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Review Article

The Journey to Achieve Absolute Anchorage

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Abstract: Any Orthodontic treatment aims to achieve desired tooth movement with a minimum number of undesirable side effects. Since the beginning of specialty, strategies for anchorage control have been a main consideration in accomplishing successful orthodontic treatment. For a long time, Orthodontists have struggled to achieve effective anchorage control. The current paper highlights various aspects of miniscrew usage like ideal requirements, fundamentals of design, indications, concepts & controversies, limitations, safe zones, placement protocols, anatomic considerations and complications.

Keywords: Anchorage control, Bone screws, Mini-implants, Skeletal Anchorage.

INTRODUCTION

Any Orthodontic treatment aims to achieve desired tooth movement with a minimum number of undesirable side effects. Since the beginning of specialty, strategies for anchorage control have been a main consideration in accomplishing successful orthodontic treatment. For a long time, Orthodontists have struggled to achieve effective anchorage control.

However, their efforts have only been partially successful owing to Newton's third law of motion. Dissatisfaction with conventional methods led some pioneer orthodontists to explore the use of implants as a source of absolute anchorage. Although the concept of temporary implant anchorage has only recently been described, it was envisioned as early as 1945.

Historical Perspective

Gainsforth and Higley, first introduced the concept of skeletal anchorage using vitallium ramal screws in dogs [1].

- In 1964, Branemark mentor of modern implant surgery, observed a firm anchorage of titanium to bone with no adverse tissue response [2].
- In 1969, he demonstrated that titanium implants were stable over 5 years. He coined the term 'osseointegration'.
- He defined it as 'living bone in direct contact with a loaded implant surface.'
- In 1969, Linkow used a blade implant in the mandibular molar region as partial abutment for a bridge that was restored before orthodontics [3].
- In 1983, Creekmore and Eklund used a vitallium bone screw to treat a patient with a deep impinging overbite [4].
- Roberts et al in 1984 studied the effects of orthodontic force on titanium implants in rabbits; of 20 acid-etched titanium implants, 19 remained stable when a force of 100 g was applied [5].

DEFINITION

TAD can be defined as a device that is temporarily fixed to the bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit (indirect anchorage) or by obviating the need of reactive unit (direct anchorage); which is subsequently removed after use [6].

Classification

According to Composition

- Bioresorbable
  - Polylactide
- Bioinert
  - Titanium
  - Carbon
- Biotolerant
  - Stainless steel
  - Chromium-cobalt alloy
- Bioactive
  - Vitroceramic apatite hydroxide
  - Ceramic oxidised aluminium

According to Shape

- Cylindrical
- Conical
- Combination

According to Size

- 1.2 mm to 2 mm in diameter
- 4 mm to 12 mm in length

According to Site

- Buccal
- Palatal

According to Technique

- Self-drilling
- Self-tapping

According to Head type [7]

- Hook
- Ball head
- Eyelet/ loop
- Bracket head/ single slot
- Cross-slot

According to Area of implantation [8]

- Sub-periosteal
- Endosteal
- Transosseous

Ideal Requirements of Orthodontic Miniscrews [9]

Biologic Properties

- Provide effective osseointegration
- Biocompatibility
  - Should not be harmful to hard and soft tissues
  - Should not contain toxic diffusible substances
  - Should be free of potentially sensitizing agents that may cause allergic reactions
  - Should have no carcinogenic or mutagenic potential
  - Should be bacteriostatic or at least not encourage bacterial growth
  - Should be tasteless and odourless

Physical Properties

- Should be dimensionally stable under all condition of service
- Should possess adequate strength and resilience and resist biting or chewing forces, impact forces and excessive wear

Handling Characteristics

- Should not generate toxic dust/ fumes during handling and manipulation
- Final product should be easy to polish and should retain the polish
- Should also be possible to repair in case of unavoidable breakage

Economic Considerations

- The cost of the material and its processing should not be too high

Fundamentals of Screw Design

- No thread for soft tissue sealing
- Wider diameter to increase cortical bone support
- Trapezoidal thread to maximize cortical bone support
- Tapered core for bone-condensing effect
- Sandblasted and acid-etched surface for biocompatibility
- 0.022-inch slot dimension
- Hexagonal head to prevent epithelial creeping
- Reverse button thread for drill-free insertion
- Narrower diameter to prevent root damage
- Corkscrew-like tip for drill-free insertion

CONCEPTS & CONTROVERSIES

Method of insertion: Drill-free v/s pre-drilling

Kim *et al*., compared the self-drilling 1.6 mm diameter screw (drill free method) with the 1.2 mm diameter screw inserted after drilling with a bur (pre-drill method) [10]. Their research suggested better stability and greater bone density between the threads of the self-drilling miniscrews.

