The use of miniscrew implants for temporary skeletal anchorage in orthodontics: A comprehensive review

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Though not a novel therapeutic concept, the use of miniscrew implants to obtain absolute anchorage has recently become very popular in clinical orthodontic approaches. The mode of anchorage facilitated by these implant systems has a unique characteristic owing to their temporary use, which results in a transient, albeit absolute anchorage. The foregoing properties together with the recently achieved simple application of these screws have increased their popularity, establishing them as a necessary treatment option in complex cases that would have otherwise been impossible to treat. The aim of this comprehensive review is to present and discuss the development, clinical use, benefits, and drawbacks of the miniscrew implants used to obtain a temporary but absolute/skeletal anchorage for orthodontic applications. Topics to be discussed include classification, types and properties (e.g., biocompatibility, osseointegration, types of anchorage, screw head, and thread design), clinical applications, site and placement method selection, clinical procedures for implant insertion, and loading and removal processes. Lastly, the potential complications and the advantages and disadvantages accompanying their use are presented. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:e6-e15)

Anchorage, defined as a resistance to unwanted tooth movement,1 is a prerequisite for the orthodontic treatment of dental and skeletal malocclusions.2,3 Its role in orthodontic treatment was appreciated early on, as prominent orthodontists such as Gunnell, Desirabode, and Angle realized the limitations of moving teeth against other teeth used for anchorage, introducing ideas such as the use of occipital, stationary, and occlusal anchorage.4

Controlling anchorage helps to avoid undesirable tooth movements. However, even a small reactive force can cause undesirable movements; it is important to have absolute anchorage to avoid them.5,6 Absolute or infinite anchorage is defined as no movement of the anchorage unit (zero anchorage loss) as a consequence to the reaction forces applied to move teeth.1 Such an anchorage can only be obtained by using ankylosed teeth or dental implants as anchors, both relying on bone to inhibit movement.7 Anchorage provided by devices, such as implants or miniscrew implants fixed to bone, may be obtained by enhancing the support to the reactive unit (indirect anchorage) or by fixing the anchor units (direct anchorage), thus facilitating skeletal anchorage.

The relevant literature lists a wide array of articles dealing with miniscrew implants; however, the majority of available studies on this issue is limited to case reports, preliminary reports, or case series studies, and the information provided is scarce and most often not evidence based.

The aim of this comprehensive review is to present and discuss the development, clinical use, benefits, and drawbacks of the miniscrew implants used to obtain a temporary but absolute skeletal anchorage for orthodontic applications.

DEFINITIONS

Terms such as mini-implants, miniscrews, microimplants, and microscrews have been used to describe devices of skeletal anchorage. Although the group of these terms describes devices smaller than conventional dental implants that provide skeletal anchorage which is discontinued after treatment, they should not be used interchangeably.

Implants and mini-implants refer to systems, which by definition imply that osseointegration sets in prior to loading, whereas screws to self-tapping devices that may be used without the condition of osseointegration.8 However, since 2004 it was agreed on that the word mini-implant should be applied both to palatal implants, to mini-implants, to miniscrews, and to microscrews.8 Intraoral extradental anchorage systems9 and temporary anchorage devices10 are other terms that have also been suggested to describe devices such as mini-implants.
that are temporarily fixed to bone to provide skeletal or absolute anchorage.

The prefixes mini- and micro- are currently used to describe implants or screws of the same dimension without any differentiation. However, since the Greek word micro is mainly used for very small dimensions, better seen under microscope, we advocate as more appropriate the use of the term miniscrew implants, which will be used in this article instead of the terms mini-implants, microimplants, miniscrews, and microscrews.

HISTORICAL DEVELOPMENT

The idea of using screws fixed to bone to obtain absolute anchorage goes back to 1945, when Gainsforth and Higley placed vitallium screws in the ascending ramus of 6 dogs to retract their canines. The first clinical use reported in the literature came in 1983 when Creekmore and Ekllund used a Vitallium bone screw inserted in the anterior nasal spine to treat a patient with a deep overbite. However, the use of mini-screw implants for orthodontic anchorage was not immediately embraced. Thereafter, a number of papers focused on the use of other means to obtain skeletal anchorage for orthodontic tooth movement, such as dental implants, onplants, and palatal implants.

