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Mini Implants through Finite Element Analysis

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Abstract

Mini-implants have influenced orthodontic treatment plans by providing possible management of complicated discrepancies than those treatable by conventional biomechanics. By the help of mini-implants, force can be applied directly to the bone-borne anchor unit. The versatility and simplicity of mini-implant installation make them a promising alternative to crown anchorage in the anterior region, especially in oral rehabilitation of patients under development. Despite limitations, it is a simple technological resource that allows a low cost intervention in a single appointment. It also provides aesthetic and functional results that can improve the patients' quality of life, reflecting on self-esteem and social integration. The finite element analysis (FEA) is an upcoming and significant research tool for biomechanical analyses in biological research. It is an ultimate method for modeling complex structures and analyzing their mechanical properties. This review articles looks into mini implants through FEA

Keywords: EFA, Despite, Mini Implants

Introduction

Dental implants have greatly evolved over the past 20 years. The idea of permanently being able to replace teeth has been a desire of civilizations since the days of the Egyptians. Luckily, our modern day methods of dental implantation are much more successful and painless. In the mid 1960s, Dr PerIngvar Branemark in Sweden

discovered that bone could grow in proximity with the titanium without being rejected and called this phenomenon as 'osseointegration,' hence the term osseointegration had been coined.

This discovery paved the way for all future dental implant work henceforth. Osseointegration, by definition, is living (newly formed) bone in contact with an implant. Stability of osseointegrated implants may depend on: the percentage of bone to implant contact; how the new bone deposited on the implant surface is attached to the surrounding bone; and the bone density (quality) of the surrounding bone. However, the percentage of bone to implant contact can be used to estimate differences in the speed of bone apposition onto the implant surface between materials and/or surface modifications. [1]

Mini implants

Mini implants have become the evolutionary change in the phase of implant placement. The most common use for mini implant is the stabilization of over denture and orthodontic treatment but now they are also used in pediatric dentistry for congenitally missing teeth and tooth loss due to trauma [2]

Type and Shapes of Mini-implant

There are 2 common types of mini implants: [3, 4]

- Self-tapping
- Self-drilling.

The self-tapping system needs predrilling and it is indicated for a prolong treatment schedule. However, the predrilling might result in inevitable complications such as: Thermal damage, root damage, and drill fractures.

In the other hand, placement of the self-drilling type is carried out in lesser time, thermal damage, and risk of fractures. Furthermore, insertion of self-drilling mini-implants is executed with manual pressure without considerable irrigation. [5] Self-drilling system is advantageous with better stability, especially in sites with low bone density like maxilla, and adolescent patients.

In contrast, in high-density bone or thick cortical bone, the self-drilling system is less advantageous as gaining adequate primary stability needs excessive pressure in that sites so the risk of micro fracture is higher. [6]

Mini-implants are mostly consists of three components: [7]

- Threaded shaft,
- Cervical area,
- Head for loading orthodontic forces.

The head design differs according to two different concepts. One type with screw head, which attaches to tension springs or round wires by means of hooks, spherical heads, eyelets, and bore holes. This mentioned type covers a wide range of indications except for anchoring rectangular wires. The second head design has a slot or a cross-slot. Clinically, the second design seems to be more universal in application and can be indicated for all types of skeletal anchorage; however, the limitation of using rectangular wires should be noticed. [6]

Advantage of mini implant [8]

- Minimally invasive,
- Single stage placement procedure, which consists of turning the implant into the bone through a starting opening, but not a prepared bone site. Hence, there is no bone damage or bone wound during implantation.
- Bleeding and postoperative discomfort are reduced,
- Healing time is shortened.

Clinical Application [7]

- Anchorage reinforcements
- Intrusion
- Bodily movements
- Extrusion

Design of orthodontic implants:

One of the conspicuous weaknesses of two-stage implants for orthodontic anchorage is the requirement for a long healing time of 4–6 months, which adds essentially to the treatment time. The bone depth needed for customary endosseous implants may likewise limit the areas accessible for implant placement. Because of these issues, implants have been planned explicitly for orthodontic purposes.

Generally, an implant used to upgrade orthodontic anchorage should be biocompatible, modest, easily implanted and removed under local anaesthesia, and be little enough to situate in different sites in the mouth. It ought to likewise osseo integrate in few days, and would be stable to orthodontic loading taking all planes of space.

The expanding desire for early loading of implants utilized for orthodontic anchorage drove Melsen to create the Aarhus implant. Because of its little measurements (6 mm length), this titanium anchorage screw can be situated in different sites, including between the roots of teeth. It is said to permit osseo-integration to happen even within the presence of quick orthodontic loading, giving the orthodontic forces (25–50 g from Sentalloy springs) go through the screw. The strain that creates in the bone surrounding the loaded screw prompts a field where expanded bone formation results. Because of the size of the screw it tends to be utilized in various areas and can be without any problem eliminated when not, at this point required.