Primary Stability: Osseointegration versus Mechanical interlocking

The orthodontic miniscrew implant is comparatively new and developing clinical tool. Whether the miniscrew undergoes osseointegration and whether osseointegration contributes to the stability of a miniscrew subjected to an orthodontic force are debatable issues.

Osseointegration is defined as a state in which, under the optical microscope, there is direct contact between the implant and bone without any intervening soft tissue and which enables transmission of the external stresses to the bone structure in a functional manner.

Some clinicians have suggested that stability of the orthodontic miniscrew is achieved through mechanical retention, that is interlocking of the miniscrew threads and cortical bone. Paik stated that the stability of the miniscrew comes from mechanical interlocking between the screw and the bone, and not by osseointegration [11]. However, more recent reports support the view that osseointegration does occur.

It seems that complete osseointegration is not mandatory for orthodontic miniscrew anchorage. According to Roberts et al as little as 10% integration at the interface with living bone is adequate for orthodontic anchorage.

Osseointegration may work as a double-edged sword by increasing the stability if the miniscrew during orthodontic treatment but at the same time making removal after treatment more difficult.

Timing of loading: Immediate v/s Delayed loading

- Waiting for a short period to allow the oral soft tissues to heal after placement of the screw comes in immediate loading category.
- Micromotion following early loading interferes with osseointegration.
- Roberts et al, in their experiments on rabbit femurs, recommended a 6-week preloading healing period to allow sufficient mature bone to adhere directly to the implant surface [12].
- Melsen and colleagues performed a histologic evaluation of the bone-screw contact after 1, 3- and 6-months intervals prior to loading based on which they advocated immediate loading [13].

- Melsen and Costa loaded 16 titanium vanadium screws with 25-50 grams of force immediately after insertion; all but 2 screws were successfully osseointegrated [14].
- Huja also recommended a short healing period of 1 week prior to loading with relatively light loads (3-5N [305-510g]) [15].

Load Characteristics and Implant Stability

- Forces applied to the orthodontic miniscrew implant are mostly light, uniform and predictable.
- Studies evaluating the effect of different loads on osseointegrated implants have shown that static loads (constant loads with uniform force levels) stimulate production of denser cortical lamellar bone and greater amount of bone-implant contact at the interface than no load or dynamic loads (cyclic loads with variable force levels).

FACTORS AFFECTING IMPLANT STABILITY [9]

Host Factors

- Optimize site selection
- Thick Cortical bone
- Good soft tissue conditions

Operator Factors

- Ensure proper manipulation
- Avoid vibration
- Minimize surgical trauma
- Standardized procedures

Implant Factors

- Minimize surgical trauma
- Maximise cortical bone support
- Distribute orthodontic load
- Use biocompatible material

ARMAMENTARIUM

Fig-1: Surgical Implant Kit
(FavAnchor™ Skeletal Anchorage System, India)

Hand Instruments

- Straight hand driver
- Short hand driver
- Contra-angle hand driver

Motor-driven Rotary Instruments

- Implant Motor
  - ➢ Low speed handpiece with contra-angle head

- Connecting Burs
- Pilot Drill

Indications

- Maximum anchorage cases: High-angle; bimaxillary protrusion cases; Patients who fail to cooperate with use of headgears
- Cases with multiple missing teeth
- Adjunctive adult orthodontics with increased need for anchorage
- Difficult tooth movements like anterior/ posterior intrusion; en-masse distalization; molar uprighting and molar distalization
- To attach orthopaedic forces to jaw like headgear/facemask in cases of lack of anchorage units

LIMITATIONS

- Systemic disease affecting bone metabolism and major medically compromising condition
- Patients younger than 12 years of age (with incomplete skeletal growth); palatal implants to be placed away from mid-palatal suture [16]
- Heavy smokers
- Bone metabolic disorders
- Areas of bone remodelling like healing socket or near a deciduous tooth
- Thin cortical bone: not advised in less than 0.5 mm cortical bone
- Lack of clinical skill of the orthodontist makes it a multi-disciplinary procedure
- Ethical issues: Should not be placed without a purpose; must be a definite indication for placement and should have a low risk-benefit ratio

SAFE ZONES [17]

Posterior region

- More apical the site; safer the placement
- Inter-radicular bone between second premolar-first molar, first molar-second molar safe for placement
- Palate; optimal site is between 4-5,5-6,6-7. Posterior palatal slope should be placed mesial to the 2nd molar (risk of injuring the greater palatine nerves and vessels

