

Orthodontic Mini-Implants: Status Quo and Quo Vadis

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Absolute anchorage has come a long way since the initial unsuccessful attempts by Gainsforth and Higley in 1945.¹ It took more than 50 years to arrive at the orthodontic mini-implant the way it is known to us today.² Noteworthy stations along this path were Linkow's endosseous blade implants (1969/1970), Creekmore and Ecklund's incisor intrusion (1983), and Melsen's zygoma ligature (1998).³⁻⁶

The use of orthodontic mini-implants is a movement which was clearly clinician driven. The first attempts were made by dedicated clinicians with the strong desire for predictably achievable high anchorage. Initially however, the specialty eyed these pioneers with suspicion, raising questions like, "Is this invasive procedure really necessary? Would mini-implants be able to live up to the high expectations? Well, time will tell..." – and time did tell. Academia soon caught on to this movement and supplied the necessary evidence that mini-implants could in fact be beneficial for orthodontic treatment, allowing tooth movement in a never-before-seen fashion.⁷⁻¹⁰ It is safe to say that today mini-implants have become a staple of the modern orthodontic practice.

The purpose of this article is to provide an overview of the current status of orthodontic mini-implants and a discussion of established techniques in an attempt to provide practitioners with the knowledge on what really works with regards to mini-implants.

Anchorage Concepts

Two anchorage concepts prevail.

Initially, nearly all mini-implant case reports in the literature used the direct anchorage approach. Direct anchorage is a set-up in which a force is directly applied from the implant to a tooth or group of teeth that need to be moved. This means that when using direct anchorage, the tooth or group of teeth that are to be moved (target teeth) are pulled toward the implant: pulling mechanics result. The clinical consequence is that the type of tooth movement dictates where the implant needs to be placed. Protraction therefore requires placement of the mini-implant mesially to the target teeth, distalization requires placement distal to the target teeth, etc. (Fig 1).

Over time, the indirect anchorage approach became increasingly popular. Here mini-implants are used to stabilize a group of teeth, creating an implanto-dental anchorage (IDA) unit. Then, target teeth are moved against this IDA. In this set-up, implant placement is almost completely independent of the type of tooth movement desired and thus other important criteria will determine the actual implant site (Fig 2).

Currently both anchorage approaches seem to be equally popular among clinicians. Both approaches have advantages and disadvantages to them and it is up to the treating orthodontist to choose the most appropriate approach for the specific situation at hand. The most important differences are the simple installation and the "hidden" force vectors associated with direct anchorage while indirect anchorage allows for use of traditional orthodontic mechanics with the difference that a group of teeth is "locked in" and will not move as a result of reciprocal forces. Indirect anchorage however is slightly more time consuming to install.

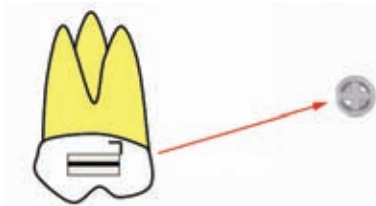


Fig 1. Direct anchorage resulting in "pulling" mechanics.

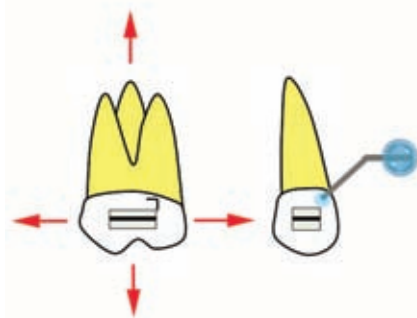


Fig 2. Indirect anchorage allowing more versatile tooth movement.

Mini-implant Design

It is accepted by now that a well-designed orthodontic mini-implant should have three parts to it: a shank, a collar and a head.

The shank is the intra-osseous portion, which provides the retention in the bone. There are two different thread designs: self-drilling (drill-free) and self-tapping (non-drill-free); and two different basic shapes for the shank: cylindrical and conical. Again, both have advantages and disadvantages to them and the interested reader can obtain in-depth information from the recent literature.¹¹⁻¹⁴ Here a more detailed discussion is not warranted. Suffice it to say that at this time, the self-drilling thread is the preferred design among orthodontic practitioners and the most advanced self-drilling shank designs are a combination of conical in the lower third and cylindrical in the top two-thirds, thus combining many of the advantages of both basic shank shapes.

