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Review Article

A descriptive review on the use of skeletal anchorage in orthodontics (Part I)

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ABSTRACT

Anchorage has been defined as a resistance to unwanted tooth movement. It is imperative for the treatment of both dental and skeletal malocclusions. Skeletal anchorage provides better chances to obtain absolute anchorage in orthodontic tooth movement. The topic of skeletal anchorage is vast and compiling it in one single article will be an injustice to the readers. So, we have divided this into two review articles under the headings of introduction, evolution and historical background, the means of skeletal anchorage which will be discussed in this first part followed by the design and function of screw-type orthodontic mini-implants, placement sites, surgical procedures, loading approaches, biocortical and resorbable implants and conclusion in the second part.

1. Introduction

Anchorage has been defined as a resistance to unwanted tooth movement. It is imperative for the treatment of both dental and skeletal malocclusions.[1] 18th century and thereafter, eminent orthodontists such as Gunnell, Desirabode, and Angle have realized upon the limitations of moving teeth against other teeth used for anchorage, introducing ideas such as the use of extraoral and occlusal anchorage.[2]

Newton's third law of motion must be considered during treatment planning. According to Proffit,[3] during treatment planning reciprocal effects of forces that are created within the dental arches should be given due consideration and they should be controlled in order to maximize the tooth movement that is desired and to minimize the occurrence of undesirable side effects. Absolute or infinite anchorage has been defined as no movement of the anchorage unit (zero anchorage loss) upon application of a force to move the teeth.[4] This is possible only by means of skeletal anchorage.

2. Classification of Anchorage

Ottofy[5] succeded E.H. Angle in classifying anchorage as simple, stationary, reciprocal, intraoral, intermaxillary, or extraoral. Moyers[6] expanded this classification by subcategorizing extraoral anchorage and splitting simple anchorage into single, compound, and reinforced subcategories.

Gianelly and Goldman[7] suggested the terms maximum, moderate, and minimum based upon the extent to which the teeth of the active and reactive units move when a force is applied.

Marcotte[8] and Burstone[9] classified anchorage into categories—A, B, and C—based upon the anchorage unit's contribution to space closure.

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Tweed[10] called it anchorage preparation which was the distal tipping of posterior teeth to utilize the mechanical advantage of the tent peg causing intrusion of the molars before retracting anterior teeth.

3. Skeletal Anchorage

Skeletal Anchorage includes all the devices fixed to the bone with the goal of increasing the anchorage for orthodontic purposes.

1. Branemark implants[11,12]
2. Retromolar implants[11]
3. Onplants[13]
4. Zygomatic wires[14]
5. Ankylosed teeth[15]
6. Palatal implants[16]
7. Miniplates[17] and mini screws[18–22]

3.1. Evolution and historical background

The constant development upon the traditional orthodontic anchorage led to the evolution of Skeletal anchorage devices. Evidentally, in 1969 when Linkow[23] used a blade implant in the mandibular 1st molar region as a partial abutment before orthodontics, was the the first report concerning the use of osseointegrated implants for orthodontic purposes. Kokich[24] and Smalley[25] and Smalley and Blanco[26] developed protocols for accurate placement of implants for both orthodontic anchorage followed by restorative therapy.

In 1983, Creekmore and Eklund[18] used a vitallium bone screw inserted in ANS to treat a patient with a deep impinging overbite. Guyman[15] 1980showed ankylosed teeth can be successfully used as anchors for palatal expansion which in 1985 was used by Kokich[27] to treat Apert syndrome. In 1995 Block and Hoffman[13] designed a thin titanium alloy disk called 'onplant' being placed in fully dentate patient.

In 1996 Jurgen Glatzmaier[28] developed implant of biodegradable polylactide with a metal superstructure. Melsen B[14] in 1988 tried zygoma ligatures as a form of maxillary anchorage, in a partially edentulous patient. In 1997 Kanomi[19] introduced a miniature implant (5.0 mm x Ø1.0 mm titanium screw). In 1998, Costa[21] presented a screw with a bracket like head to be used as orthodontic implant. Since then, multiple other implants have been introduced each presenting different designs and features.

3.2. Means of skeletal anchorage

3.2.1. Intentionally ankylosed tooth for anchorage

Guyman[15] in 1980, found that ankylosed teeth can successfully be used as anchors for palatal expansion in nonhuman primates.

Advantages are[29]

1. The tooth is biocompatible
2. Produces skeletal rather than dental movement
3. The procedure is effective with negligible risk

Disadvantage

The ankylosed tooth has a limited life expectancy before complete root resorption and exfoliation.

After Kokich et al,[27] Sheller[29] In 1991 conducted a study to develop a simple and inexpensive procedure to ankylose primary teeth, to be used for protraction.

