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THE SUM AND SUBSTANCE OF SKELETAL ANCHORAGE SYSTEM – A NARRATIVE REVIEW

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ABSTRACT

The introduction of skeletal anchorage system (SAS) in the field of orthodontics has expanded the spectrum of skeletal correction of malocclusion beyond its existing boundaries. Miniplates have proven to be a reliable, effective and predictable treatment modality. The treatment planning of borderline and severe jaw deformities has become simpler and less invasive with SAS. In addition, now nonsurgical and non extraction treatment options are available for a variety of conditions such as molar distalisation or vertical maxillary excess. This review illustrates the basics of skeletal anchorage system and its versatility in the correction of malocclusion with orthodontic or orthopaedic movement in all three planes of space. The advantages and disadvantages over the conventional mini implants alongwith the scope of biodegradable miniplates in orthodontics has also been discussed.

KEYWORDS: Bone Plates, Jaw Abnormality, Malocclusion, Osseointegration.

1. INTRODUCTION

A fundamental requirement of successful treatment of various malocclusions in the field of orthodontics is the presence of secure anchorage. Achieving controlled tooth movement without undesirable reciprocal movement of the anchorage unit during space closure is one of the prime considerations before treatment commencement. It is essential to predetermine the reactive load on the anchor tooth during active tooth movement. This is based on the force magnitude, type, direction and duration applied on the reciprocal teeth. If the patient's innate periodontal anchorage potential is unable to accommodate for the potential required, additional intra-oral or extra-oral anchorage devices have to be employed to prevent any side effects.[1] Over the years, many devices and techniques have been developed by various orthodontists to provide the same.

The traditional auxiliary anchorage devices such as headgear or intermaxillary elastics possess certain disadvantages such as visibility, dependency on patient compliance and the risk of unwanted side effects. For example, the use of Class-II elastics can lead to canting of the occlusal plane in the clockwise direction, extrusion of teeth and protrusion of the maxillary incisors.[1] The skeletal anchorage system provides Type A anchorage which is usually difficult to obtain with the traditional devices.

The aim of this article is to exemplify the basics of skeletal anchorage and describe its applications in various clinical scenarios.

1.1 History of Skeletal Anchorage

The first possible mention of the skeletal anchorage system was by Creekmore and Eklund in 1983,[2] who suggested the use of a vitallium bone screw for intrusion of the maxillary central incisors. Jenner and Fitzpatrick.[3] reported the use of a bone plate as an additional orthodontic anchor to retract lower molars. The first use of titanium miniplates and miniscrews in orthodontics was described by Sugawara et al,[4] where due to lack of molar anchorage in the lower arch, a titanium miniplate and a miniscrew was added to correct a severe crossbite. Subsequently in 1998, Sugawara et al,[5] utilized the skeletal anchorage system (SAS) comprising of titanium miniplates for Class III correction by lower molar distalization. Sherwood in 2002,[6] stated that the intrusion of maxillary molars using miniplates resulted in counterclockwise mandibular rotation and correction of anterior open bite. Sugawara and Nishimura (2005) described the skeletal anchorage system (SAS) as an orthodontic anchorage modality utilizing titanium miniplates and monocortical screws temporarily fixed in the maxilla and/or mandible for absolute orthodontic anchorage.[7] Over the years, many modifications such as the Beneplate system consisting of a 1.2mm-thick stainless steel plate connected to the orthodontic appliance with a .045" stainless steel wire have been introduced.[8]

Thus, skeletal anchorage system is currently quite popular as a system to compensate for malocclusions that cannot be corrected with traditional orthodontics.

2. Disadvantages of Mini implants

Orthodontic miniscrews have a failure rate of 13.5 %. Unlike prosthetic implants, the stability of miniscrews is not based on the principle of osseointegration suggested by Branemark.[9] In contrast, it depends on the mechanical locking of threads into the bony tissues which consequently hold up the orthodontic loading.[10] The risk factors associated with the stability of miniscrews are general factors like age, tobacco smoking, systemic diseases like diabetes, infective endocarditis or juvenile idiopathic arthritis or local factors like bone quality, poor oral hygiene, type of mucosa etc.[11]

Many complications witnessed with the use of miniscrews over the years have lead the researchers towards the use of skeletal anchorage systems. Some of them include screw fractures due to the effect of insertion torque and bone quality at the site of the insertion and undesired effects like screw loosening and fracture.[12,13] Irreversible damage to the adjacent teeth and the periodontium have also been reported. Further, screw–root proximity is considered a major risk factor for screw failure as it has the potential to induce pain, infection and root resorption. However, damage to the adjacent soft tissues is often reported to be transient.[12] Rare complications such a nerve injury, air subcutaneous emphysema and maxillary sinus perforation have also been observed.[14]