Anterior region

- Optimum site for placement in upper anterior region is 6 mm apical to CEJ between maxillary central and lateral incisor
- Optimum site for placement in lower anterior region lies between mandibular lateral incisor and canine
- Can also be placed in ANS region in upper anteriors

Other locations

- Mandibular symphysis
- Retromolar region
- Infra-zygomatic areas
- Maxillary tuberosity region

Placement Protocol

Pre-operative information for Patients

- It takes about 10 min to place one implant
- During surgical placement, a feeling of stiffness may occur in spite of local anesthesia
- The teeth may be sore even though they are not touched during the procedure
- Soft tissue surgery such as frenectomy may be necessary
- The position of the implant can be modified during the process of treatment
- It is crucial that the patient make his or her own choice, and informed consent is required for the purpose of risk management in the event that unwanted results, such as loosening, occur

Sterilization and preparation for Placement

- The patient is instructed to rinse with a chlorhexidine solution
- Wipe the patient's mouth area with an oral disinfectant
- Place a sterile drape over the patient's face to isolate the field
- Wipe the recipient area with an oral disinfectant
- Apply a topical anesthetic gel
- Infiltrative anesthesia is given with 2% lidocaine with epinephrine 1:50000

Stages of Placement

Pre-operative examination Stage

- Insertion site is selected according to the anatomic conditions and biomechanical requirements

Marking Stage

- Insertion site should be cleaned with povidone iodine
- Periodontal probe is used to perforate gingiva at the correct insertion site

Perforating Stage

- This stage is important because cortical bone is the component most resistant to implant insertion
- Following two ways can be used to perforate
- Surgical drill
- Use of an implant

Guiding Stage

- The screw should be engaged with the bone and inserted at a planned angle
- Implant should be inserted through rotation of the screw with minimal vertical force
- Palm Grip recommended for perforating and guiding stage

Finishing Stage

- Implant should be inserted to the planned depth, and the implant head should be exposed to an adequate extent
- Finishing solely with rotational force is crucial to maximize contact with the cortical bone
- For the finishing stage, it is better to use the finger grip because rotation should be applied very cautiously. The handle should be grasped gently with only 3 fingers

Post-Operative Instructions

- There may be some amount of pain
- Ulceration may occur because of mechanical irritation
- Brushing of the implant is also necessary, brush as gently as possible
- Never touch implant with finger or with the tongue
- During meals, hard food may be a reason for mechanical irritation
- Irrespective of the type implant placed, patients are instructed to rinse their mouth with water for the first 24 hours after surgery
- On the first post-operative day, chlorhexidine digluconate rinses are prescribed three times daily for 30 seconds and continued for 10 days

Removal

- If the open method of microimplant placement is used, the clinician can engage the microimplant head with a hand-driver and turn it in a direction opposite to that of insertion (i.e. counterclockwise) for easy removal
- In the closed method, a small incision first is required to expose the head of the microimplant. In this case, anesthesia is advisable
- During microimplant removal, the initial turn sometimes offers significant resistance. Therefore, caution should be exercised during the first turn in order to avoid implant breakage
- Patients should avoid eating hot and salty foods for 2 days to prevent pain or aggravation of the wound

ANATOMIC CONSIDERATIONS

Maxilla

In the maxilla, the commonly used sites for miniscrew placement are the buccal/palatal alveolar area, the midpalatal region and the maxillary tuberosity. The anatomic structures that need to be considered are:

- Tooth roots
- Greater palatine neuromuscular bundle
- Nasal cavity
- Maxillary sinus

Tooth Roots

- Ensure sufficient inter-radicular space at the chosen site. The inter-radicular space is greater between tooth roots that diverge from each other

- In the maxilla, the inter-radicular space between the roots of second premolar and molar tends to be greater than between the first and second molars at a level 5-7 mm apical to the alveolar crest
- Due to the conical shape of the tooth roots, the inter-radicular space increases towards the apical area
- In most patients the miniscrews can be placed at the level of the junction between the cervical and middle thirds of the root
- It is preferable to insert a miniscrew after the leveling and aligning of the teeth is complete

Greater palatine neuromuscular bundle

- It enters the oral cavity through the greater palatine foramen at the junction between the palatine process of the maxilla and the oral surface of the palatine bone, medial to the third molars
- Placing the palatal alveolar miniscrew within 10 mm from the cementoenamel junction reduces the risk of damaging it

Nasal Cavity

- The midpalatal suture, the region with the thickest cortical bone in the palate, is one of the most suitable sites for miniscrew implant placement
- However, placement of the miniscrew implant in this area should be avoided in growing children because ossification of the suture is incomplete before the age of 23 years
- As the bone thickness is limited nasal cavity maybe perforated if the miniscrew used is too long

Maxillary Sinus

- The stability of the buccal alveolar miniscrew is compromised when the floor of the maxillary sinus extends inferiorly to the alveolar bone between the maxillary posterior teeth.