3.2.2. Zygoma wires

Melsen B[14] in 1998 introduced the Zygomatic ligature which is an inexpensive and simple method of anchorage for mechanics required in maxillary incisors. He suggests that, the best bone quality in a partially edentulous patient is found in the region of the zygomatic arch and the infrazygomatic crest which can be used for anchorage purposes.

Advantages:

1. No special equipment needed
2. Inexpensive material
3. Immediate use post insertion for anchorage
4. Lesser treatment duration
5. Removal is quick and easy

3.2.3. Conventional dental implants

The number of orthodontic adult patients is increasing who are often partially edentulous. For using conventional dental implants as anchors in such case firstly orthodontic treatment is completed and the implant is used later as abutments for fixed restorations.

3.2.4. Palatal implants and onplants

Palatal implants and onplants are miniature, osseointegrated devices, but because they are removed after orthodontic treatment, they qualify as Temporary Anchorage Devices (TADs). Used in fully dentate arches which cannot accommodate implants in the alveolar process and also do not hamper space closure. Consequently, implants have to be placed in other locations.[30] For the maxilla, both the midsagittal[31] and paramedian[32] regions of the hard palate have been proposed for easy accessibility and excellent peri-implant conditions beIng covered by attached mucosa.

Palatal implants are osseointegrated and can be connected by a transpalatal arch (TPA), thereby offering absolute orthodontic anchorage.[33]

Advantages of palatal implants include –

1. Easy to use.
2. Increased stability.
3. No requirement of patient cooperation.
4. Increased aesthetics.

Palatal implants compensate for small length by having a machined or modified surface (SLA meaning sand blasted, large grit, acid).

Currently palatal implants are available in two systems-

1. The Straumann Orthosystem.
2. The flange fixture.

The Straumann Orthosystem was developed by Wehrbein.[16] The flange fixture is primarily used for anchoring facial prostheses but due to its small length it is also been used in the palate.[33]

Uses of palatal implants-

1. For creating or closing maxillary spaces
2. For maxillary mesialization or distalization
3. For correcting asymmetries involving midline and intercuspation
4. In cases of partial edentulism of posterior region such that the anterior teeth can be altered three dimensionally.
5. Adult maxillary expansion

3.3. *Resorbable palatal implants*

In 1996 Jurgen Glatzmaier[28] developed implant of biodegradable polylactide with a metal superstructure which resorb without a foreign body reaction and prevents the need for surgical intervention during removal.

The volume of bone available for placement of palatal implants in the hard palate is determined by using Lateral cephalograms and cone beam computed tomography presurgically.[34]

3.4. *Orthodontic Mechanics with palatal implants*

The loading of the implants can be done either directly or indirectly depending on the clinical situation and the treatment plan. Both the standard and the chair-side procedure can be used for connecting the teeth to be stabilized with the palatal implant.[35,36]

By direct loading we mean that the forces that are required for the acheivable tooth movement are directly introduced onto the implant. The translatory movements which are the resultant are achieved with a constant force with the help of NiTi springs or E-chains as seen with levers.[34]

3.5. *Removal procedure*

For removal of the orthodontic implant, osseointegration needs to be broken which is done by minimally invasive counterclockwise rotation using a force of up to 55 Ncm.[34]

3.6. *Complications of palatal implants*

1. Loss of implant caused by peri-implantitis and implant loosening.
2. Perforation of nasal floor or maxillary sinus.

During the initial healing period, slightly mobile implants may gain stability within 6 weeks.

Use of Chlorhexidine digluconate rinses thrice daily and mechanical cleaning with a soft toothbrush may control loosening of the implant.

3.7. *Palatal onplants*

In 1995 Block and Hoffman,[13] designed 'onplant' which is a thin titanium alloy disk for use as TAD. The onplant surface that lies against the bone is textured and coated with a 75 μm thick layer of hydroxyapatite while the one facing the soft tissue is smooth titanium alloy with an internal threaded hole at its center for abutment placement. The placement of the onplant is similar to that of the palatal implant. It has a healing period of approximately 12 weeks after which orthodontic forces are loaded on the abutment.

Block and Hoffman[13] in their animal study showed that it provides sufficient anchorage to successfully move and anchor teeth.

It was Xiang Chen[36] in 2007 who investigated the biomechanical properties and the degree of osseointegration of onplants during various healing periods in an animal model.

Feldmann[37] in their investigation evaluated the orthodontic anchorage capacity of 4 anchorage systems during all phases of maxillary extractions cases.

Bantleon[38] (2002) reported a 92% success rate for osseointegration in a subjective report of 40 Orthosystem palatal implants.

3.7.1. *Miniplates*

In 1999, Unemori et al[17] reported the use of miniplates for posterior intrusion in anterior open bite cases. In comparison to other TADs miniplates are advantageous as they do not interfere with tooth movement and the use of multiple screws provide more secure anchorage which is especially beneficial in patients with extremely thin cortical bone.

