Review Article

Risks and complications of miniscrew anchorage in clinical orthodontics

Shingo Kuroda DDS, PhD*, Eiji Tanaka DDS, PhD

Department of Orthodontics and Dentofacial Orthopedics, Institute of Health Biosciences, The University of Tokushima Graduate School, Tokushima, Japan

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Summary Miniscrew anchorage has greatly expanded the limit of clinical orthodontics. Even without patient compliance, miniscrews can provide stationary anchorages for various tooth movements and even make it possible to move the tooth in directions which have been impossible with traditional orthodontic mechanics. On the other hand, the clinical use of miniscrew anchorage includes some risks. Screw fracture might be one of the most undesirable side effects in clinical use of miniscrew anchorage, which occurs in not only the placement but also the removal. A lot of factors are suggested to relate with screw failure, but screw-root proximity and the mandible are considered as two common factors. Damages of soft tissues are temporary in most cases, but damages of hard tissues are irreversible and should be avoided. We have to understand these risks and complications of miniscrew anchorage, and pay attention for their safety-conscious use.

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KEYWORDS
Miniscrew; Anchorage; Orthodontic; Screw fracture; Screw failure; Success rate

Contents
1. Introduction ........................................... 80
2. Screw fracture ...................................... 80
3. Screw failure ....................................... 81
4. Damage of hard tissues ............................ 82
5. Damage of soft tissues .............................. 82
6. Tooth movement to the edentulous area ........ 83
7. Pain and discomfort after implantation ......... 83
8. Conclusion .......................................... 83
Conflict of interest .................................... 84
References ............................................ 84

* Corresponding author at: Department of Orthodontics and Dentofacial Orthopedics, Institute of Health Biosciences, The University of Tokushima Graduate School, 3-18-15 Kuramoto-Cho, Tokushima 770-8504, Japan. Tel.: +81 88 6337357; fax: +81 88 6339139.
E-mail address: kuroda@tokushima-u.ac.jp (S. Kuroda).

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1. Introduction

Anchorage control is one of the most important keys for achievement of success in clinical orthodontics. To get the appropriate anchorage, numerous anchorage devices are proposed and used for more than a century. Extraoral anchorages such as headgears or facemasks are the most powerful tools but they have a weak point that their effectiveness depends on the patient compliance. Intermaxillary elastics also have the same disadvantage. Intraoral anchorages, i.e. transpalatal arch, lingual arch, holding arch and so on, do not require patient compliance but it is impossible to provide absolute anchorage.

In 1980s, Creekmore and Eklund [1] threw a concept of skeletal anchorage in orthodontic field. They placed a titanium screw under the nasal spine, which has been used as intermaxillary fixation after orthognathic surgery, and intruded the maxillary incisors. Roberts et al. [2] placed an implant fixture in the retromolar area. A canine was connected to the fixture with a bypass wire and used for mesializing the mandibular molar to the edentulous area. In 1990s, orthodontic anchorage devices, such as miniscrews and mini-plates, were newly developed in eastern Asia and these devices have been well accepted in all over the world [3—7]. Nowadays, they are often called temporary anchorage devices (TADs) [8]. Several kinds of TAD have been marketed, however; miniscrews made from Ti-6V-4Al alloy has gained acceptance among orthodontists and patients because of their biocompatibility, little discomfort, relatively noninvasive, and fewer limitation in placement [9,10]. Despite their small diameter and short length, miniscrews can provide stable anchorage for various types of tooth movements, including intrusion, retraction, and protraction [11—33].

On the contrary, the clinical use of miniscrew anchorage accompanies some risks and complications, which occur during screw insertion, under orthodontic loading, and during removal [34]. Screw fracture might be one of the most undesirable side effects in clinical use of miniscrew anchorage, which occurs in not only the placement but also the removal [35]. A recent systematic review showed that overall success rate of 4987 miniscrews in 2281 patients was 86.5% [36]. A lot of factors are explored and being suspected to associate with the screw failure. Damages of soft tissues are temporary in most cases but damages of hard tissues are irreversible, therefore, we have to take care not to damage the periodontal tissues. Furthermore, pain and discomfort after implantation and root resorption caused by the tooth movement to a bone deficient area are also concerned in implant-anchored orthodontics. In this article, we discuss the risks and complications of miniscrew anchorage in clinical orthodontics.

