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Review Article

Orthodontic Mini Implants, an Update

Mohammed Jaradat[1]* and Sawsan Al Omari[2]

[1]Assistant Professor in Orthodontics, Department of Orthodontics and Paedodontics, Arab American University of Palestine (AAUP), Palestine
[2]Full Time Lecturer and Specialist Orthodontist, Department of Preventive Dentistry, Jordan University of Science and Technology (JUST), Irbid, Jordan

***Corresponding Author:** Mohammed Jaradat, Assistant Professor in Orthodontics, Department of Orthodontics and Paedodontics, Arab American University of Palestine (AAUP), Palestine.

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Abstract

Anchorage control is of prime importance in the everyday orthodontic practice being one of the keys for successful orthodontic treatment. Various extra-oral and intra-oral anchorage reinforcing appliances were used but none of them was idea. Implant-like devices inserted into the jawbone have been introduced in orthodontics for the purpose of absolute anchorage provision. These are called Temporary Anchorage Devices.

A Temporary Anchorage Device is any device that is temporarily inserted into the bone for the purpose of enhancing orthodontic anchorage. They can be used for various goals such as incisor retraction, molar distalization, intrusion of posterior and anterior teeth for the purpose of correcting deep bite, open bite and canted occlusal planes. Whether made from titanium alloys or surgical Stainless Steel they have three main parts: head, neck and body. These mini-implants are placed either by self -tapping or self -drilling techniques with comparable success rates.

Generally, orthodontic mini implants are shown to be clinically reliable with a modest failure rate of about 13.5%. their success depends on multiple factors including patient related factors, mini-implant related factors and operator related factors. Although their use may result in some complications such as pain, screw failure and fracture they are now considered as the only method for absolute anchorage provision.

Keywords: *Anchorage; Temporary Anchorage Devices; Primary Stability; Mini-Implant Failure*

Introduction

Anchorage control is of prime importance in the everyday orthodontic practice being one of the keys for successful orthodontic treatment. Various extra-oral and intra-oral anchorage reinforcing appliances were used but none of them was ideal nor provided absolute anchorage control. Some of them (as headgear) had compliance issues and others (like the non-compliant intra-oral devices) had limited anchorage reinforcement efficiency [1]. For this reason, implant-like devices inserted into the jawbone have been introduced in orthodontics for the purpose of absolute anchorage provision. These implant-like devices are referred to as temporary anchorage devices (TADs) [1].

In view of the increased use of orthodontic mini- implants, this scientific review article aims to provide the readers with an evidence-based overview regarding orthodontic mini-implants including their parts, indications, insertion sites, placement techniques, timing of loading and more importantly their success and failure rates.

Definition and history

A temporary anchorage device is any device (implant, screw, pin, or onplant) that is temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or eliminating the need for the reactive unit altogether, and which is subsequently removed after use [2]. The first clinical report on humans in literature was in 1983 by Creekmore and Eklund, where they used a vitallium screw placed in the anterior nasal spine area in order to intrude the upper incisors in a patient with a deep overbite. They used an elastic thread tied between the screw and the arch wire ten days following screw placement. The incisors intruded six millimeters in a year and the screw maintained its stability throughout a treatment period of one year. Despite this achievement, the use of these screws was not widespread and did not gain immediate acceptance perhaps due to the included surgical procedures and the lack of scientific data on the use of an implantable material [3].

Nowadays, orthodontic mini-implants are used routinely since they pose many advantages and can be used for many treatment aspects [4,5].

Indications

Orthodontic temporary anchorage devices can be used for various tooth movements. They can be useful in retraction of incisors (Figure 1), distalization of molars (Figure 2), intrusion of posterior and anterior teeth including correction of canted maxillary planes (Figure 3 and 4) [4-8].

