Surface deterioration and elemental composition of retrieved orthodontic miniscrews

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Introduction: This study provides insight into surface and elemental analyses of orthodontic retrieved miniscrew implants (MSIs). The sole purpose was to investigate the behavior of MSIs while they are in contact with bone and soft tissues, fluids, and food in the oral cavity. The information thus gathered may help to understand the underlying process of success or failure of MSIs and can be helpful in improving their material composition and design. **Methods:** The study was carried out on 28 titanium-alloy MSIs (all from the same manufacturer) split into 3 groups: 18 MSIs were retrieved after successful orthodontic treatment, 5 were failed MSIs, and 5 were as-received MSIs serving as the controls. All MSIs were subjected to energy dispersive x-ray microanalysis to investigate the changes in surface elemental composition and to scanning electron microscopy to analyze their surface topography. Data thus obtained were subjected to suitable statistical analyses. **Results:** Scanning electron microscope analysis showed surface manufacturing imperfections of the as-received MSIs in the form of stripes. Their elemental composition was confirmed to the specifications of the American Society for Testing of Materials for surgical implants. Retrieved MSIs exhibited generalized surface dullness; variable corrosion; craters in the head, neck, body, and tip regions; and blunting on tips and threads. Energy dispersive x-ray analyses showed deposition of additional elements: calcium had greater significance in its proportion in the body region by 0.056 weight percent; iron was seen in greater proportion in the failed retrieved MSIs compared with the successful miniscrews; cerium was seen in greater proportions in the head region by 0.128 weight percent and in the neck region by 0.147 weight percent than in the body and tip regions of retrieved MSIs. **Conclusions:** Retrieved MSIs showed considerable surface and structural alterations such as dullness, corrosion, and blunting of threads and tips. Their surfaces showed interactions and adsorption of several elements, such as calcium, at the body region. A high content of iron was found on the failed MSIs, and cerium was seen in the head and neck regions of retrieved MSIs. (Am J Orthod Dentofacial Orthop 2015;147:S88-100)

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The orthodontic miniscrew, a temporary anchorage device, was introduced by Gainsforth and Higley[1] in an animal study. In each of 5 dogs, a Vitallium screw was placed in the anterior border of the ramus of the mandible to apply traction by means of an orthodontic elastic connected to a maxillary appliance for skeletal anchorage. However, Kanomi[2] in 1997 first described the "mini-implant" specifically designed for orthodontic applications. Over the last 2 decades, titanium miniscrews have gained enormous popularity in orthodontics and are often regarded as the source of absolute intraoral anchorage for clinical purposes.[3] The popularity of these devices is due to their low cost, small dimensions, ease of insertion and removal, and the possibility of applying immediate loading, thereby reducing the total orthodontic treatment duration.[4,5] The introduction of miniscrew implants (MSIs) in the orthodontic armamentarium has widened the scope and envelope of orthodontic treatment to some extent. It is possible

to treat patients with moderate to severe skeletal discrepancies and obtain complex tooth movements that were not possible previously. Compared with other forms of compliance-dependent anchorage, MSI-supported anchorage offers a more predictable outcome.

MSIs are manufactured from commercially pure titanium and grade V titanium alloy. Titanium alloy is favored because of its higher strength relative to commercially pure titanium. Contemporary MSIs are designed for ease of insertion and are generally safe to use. However, they have been reported to cause gingival injuries and have occasionally been found to undergo fracture because of mechanical failure in the oral environment. Failed MSIs necessitate their removal or replacement.[6] Several factors influence the success of orthodontic MSIs, including careful patient selection, the characteristics of the implantation site, and the macrostructure and microstructure properties of the implants.[7-9] Even though titanium alloys are known to be exceptionally corrosion resistant because of the stability of the passive titanium oxide layer on the surface, MSIs have been reported to undergo corrosion after clinical applications.[10] Generally, corrosion is observed when the titanium oxide film breaks down locally, and rapid dissolution of the underlying metal occurs in the form of pits.[11] Crevice corrosion occurs between 2 close surfaces or in constricted places where oxygen exchange is not available.[11] When an implant is milled and placed in bone, the stress on the MSI might lead to stress corrosion or cracking of the alloy. This cracking may propagate in the physiologic or the corrosive environment.

Once the required orthodontic objectives have been achieved, the MSIs are removed from patient's bone. After removal, the retrieved devices are usually discarded. However, economic factors or environmental conservation might influence clinicians to consider reusing MSIs. Not all temporary implant devices can be reused, but metal implants, such as those made from titanium alloy, may be more amenable to reuse because they can be mechanically and chemically cleaned and resterilized with potentially little or no loss of form or function.[12]

Several studies related to mechanical, chemical, and surface characteristics of prosthetic dental implants are available in the literature.[13-15] On the other hand, we located 4 studies describing the surface and mechanical natures of retrieved orthodontic MSIs.[8,16-18] Eliades et al[8] characterized the morphologic, structural, and compositional alterations, and assessed the changes in the hardness of orthodontic MSIs retrieved after successful service. They reported that used titanium-alloy MSIs have morphologic and surface structural alterations. Their Vickers microhardness testing showed no change in surface hardness of the retrieved specimens compared with the controls. Mattos et al[16] compared the surface morphology and fracture torque resistance of as-received, sterilized, and retrieved mini-implants to evaluate the fracture risks of reusing orthodontic mini-implants after sterilization. They reported that no defects or corrosion could be identified in autoclaved and retrieved mini-implants, but worn surfaces and scratch marks were observed. A statistically significant difference in the fracture torque was observed between the as-received and retrieved groups. Sebbar et al[17,18] assessed the surface changes in MSIs retrieved after usage and compared them with as-received MSIs under an optical microscope. Used MSIs showed signs of corrosion mainly at the sites of manufacturing defects.

The literature lacks comprehensive information on used miniscrews regarding their surface and elemental composition. Therefore, a study aimed at surface and elemental analyses of successful miniscrews after retrieval compared with failed and as-received miniscrews was undertaken. Our sole purpose was to investigate the behavior of MSIs while in contact with bone and soft tissues, oral fluids, and food. The information thus gathered may help orthodontists to understand the intricacies of success or failure of MSIs related to their design and material composition.

MATERIAL AND METHODS

This study was conducted with 28 MSIs, 8 mm long, 1.5 mm in diameter, bracket head type, self-drilling, made from grade V titanium alloy. All MSIs were procured from same manufacturer (Absoanchor; Dentos, Daegu, Korea) to prevent any bias in design and material properties. Of the 28 MSIs, 18 were retrieved from patients after successful service of 12.89 $\pm$ 5.33 months. Five MSIs, which had to be retrieved because of loosening failure during treatment (duration, 6.8 $\pm$ 2.86 months), constituted the failed retrieved group. All MSIs were retrieved from buccal interradicular bone between the second premolar and the permanent first molar. These retrieved MSIs were used in 8 patients (4 male, 4 female; mean age, 17.75 $\pm$ 6.08 years) with Class I bimaxillary protrusion malocclusions. These MSIs were used for en-masse retraction of anterior teeth (11 in the maxillary arch, 12 in the mandibular arch). An orthodontic force of 200 g was applied on each MSI. We used Nitinol closed-coil springs of 9 mm length (GAC International Inc, Central Islip, NY), which applied a consistent retraction force. These retrieved miniscrews were part of the ongoing research in which a standard protocol of insertion and force application was used.