In 1997, Kanomi described a mini-implant specifically made for orthodontic use, and in 1998, Costa et al. presented a screw with a bracketlike head. Several other mini-screw implants have been introduced since then, each presenting different designs and features. Further, during the last decade, other means of bone anchorage have also been proposed, including zygoma wires, miniplates, and zygoma anchors.

CLASSIFICATION

Skeletal anchorage devices can be classified into 2 main categories, based on their origin. The first category has its origins in osseointegrated dental implants and includes the orthodontic mini-implants, the retro-molar implants, and the palatal implants. The second category finds its origin in the surgical mini-implants, such as the one used by Creekmore and Ekllund and those described later by Kanomi and Costa et al. The main differences between the 2 categories are that devices of the second category are smaller in diameter, have smooth surfaces, and are designed to be loaded shortly after insertion.

In a similar manner, Cope classified the current available methods of skeletal anchorage as either biocompatible or biologic in nature. The biologic group included ankylosed and dilacerated teeth, whereas the biocompatible group included temporary anchorage devices. He further subclassified both groups—based on the manner in which they are attached to bone—into biochemical (osseointegrated) or mechanical.

In a more thorough classification of implants used for orthodontic anchorage, Labanauskaite et al. suggested the following classification:

- according to the shape and size
  - conical (cylindrical)
  - miniscrew implants
  - palatal implants
  - prosthodontic implants
- according to the implant bone contact
  - osseointegrated
  - nonosseointegrated;
- according to the application
  - used only for orthodontic purposes (orthodontic implants)
  - used for prosthodontic and orthodontic purposes (prosthodontic implants).

TYPES AND PROPERTIES

The main differences between the currently available mini-screw implants relate to their composition, size, and design and include: (1) the alloy or metal used for their fabrication, (2) the diameter of threaded portion, (3) the length of the implant, and (4) the design of the head.

An ideal mini-screw implant used for orthodontic anchorage would satisfy a large set of requirements, which basically make it biocompatible; available in different diameter calibers and length sizes, and different designs (i.e., button or bracket head); simple and easy to insert, with the option of self-taping and self-drilling; capable of immediate loading; removal without the need for complicated accessory equipment; and low cost. Currently, there are a number of commercially available mini-screw implant systems for orthodontic use (Table I); representative samples are shown in Fig. 1.

Biocompatibility

With the exception of the Orthodontic Mini Implant, which is fabricated from stainless steel, all other aforementioned systems are made of medical type IV or type V titanium alloy.

Osseointegration

Because complete osseointegration of screws used in orthodontic applications is a disadvantage that complicates the removal process, most of these devices are manufactured with a smooth surface, thereby minimizing the development of bone ingrowth and promoting
soft tissue attachment at ordinary conditions and in the absence of special surface treatment regimens.8,26,27

**Types of anchorage**

The miniscrew implants can provide 2 different types of anchorage: direct and indirect. When used for indirect anchorage, they are connected through bars or wires to the reactive unit, whereas when used for direct anchorage, they directly receive the reactive forces by acting as an anchor unit.

**Head design**

Most miniscrew implant systems are available in different designs to accommodate both direct and indirect anchorage and avoid tissue irritation. The most frequent is the buttonlike design with a sphere or a double spherelike shape or a hexagonal shape. Miniscrew implants available with this design include the Aarhus Anchorage System, the AbsoAnchor System, the Dual-Top Anchor System, the IMTEC Mini Ortho Implant, the Lin/Liou Orthodontic Mini Anchorage Screw, the Miniscrew Anchorage System, the Orthoanchor K1 System, and the Spider Screw Anchorage System. With a hole through the head or the neck of the screw, usually 0.8 mm in diameter, this design is mostly used for direct anchorage.

A bracketlike design is also available, which can be used for either direct or indirect anchorage as provided by the Aarhus Anchorage System, the AbsoAnchor System, the Dual-Top Anchor System, the Spider Screw Anchorage System, and the Temporary Mini Orthodontic Anchorage System. Finally, a further hook design is used by the TOMAS miniscrew implant.

**Thread design**

The thread body can be either conical as in the Aarhus Anchorage System, the AbsoAnchor System,
the Miniscrew Anchorage System, and others, or parallel tapering only at the end as in the Orthodontic Mini Implant.