While trying to deliver an implant that is little and simple to place and remove, Kanomi has portrayed a mini implant, which is 6 mm long and 1.2 mm in diameter. This implant, which was created from a mini bone screw utilized for fixing bone plates, is screwed into the alveolus under local anesthesia, to inside 3 mm of the apices of the teeth. Resulting to healing and osseo-integration, a titanium bone plate is fixed to the screw, and goes about as a hook for the attachment of an orthodontic ligature wire to help intrusion of the corresponding teeth. Because of possible oral hygiene issues, the ligature isn't attached straightforwardly to the implant. The author didn't explain how long the healing period is permit osseo-integration, however did remark on the utilization of this implant for orthodontic space closure and molar distalization. [9]

Factors that influence the stability of orthodontic mini-implants

1. Host factors – As bone is a dynamic tissue in which the modeling and remodeling processes are continuous throughout. The condition of the hard tissue depends on the age and sex and anatomical location of the implant placement site; the quantity and quality of the host bone also a major factor, as the stability in case of dense trabecular bone is more favorable than low density trabecular bone. Extremely dense cortical bone may also increase stress during placement, which results in degradation of bone tissue at the implant-bone interface4,5 Also, the host's soft tissue also important in deciding the stability of the implant as an implant placed in the attached gingival has a more stable soft tissue-implant interface in comparison to the implants in the mucosa or movable soft tissue, and thus low stable soft tissue-implant interface; are likely to cause soft tissue problems, such as infections.6 Also, the excessive local forces may occur during mastication in the area between the mandibular first and second molars may compromise the stability of the orthodontic implants.

2. Operator/dentist's factor – the primary stability of any procedure is also dependent upon the fine skills of the operator either it may be root canals or implant placement or any other procedure. Proper surgical protocols are very important in preventing unnecessary surgical trauma.

3. Implant factors – One of the implant factors that decide its stability is its biocompatible nature and implant design. The physical properties of the implant materials, particularly those on the surface in direct contact with tissue, determine the adsorption of biomolecules or foreign materials and cell adhesion patterns, and these materials may be considered bioactive, bioinert, or biotolerant and it has been reported that, when used in implants, bioactive materials such as hydroxyapatite or aluminum oxide can form chemical bonds with bone.

The implant design influences the distribution of stress to the adjacent bone tissues. The length of the mini-implant was shown to have little effect on the distribution of stress but the designing of implant threads and its diameter had a significant effect on the distribution forces and so this indicates role of thread design & diameter of the implants. The orthodontic miniimplant made up of titanium alloy grade V (Ti - 6AL - 4V) is designed to be used transmucosally for osseous orthodontic anchorage and orthodontic mini screw has four components – Head – Has a slot for placement of orthodontic arch wire. Neck –It is an isthmus between head and platform for attachment of elastic, NiTi coil spring or other accessories. Platform – It is of three different sizes (1mm, 2mm, and 3mm) for an accommodation of different soft tissue thickness at different implant site. Body – It is parallel in shape and is self- drilling with the wide diameter and deep thread pitches. It provides better mechanical retention, less loosening breakage, and stronger anchorage.

4. Oral hygiene – The oral hygiene is also playing an important role in the success of implants, as the poor oral health may lead to chronic inflammation and thereby may lead to failure to the procedures. [10]

Unlike conventional dental implants that behave as ankylosed teeth interfering with bone growth, orthodontic mini-implants without surface treatment present minimum osseointegration. These implants rarely causes tissue damage when removed, a factor that may potentially minimize dimensional losses of alveolar ridges for planning definitive rehabilitation. This low cost technique demands minimally invasive technique and easy clinical applicability; it also gives additional advantages to enable prosthetic rehabilitation intervention in only one appointment. [11]

Nowadays, skeletal anchorage systems such as miniplates, palatal plates, and mini implants have revolutionized in providing a much more stable anchorage. Studies have shown that mini implants are one of the best options for this purpose due to the multiple advantages they offer mainly easy management and placement in various anatomical areas as well as their low cost. [12]

Potential complications of mini implants

As with any treatment, several potential complications are associated with orthodontic mini-implants. A common complication is failure of the mini implant. Currently, approximately 10% of orthodontic mini-implants fail. This rate is slightly higher than that for dental implants and can be attributed to the fact that the orthodontic mini-implant is not designed to osseointegrate. Osseointegration would complicate implant removal and is therefore not desired.

The reasons for reduced implant success are improper implant site selection, overheating of the bone when drilling a pilot hole, lack of primary stability, gingival inflammation around the implant, trauma, poor oral hygiene, and idiopathic factors. Implant failure might delay treatment time. Some systems offer mini-implants of significantly larger diameter that can be placed immediately in the site of the failed implant. Extreme caution must be used to prevent damage of the adjacent roots. A healing time of 2 to 3 months before placing a new implant of the same diameter in the same location is necessary to allow for the bone to fill in.