2. Screw fracture

Screw fracture during placement is closely related with insertion torque. Insertion torque of miniscrews generally ranges from 3 to 10 N cm, which is much smaller than the breaking torque disclosed by the manufacturer's instruction [37,38]. Therefore, majority of miniscrew fracture can be prevented by attending to their insertion torque. Screw fracture frequently occurs in the mandible where cortical bone thickness is significantly thicker than the maxilla [39]. Screw insertion in the mid-palate also has a tendency of high insertion torque, therefore, the place 3 mm apart from the midpalatal suture is suitable for implantation avoiding excessive insertion torque [40]. Moreover, insertion torque might be enlarged when miniscrews are touched to the adjacent root. The miniscrew root proximity should be avoided for preventing screw fracture during screw insertion.

Miniscrews are easily removed with a screwdriver even though they are retained in the bone for more than a year during the active orthodontic treatment. We measured removal torque of orthodontic miniscrews and looked for the related factors affecting the torque. Sixty-eight screws placed with a self-tapping method and retained for more than 3 months were subjected (Absoanchor, Dentos Inc., Daegu, South Korea; diameter, 1.4 or 1.5 mm; length, 6—8 mm). The average removal torque was $-4.56 \pm 1.65$ N cm ($-1.74$ N cm to $-8.95$ N cm). The removal torque showed no statistical significances between gender, screw length, screw diameter, jaw type, placement sites, and retention period. The breaking points of miniscrews used in the study was at least 20 N cm, therefore, the screws could be basically removed without fracture. However, screw fracture happens when osseointegration is completed (Fig. 1). Indeed, some screws showed a partial osseointegration after removal (Fig. 2).

We have removed 191 miniscrews (Absoanchor; Dual-top auto screw, Jeil Co., Seoul, South Korea; Induce MS, Ortholusion Co., Ltd., Seongnam, South Korea) in the latest three years and experienced one screw fracture (0.5%). Suzuki and Suzuki [35] removed 280 miniscrews with a diameter of 1.5 mm and reported four fractures (1.4%). Therefore, orthodontists always have to be aware of the possibility of screw fracture in removing procedure. Most fracture is occurred at the neck through cortical bone because mechanical stress in the miniscrew is concentrated at that point. To prevent the fracture, a screwdriver has to be turned slowly without changing the axis. If screw fracture unfortunately happens, the broken screw is tried to remove surgically. However, it is sometimes retained inside of alveolar bone to avoid excessive surgical invasion because of its biocompatibility.

Figure 1 A screw fractured at the removal. After the fracture, the tip of screw was carefully removed with a flap surgery.
3. Screw failure

Most of screw failure occurs in a week after the implantation (Fig. 3). A lot of factors are proposed for the relation with screw failure. For the host factors, age [41,42], smoking [36], oral hygiene control [43,44], implant site [10,36,41,43,44], keratinized tissue [45], cortical bone thickness [46,47], bone density [46,48] are reported. For the technical factors, screw diameter [43,46,48,49], screw length [43,50], screw taper [51,52], shape of screw thread [48], insertion method (self-drilling vs self-tapping) [53,54], insertion torque [36,37,52,54], insertion angle [55,56], treatment period [50], amount of loading [43], direction of loading [57], microfracture of alveolar bone [58] are suggested (Table 1).

Papageorgiou et al. [36] recently reported a meta-analysis in 82 scientific papers describing success rates of orthodontic miniscrews or risk factors for screw failure. They analyzed a lot of factors and found the two factors closely related with the success rates, which are the screw contact to the adjacent root and screw placement in the mandible. Kuroda et al. [59] initially reported that a screw root proximity was one of the major risk factors for screw failure. They analyzed dental radiographs taken after the screw insertion and each screw was classified according to its proximity to the adjacent root; category I, the screw was absolutely separate from the root; category II, the apex of the screw appeared to touch the lamina dura; and category III, the body of the screw was overlaid on the lamina dura. Category I and II showed high success rates of 92.9% and 87.2%, respectively, but category III showed 62.5%. This tendency was more obviously demonstrated in the mandible. Several reports recently indicated same conclusion by using a three-dimensional computed tomography [60,61].

<table>
<thead>
<tr>
<th>Host factors</th>
<th>Technical factors</th>
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<tr>
<td><strong>Systemic</strong></td>
<td><strong>Screw</strong></td>
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<tr>
<td>Age</td>
<td>Diameter</td>
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<td>Smoking</td>
<td>Length</td>
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<td>Oral hygiene control</td>
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<td>Shape of thread</td>
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<td><strong>Local</strong></td>
<td><strong>Insertion</strong></td>
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<td>Implant site</td>
<td>Method (self-drilling vs self-tapping)</td>
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<td>Keratinized tissue</td>
<td>Torque</td>
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<td>Cortical bone thickness</td>
<td>Angle</td>
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<td>Bone density</td>
<td>Microfracture of bone</td>
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<td>Loading</td>
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Figure 2  A screw after removal. Note bony tissues shown at the tip of screw (arrow).

