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Mini Screws As Temporary Anchorage Device in Orthodontics: A Narrative Review

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Abstract: *Anchorage plays an important role in orthodontics. Miniscrews as a temporary anchorage device have gained popularity because of its small size, ease of insertion and removal, low cost, immediate loading and ability to be inserted in different locations of the alveolar bone. The aim of this narrative review is to discuss the evolution, clinical applications, and risk factors advantages and disadvantages of using miniscrews implants.*
Keywords: *Biomarker,immediateloading,mini implant,miniscrew,orthodontics,temporary anchorage device*

I. Introduction

Anchorage control is a pre-requisite for the treatment of dental and skeletal malocclusion with fixed appliances. The success of orthodontic treatment generally relies on anchorage protocol planned for that particular case. Though the principle of orthodontic anchorage has been understood since 17th century, it does not appear to have been clearly articulated until the time of Ottofy [1]. Later Daskalogiannakis [2] defined anchorage as "resistance to unwanted tooth movement". Edward Angle was one of the earliest to advocate the use of equal and opposite appliance forces to control anchorage [3]. It can also be explained by 3rd law of Newton, which states that every action creates a reaction, which is equal and opposite in direction.

There are limitations in our ability to control all aspects of tooth movement. We often have inadequate mechanical systems with which to control anchorage, which leads to anchorage loss of reactive units and often incomplete correction of intra and inter arch alignment problems. Extraoral devices like headgear are dependent on patient's compliance .The conventional intra- oral anchorage in fixed appliances like Transpalatal arch and Nance arch do help in reinforcing the molars, however their worthiness in providing absolute anchorage is doubtful. The increasing demand for orthodontic treatment methods requiring minimum compliance and maximum anchorage control has led to exploration of "Bone supported anchorage" i.e. skeletal anchorage.One category originated as osseo-integrated prosthodontic dental implant, their retention is very stable under occlusal loading but one must wait at least 4-6 months before using them for occlusal restoration or orthodontic loading, which includes additional surgery of raising flap. In search of small dimension implants with the property of mechanical stability and that can be loaded immediately for orthodontic purpose, the present day orthodontic *mini implants* were developed.

II. Evolution Of Mini Implants/Miniscrews

The evolution of minicrews begins way back in 1945, when Grainsforth and Higley [4] placed vitallium screws in ramus of 6 dogs to distalize maxillary canine. However, the initiation of force resulted in screw loss in 16 to 31days. Later, Creekmore and Eklund [5] evaluated that a small sized vitallium bone screw could be inserted just below the anterior nasal spine to treat a patient with a deep impinging overbite. Roberts et al [6] reported the osseous adaptations of rigid endosseous implants to continuous loading of 100 gms in rabbit femurs. Results indicated that titanium implants provided firm osseous anchorage for orthodontics and dentofacial orthopedics. Eugene Roberts [7] conducted extensive research on the use of retromolar implants for orthodontic anchorage. The classic example of a subperioosteal implant, that is the Onplant was first introduced by Block and Hoffman [8] Bosquet et al [9] introduced the earlier variant of interdental implants, that were endosseous implants but of smaller diameter. Later, Ryuzo Kanomi [10] reported that 1.2mm diameter and 6-7 mm length titanium mini-implants, could be used successfully for anterior intrusion and retraction, and molar intrusion. Later, Costa [11] introduced, the Aarhus Anchorage System, a miniscrew with a bracket like head which facilitated the insertion of a full sized wire. Melsen and Costa in [12] described primary stability as an important factor for mini implant success. Primary stability is important during the healing and remodeling period, especially when the implant is immediately loaded. Ohmae and colleagues [13] reported the results of a clinical and histological evaluation of titanium mini- implants used as anchors for orthodontic intrusion in beagle dogs. Park et al [14] showed that 1.2mm diameter microscrews could be inserted between the roots of the teeth to retract the six anterior teeth *en mass* and intrude mandibular molars at the same time.

