Risks and complications of orthodontic miniscrews

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The risks associated with miniscrew placement should be clearly understood by both the clinician and the patient. Complications can arise during miniscrew placement and after orthodontic loading that affect stability and patient safety. A thorough understanding of proper placement technique, bone density and landscape, peri-implant soft-tissue, regional anatomic structures, and patient home care are imperative for optimal patient safety and miniscrew success. The purpose of this article was to review the potential risks and complications of orthodontic miniscrews in regard to insertion, orthodontic loading, peri-implant soft-tissue health, and removal. (Am J Orthod Dentofacial Orthop 2007;131:00)

Miniscrews have proven to be a useful addition to the orthodontist's armamentarium for control of skeletal anchorage in less compliant or noncompliant patients, but the risks involved with miniscrew placement must be clearly understood by both the clinician and the patient.[1-3] Complications can arise during miniscrew placement and after orthodontic loading in regard to stability and patient safety. A thorough understanding of proper placement technique, bone density and landscape, peri-implant soft-tissue, regional anatomical structures, and patient home care are imperative for optimal patient safety and miniscrew success.

COMPLICATIONS DURING INSERTION

Trauma to the periodontal ligament or the dental root

Interradicular placement of orthodontic miniscrews risks trauma to the periodontal ligament or the dental root. Potential complications of root injury include loss of tooth vitality, osteosclerosis, and dentoalveolar ankylosis.[4,5] Trauma to the outer dental root without pulpal involvement will most likely not influence the tooth's prognosis.[6] Dental roots damaged by orthodontic miniscrews have demonstrated complete repair of tooth and periodontium in 12 to 18 weeks after removal of the miniscrew.[4]

Interradicular placement requires proper radiographic planning, including surgical guide with panoramic and periapical radiographs to determine the safest site for miniscrew placement.[7-11] In the maxillary buccal region, the greatest amount of interradicular bone is between the second premolar and the first molar, 5 to 8 mm from the alveolar crest.[12-14] In the mandibular buccal region, the greatest amount of interradicular bone is either between the second premolar and the first molar, or between the first molar and the second molar, approximately 11 mm from the alveolar crest.[12-14]

During interradicular placement in the posterior region, there is a tendency for the clinician to change the angle of insertion by inadvertently pulling the hand-driver toward their body, increasing the risk of root contact (Fig. 1). To avoid this, the clinician may consider using a finger-wrench or work the hand-driver slightly away from their body with each turn. If the miniscrew begins to approximate the periodontal ligament, the patient will experience increased sensation under topical anesthesia.[11,15] If root contact occurs, the miniscrew may either stop or begin to require greater insertion strength.[15] If trauma is suspected, the clinician should unscrew the miniscrew 2 or 3 turns and evaluate it radiographically.

Miniscrew slippage

The clinician might fail to fully engage cortical bone during placement and inadvertently slide the miniscrew under the mucosal tissue along the periosteum. High-risk regions for miniscrew slippage include sloped bony planes in alveolar mucosa such as the zygomatic buttress, the retromolar pad, the buccal cortical shelf, and the maxillary buccal exostosis if present. Slippage in the retromolar pad can lead to the greatest risk of iatrogenic harm if the miniscrew moves lingually in the submandibular or lateral pharyngeal space near the lingual and inferior alveolar branch nerves (Fig 2). In the retromolar region, serious consideration should be given to

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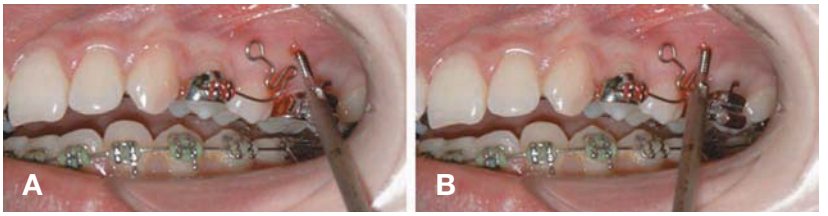

Fig 1. A, Desired angle of miniscrew insertion; **B,** inadvertent change of insertion angle.