While the shank and the head can be found in every mini-implant, the collar is omitted in some designs, depending on the manufacturer. This is incomprehensible considering the importance of this part of the mini-implant. The collar represents the transgingival portion of the mini-implant. This is where soft tissue adaptation is meant to take place. Therefore the design of the collar should be solid (without perforation), smooth, highly polished and ideally conical – with the base of the collar having a smaller diameter than the top of the collar. This guarantees minimal compression and damage to the surrounding soft-tissues while immediate tissue adaptation can take place. A tight seal results and invasion of oral bacteria is kept to a minimum. A proper analogy for the fit of a conical collar in the insertion site, especially when used with a properly sized tissue punch, would be the fit of a cork in a wine bottle. The consequence is a very favorable healing environment, which might aid in increasing clinical success and patient comfort. Under all circumstances a multi-faceted collar should be avoided since this is an indication that the insertion instrument (such as the driver) attaches here. Such a design guarantees severe soft tissue trauma not only from the implant itself, but also from the driver. To avoid this, drivers should attach at the implant head.

The shank provides the mechanical retention of the implant in the bone and the collar allows soft tissue adaptation – in other words, shank and collar influence biological parameters that may impact clinical success rates. The head design has little direct impact on survival of the orthodontic mini-implant. The head is the coupling site through which the implant is connected to the dentition. Therefore it is closely linked to the orthodontic biomechanics. The head design largely determines what type of anchorage (as explained above) can be installed and thus might indirectly influence where the implant needs to be placed. From the standpoint of clinical applicability, a versatile head design, which allows for a maximum of biomechanical options appears to be the most favorable design. Contemporary orthodontic mini-implant head designs can be grouped into two major categories with multiple subgroups. The first category would be the so-called anchor-head mini-implants with or without eyelet. These allow only the attachment of elastic modules or steel ligatures (Fig 3). The second category are the so-called bracket head designs which are equipped with either a single or a cross slot and which allow, in addition to the attachment of elastic modules as described above, the ligation of a wire segment. This is vitally important should dependable indirect anchorage be desired (Fig 4). In addition a slot in the implant head creates compatibility with multiple different auxiliaries, which creates true biomechanical versatility (Fig 5).

Two different options exist for wire ligation into a bracket head implant: ligature ligation and ligature-free ligation using composite. Ligature ligation requires either



Fig 3. Anchor head implant with direct anchorage mechanics.



Fig 4. Cross-slot implant with engaged wire segment for pre-prosthetic tooth movement using indirect anchorage.



Fig 5. TOMAS pin with attached auxiliary for molar uprighting (TOMAS uprighting spring).

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Popular Implant Sites

A brief discussion of popular implant sites using the most current evidence follows.¹⁷⁻²³

- Buccal alveolus – posterior segments (distal of canine to mesial second molar): the buccal alveolus is a very suitable site for orthodontic mini-implant insertion because it presents with favorable hard- and soft-tissue relationships, adequate root divergence and very few anatomical structures that can be permanently damaged. Loose adaptation of cheeks in that area ensures patient comfort and reduces likelihood of mucosal irritation.
- Buccal alveolus – anterior segments (mesial of canine to mesial of canine): Insufficient interradicular distance, reduced attached gingiva in the mandible, unfavorable CBT, and deep insertion of frenula can often times be found here. Additionally adaptation of the lips is very tight due to high orbicularis oris tone, which can lead to aphthae and mucosal irritations. Routine insertion of mini-implants at this site can therefore not be recommended.
- Lingual alveolus - maxilla: A very suitable insertion site for orthodontic mini-implants, especially in the posterior segments. In the anterior segment root proximity is often present which may interfere with the placement.
- Lingual alveolus – mandible: failure rates of nearly 100 percent make this site most unsuitable for mini-implant placement.
- Palate: The lack of roots and presence of masticatory mucosa make this a very versatile insertion site from which nearly all indications in the maxilla can be treated. Certain areas in the palate should be avoided though because they are unsuitable for orthodontic mini-implants: the posterior palate presents with excessive soft-tissue thickness and lack of overall bone volume, making nasal perforation likely.

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an eyelet or tie-wings. Ligature-free ligation using composite requires neither and thus the implant head can be smaller, lower profile and less contoured, allowing for better hygiene and providing greater patient comfort. In addition the composite connection is very rigid and fail-safe, providing truly dependable absolute anchorage while presenting with a smooth self-cleansing surface. This should be preferred over the eyelet version, which acts as a plaque trap or the high-profile tie-wing version. To date only one implant system is specifically designed for ligature-free ligation.