III. Classification

1. Based on the location [15, 16]
Subperiosteal: The implant body lies over the bony ridge.
Transosseous: The implant body penetrates the mandible completely.
Endosseous: These are partially submerged and anchored within bone, and have been the most popular and the widely used ones in orthodontics.

2. Based on the configuration design
Root form implants: These are the screw type endosseous implants and the name has been derived due to their cylindrical structure
Blade / Plate implants:

3. According to the composition
Stainless steel, Cobalt-Chromium, Molybdenum, titanium, Ceramic Implants.
Miscellaneous such as Vitreous carbon and composites

4 According to the insertion
Threaded or Non-threaded: The root form implants are generally threaded as this provides for a greater surface area and stability of the implant.
Porous or Non Porous: The screw type implants are usually non porous, whereas the plate or blade implants (non Threaded) have vents in the implant body to aid in growth of bone and thus a better Interlocking between the metal structure and the surrounding bone.

5. According to mode of insertion
Pre-tapped screws: Used in harder, less compressible materials, such as in metal or in cortical bone.
Self- tapping screws: Used in softer, less compressible materials and forms threads by compressing and cutting the surrounding materials.
Self-drilling screws: Referred as drill-free screws have a corkscrew like tip, therefore, neither predrilling nor tapping procedures are needed.

6. Based on their origin [17]
Osseointegrated dental implants- include orthodontic mini-implants, the retromolar implants, and the palatal implants.
Surgical miniimplants - such as the one used by Creekmore and Eklund and those described later by Kanomi and Costa et al.

7. Cope classification [18]
Biocompatible: Temporary anchorage device
Biologic in nature: Ankylosed teeth and dilacerate teeth
In a more thorough classification of implants used for orthodontic anchorage, Labanauskaite et al [19] suggested the following classification:

8. According to the shape and size
Conical (Cylindrical)
Miniscrew Implants
Palatal Implants
Prosthodontic Implants
Miniplate Implants
Disc Implants (Onplants)

9. According to implant and bone contact
Osseointegrated, Non-osseointegrated.
10 According to the application

Used only for orthodontic purposes (orthodontic implants)
Used for prosthodontic and orthodontic purposes (prosthodontic implants).

IV. Basic Design Of A Screw

"Might skeletal anchorage be applied to orthodontic tooth movement and orthopedic jaw movement?" With this question in 1983, Creekmore and Eklund were the first orthodontists to suggest in print that a small metal screw could withstand a constant force of sufficient magnitude and duration to reposition an entire anterior maxillary dentition without becoming loose, painful, infected, or pathologic [5]. Their case opened an entirely new area for managing orthodontic anchorage, but may have been too progressive and too invasive for its time. More recently, new onplants, miniplates, and palatal implants have been developed specifically for use in orthodontics. Repeating the experience of Creekmore, they have found that small screws, like those used for rigid fixation in maxillofacial surgery, work well for orthodontic anchorage [10,21] The size of the screws has been reduced even further in the last few years [22,]. The material generally used for miniscrews is medical grade 4 or 5 titanium, although stainless steel has been proposed as an alternative. Recent histological studies in animals have shown that the osseointegration of titanium miniscrews is less than half that of conventional dental implant [23]. Incomplete osseointegration represents a distinct advantage in orthodontic applications, allowing for effective anchorage with easy insertion and removal. Differences among various miniscrew head designs have also been noted with regard to soft-tissue healing. The conical screws used in the Miniscrew design, made of medical grade 5 titanium, are available in three sizes. Type A has a diameter of 1.3 mm at the neck and 1.1 mm at the tip. Type B is 1.5 mm in diameter at the neck and 1.3 mm at the tip. Both types are 11mm long. Type C, which is 9 mm long has a diameter of 1.5 mm at the neck and 1.3 mm at the tip. The screw head consists of two fused spheres (the upper 2.2 mm in diameter, the lower 2 mm), with an internal hexagon for insertion of the placement screwdriver. A .6mm horizontal slot at the junction of the two spheres allows for the attachment of elastics, chains, coil springs, ligature wires, or auxiliary hooks.