Miniscrew implants are available in different lengths and diameters to accommodate placement at different sites in both jaws. Costa et al. evaluated the depths of the hard and soft tissues of 20 patients and concluded that miniscrew implants of 4 to 6 mm in length are safe in most regions, but individual patient variation dictates individual evaluation of bone depth in all patients.

Decreased diameter threads facilitate insertion to sites with root proximity without the risk of root contact. However, a major concern regarding the thread diameter of the miniscrew implants is the increased fracture noted in diameters less than 1.2 mm. Most miniscrew implants have a thread diameter ranging from 1.2 to 2.0 mm and a length from 4.0 to 12.0 mm, although some of them are also available at lengths of 14.17 or even 21 mm.

**CLINICAL APPLICATIONS**

In general, the various miniscrew implant systems can be used in cases where the support of dental units is quantitatively or qualitatively compromised, as in partial edentulous patients or periodontally involved teeth. In addition, an absolute indication is the requirement for minimum undesired reactive forces.

Melsen suggested using miniscrew implants as anchorage for tooth movements that could not otherwise be achieved, such as in patients with insufficient teeth for the application of conventional anchorage, in cases where the forces on the reactive unit would generate adverse side effects, in patients with a need for asymmetrical tooth movements in all planes of space, and finally in some cases as an alternative to orthognathic surgical procedure.

During the past few years, the application of miniscrew implants has been expanded to include a wide array of cases, including the correction of deep over-
Fig. 2. Two miniscrew implants (Aarhus Anchorage System) used as indirect anchorage for maxillary molar distalization. A, Before fixation of the distalization appliance. B, After fixation of the distalization appliance.

Possible sites for placement

Localization of the point of insertion. Possible sites for miniscrew implant placement in the maxilla include the area below the nasal spine, the palate (on the median or the paramedian area [Fig. 2]), the infrazygomatic crest, the maxillary tuberosities, and the alveolar process (both buccally and palatally between the roots of the teeth [Fig. 3]). Possible sites in the mandible include the symphysis or parasympysis, the alveolar process (between the roots of the teeth), and the retro-molar area (Fig. 4).  

In a recent study using volumetric tomographic images, it was found that, in the maxilla, the safest insertion sites are located in the anterior and apical portion. The least amount of bone was found to be in the tuberosity, making this area unsuitable for miniscrew implant insertion. In the mandible, the safest sites were found to be between the first and second molars and between the first and second premolars, at all depths investigated.

In the palate, studies have shown that there is sufficient bony support for the implantation of small implants, ranging from 4 to 6 mm in the midpalate. An alternative palatal site that offers a higher amount of bone support was found to be located 6 to 9 mm posterior to the incisive foramen and 3 to 6 mm paramedian; this site should be considered when miniscrew implants larger than 4 mm length are chosen (Fig. 5).
In another study investigating factors associated with failure of miniscrew implants, an association was found between miniscrew implant failure and patients with high mandibular plane angles, a finding possibly attributed to the thin cortical bone. However, in a radiographic evaluation of bone availability for placement of miniscrew implants, it was found that adequate bone for placement was located in the apical half of root length, which is likely to be covered by movable mucosa. That means that placement of miniscrew implants in the attached gingiva to supposedly decrease soft tissue irritation should be avoided. To overcome this problem, design modifications of miniscrew implants may be necessary to decrease soft tissue irritation.

**Direction of implant insertion.** Placing miniscrew implants perpendicular to the bone surface is not always possible—especially when teeth may be present—because of the high risk injury involved. Melsen recommends the placement of miniscrew implants at an oblique angle in the maxilla, in an apical direction, whereas in the mandible, the screws should be inserted as parallel to the roots as possible if teeth are present. Kyung et al. propose inserting miniscrew implants at a 30° to 40° angulation to the long axes of the teeth in the maxilla, and 10° to 20° angulation in the mandible. Carano et al. also suggested an angulation of 30° to 45° in the maxilla, but in addition, they advised inserting the miniscrew implant in a more perpendicular angulation in the area of the maxillary sinus to avoid any damage to the sinus.