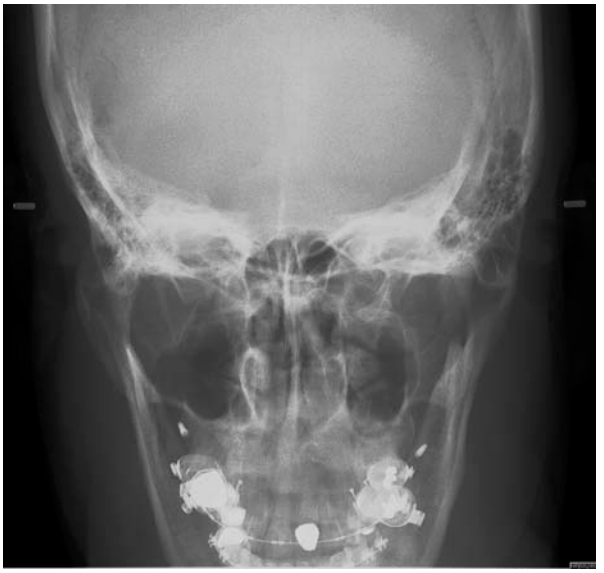

Fig 2. Posteroanterior cephalogram of patient with 2 retromolar pad miniscrews. Miniscrew on patient's right slipped and entered posterior submandibular space. Buccal flap was placed by the oral surgeon to remove the miniscrew. Patient reported 6 weeks of mild paresthesia at commissure of lower lip.

flap exposure for direct visualization and a predrilled pilot hole, even for self-drilling miniscrews. If the alveolar tissue is thin and taut, some clinicians advocate placing the pilot hole with a transmucosal method, using a slow-speed bur to perforate both tissue and cortical bone without making a flap.[16]

Miniscrew slippage can occur in dentoalveolar regions of attached gingiva if the angle of insertion is too steep. Placement of miniscrews less than 30° from the occlusal plane, typically to avoid root contact in the maxilla or to gain cortical anchorage in the mandible, can increase the risk of slippage. To avoid this, the clinician can initially engage bone with the miniscrew at a more obtuse angle before reducing the angle of insertion after the second or third turn. Miniscrews should engage cortical bone after 1 or 2 turns with the hand-driver. Only minimal force should be used with the hand-driver, regardless of bone density. Greater forces increase the risk of miniscrew slippage.

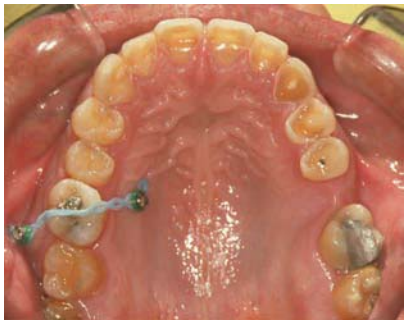

Fig 3. Miniscrew in palatal slope at medial side of greater palatine nerve.

Nerve involvement

Nerve injury can occur during placement of miniscrews in the maxillary palatal slope, the mandibular buccal dentoalveolus, and the retromolar region. Most minor nerve injuries not involving complete tears are transient, with full correction in 6 months.[17] Long-standing sensory aberrations might require pharmacotherapy (corticosteroids), microneurosurgery, grafting, or laser therapy.[17]

Placement of miniscrews in the maxillary palatal slope risks injury to the greater palatine nerve exiting the greater palatine foramen. The greater palatine foramen is located laterally to the third molar or between the second and third molars.[18-20] Location, size, and shape of the foramen can vary with ethnicity.[18,20] The greater palatine nerve exits the foramen and runs anteriorly, 5 to 15 mm from the gingival border, to the incisive foramen. Miniscrews inserted in the palatal slope should be placed medial to the nerve and mesial to the second molar (Fig 3). Placement of the miniscrew above the nerve could increase the risk of palatal root contact and reduce biomechanical control.

Placement of the miniscrews in the mandibular buccal dentoalveolus risks injury to the inferior alveolar nerve in the mandibular canal. The mandibular canal travels forward in an S-shaped curve moving from buccal to lingual to buccal.[21] The inferior alveolar nerve occupies its most buccal position within the body of the mandible at the distal root of the second

Fig 4. A, Mucosal punch in attached tissue with erroneous use of air-water syringe. **B,** Immediate soft-tissue swelling of maxillary buccal region and vestibule. Miniscrew was not inserted on right. **C,** Extraoral photograph minutes after initial soft tissue distension. Note air subcutaneous emphysema with extraoral swelling.

molar and the apex of the second premolar, before exiting from the mental foramen.[21,22] Miniscrews inserted near the mandibular second molar and the second premolar are at greatest risk for accidental damage to the inferior alveolar nerve.[21] The soft-tissue appearance of the dentoalveolus can be deceptive, and a panoramic radiograph should be taken to determine the vertical position of mandibular canal and the location of the mental foramina. Greater caution is needed in adult patients who might have a more occlusal position of the mandibular canal due to resorption of the alveolar ridge.