The most common is the button-like design with a sphere or a double sphere-like shape or a hexagonal shape. Miniscrew implants available with this design include the Aarhus Anchorage System (Fig. 1), the Abso Anchor 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 (Fig. 2 and Fig. 3). With a hole through the head or the neck of the screw, usually 0.8 mm in diameter is mostly used for direct anchorage. A bracket like design is also available, which can be used for either direct or indirect anchorage as provided by the Aarhus Anchorage System, the Abso Anchor System, the Dual-Top Anchor System, the Spider Screw Anchorage System, and the Temporary Mini Orthodontic Anchorage System. Finally, TOMAS have designed hooks in their miniscrew implant.The thread body can be either conical as in the Aarhus Anchorage System, the Abso Anchor System, the Miniscrew Anchorage System, and others, or parallel tapering only at the end as in Orthodontic Mini Implant [24].

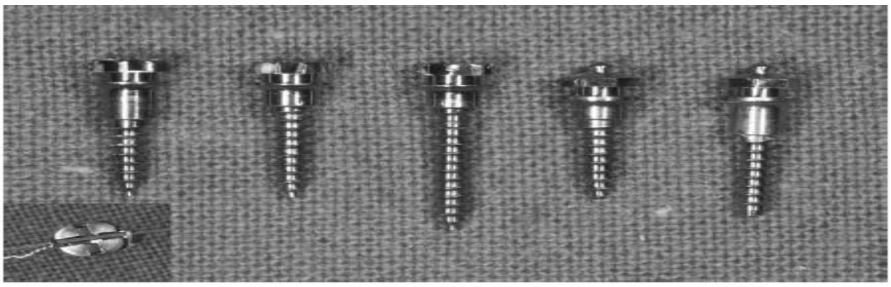
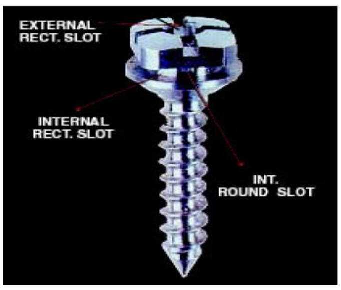


Fig. 1 The Aarhus Anchorage System.



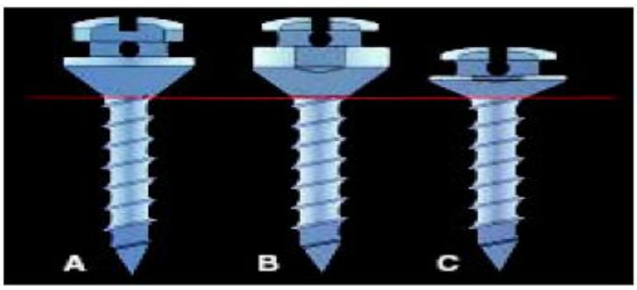


Fig. 2 The Spider screw **Fig. 3** Different height of spider screw (A - Regular, B – Low Profile, C - Low Profile Flat)

V. Possible Sites For Placement

1. Localization of the point of insertion (Fig. 4 and Fig. 5)
A volumetric tomographic image study was done to provide an anatomical map to assist the clinician in miniscrew placement in a safe location between dental roots [25].

The order of the safer sites available in the interradicular spaces of the posterior maxilla is as follows

- On the palatal side, the interradicular space between the maxillary first molar and second premolar from 2 mm to 8 mm from the alveolar crest.
- On the palatal side, the interradicular space between the maxillary second and first molars, from 2 mm to 5 mm from the alveolar crest.
- Both on buccal or palatal side between the second and first premolar, between 5 and 11 mm from the alveolar crest.
- Both on buccal or palatal side between the first premolar and canine, between 5 and 11 mm from the alveolar crest.
- On the buccal side, in the interradicular space between the first molar and second premolar, from 5 to 8 mm from the alveolar crest (Fig. 6).
- In the maxilla, the more anterior and the more apical, the safer the location becomes.

