant in maxilla

Ryc. 1. Nachylenie implantu ortodontycznego w szczęce

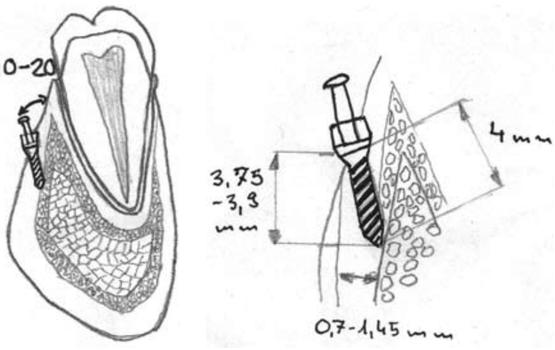

Fig. 2. Angulation of orthodontic implant in mandible

Ryc. 2. Nachylenie implantu ortodontycznego w żuchwie

screw 6 mm long, the penetration of the screw in the bone is no more than 1.5 mm (Fig. 2). Similarly to maxilla, the possibility of root invasion by the implant is evidently reduced. Moreover, the thickness of the cortical bone in the lower arch is greater than in the upper arch, that promotes the stability of the implants. Park reports that mean thickness of the cortical bone in the lower arch in the posterior regions ranges from 2.48 mm to 3.17 mm. Minimal thickness of the cortical bone ranges between 0.71 mm do 0.93 mm. With angular placement and thick cortical bone it is possible to achieve the retention exclusively within the cortical bone that fundamentally decreases the risk of root damage by the implants.

Conclusions

The following conclusions can be drawn when analyzing the risk of the root injury during implantation.

1. Minor root damage induce external root resorption, that may be ceased and the lesions are covered with secondary cementum.

2. Extensive root damage may result in ankylosis, inhibiting orthodontic tooth movement.

3. Manual implant insertion providing control of resistance changes suggesting contact between the implant and the root, as well as proper implant angulation to the dental axes in maxilla (30°–40°) and in mandible (10°–20°) are the non-invasive clinical factors evidently minimizing risk of complication – dental root injury.

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