**Insertion method**

Miniscrew implants can be either self-drilling (such as the Aarhus Anchorage System, the AbsoAnchor System, the Dual-Top Anchor System, and the Lin/Liou Orthodontic Mini Anchorage Screw) or non–self-drilling. The advantage of the self-drilling screws over the non–self-drilling is the avoidance of the pilot drilling step during the insertion procedure. However, pilot drilling may also be required by the self-drilling screws in cases where the cortex is thicker than 2 mm, because dense bone would eventually bend the fine tip of the screw. The pilot drill should preferably be 0.3 mm thinner, reaching no more than 2 to 3 mm deep. It is advisable that the insertion of the miniscrew implants should be performed by an oral surgeon, especially when drilling is necessary.

Since contact of the miniscrew implants to the root surfaces of the adjacent teeth should be avoided, taking an intraoral radiograph with a surgical guide made from a rectangular wire bonded to teeth in the region where a miniscrew implant is to be placed, can significantly help for a more accurate identification of that region. Some authors have suggested using an ad-
justable surgical guide or a stent for placement of the miniscrew implants.

Clinical procedures of implant insertion

Miniscrew implant placement procedures are usually available in the product brochure. Some basic guidelines follow: (1) A small amount of local anesthesia is usually sufficient for the placement of miniscrew implants, and it is advocated not to achieve profound anesthesia of the teeth but only of the soft tissue. In case of non–self-drilling miniscrew implants, a pilot hole is necessary. Pilot drilling should be done in a surgical environment, and if necessary, by an oral surgeon. Firstly, soft tissue from the site of the placement is either incised or removed using a soft tissue punch. Thereafter, a pilot hole is drilled using a drill rotating no more than 1000 rpm. The pilot drill is usually 0.2 to 0.3 mm thinner than the miniscrew implant. The miniscrew implant is then screwed in place by using an appropriate screwdriver. (3) In case of self-drilling miniscrew implants, no incision or soft tissue removal is necessary. Infection control is similar to that for an extraction. After selecting the appropriate site, the miniscrew implant, and the corresponding site of placement, it is inserted in place.

Loading and anchorage considerations

In contrast to dental implants, orthodontic miniscrews are loaded immediately, and most authors suggest the use of light forces early on. Only a few studies, mostly on animals, have dealt with the investigation of tissue reaction to immediate loading of miniscrew implants. These unanimously suggest that immediate loading with orthodontic forces can be performed without any complications. In a study using finite element analysis, it was found that immediate loading should be limited to 50 cN of force in a 2 mm diameter miniscrew implant. In another study on 51 patients in which 134 titanium screws of 3 types (1.0 mm, 1.5 mm, and 2.0 mm in diameter) and 17 miniplates were used, no significant association was found between the success rate and immediate loading, and it was concluded that immediate loading is possible if the applied force is less than 2 N.

The ability of orthodontic miniscrews to provide absolute anchorage was shown by a recent study comparing canine retraction anchorage loss with the use of miniscrew implants and with conventional molar anchorage. However, it is questionable if the miniscrew implants remain stationary throughout their period of loading. In fact, Liou et al. found that miniscrew implants might move according to orthodontic loading in some patients, and it is therefore advised to allow 2 mm of safety clearance between the miniscrew implant and dental roots of the adjacent teeth.

Clinical procedures of implant removal

Usually, miniscrew implant removal is uneventful, and the wound does not require any special treatment. The removal procedure can be achieved without the use of anesthesia, but topical or local anesthesia can be used—especially when there is tissue covering the miniscrew implant. The miniscrew implant is unscrewed using the screwdriver of the corresponding manufacturer. In the event it cannot be removed, it is advised to wait 3 to 7 days after the initial attempt of its removal, because it is believed that microfractures or bone remodeling as a result of the initial attempt will cause the screw to loosen. If the miniscrew implant fractures during removal, a small surgical procedure to remove it may be necessary.

COMPLICATIONS

Inflammation, infection, and tissue irritation

Inflammation and infection of the tissues around the implant site might occur, although infection is generally not a problem. Meticulous oral hygiene is critical, and the use of 0.2% chlorhexidine mouthrinses or dental floss dipped in 2% chlorhexidine can be used to avoid and control any inflammation or infection that might occur. In the event where the patient has purulence, palor, or inflammation, management with an appropriate antibiotic is indicated. One important factor to help avoid tissue inflammation is the determination of the best site for miniscrew implant insertion. It is advised that the miniscrew implants should be inserted in keratinized gingiva when possible, and that frenum and muscle tissue should be avoided. Hypertrophy of the mucosa covering the implant might occur as a complication of placing it in nonkeratinized gingiva. In such cases, the placement of a healing cap abutment is recommended at the time of insertion, or the clinician could allow the mucosa to cover the miniscrew implant, with only a wire or an attachment on it passing through the mucosa.