The following is the order of the safer sites available in the interradicular spaces of the posterior mandible

- Interradicular spaces between the second and first molar.
- Interradicular spaces between the second and first premolar.
- Interradicular spaces between the first molar and second premolar at 11 mm from alveolar crest.
- Interradicular spaces between the first premolar and canine at 11 mm from the alveolar crest.
- These findings are statistical evaluations of data coming from a group of nontreated patients. They represent a guide for the clinicians but do not eliminate the need for a radiographic evaluation in each individual case before miniscrew insertion.
- The features of the ideal titanium miniscrew for orthodontic skeletal anchorage in the interradicular spaces should be 1.2 to 1.5 mm maximum diameter, with 6 to 8 mm cutting thread and a conic shape.

A recent study on ‘‘Safe Zones’’ for miniscrew implant placement in different dentoskeletal patterns [26], the safest zones were the spaces between the second premolar and the first molar in the maxilla, and between the first and second premolars and between the first and second molars in the mandible. Maxillary interradicular spaces, particularly between the first and second molars, in the subjects with skeletal Class II patterns, were greater than those in the subjects with skeletal Class III patterns. In contrast, in the mandible, interradicular spaces in the subjects with skeletal Class III patterns were greater than those in the subjects with skeletal Class II patterns.

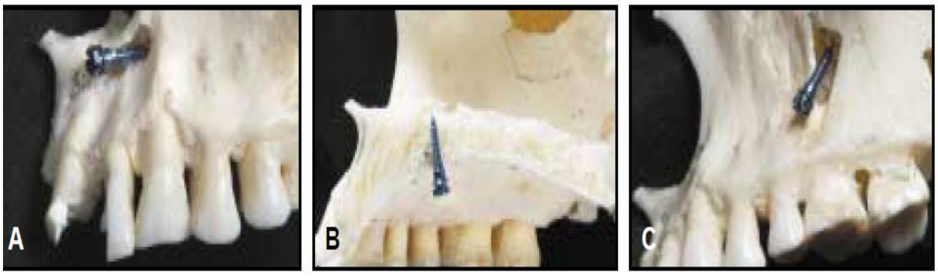


Fig. 4 Maxillary Mini screw location (A – Below nasal spine, B – In the palate, C – Infrazygomatic crest)

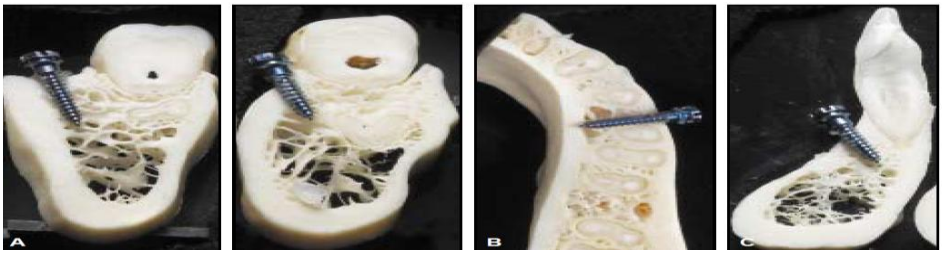


Fig. 5 Mandibular Miniscrew location (A - Retromolar area and molar region, B – Alveolar process, C – Symphysis)

Fig. 6 Placement of Miniscrew between 2nd premolar and 1st molar interradicular region.

Fig. 7 Loading of Miniscrew done with closed coil niti spring.

2. Direction of implant insertion

Melsen [27] 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 [28] 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 [29] 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.

Recently a finite element study has been done to optimize orthodontic palatal miniscrew implant insertion angulation [30] and showed that, the 30° angulation of miniscrew insertion towards the direction of applied force could lower the cortical bone stress and strain. Another study on insertion [31] concluded that placement of the miniscrew perpendicular to the cortical bone is advantageous in terms of biomechanical stability. Placement angles of less than 60° can reduce the stability of miniscrews when orthopedic forces are applied in various directions.