Placement of miniscrews in the retromolar pad risks injury to the long buccal nerve and the lingual nerve. The long buccal nerve branches off the mandibular nerve trunk and crosses high on the retromolar pad supplying the mucosa of the cheek. The lingual nerve runs immediately under the floor of the mouth and supplies general sensory innervation to the anterior two thirds of the tongue. To avoid nerve involvement and slippage, we recommend that the retromolar miniscrews should be no longer than 8 mm and placed in the buccal retromolar region below the anterior ramus.

Air subcutaneous emphysema

Air subcutaneous emphysema is the condition in which air penetrates the skin or submucosa, resulting in soft-tissue distention.[23] Subcutaneous emphysema can occur during routine operative dental procedures if air from the high-speed or air-water syringe travels under the gingival tissues.[24-26] The main symptom of air subcutaneous emphysema is immediate mucosal swelling with or without crepitus (crackling).[27,28] Additional sequelae include cervicofacial swelling, orbital swelling, otalgia, hearing loss, mild discomfort, airway obstruction, and possibly interseptal and interproximal alveolar necrosis.[28-30] Clinically visible swelling of the skin and mucosa occurs within seconds to minutes after air has penetrated the submucosal space and typically spreads to the neck (in 95% of cases) or the orbital area (in 45% of cases).[23,24]

The clinician should be alert for subcutaneous emphysema during miniscrew placement through the loose alveolar tissue of the retromolar, mandibular posterior buccal, and the maxillary zygomatic regions. If a purchase point or pilot hole is to be drilled through the mucosa, the clinician should use slow speed under low rotary pressure. If either a pilot hole or a mucosal punch is placed, an air-water syringe should never be used. Air from the syringe can enter the submucosal space through the small tissue opening, even in attached tissue (Fig 4). Bleeding and saliva should be controlled with suction, cotton, and gauze, rather than an air-water syringe.

In case of subcutaneous emphysema, the clinician should immediately discontinue the procedure and take

Table. RICE protocol for soft-tissue swelling

Rest	Avoid heavy mastication.
Ice	Apply ice pack to injury for 20 minutes on and 20 minutes off every few hours on first day. Ice relieves pain and swelling.
Compression	Apply compression with ice pack to minimize swelling.
Elevation	Lie down, but keep injured area elevated.

Fig 5. Miniscrews used for intrusion placed in edentulous spaces perpendicular to alveolar ridge and parallel to sinus floor.

periapical and panoramic radiographs to determine the extent of the condition.[23] The patient should not be dismissed until the swelling begins to regress and an infection can be ruled out. Upon dismissal, the patient should be instructed to apply light pressure with an ice pack for the first 24 hours (Table). The clinician could prescribe a mild analgesic, an antibacterial rinse, such as chlorhexidine, and an antibiotic prophylaxis for a week.[23,28,29] In most cases of subcutaneous emphysema, careful observation for further problems or infection is adequate, and swelling and symptoms generally subside in 3 to 10 days.[23,27,28]

Nasal and maxillary sinus perforation

Perforation of the nasal sinus and the maxillary sinuses can occur during miniscrew placement in the maxillary incisal, maxillary posterior dentoalveolar, and zygomatic regions. A posterior atrophic maxilla is a major risk factor for sinus perforation.[31] The sinus floor is deepest in the first molar region and can extend to fill a large part of the alveolar process in posterior edentulous spaces. Penetration of the Schneiderian membrane is a well-documented phenomenon that often occurs when the thin, lateral wall of the sinus is infractured from the buccal side.[31] Small (<2 mm) perforations of the maxillary sinus heal by themselves without complications.[31-33] Ardekian et al[31] and Branemark et al[34] reported that immediately loaded dental implants that perforated the nasal and maxillary sinuses showed no differences in implant stability.

If the maxillary sinus has been perforated, the small diameter of the miniscrew does not warrant its immediate removal. Orthodontic therapy should continue, and the patient should be monitored for potential development of sinusitis and mucocele. For miniscrews placed in pneumatized, edentulous regions of the maxilla, or placed higher in the posterior maxilla when intrusive forces are desired, the clinician should consider angulating the miniscrew perpendicular to the alveolar ridge to avoid damage to the sinus[7] (Fig 5).