3. Principle

Branemark's principle of osseointegration largely forms the basis of skeletal anchorage. Osseointegration is described as the direct contact between living bone and an implant visible through an optical microscope.[9] The miniplates are anchored to the bone by means of the monocortical miniscrews. These screws are more vulnerable to failure during the early stages due to the presence of immature interfacial bone. Post insertion, the immediate retention of the plates is entirely based on bone strength and the design of the screw.[15] Previous histological studies have reported increased bone remodeling activity at the screw or implant-bone interface with time.[16,17] It has been demonstrated that within 1 mm of an implant surface the bone displays a lower microhardness and a sustained elevated remodeling rate preventing the supporting bone from fully mineralizing.[18] In addition, higher bone contact may be achieved with the use of self-drilling screws.[19] Cortical plate thickness at the site of insertion is also related to the primary stability. The cortical plate thickness varies from approximately 0.8 to 2.4 mm. At some sites, only a single thread engaged the cortical bone while at some other sites 3 threads of the screw were engaging the cortical bone, providing for more primary stability.[15]

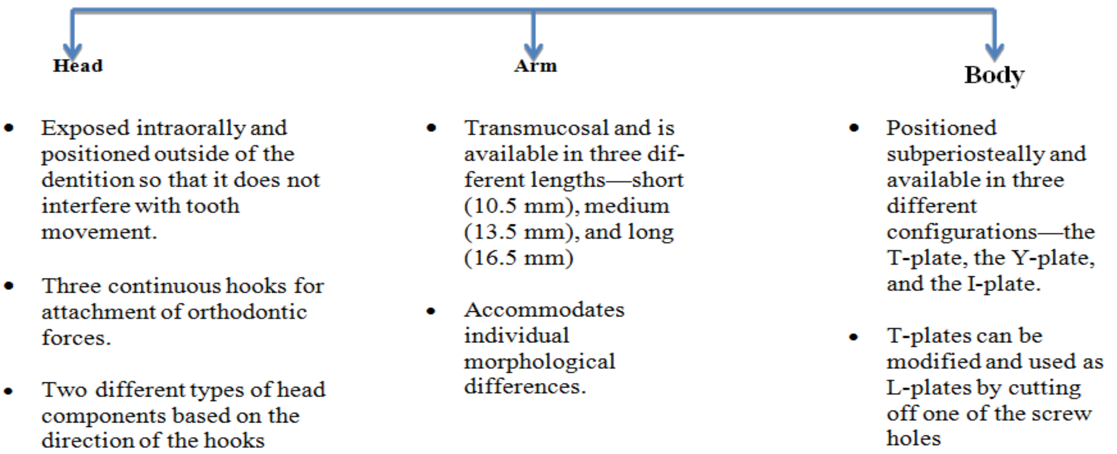
Post treatment completion, it is desirable that the screws can be easily removed by hand removal with a surgical driver without the use of trephines. To facilitate easy removal, the screws are not subjected to pre insertion surface treatments such as sandblasting, etching or plasma spraying which are usually done to increase the percentage of bone attachment. As a result, primary stability is important for early survival.[20]

4. Components of SAS

The disadvantage of using standard miniplates of maxillofacial surgery in orthodontics is that the emergence area of these plates is not rounded and they have sharp corners causing delayed wound healing and soft tissue irritation. Emergence point of the plate is defined as the point where the plate arm is exposed or perforating the oral mucosa and is an important consideration during insertion of the miniplate.[19]

SAS is comprised of bone plates and fixation screws.[4]

4.1 Bone Plate



Fixation Screws

The miniplates are fixed on the bone using screws. Depending on the diameter of the fixations screws, the miniplate systems can be classified as the 1.0, 1.5, 2.0 or 2.3 mm systems. The surface areas of higher diameter (2 or 2.3 mm) screws are larger and have greater mechanical strength. With increase in diameter of the screw, the chances of root damage increase, however with a small screw (diameter is smaller than 2 mm), mechanical stability may not be sufficient for orthodontic anchorage.[19]

The site of miniplate insertion requires at least 2 mm of cortical bone thickness. The screws used are monocortical in nature with 2.0 mm in diameter and 5.0 mm in length. The screws have an internal tapered square head with a self-tapping threaded body.[4] The advantage of using a self-tapping design is the attainment of higher bone contact.[20]

Screws with 2.5 mm diameter are used as emergency screws.

4.3 Material

Miniplates are generally made of Stainless steel (SS), commercially pure Ti (grade 3) and Ti-Ag (2 at% Ag) alloys, all highly biocompatible materials.[21] One of the characteristic differences between them is the presence of direct bone contact (osseointegration) between dental implants and the host bone with the Titanium.[22] However, Stainless Steel has a tendency to develop a fibrous tissue interface between the screw and bone.[23,24] But, inspite of these differences, studies have proven that both materials display predictable clinical outcomes and fulfill the biochemical requirement of stability.[25-27] Papadopoulos et al.[28] conducted a meta-analysis where they reported success rates of 87.7% for both TiA and SS. A major difference between the two materials is the greater mechanical characteristic seen with stainless steel when the insertion or removal torque exceeds the torsional strength.[28-31] In addition, as the stainless steel is stronger that the traditional Titanium alloy, it has a lesser risk for breakage.[32,33] A study by Gritsch et al.[34] found that there were no significant differences in percentage of bone to implant contact between the two metals. However, 4 weeks after placement of the stainless steel screw, a 5% threshold of bone-to-implant contact lead to increased survival rate values.