Implant Site Selection

The rule of thumb is that mini-implants should be inserted in areas where damage to adjacent structures is unlikely and the local anatomy is favorable for long-term stability. This means that implants should be placed clear of roots, veins, arteries, nerves, the maxillary sinus and the nasal cavity. We now know that long-term stability consists of adequate primary and secondary stability. Adequate primary stability is directly linked to sufficient cortical bone thickness (CBT) and thus, mini-implants should not be placed in less than 0.5mm-1mm of cortical bone thickness (depending on the authors).^{15,16} Individual three dimensional imaging can reveal the local CBT. Another option is the use of average CBT data such as supplied by myself and Dr. Mark G. Hans.¹⁷

Implant Site Preparation and Mini-implant Insertion

When using a self-drilling mini-implant, in theory, no implant site preparation is necessary since it can be inserted directly through the soft tissue and into the bone using a manual driver or other instrument.¹¹ While this is the simplest procedure, multiple steps in terms of implant site preparation can be added to the insertion procedure. Since many different insertion protocols exist, depending on the manufacturer or clinician, it is often times regarded a matter of personal preference which insertion protocol is being used. For some steps this might be true, since there is lack of evidence that one procedure is superior to another – however, for other procedures compelling evidence exists as to which procedure will deliver the best results.

Soft-tissue Preparation

The alternatives range from no preparation to elevation of a surgical flap. While the literature shows that elevation of a surgical flap causes increased post-operative discomfort, there appears to be no benefit to soft-tissue preparation in terms of success rates.^{25,26} However some clinicians advocate a tissue punch procedure which creates a fenestration in the gingiva that allows for a very atraumatic placement with defined tissue borders, good tissue adaptation and adequate perfusion of the peri-implant tissues immediately post-operatively.

Preparation of the Implant Bed

The necessity to pre-drill the implant site has been extensively discussed and it is now generally accepted that there is no “black or white” for an answer. The truth lies somewhere in between. While self drilling mini-implants technically do not require any pre-drilling of the implant site, it appears as though it is ultimately a function of where the implant will be placed if pre-drilling is necessary or not. Successful mini-implants require adequate primary and secondary stability. Primary stability is the initial stability of the implant – obtained from mechanical retention in the bone. Secondary stability is the implant stability after the healing and remodeling has taken place at the implant site. It results from a positive biological response of the host. Therefore a successful mini-implant insertion should be aimed at obtaining adequate primary stability while at the same time trauma through compression

of the peri-implant tissues should be avoided because it would affect secondary stability negatively. One way to achieve this would be to insert the implant directly in areas of thinner cortical bone and create a purchase point or small perforation in implant sites where thicker cortical bone is to be expected.¹⁶ Cortical bone thicknesses can be obtained from individual 3-D imaging or from average samples as suggested in the study mentioned above.¹⁷

Orthodontic mini-implants have evolved into sophisticated treatment aides, which help manage difficult anchorage situations or non-compliant patients more predictably. Theoretically mini-implants can be placed anywhere there is bone, however only three insertion sites are suitable for mini-implant insertion on a regular basis and it is strongly recommended that clinicians limit their efforts to those sites in order to achieve maximum clinical success rates. In other words, mini-implants should be placed in anatomically favorable sites where maximum clinical success rates are to be expected. Then the proper biomechanics (direct/indirect) can be designed depending on the placement site and the intended tooth movement. This however can only be done when using a mini-implant with bracket head design as explained above.

A Glance Into the Future

This article provided an overview of where our specialty currently stands in regards to orthodontic mini-implants – the status quo. Ten years ago this would have sounded like science fiction to most practitioners. Therefore it is a challenging task to predict where our specialty is heading in this specific field.

Some developments however are very likely to happen. Better evidence in form of randomized clinical trials will shed more light on how clinical success rates can be improved and studies will provide insight on the stability of the achieved tooth movements. Some of the current indications will disappear because we will learn that these movements are not stable over the long-term and other indications will emerge. A tendency to use more prefabricated auxiliaries is evident already and this tendency will most likely increase since it makes clinical application simpler and the anchorage devices more versatile. Mini-implant designs will consolidate until most mini-implants look alike and allow for both direct and indirect anchorage and the use of all sorts of different auxiliaries. Most importantly: mini-implants are here to stay. ■

References for this article can be found on www.orthotown.com.

The palatal suture, when completely ossified, can hold mini-implants. However, individual variation is so great that it should be avoided as an implant site. Mini-implants should not be placed anywhere close to the nasopalatine canal and the greater palatine foramina. The most ideal insertion area in the palate can be found at the level of the first and second bicuspid.

- **Infrazygomatic crest:** While biomechanically very useful, especially for intrusion mechanics, on average the infrazygomatic crest does not provide sufficient bone volume for the insertion of orthodontic mini-implants without perforation of the maxillary sinus. Unless individual 3-D imaging is possible to evaluate the individual bone volume, the infrazygomatic crest should be avoided as an insertion site. Another reason to avoid this site is that placement would take place so deep in the vestibule that the implant would always be surrounded by very mobile mucosa – this can lead to soft tissue irritation, inflammation, or tissue overgrowth and would complicate clinical use of the implant.
- **Retromolar pad/ramus:** Excessive CBT and soft tissue thickness make this site very difficult to use. It is also difficult to reach so placement is less precise. Studies have demonstrated increased failure rates at this site.

Author's Bio

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