Miniscrew bending, fracture, and torsional stress

Increased torsional stress during placement can lead to implant bending or fracture, or produce small cracks in the peri-implant bone, that affect miniscrew stability.[35-37] Self-drilling miniscrews should be inserted slowly, with minimal pressure, to assure maximum miniscrew-bone contact. A purchase point or a pilot hole is recommended in regions of dense cortical bone, even for self-drilling miniscrews. During miniscrew placement in dense cortical bone, the clinician should consider periodically derotating the miniscrew 1 or 2 turns to reduce the stresses on the miniscrew and the bone. The clinician should stop inserting the miniscrew as soon as the smooth neck of its shaft has reached the periosteum. Overinsertion can add torsional stress to the miniscrew neck, leading to screw loosening and soft-tissue overgrowth.[38] Once the miniscrew has been inserted, torsional stress from wiggling the hand-driver off the miniscrew head can weaken stability.[38] When removing the hand-driver from the miniscrew head, the clinician should gently separate the hand-driver handle from its shaft and then gently remove the shaft from the miniscrew head (Fig 6).

COMPLICATIONS UNDER ORTHODONTIC LOADING

Stationary anchorage failure

According to the literature, the rates of stationary anchorage failure of miniscrews under orthodontic loading vary between 11% and 30%.[39-42] If a miniscrew loosens, it will not regain stability and will probably need to be removed and replaced.[6] Stability of the orthodontic miniscrew throughout treatment depends on bone density, peri-implant soft tissues, miniscrew design, surgical technique, and force load.[38,43-47]

The key determinant for stationary anchorage is bone density.[48-50] Stationary anchorage failure is often a result of low bone density due to inadequate cortical thickness.[6] Bone density is classified into 4 groups (D1, D2, D3, and D4) based on Hounsfield units (HU)—an x-ray attenuation unit used in computed tomography

Fig 6. Remove hand-driver by first detaching grip to minimize torsional stress.

scan interpretation to characterize the density of a substance.[51] D1 (>1250 HU) is dense cortical bone primarily found in the anterior mandible and the maxillary midpalatal area.[52] D2 (850-1250 HU) is thick (2 mm), porous cortical bone with coarse trabeculae primarily found in the anterior maxilla and the posterior mandible. D3 (350–850 HU) is thin (1 mm), porous cortical bone with fine trabeculae primarily found in the posterior maxilla with some in the posterior mandible. D4 (150–350 HU) is fine trabecular bone primarily found in the posterior maxilla and the tuberosity region[48] (Fig 7).

Sevimay et al[47] reported that osseointegrated dental implants placed in D1 and D2 bone showed lower stresses at the implant-bone interface. D_1-D_3 bone are optimal for self-drilling miniscrews. Placement of miniscrews in D1 and D2 bone might provide greater stationary anchorage under orthodontic loading. Placement of miniscrews in D4 bone is not recommended due to the reported high failure rate.[53-55] In general, stationary anchorage failure is greater in the maxilla, with the exception of the midpalatal region, due to the greater trabeculae and lower bone density.[7,49,52,56] Loss of midpalat miniscrews is likely a result of tongue pressure.

Peri-implant soft-tissue type, health, and thickness can affect stationary anchorage of the miniscrew. Miniscrews placed in nonkeratinized alveolar tissues have greater failure rates than those in attached tissues.[41] The movable, nonkeratinized alveolar mucosa is easily irritated; soft-tissue inflammation around the miniscrew is directly associated with increased mobility.[44] Additionally, miniscrews placed in regions of thick keratinized tissue, such as the palatal slope, are less likely to obtain adequate bony stability.[49,57] Thin, keratinized tissue, seen in the dentoalveolar or midpalatal region, is ideal for miniscrew placement.[49,57]

Miniscrew geometry and surgical technique directly influence the stress distribution of peri-implant bone.[43] Most miniscrew losses occur as a result of excessive stress at the screw-bone interface.[39] Self-drilling miniscrews can have greater screw-bone contacts (mechanical grip) and holding strengths compared with self-tapping screws.[58,59] Heidemann et al[58] reported greater residual bone between screw threads of self-drilling miniscrews compared with self-tapping miniscrews. Self-tapping miniscrews, like self-drilling screws, can be placed without a predrilled pilot hole in the dentoalveolar region if the cortical bone is thin.[60] If a pilot hole is to be used, for either self-drilling or self-tapping miniscrews, the pilot hole size should be no greater than 85% of the diameter of the miniscrew shaft for optimal stability.[35,61]