Figure 3  A screw failed during loading. Slight inflammation was shown around the screw.
To avoid the screw root proximity, screws can be placed out of dentition, i.e. midpalate or retromolar area. However, the screws require some complicated auxiliaries for loading to teeth, which sometimes make the patients discomfort. Therefore, we strongly recommend an oblique angle insertion of interradicular miniscrews (Fig. 4). Roots get thinner when it goes close to the apex, and the interradicular spaces become wider [39]. Hence the position of screw insertion had better be placed high as possible to avoid the root proximity, however; the alveolar bone apart from the clinical crown is normally covered with non-keratinized tissue. Some reports suggested that screw placed through non-keratinized mucosa had higher failure rate [45], and it sometimes become cause of pain and discomfort. Then, screw should be placed through keratinized mucosa (attached gingiva) with an oblique angle insertion. The oblique insertion decreases the possibility of screw root contact not only in insertion but also during active tooth movement, which is quite useful in the cases of molar intrusion or group distalization. Moreover, the oblique inserted miniscrews increase the cortical bone—screw contact and must contribute to enhance the initial stability.

4. Damage of hard tissues

When miniscrews are placed in the alveolar bone, there is a possibility to hurt periodontal tissues. If root damage is included inside of cementum and dentin, a repairing mechanism by periodontal tissues works well, and no serious problem will occur clinically [62]. Ahmed et al. [63] evaluated the reparative potential of cementum histologically after intentional root contact with a miniscrew. The roots of the premolars were intentionally injured with a miniscrew and extracted at 4, 8, or 12 weeks after the injury. Despite varying depths of the injuries, including involvement of dentin, reparative cementum formation was observed in all sections. Healing cementum was almost exclusively of the cellular type; 70% of all the teeth exhibited good repair by the end of week 12. Conclusively, this study established that healing of cementum takes place after an injury with a miniscrew, and it is a time-dependent phenomenon. On the other hand, root damage through the dental pulp is irreversible, and root canal filling after pulpectomy or tooth extraction should be necessary. Few reports describe about root damage by orthodontic miniscrews clinically, however, there are some interesting reports showing root damage by intermaxillary fixation screws placed after orthognathic surgery or replacement of maxillofacial bone fractures. Schulte-Geers et al. [64] analyzed 1663 osteosynthesis screws in panoramic radiographs and categorized them according to the root damage. Screws having tangential contact to the dental root were 10.6%, screws penetrated the root without damage to the dental pulp were 3.6%, and screws having contact to the dental pulp was 3.1%. Alves et al. [65] reviewed root damages by 4452 intermaxillary fixation screws in 6 papers, and concluded that the screws of 1.3% showed some root damage and one third of them required pulpectomy or tooth extraction. These suggest that root damage is frequently occurred during the placement of interradicular screws. However, there are some differences in clinical usage of orthodontic miniscrews and intermaxillary fixation screws. Compared to orthodontic miniscrews; fixation screws are (1) generally placed under the general anesthesia; (2) thicker and longer; and (3) inserted transgingivally (horizontally). Therefore, the possibility of root-contact is significantly higher than orthodontic miniscrews.

According to these findings, the following techniques are considered to be effective for avoiding the root damage in clinical application of interradicular miniscrews: (1) minimum local anesthesia (a patient feels pain when a screw touches the periodontal ligament); (2) placement of a screw into the wider interradicular area; (3) choosing a small and short screw as possible; (4) oblique insertion; (5) placing with a self-tapping method; and (6) using a screwdriver with a torque limiter. These are also effective to reduce the possibility of screw fracture and failure (Table 2).

5. Damage of soft tissues

When a screw is inserted with an oblique angle to the bone surface, a clinician has to take care not to slip the screw. To prevent the soft tissue damage by the slippage, a self-tapping method, pre-drilling with a round bar on the cortical bone, must be effective.

Screws placed through the non-keratinized gingiva or movable gingiva stimulate surrounding soft tissue and sometimes evoke the peri-implantitis. Chang et al. [45], reported that miniscrew placement through non-keratinized tissue sometimes caused screw failure. Moreover, the screws are often covered with surrounding movable mucosa and it will become cause of pain and discomfort (Fig. 5). Therefore, miniscrews had better be implanted in the range of attached/keratinized gingiva.