3. 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 [32].

VI. Loading And Anchorage Considerations

A systematic review was done on the loading protocols used for implants and/or screws in orthodontic treatments [33]. The study concluded that Loading protocols for implants involve a minimum waiting period of two months before applying orthodontic forces while loading protocols for screws involve immediate loading or a waiting period of two weeks to apply forces. Success rates for implants were on an average higher than for screws.

To evaluate the effects of the drilling procedure on the stability of the screws under early orthodontic loading [34] thirty two screws were inserted into the jaws of two beagles. The results showed that screws in the drill-free group showed less mobility and more bone-to-metal contact; they had more bone area compared with the drilling group. A total of 200 mini-implants (102 Abso Anchors and 98 Dual Tops) were placed in the mandible of eight minipigs [35] to determine the clinical and biomechanical outcome of two different titanium mini-implant systems activated with different load regimens, and concluded that immediate loading of miniimplants can be performed without loss of stability. A study was done to compare the loading behavior of predrilled and self-drilling miniscrews placed in the infrazygomatic crest of the maxilla [36]. The predrilled and self-drilling miniscrews were all significantly displaced in accordance with the force direction of the nickel-titanium coil springs. The amounts of miniscrew displacement were similar between the predrilled and self-drilling miniscrews

VII. Advantages And Disadvantages Of Miniscrews

Miniscrews are inexpensive, small in diameter, available in several lengths, can be inserted in any desired location including interradicular space and can be loaded immediately and withstand typical orthodontic forces of 200-300 gms for the entire length of treatment. Miniscrews does not need osseo-integration and can be easily removed by orthodontist. Since the primary means of retention of most micro implants is a mechanical lock within the bone, their stability depends almost entirely on the quality and quantity of available cortical and trabecular bone.

VIII. Clinical Applications

Miniscrews are used in closure of extraction space (Fig. 7), for symmetric incisor intrusion, correction of canted occlusal plane, dental midline corrections, extrusion of impacted canines, molar intrusion, molar distalization, molar meliazilation, intermaxillary anchorage, upper 3rd molar alignment [37].

Risk Factors For Dental Implants Placement [38]

Although dental implants may be placed under local anesthesia and require minimal surgery, good general health is an important consideration for uneventful healing and avoidance of inflammation around the implant.

1. Tobacco smoking (more than 10 cigarettes a day): A higher failure rate and greater marginal bone loss occurs in patients who smoke. Cessation of smoking at least one week before and eight weeks after dental implant surgery is recommended.
2. Age: As many Temporary Anchorage Device (TAD) are small, they should not influence the bone growth. Age restriction is for insertion of TADs in the median region of palate. It should be delayed until adulthood or at least until the midpalatal suture has calcified.
3. Risk of infective endocarditis: Placement of TADs causes an insult to oral mucosa and underlying bone, a prophylactic antibiotic has been recommended.
4. Diabetes: Placement of TADs and orthodontic treatment should be avoided in patients with poorly controlled insulin dependent diabetes, because these patients are susceptible to periodontal breakdown and have poor wound healing. Even in well - controlled diabetes good oral hygiene is essential, since these patients are more prone to gingival inflammation which can cause an implant to fail.
5. Juvenile idiopathic arthritis: There is no contraindication for the use of TADs in these cases. The clinician should however assess whether wrist joint is affected as these patients find difficulty in tooth brushing and flossing.
6. Medication: Any medication likely to hinder wound healing, gingival health and tooth movement should be taken into account prior to placement of a TAD. Examples: Bisphosphonates, immune modulators, anti-epiletics, anti-aggregation medication and anticoagulants.