5. Sites of Placement[35]

The sites of the placement in the maxilla and mandible are dependent on a variety of factors such as the bone cortical thickness, level of maxillary sinus lining etc. The anterior maxillary sinus wall is too thin for fixing the miniplate with monocortical screws. Thus, the sites often used in the maxilla are the piriform rim and zygomatic buttress as the thickness of the cortical bone in these regions allows the securing of the miniplate with multiple fixation screws. I shaped plates are usually placed at the piriform rim for the intrusion and protraction of upper molars while the Y shaped plate is placed over the buttress to intrude and distalize upper molars. Some studies have reported minor perforations in the sinus membrane with predrilling, which necessarily may not be a concern. Increasing the primary stability of fixation screws in the maxilla has been observed with self drilling screws as they do not require a pilot hole.[36] At least two miniscrews should be inserted to avoid rotation and to resist the orthodontic forces applied but three screws are preferred.

Lateral cortical bone in the mandible is used for screw fixations in majority of the locations in the mandible except the area adjacent to the mental foramen. In the mandible, usually the T-plate or the L-plate is placed in the mandibular body to intrude, protract or distalize the lower molars. The L plate can also be placed at the anterior border of the mandibular ramus where it can be used for the extrusion of impacted molars. Monocortical screws are used when the miniplate is positioned directly over the mandibular canal or near the mental foramen to avoid injury to the inferior alveolar neurovascular bundle. The thickness and density of the mandibular cortical bone may cause fracture of the screw when using a self-drilling screw.[37,38] Thus, in the mandible, it is essential to create a pilot hole for use with both self-tapping and self-drilling fixation screws.

6. Applications

6.1 Forces

The miniplates are loaded about three weeks after their surgical placement. The time period of three weeks is mainly required for soft tissue healing and not for osseointegration. The anchor plates are immediately removed after orthodontic treatment. They withstand approximately 500 – 900 g of force.[4]

6.2 Direction

Miniplates have been used to carry out the desired movements in both the vertical and the sagittal plane.[40]

Sagittal plane – Retraction, Complete arch distalization, Molar protraction and orthopaedic forces for skeletal correction.

Vertical plane – Complete arch or individual tooth intrusion.

Several case studies have been carried out where the miniplates have been used for various purposes such as maxillary protraction with bone plates in the lateral nasal wall,[41] complete arch distalization of the maxillary arch with palatal plates,[42] molar protraction using miniplates at the piriform rim or the anterior mandibular body or molar intrusion with plates at the zygomatic buttress or posterior mandibular body.[40]

7. Contraindications of Miniplate Placement

Systemic diseases e.g. infective endocarditis, diabetes, epilepsy or local factors such as reduced mouth opening are considered as risk factors for miniplate placement. Another factor that affects the miniplate placement is the bone density where thick dense, cortical bone is considered better for primary stability than less dense cancellous bone.[11] Moreover, younger age increases the risk of failure because of lower bone density, thin cortical bone and their relations to poor primary stability of the fixation screws.[36]

7.1 Complications

Miniplates are associated with several complications such as requirement of surgery to place and remove the miniplates, increased chances of acute infection with clinical evidence of pain, swelling and pus or mucosal coverage or numbness over the placement site. In addition to these plate loosening, plate fracture or mucosal dehiscence around the plate or perforation of the maxillary sinus in the posterior region of atrophic maxillae and in the zygomatic region can be visualized.[36,43]

7.2 Stability

The success rate of the SAS miniplates was high at 98.6%. The failure rate due to miniplate mobility in the mandible was higher due to inflammation or infection, progressive compression necrosis of the bone around the screws and repeated excessive impact during mastication.[36,43]

8. Further Scope

The titanium miniplates used are often associated with certain disadvantages such as breakage, requirement of an additional surgical intervention for removal, thermal sensitivity, plate migration and interference with diagnostic imaging.[45-48] In order to overcome these drawbacks, the concept of plates made of a bioresorbable and biodegradable material such as the polylactic or polyglycolic acid were introduced in maxillofacial surgery. It is considered to be an effective fixation system as it offers several advantages over titanium fixation such as the absence of corrosion and accumulation of metal in tissues, decreased pain, no need for additional surgery for plate removal and reduced stress shielding.[45,47,49,50-51]

Previously, some animal studies have been done in orthodontics where the researchers have investigated the possibility of using a bioabsorbable implant as orthodontic anchorage.[52] The implant used was 2.0 mm X 8.0 mm, made from poly-L-lactic acid (PLLA; molecular weight: 200,000). It was found that the implant had favorable biocompatibility and strength. However, a sudden decrease in the mass of the screw due to phagocytosis was reported to commence usually after 18 to 24 months.[53,54] Post 18- 24 months, they degrade and disintegrate harmlessly in the patient.

However, some problems have been associated with their use such as a high inflammatory response, rapid loss of initial implant strength, inadequate stiffness and weakness compared to metallic implants.

Thus, the introduction of these plates in orthodontics requires prior extensive research to overcome the associated drawbacks and enhance biocompatibility, mechanical strength and bioactivities.

Conflict of interest: None

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