The screw head placed close to the muco-gingival junction irritates the movable mucosa and it becomes cause of ulcer. Auxiliaries attached between the screw head and the archwire, i.e. coil springs, elastomeric chains, hooks, and ligation...

<table>
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<th>Table 2</th>
<th>Techniques for avoiding the root damage, screw fracture and failure.</th>
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<tbody>
<tr>
<td>Minimum local anesthesia</td>
<td>Placement of a screw into the wider interradicular area</td>
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<tr>
<td>Choosing a small and short screw as possible</td>
<td>Oblique insertion of miniscrew</td>
</tr>
<tr>
<td>Placing with a self-tapping method</td>
<td>Using a screwdriver with a torque limiter</td>
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</table>
wires, should be adjusted not to touch the gingiva or oral mucosa to avoid the pain and discomfort a patient (Fig. 6). A palatal miniscrew sometimes induces pain and injury on the surface of tongue.

Use of miniscrews makes it possible to distalize the whole dentition, which breaks the methodological limitation of tooth movement. However; an excessive distal movement causes impaction of the second molar under the gingiva and evokes peri-coronitis, especially in the mandible. Proper diagnosis based on the clinical examinations is important in the implant-anchored orthodontics.

6. Tooth movement to the edentulous area

Tooth movement through bone-deficient areas (e.g., the maxillary sinus, the atrophic alveolar ridge) is a challenging matter for orthodontist. Emergence of implant-anchored orthodontics can clear mechanical considerations, however; environmental factors still remain. Several reports demonstrated that tooth movement to the bone-deficient areas might reduce the alveolar bone height and/or the root length [66,67]. In contrast, some reports have suggested that a tooth with normal supporting apparatus height can be orthodontically moved through the maxillary sinus while maintaining pulp vitality and bone support and exhibiting normal width of the periodontal ligament on both compression and tension sides [68].

Recently, we moved the maxillary first molar of 20 mice toward the palatal side for 1–14 days, and evaluated the bone remodeling around the root [69]. When proper mechanical stress was applied to the tooth, the periodontal ligament on the palatal side was immediately compressed to approximately half of its original width. At the same time, osteoblasts deposited new bone on the sinus wall prior to bone resorption by osteoclasts on the periodontal ligament side. As a result of these sequential processes, bone on the sinus wall maintained a consistent thickness during the entire observation period. No root resorption was observed. On the other hand, strong force application stimulated more bone formation on the sinus wall but bone resorption on the periodontal ligament side was delayed because of the hyalinization of periodontal ligament. The resulting temporary increase in total thickness of the sinus wall essentially indicates that strong force application will not accelerate tooth movement. Moreover, some root resorption was induced under the excessive force application. Conclusively, mechanotransduction of appropriate mechanical stress can be exploited to induce bone formation in the maxillary sinus so that tooth can be moved into the sinus without abnormal bone and root resorption. However, excessive force decreases efficiency of tooth movement and induces root resorption.

7. Pain and discomfort after implantation

When the miniscrew insertion is proposed to patients, most of them are initially afraid and ask “Is it OK to put a screw through the gingiva? Is it painful?” But it is true that placement and removal of miniscrew are not invasive and most patients do not feel pain during and after implantation [10,70].

We previously evaluated the postoperative pain and discomfort after implantation of miniscrews, screws, and miniplates using a retrospective questionnaire in 75 patients [10]. Most patients receiving screws or mini-plates with mucoperiosteal flap surgery reported pain 1 day after the implantation, and 35% of them have still felt pain a week after. Moreover, most patients appealed the discomfort and swelling after the surgical procedure. On the other hand, 35% of the patients placed miniscrews without flap surgery reported slight pain immediately after the implantation, and only 8% of them felt pain at 1 day after. None reported pain at one week after the insertion. Conclusively, miniscrews placed without flap surgery have suitable characteristics as orthodontic anchorage because of less pain and discomfort.

8. Conclusion

This article has highlighted the potential risks and complications for clinical usage of orthodontic anchor screws with the
hope of educating clinicians. Clinicians keep in mind that screw fracture will occur not only at placement but also at removal. All possible efforts need to be made for preventing screw fracture and failure. To reduce patient discomfort during implant-anchored orthodontics, a complicated placement surgery should be avoided and simple treatment mechanics is recommended. Miniscrews are not a magic wand, but rather a valuable tool to enhance the quality of orthodontic treatment if they are properly used.

Conflict of interest

The authors declare that they have no conflict of interest.

References