Figure 1: *Mini-implant used for anchorage during retraction of incisors.*

Figure 2: *Mini-implant used for molar distalization.*

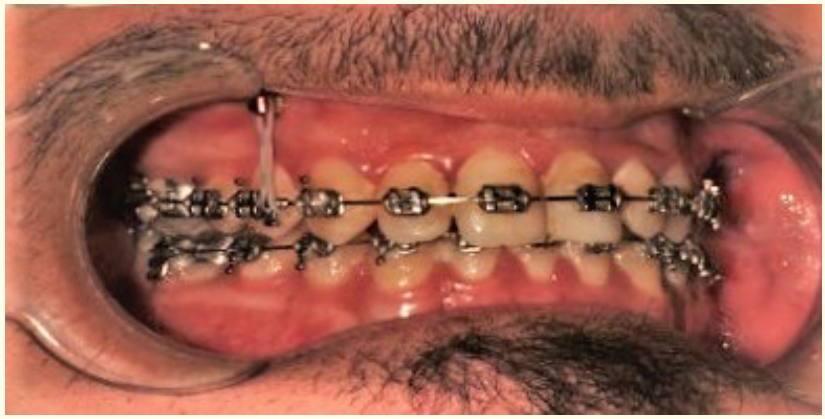

Figure 3: *Mini-implant used for correction of maxillary occlusal cant.*

Figure 4: *Mini-implant used for maxillary molar intrusion.*

Mini-implant parts

Orthodontic mini-implants are generally made of titanium alloys or surgical Stainless Steel since both materials are highly biocompatible [9].

They have three main parts: head, neck and body. The mini -implant Head emerges from the mucosa and designed in a way that facilitates the connection of orthodontic auxiliary devices, such as coil springs, ligature wires, and elastics. The mini implant Neck forms the connecting part between the mini implant head and body, and it generally has two forms; the small neck form which is used in most of the cases and the long neck form which is used in areas where the mucosa is thick as in the palatal area and retro-molar area. The mini implant Body has different thread designs, these threads and grooves are designed in order to be in contact with the bone when inserted. Generally, it has two shapes; the parallel shaped body and the tapered shaped body which is used more commonly as it poses less risk in touching and damaging the neighboring roots [10]. Mini-implants are manufactured with different lengths and diameters, and their surface is generally smooth in order to limit the osseointegration [1].

Mini implant placement techniques

Nowadays, mini-implant insertion has become an important part of routine practice in orthodontic therapy. The mini-implant can be placed either by self-tapping or self -drilling techniques. The self-tapping (drill) method requires predrilling with a pilot drill preceding mini implant placement. This method is indicated when small diameter mini implants or low-grade pure titanium mini implants are to be used. On the other hand, in the self-drilling (drill free) method, the mini implant itself will drill into the bone as it is being driven. The later method is indicated when larger diameter or titanium alloy mini implants are to be inserted [10]. Gupta., *et al*. (2012) found that both the self-tapping and the self-drilling mini implant are effective in providing orthodontic anchorage. Self- drilling mini implants have the advantage of decreasing the operative time with little bone debris, less thermal damage, lower morbidity, and minimal patient discomfort compared with the predrilling mini implants [11].

Mini implant placement sites

Orthodontic mini implants can be placed at various intraoral sites. Most commonly they are placed interdentally between the teeth roots. Additionally, they can be placed palatally (either interdentally or at median or para-median sites), at the maxillary tuberosity area, infra-zygomatic crest area, retro-molar area and at the buccal shelf area. This diversity in mini implant placement areas represents an advantage over the conventional dental implants since the later have limited insertion sites because of the anatomic limitations.

Mini-implants should be placed in a safe zone without jeopardizing the neighboring anatomic structures including the teeth roots, nerves and blood vessels. For mini-implants placed in the anterior area, the interdental area between the central and the lateral incisor and between the lateral incisor and the canine (at 6-mm level from the cemento-enamel junction) represents the safest zone in the maxillary and mandibular arches respectively [12].

In all patients with different skeletal patterns, the interdental space between the second premolar and the first permanent molar buccally represents the safest zone for mini implant placement in the posterior maxilla. While the buccal inter-radicular space between the first and second premolars and between the first and second permanent molars represent the safest zones for mini implant placement in the posterior mandible [12].

For the inter-radicular palatal areas, Chaimanee., *et al*. (2011) found the area between maxillary first and second premolars as an optimal placement site due to the highest amount of cortical bone thickness [13]. Bourassa., *et al*. (2019) found a higher primary stability at the sites at or anterior to the second premolars and para-sagittally adjacent to the permanent first molars [14].

Although mini-implants placed in the infra-zygomatic crest area have high incidence of maxillary sinus penetration; penetrating through double cortical bone plates and limiting the penetration depth within one millimeter are recommended for mini-implant anchorage [15].

Orthodontic mini-implants can be placed in the posterior part of the lower jaw in the buccal shelf area (buccal to the roots of the mandibular first and second permanent molars and anterior to the oblique line of the ramus). Nucera., *et al*. (2017) found the buccal bone corresponding to the distal root of second permanent molar, with mini implant insertion of 4 millimeters buccal to the cemento-enamel junction as an optimal anatomic location. For buccal shelf mini implants, pre-drilling is recommended preceding mini-implant placement just to avoid high insertion torque and subsequent failure [16].