Mandible

- The mandible is a relatively risk-free area for miniscrew placement
- The anatomic structures that need to be considered are mainly the tooth roots.
- All the other important mandibular structures: the mandibular canals, mental foramina, buccal and lingual nerves-are located at a distance so there is little risk of damage during routine miniscrew placement.

Tooth Roots

- In the mandible, the inter-radicular distance is greatest between the first and second molars, 5-7 mm apical to the alveolar crest

Preferable to place the miniscrew, when levelling and alignment is complete

Bone Quality [18]

- According to Misch classification, the maxillary alveolar bone is mostly composed of porous bone, corresponding to D3 or D4, whereas the mandible has dense bone classified as D2 or D3
- The maxillary cortical plate is thicker in the palate than on the buccal surface
- The palatal cortical bone thickness at 4 mm or more apical to the cementoenamel junction is uniform throughout
- The mean cortical thickness of the mandibular buccal alveolar bone increases towards the ramus

Soft tissue thickness

- The thin, keratinized soft tissue in the midpalatal area is more favorable for miniscrew placement than the thick soft tissue on the palatal slopes
- The retromolar pad is covered with thick keratinized gingiva and an incision is required before the placement of the miniscrew
- A miniscrew with a longer soft tissue interface or neck is useful for this purpose

COMPLICATIONS [7]

Success rate for miniscrews range from 80-100%; slightly lower than that of mini plates. Factors responsible for prolonged stability of the mini screws

- Careful operator technique
- Screw design
- Proper insertion site

Immediate Failure

Occurs during the initial healing phase. Can be because of following reasons:

- Improper insertion sites
  - Recent extraction sockets

- Rare cortical bone
- Redundant overlying soft tissues
- Improper handling during insertion
  - Wobbling
  - Abrupt change of path during insertion

Percussion test/ Periotest measurements to be taken post implant placement.

Delayed Failure

Even if initial insertion seems favourable miniscrew loosening may take place during active orthodontic treatment; exact reason not clear.

Possible reasons

- Excessive loading from the elastic component
- Sudden impact on miniscrew head during mastication
- Possible contact with the root surface
- Excessive/ insufficient bone remodelling

Other Complications

- **Soft Tissue Inflammation**
  - Inflammation/ abscess relatively rare when miniscrews are placed in the attached gingiva and proper oral hygiene is maintained
  - Buccal frenum impingement should be taken care of as it may pass unnoticed due to stretching of buccal mucosa during insertion
  - Incisional frenectomy can be performed if insertion is critically indicated in frenum area
  - Orabase/ utility wax to be used in cases of ulceration

- **Root Damage**
  - Serious injury like root perforation or fracture is very rare in cases with self-drilling miniscrews; as difference between the relative hardness of bone and cementum can be readily sensed by the operator
  - Minor injuries on cementum undergo spontaneous resolution after removal of miniscrews [19]
  - Invasion of miniscrews in periodontal tissue may not cause any discomfort or pain to the patient
  - Root contact during tooth movement: Should be assessed clinically by no movement of tooth, excessive tipping of tooth or loosening of miniscrew. Often asymptomatic

- **Miniscrew Fracture**
  - Rare if miniscrew diameter is more than 1.5 mm and is tapered
  - Guide drilling is indicated in cases associated with increased resistance by the bone
  - With miniscrew fracture, removal of bone around the miniscrew is indicated

- **Pain**
  - Pain comes from nerve endings in the soft tissue and periosteum, not necessarily from the bone proper
  - Initial two days is normal; mild analgesics should be administered to alleviate pain

- **Bleeding and Numbness**
  - Not associated with miniscrew placement in interdental/ midpalatine areas
  - Care should be taken not to hurt the greater palatine neurovascular bundle

CONCLUSION

Inhibition of undesirable tooth movement in both arches is possible with the use of skeletal anchorage. The use of implants and bone screws has widened the envelope of Orthodontic treatment, providing an alternative to orthognathic surgery (particularly in the vertical dimension) and allowing asymmetric tooth movement in three planes of space.

Miniscrews offer the biomechanical lead that permits more effective and efficient treatment with fewer auxiliaries. Envisaging resistance to tooth movement can curtail adverse responses, lead to more successful treatment of complex problems, and deliver efficient care in less time. Teeth can be moved directly (without anchorage loss) to their final positions.

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