Injury to adjacent structures

Another complication concerning miniscrew implant insertion is injuring adjacent roots, periodontal ligaments, nerves, and blood vessels. If such a phenomenon occurs, the patient usually shows pain on percussion and mastication in cases of periodontal injury symptoms, and sensitivity to hot and cold in cases of root injury. In such circumstances, the miniscrew implant should be removed. The prognosis of the injured tooth depends on whether or not there has been injury to the pulp.
animal experimental study, histological examination of the roots of 3 teeth that had been damaged by mini-screw implant placement demonstrated an almost complete healing of the periodontal structures in a period of 12 weeks following removal of the screws.80

Fabbroni et al. studied the incidence of dental damage caused by transalveolar screws used for temporary intermaxillary fixation of fractured mandibles and found the incidence of root injury to be very low.81 It could be assumed that the incidence of root damage from using miniscrew implants for orthodontic anchorage is even lower when considering the careful planning that takes place before insertion of the miniscrew implant, unlike those placed in an emergency situation.

Failure

Failure of the miniscrew implants might occur if there is lack of stability at insertion time due to inadequate thickness of the cortical bone.34 If this complication occurs, a different site should be chosen to insert the miniscrew implant.34,36

The miniscrew implant may be lost or become loose as a result of various factors, such as inflammation of the peri-implant tissues and improper placement.34,35 In a study by Miyawaki et al.,69 it was found that instability and failure of titanium miniscrew implants placed in the buccal alveolar bone of the posterior region were associated with an implant thread diameter of 1.0 mm or less. In the same study, it was also found that patients with high mandibular plane angles may not be suitable candidates for miniscrew implantation, because they often present thin cortical bone, a fact that could also lead to implant failure. In a more recent study,82 45 miniscrew implants were placed in 25 patients for the purpose of intermaxillary fixation. The miniscrew implants were assessed for stability and causes of failure. The mean follow-up period was 16 months and the overall success rate was 91%. The length of the miniscrew implants was found to be related to the success rate, the longer the miniscrew, the higher the rate of success. The location of the mini-implant was found to be the only significant risk factor for failure, with miniscrew implants placed in the ramus having the highest failure rates.

Fracture

Fracture of the miniscrew implant may occur during removal if the neck of the screw is too narrow.24,48 To avoid this complication, it is advised that miniscrew implants should be used with a diameter of 2 mm or larger.48 In addition, fracture may also occur if the thread diameter of the miniscrew implant is less than 1.2-mm thick.29

CONCLUSION

In summary, miniscrew implants present the following advantages when used for orthodontic anchorage purposes:

- Insertion and removal does not require any particular surgical procedure, in contrast with other means available such as orthodontic implants, miniplates, and onplants that require flap surgery.
- Miniscrew implants can be easily inserted chair side in one appointment, even by the orthodontist.
- There is no need for complicated clinical and laboratory procedures (i.e., fabrication of acrylic splints by taking imprints with additional implant copying systems to accurately transfer the implant position to cast models) to facilitate safe and precise implant insertion.
- Miniscrew implants can be immediate loaded (there is no need for a waiting period for osseointegration, in contrast to orthodontic implants), reducing the total treatment time.
- Miniscrew implants offer a variety of locations that can be inserted, unlike conventional dental implants used for orthodontic anchorage.
- The provided absolute anchorage eliminates undesirable effects on the teeth that otherwise would have been normally used as anchorage.
- Patient cooperation is limited to maintaining immaculate oral hygiene.
- Miniscrew implants can be easily removed.
- Cost is relative compared with other conventional methods used for anchorage, while much lower in comparison to the orthodontic implants.

The following disadvantages must be considered when miniscrew implants are used for orthodontic anchorage purposes:

- Damage of the adjacent tissues or root injuries might occur as a result of improper insertion.
- Irritation or inflammation of peri-implant tissues and consequent failure of the miniscrew implant is also possible, especially by patients with poor oral hygiene.
- In cases when the oral surgeon is involved for insertion (mainly when drilling is required), there is an additional cost to the patient.

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REFERENCES


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