Mini implant success/failure

Generally, mini-implants that could be maintained for orthodontic anchorage for more than 6 months were considered to be successful [17]. Orthodontic mini implants are shown to be clinically reliable with a modest failure rate of about 13.5% [18].

The clinical success of mini-implants is directly related to their stability immediately following placement which is termed mini implant primary stability. Other factors that control the success rate include the engineering design of the mini-implant, type of gingiva, the placement technique used and the presence of smoking habit [19-21].

In general, the success of mini implant is dependent on multiple factors which are described below.

Operator related factors

Sites of insertion

Mini implants s should be placed in a safe zone without jeopardizing the neighboring anatomic structures including the dental roots, nerves and blood vessels. The maxilla represents a better placement site for insertion (mean success rate, 90.19 ± 7.01%) than the mandible (mean success rate, 83.32 ± 9.96%) [22]. The evidence suggests that mini-implants placed in the mid palatal locations have the least failure rate (about 1.3%). Mini implants placed in the buccal shelf area are highly successful (about 93%) [23]. On the other side, mini implants inserted in the zygomatic buttress and maxillary tuberosity areas have a higher failure rate (about 16.4% and 26.3% respectively) [24].

Mini implant placement technique

As mentioned above, the mini-implants can be placed either by self-tapping or self-drilling techniques. Reynders and Cacciatore (2016) found that the success rates of self-tapping and self-drilling mini implants are similar. Determination of the position and direction of placement should be more precise when self-drilling mini implants are used in sites with narrow root proximity [25].

Loading: Immediate vs delayed

It is well known that conventional dental implants are not loaded immediately following their insertion in order to provide enough time for osseo-integration between the dental implant and the jaw bone. The Osseo-integration process represents the primary source of success for conventional dental implant. It takes about three to four months to develop in the maxillary and mandibular arches respectively. The scenario is different in the case of orthodontic mini-implants since the primary stability-rather than the secondary stability- is the main source of mini implant success [14].

Freire., *et al*. (2007) conducted a study to evaluate the bone response to statically loaded orthodontic mini-implants (with a diameter of 2.5 millimeters) activated following various healing periods in a dog model. their results showed that early orthodontic static loading did not affect the mini-implant clinical performance [26]. This was supported by Luzi., *et al*. (2009) who found that immediate loading of orthodontic mini-implants with light forces did not negatively affect the bone healing pattern. Moreover, they found that mechanical loading seems to induce an earlier increase in bone formation and a decrease in bone resorption, thus confirming the positive role of mechanical loading in increasing bone activity in comparison to unloaded mini-implants [27].

Zhanga., *et al*. (2010) in their study investigated the desirable healing time of mini-implants by histomorphologic and histo-morphometric evaluations of osseointegration after immediate and early loading in beagle dogs. They concluded that all mini-implants whether loaded immediately, after 4 weeks or after 8 weeks can provide stable orthodontic anchorage. However, to obtain improved stationary anchorage, a 4-week healing time is recommended before orthodontic loading [28].

Mini implant design related factors

Mini implant diameter and length

Orthodontic mini-implants are manufactured with various lengths and diameters. The literature showed contradictory results regarding the effect of mini-implant length and diameter on its stability due to the variability in the used techniques and samples. Wu., *et al*. (2009) reported that length and type of mini-implants were not associated with mini-implant failure [16] while Miyawaki., *et al*. (2003) found that the one year success of mini implants with one millimeter diameter were significantly lower than those with 1.5 or 2.3 millimeters when placed in the posterior buccal region [29].

Chatzigianni., *et al*. (2011) found a significant correlation between mini implant stability and its length and diameter only when a high force level is applied (2.5 Newton Vs 0.5 Newton) [30]. They found that the 9 millimeters long mini-implants were displaced significantly lower than the 7 millimeters long mini implants and the 2 millimeter wide significantly less than the 1.5 millimeter implants [30].

Patient related factors

Gender

For conventional dental implants, Cooper 2010 [31] found that females had a 1.54 higher risk of primary implant stability failure compared to male patients. Contrary to conventional dental implants, different studies reported no gender difference in mini implant failure rate between male and female patients [1,5].

Patient age

The literature revealed contradictory results regarding the effect of patient's age on mini-implant stability. Wu., *et al*. (2009) reported no association between mini implant stability and the patient's age. On the other side, Dalessandri., *et al*. (2013) reported that patients over the age of 20 years have higher success rate due to the increased bone density compared with younger patients [1,16].