It is still not clear the maximum force-load a miniscrew can withstand in regard to stationary anchorage.[1] Dalstra et al[62] reported that miniscrews inserted into thin cortical bone and fine trabeculae should be limited to 50 g of immediate loaded force. Buchter et al[40] reported that miniscrews placed in dense mandibular bone remained clinically stable with up to 900 g of force. Many articles reported miniscrew stability with loading forces of 300 g or less.[40,46,63-65] In regions of poor bone density, simply placing a longer miniscrew under smaller orthodontic force does not ensure stationary anchorage.[66]

Miniscrew migration

Orthodontic miniscrews can remain clinically stable but not absolutely stationary under orthodontic loading.[66] Unlike an endosseous dental implant that osseointegrates, orthodontic miniscrews achieve stability primarily through mechanical retention and can be displaced within the bone. Liou et al[66] reported that orthodontic miniscrews loaded with 400 g of force for 9 months extruded and tipped –1.0 to 1.5 mm in 7 of 16 patients. To account for potential migration, the clinician should allow a 2-mm safety clearance between the miniscrew and any anatomical structures.[66]

SOFT-TISSUE COMPLICATIONS

Aphthous ulceration

Minor aphthous ulcerations, or canker sores, can develop around the miniscrew shaft or on the adjacent buccal mucosa in contact with the miniscrew head. Aphthi are characterized as mildly painful ulcers affecting nonkeratinized mucosa.[67] Minor aphthous ulcerations are typically caused by soft-tissue trauma but might occur as a result of genetic predisposition, bacterial infection,

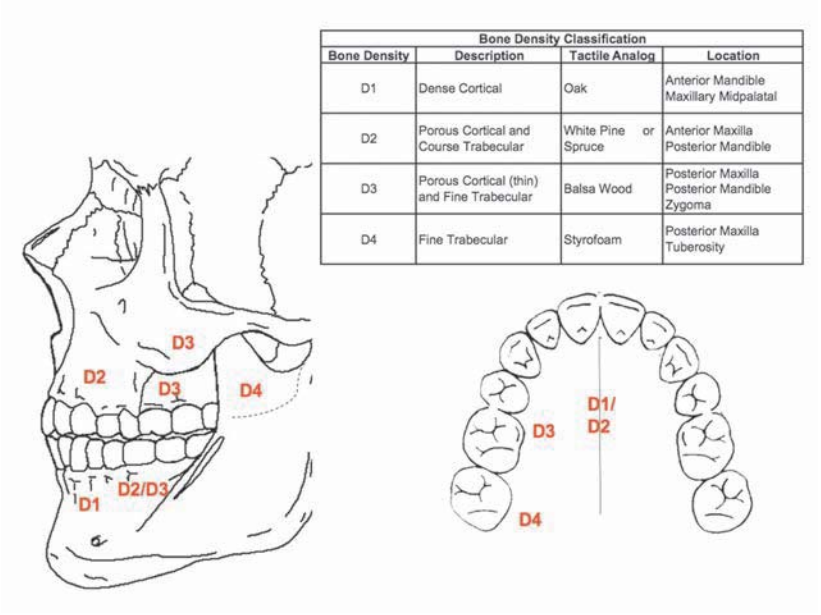

Fig 7. Bone density diagram.

allergy, hormonal imbalance, vitamin imbalance, and immunologic and psychologic factors.[67] Minor aphthous ulcerations are self-limiting and resolve within 7 to 10 days without scarring.[67] Placement of a healing abutment, a wax pellet, or a large elastic separator over the miniscrew head, with daily use of chlorhexidine (0.12%, 10 mL), typically prevents ulceration and improves patient comfort. The occurrence of an aphthous ulceration does not appear to be a direct risk factor for miniscrew stability, but its presence might forewarn of greater soft-tissue inflammation.

Soft-tissue coverage of the miniscrew head and auxiliary

Miniscrews placed in alveolar mucosa, particularly in the mandible, might become covered by soft tissue. The bunching and rubbing of loose alveolar tissue can lead to coverage of both the miniscrew head and its attachments (ie, coil spring, elastic chain) within a day after placement. Soft-tissue coverage might be a risk factor for miniscrew stability, as well as a clinical concern for the patient, who might think that the miniscrew has fallen out. Miniscrew attachments (elastic chain, coil spring) that rest on tissues will likely become covered by tissue. The soft-tissue overlaying the miniscrew is relatively thin and can be exposed with light finger pressure, typically without an incision or local anesthetic. Soft-tissue overgrowth can be minimized by placement of a healing abutment cap, a wax pellet, or an elastic separator.[68] In addition to its antibacterial properties that minimize tissue inflammation, chlorhexidine slows down epithelialization and might reduce the likelihood of soft-tissue overgrowth.[69] The authors suggest partial insertion with a longer miniscrew (10 mm) in regions of loose alveolar mucosa, leaving 2 or 3 threads of the shaft exposed to minimize the possibility of soft-tissue coverage (Fig 8).