Local risk factors:

1. Gingivitis and periodontitis: Patients with periodontitis should have their periodontal health improved prior to orthodontic treatment and placement of TADs. Because, it is one of the major contributing factors to the failure of TADs.
2. Reduced mouth opening: This should not be overlooked during the examination. Placement and regular cleaning of TADs and access to orthodontic attachments can be difficult, if not impossible, in a patient with limited mouth opening.
3. Bone quality: It is not necessary to wait for bone healing and osseointegration to occur because a TAD gains its primary stability from mechanical retention and can support immediate orthodontic loads. Bone quality or density influences primary stability: thick dense, cortical bone provides better mechanical locking for the implant than less dense, cancellous bone. Mandibular plane angle may influence the thickness of the

cortical bone and hence the stability of TADs. Patients with higher mandibular plane angle have significantly thinner buccal cortical bone compared with patients with average or low mandibular plane angles.

4. Radiotherapy: To enhance wound healing in TAD sites in patients receiving radiotherapy, hyperbaric oxygen therapy should be considered. This therapy is only effective on the vascular components of healing tissue. The cellular components regenerate spontaneously after cessation of radiotherapy.

IX. Complications Of Orthodontic Mini Screws [39]

Complications categorized in to three categories.

1. Complications during insertion
2. Complications during orthodontic loading
3. Soft tissue complications
4. Complications during removal

1. Complications during Insertion

Trauma to periodontal ligament or dental root Miniscrew slippage Nerve involvement Air subcutaneous emphysema Nasal and maxillary sinus perforation

2. Complications during Orthodontic Loading Stationary anchorage failure Miniscrew migration Soft tissue coverage of the miniscrew head and auxillary Soft tissue inflammation, infection and implantitis

3. Soft tissue complications Aphthous ulceration Soft tissue coverage of the miniscrew head and auxillary Soft tissue inflammation, infection and implantitis

4. Complications during removal Miniscrew fracture Partial osseointegration

X. Recent Studies On Biomarkers - To Asses The Health Of Dental Implants

Meffert indicated that when implant failure occurs,it is clinically accompanied by increased probing depth, patient reports of pain, and/or radiographic bone loss. This process has been named peri-implantitis. Kao et al reported that IL-1 could be identified in the implant crevicular fluid (ICF) and it should be used as a marker for monitoring the health status of dental implants. They also observed that the levels of IL-1 were significantly higher in patients with failing implants versus those with healthy implants

In the year 2007 a study was done to evaluate the IL-1 levels in healthy peri-microscrew implant crevicular fluid (MICF) and compare these with the IL-1 levels in healthy gingival crevicular fluid (GCF) around natural teeth during 3 weeks of distal canine movement. The results showed that microscrew implants did not demonstrate increased 1L-1 level during tooth movement. This supports the concept that microscrew implants might be useful as absolute anchorage devices [40].

Later ,Imjai Intachai did a study to monitor changes in chondroitin sulphate (CS; WF6 epitope) levels in peri-miniscrew implant crevicular fluid (PMICF) during orthodontic loading [41] The results showed that, CS (WF6 epitope) levels in PMICF can be detected and may be used as biomarkers for assessing alveolar bone remodelling around miniscrew implants during orthodontic loading. Nihal Hamamci et al studied the levels of interleukin (IL)-2, IL-6, and IL-8 around miniscrews used for anchorage during canine distalization [42] Interleukins were significantly increased, TNF-α levels increased significantly at 24 hours, Filis Acun Kya et al [43] the OPG and RANKL levels varied around loaded and unloaded miniscrew implants by Sukru Enhos et al [44] while in a recent study on interleukin 1β levels by Emul Sari [45] there was a trend of gradually reducing IL-1β levels around the miniscrew over the period after loading towards baseline which is suggestive of adaptive bone response to stimulus.

XI. Conclusion

Using mini implants as a temporary anchorage device is a boon for orthodontist, as there is no need for complicated clinical and laboratory procedures to facilitate safe and precise implant insertion. Miniscrews provide absolute anchorage, with the advantage of immediate loading when appropriate physiological forces are applied.

Because miniscrew provides an alternative to conventional mechanics, the use of miniscrew has offered a wide variety of treatment alternatives, mainly while treating challenging cases. Further studies on development of new design and miniscrew supported appliance in orthopedic field is yet to be done.

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