Type of gingiva

Most of the literature suggests lower failure rates when mini-implants are placed in attached gingival tissues compared with movable mucosa [32,33] on the other side, Sharma., *et al*. (2011) reported higher success rate for mini implants placed in non- keratinized gingiva [34].

Influence of antibiotic prophylaxis on the stability of orthodontic micro implants

In their study, Łyczek., *et al*. (2018) investigated the influence of antibiotic prophylaxis (Amoxicillin -one hour before mini-implant placement) on the stability of orthodontic mini-implants. They found that the antibiotics provided no benefit in terms of mini- implant stability, inflammation of soft tissues, or postoperative pain [35].

Influence of chlorhexidine and probiotics solutions on orthodontic micro-implants surface

Pavlic., *et al*. (2019) found that Probiotics increase the roughness of orthodontic titanium mini-implants, while Chlorhexidine seems to increase the roughness of orthodontic steel mini-implants. So, for oral-hygiene considerations, Chlorhexidine can be recommended for titanium mini-implants, and probiotics for stainless steel mini-implants [36].

Smoking and mini implant stability

Many papers shed the light on the effect of cigarette smoking and conventional implant stability. The literature indicates that the risk of marginal bone loss and implant failure is increased in smokers compared to non-smokers [37,38]. On the other hand limited data is available in the literature about the effect of smoking on mini implant stability. Bayat and Bauss (2010) found a detrimental effect for heavy smoking (defined as more than ten cigarettes per day) on the success rate of orthodontic mini implants**.** They found no significant difference in the success rate between non-smokers and light smokers (less than ten cigarettes per day) [39].

Complications

Pain

Pain is usually experienced by orthodontic patients during the various stages of fixed orthodontic appliance treatment. Many studies indicated that pain was significant during the first two days following the placement of initial arch wire and it returns to baseline level after one week [40,41]. The use of orthodontic mini-implants is a relatively accepted option during the course of orthodontic treatment since the patients response toward the procedure is positive. Mirhashemi., *et al*. 2016 reported that the maximum amount of pain was reported one hour following mini-implant insertion which decreased during the first week of mini-implants insertion [42]. Similarly, Kawaguchi., *et al*. (2014) reported that 35% of the patients reported slight pain immediately following mini implant placement and only 8% of them felt pain at 1 day after mini implant placement and none of the patients reported pain seven days following mini implants placement [43].

Tissue damage

Following root contact with mini-implants, the quality of root repair depends on the amount of damage caused by the mini-implant. If the damage is limited to the cementum or dentin, then healing and thorough repair of the periodontal structure will mostly occur [44]. Ahmed., *et al*. 2012 found that healing is time dependent phenomenon and about 70% of the injured teeth required 12 weeks to achieve good repair [45]. On the other side, if the mini-implants injure the pulp there is decreased chances of complete repair [44].

Mini-implants fracture

orthodontic mini implants can be fractured either during insertion or removal. During insertion, the application of high insertion torque can lead to mini-implant fracture, especially in the mandible due to its higher boney thickness compared with the top arch. For inter-radicular mini implants, they should be inserted in a manner that avoids root proximity. In order to avoid fracture when placed in the palate. orthodontic mini-implants should be placed three millimeters away from the mid-palatal suture. This placement manner is enough to avoid the high insertion torque which may lead to mini-implant fracture [46].

Although its occurrence is rare, fracture of orthodontic mini implants during removal could happen. Fracture during mini-implants removal could result from various factors such as rapid removal or due to the developed complete osseointegration which strengthens the bond between the mini-implants and the jawbone. Kuroda and Tanaka reported mini implant fracture rate of about 0.5% while Suzuki and Suzuki reported a mini-implants fracture of 1.4% during removal [46,47].

Mini-implants failure

Most of failure occurs usually during the first week of mini-implants placement. Several factors are suggested to increase the risk of failure as shown above.

Conclusion

There is no doubt that the evolution of orthodontic mini-implants had a noticeable positive impact on the orthodontic treatment efficiency. They solved the long-lasting anchorage problems which by itself reduced the treatment duration and made the treatment progress less complicated. Although the clinical use of orthodontic mini-implants is accompanied by some complications that occur during insertion, loading, and removal, they have many advantages including the easy insertion, possibility of immediate loading, not relying on patient's compliance and a relatively low failure rate.

Main Points:

1. Mini implants had widespread use in contemporary orthodontics.
2. orthodontic mini implants are shown to be clinically reliable with a modest failure rate.
3. They can be used for various goals such as incisor retraction, molar distalization, intrusion of posterior and anterior teeth for the purpose of correcting deep bite, open bite and canted occlusal planes.

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