Soft tissue inflammation, infection, and peri-implantitis

Healthy peri-implant tissue plays an important role as a biologic barrier to bacteria.[70] Tissue inflammation, minor infection, and peri-implantitis can occur after miniscrew placement.[71] Inflammation of the peri-implant soft tissue has been associated with a 30% increase in failure rate.[44] Peri-implantitis is inflammation of the surrounding implant mucosa with clinically and radiographically evident loss of bony support, bleeding on probing, suppuration, epithelia infiltrations, and progressive mobility.[69] The clinician should be forewarned of soft-tissue irritation if the soft tissues begin twisting around the miniscrew shaft during placement. Some clinicians advocate a 2-week soft-tissue healing period for miniscrews placed in the alveolar mucosa before orthodontic loading. [67]

COMPLICATIONS DURING REMOVAL

Miniscrew fracture

The miniscrew head could fracture from the neck of the shaft during removal. The authors recommend a minimum diameter of 1.6 mm for self-drilling miniscrews that are 8 mm or longer placed in dense cortical bone. The proper placement technique can minimize the

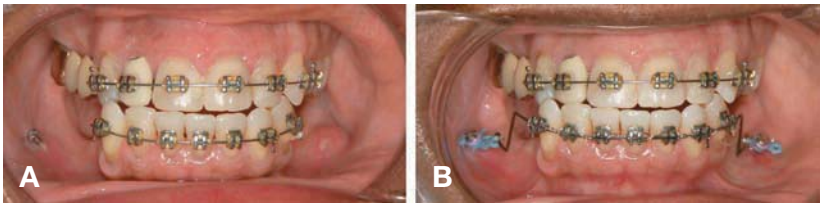

Fig 8. A, Aphthous ulceration around right miniscrew (10-mm length) and soft-tissue overgrowth of left miniscrew (8-mm length). **B,** Miniscrew exposed same day with light finger pressure only, without anesthesia. Tissue held taut with elastic o-ring (*pink*) on top of elastic chain (*blue*).

risk of miniscrew fracture during its removal. If the miniscrew fractures flush with the bone, the shaft might need to be removed with a trephine.[6]

Partial osseointegration

Although orthodontic miniscrews achieve stationary anchorage primarily through mechanical retention, they can achieve partial osseointegration after 3 weeks, increasing the difficulty of their removal.[6,72] The miniscrew typically can be removed without complications a few days after the first attempt of removal.[6]

PATIENT SELECTION AND HOME CARE

Orthodontic miniscrews are approved by the US Food and Drug Administration for adults and adolescents (age 12 and older).[73] Patients older than 12 who have not yet completed skeletal growth (as shown by a hand-wrist radiograph) should have palatal miniscrews placed away from the midline suture in the paramedian region.[73] Miniscrews are contraindicated in heavy smokers and patients with bone metabolic disorders.[38] Optimal oral hygiene is imperative to minimize miniscrew complications. Chlorhexidine (0.12%, 10 mL) should be used a minimum of twice daily and preferably after each meal. The cationic nature of chlorhexidine allows for its sustantivitiy, or persistent adherence to the enamel and soft tissue, providing a prolonged bacteriocidal and bacteriostatic effect. However, this sustantivity stains enamel, frequently causing patients to want to brush immediately after rinsing. The clinician should strongly advise the patient against this for 2 reasons: the surface contact from the toothbrush can remove the chlorhexidine coating, and the anionic agents in the toothpaste can rapidly reduce the activity of the cationic rinse.[74] We advocate rinsing with chlorhexidine and waiting 30 minutes before fluoridated brushing. Additionally, the patient can be taught to use a plastic toothpick to press down the soft tissue or lift the miniscrew attachments away from the tissue periodically.

CONCLUSIONS

This article has highlighted the potential risks and complications of miniscrew placement with the hope of educating both clinician and patient. Bone density and soft-tissue health directly affect implant stability. Proper miniscrew home care by the patient is as important as proper placement by the orthodontist. Above all, maximum effort should be made to simplify the surgery and then modify the mechanics. Miniscrews are not a catholicon to be prescribed without precautions, but rather a valuable tool to be pulled from the orthodontist's belt and used at the appropriate time .

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