Different systems using miniplates as anchors –

1. Skeletal Anchorage Systems (SAS by Sugawara[39] in 2000
2. Zygoma Anchorage System (ZAS by De Clerck[40] in 2002

4. Skeletal Anchorage Systems

Sugawara[39] devised skeletal anchorage system (SAS) utilizing titanium miniplates and monocortical screws that are temporarily fixed in the jaws for absolute anchorage. It offers a nonsurgical, as well as a nonextraction treatment approach for maxillary or mandibular protrusion, and/or anterior crowding in adult patients, retreatment cases, and patients with complex orthodontic problems.

5. Appliance Design

The SAS comprises of bone plates and fixation screws[39] which are made of boicompatible pure titanium which is suitable for osseointegration. The anchor plate consists of the head, the arm, and the body. The head is exposed intraorally and positioned outside of the dentition so that it does not interfere with tooth movement. The arm is transmucosal while the body is positioned subperiosteally and is available in three different configurations—

1. The T-plate,
2. The Y-plate, and
3. The I-plate

The site of placement for the Y-plate is the zygomatic buttress to intrude or distalize upper molars, the I-plate is the anterior ridge of the piriform opening for intrusion of upper anterior teeth or protraction of upper molars and the T-plate is the mandibular body to intrude, protract, or distalize lower molars, or at the anterior border of the ascending ramus to extrude impacted molars. Costa recommend the use of computerized tomographs along with traditionally uused panoramic and periapical x-rays

5.1. *Complications*

Most patients who undergo SAS placement show mild to moderate facial swelling for several days after surgery. Infection onsite has been reported in about 10% of patients. Mild infections can be controlled by use of antiseptic mouthwash and careful brushing techniques. In more severe cases, antibiotics are required. Other potential complications include plate fracture and mucosal dehiscence around the plate.

5.1.1. *Advantages of SAS*

1. Bio-compatible.
2. Most rigid available skeletal anchorage.
3. Noninterference in tooth movement due to site of location.
4. No need for patient compliances.
5. Predictable treatment results.
6. Decreased need of extraction and surgery.

Quite similar to SAS, De Clerck[40] in 2002 devised Zygoma Anchorage System (ZAS) using titanium miniplate. The zygomatic anchorage system is one of the safe anchorage methods. Because of the location and solid bone structure, the inferior border of the zygomaticomaxillary buttress, between the first and second molars, was chosen as the implant site, near the center of resistance of the first permanent molar.

5.2. *Main indications*

1. Enmasse distalization.
2. Mesialization of posteriors.
3. Intrusion of a single tooth or a group of a teeth;
4. Orthopedic intermaxillary traction.

Removal of ZAS is under local anesthesia through a small vertical incision in the gingival covering the miniplate. A special screwdriver, that fits into the pentagonal outer holes of the screw heads is used.

5.3. *Advantages of ZAS*

1. The ZAS uses three miniscrews, thus increasing total anchorage.
2. Immediate loading is possible
3. The point of application of the orthodontic forces is brought down to the level of the furcation of the upper first molar roots.
4. Does not interfere with tooth movement.
5. The vertical slot with the locking screw makes it possible to attach an auxiliary wire, which can move the point of force application some distance from the anchor.

6. Miniscrew - Implants as Anchors in Orthodontics

The treatment using micro-implant is independent upon patient compliance, make treatment time shorter, and can achieve good result. The Micro-implants could provide absolute anchorage and have revolutionized the orthodontic treatment options. These are also called as Temporary Anchorage Devices.

7. Temporary Anchorage Devices

A temporary anchorage device (TAD) is a device that is temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obliviate the need for the reactive unit altogether, and which is subsequently removed after use. They can be located transosteally, subperiosteally, or endosteally; and they can be fixed to bone either mechanically (cortically stabilized) or biochemically (osseo-integrated). TADs into orthodontic treatment made possible infinite anchorage, showing no movement (zero anchorage loss) as a consequence of reaction forces.[2]

Synonyms used to describe devices of skeletal anchorage.

1. Mini-implants,
2. Microscrew implant,
3. Micro-implant,
4. Minidental implant,
5. Screw-type implant,
6. Intraoral anchorage systems,
7. Temporary anchorage devices

8. Conclusion

Skeletal orthodontic anchorage has majorly changed the possibilities and paradigms in orthodontic treatment. It obliviates the need for significant patient compliance, particularly with regard to extraoral appliances, which allows more predictable treatment results. The second part to follow will continue with the design and function of screw-type orthodontic mini-implants, placement sites, surgical procedures, loading approaches, biocortical and resorbable implants and conclusion.

9. Conflicts of Interests

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