Another alternative could be to replace the original monocortical screw with a longer bicortical screw. The use of bicortical screws when monocortical screws fail needs further investigation.

The greatest danger of mini-implant failure is aspiration if the implant becomes completely dislodged from the appliance. However, since aspiration of foreign objects is a rare occurrence in awake patients, the risk of this is negligible in a neurologically normal person.

Damage to adjacent structures can occur even though orthodontic mini-implants and pilot drills are specifically designed to not cut into roots. Therefore, damage of the root proper is rare, but it is possible to damage the structures of the periodontal ligament. In that case, different host responses are possible, ranging from complete repair to point ankylosis.

Damage of the periodontal ligament should be carefully avoided by proper implant planning and placement. The minimal space requirement between roots is 0.5 mm mesial and distal to the implant, or 1 mm more than the implant diameter.

Theoretically, other structures such as the inferior alveolar nerve or the maxillary sinuses are also at risk, but they can usually be avoided by proper treatment planning. Patient feedback when using only topical anesthetic is helpful for avoiding important structures. Implant fractures during implant placement are rare and can be almost completely prevented by not applying excessive torque moments. Therefore, systems including a torque control ratchet are preferred Maximum torque moments range from 20 to 40 N per centimeter depending on the system used and should be provided by the manufacturer on request. [13]

Finite element method

The finite element analysis (FEA) is an upcoming and significant research tool for biomechanical analyses in biological research. It is an ultimate method for modeling complex structures and analyzing their mechanical properties. FEA has now become widely accepted as a non-invasive and excellent tool for studying the biomechanics and the influence of mechanical forces on the biological systems. The finite element method (FEM) is basically a numerical method of analyzing stresses and deformations in the structures of any given geometry. The structure is discretized into the so called ‘finite elements’ connected through nodes. The type, arrangement and total number of elements impact the accuracy of the results. The steps followed are generally constructing a finite element model, followed by specifying appropriate material properties, loading and boundary conditions so that the desired settings can be accurately simulated. Various engineering software packages are available to model and simulate the structure of interest may be implants or jawbone.

In Implantology, FEA has been used to study the stress patterns in various implant components and also in the periimplant bone.

Several FEA studies postulated that the stress pattern on peri-implant bone is affected by the implant number, diameter, length, thread profile, material properties of implant components and also by the quality and quantity of surrounding bone. [14]

Few of the FEA studies pertaining to various attributes of mini implants are:

Hisam M J(2019)-It was concluded that the higher the thread pitch of a mini dental implant, the higher the maximum induced stress on the peri-implant bone. It was also found that mini dental implant with lower thread pitch distributed the stress more evenly to the peri-implant bone. In terms of strain, there was very small difference between the induced strain by the mini dental implant with different thread pitches.[15]

Mesic E (2021)- In order to achieve favourable primary stability of the miniimplant (temporary anchorage device), careful selection of the implant system combined with adequate bone quality and a proper insertion protocol are strongly suggested to minimize the destructive influence of loading forces on the surrounding dental implant .[16]

Marimuthu V K et al (2015) - Placement of mini implant perpendicular to the long axis of the tooth reduces the stress concentration around the mini-implant and its interface, thereby increasing the likelihood of implant stability. The direction of orthodontic force has no significant effect on implant stability. [17]

Sidhu et al.(2020) - Placement of the MI at 90° appears to be an ideal angulation when applied with a horizontal load. Force range used is within clinically recommended levels; however, the increase in load causes an increase in the stress values.[18]

Sana S et al (2019) - mechanical testing of different mini-implants, the result demonstrated that Orthoimplant type with a larger diameter, smaller pitch and shorter taper length have better primary stability, and also have low stresses within the mini-implants and surrounding bone amongst the three groups.[19]

Agarwal A and Subash P - (2021)- The force from an implant placed at a higher level from the anterior retraction hook will cause intrusion; an implant placed at the medium level shows bodily movement; and an implant placed at a lower level shows tipping forces in consolidated arches.[20]

Conclusion

Mini-implants have influenced orthodontic treatment plans by providing possible management of complicated discrepancies than those treatable by conventional biomechanics. By the help of mini-implants, force can be applied directly to the bone-borne anchor unit. [2]The versatility and simplicity of mini-implant installation make them a promising alternative to crown anchorage in the anterior region, especially in oral rehabilitation of patients under development. Despite limitations, it is a simple technological resource that allows a low cost intervention in a single appointment. It also provides aesthetic and functional results that can improve the patients' quality of life, reflecting on self-esteem and social integration. [7]

FEA has various advantages compared with studies on real models. The experiments are repeatable, there are no ethical considerations and the study designs may be modified and changed as per the requirement. [14]

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