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Hard and soft tissue considerations at mini-implant insertion sites

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Various factors influence where orthodontic mini-implants will be placed. This article highlights the pertinent variables that should find consideration when planning the placement of orthodontic mini-implants.

Key words: Mini-implants, miniscrew, insertion site

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Introduction

An orthodontic mini-implant is a small screw-like device that is temporarily implanted into a patient's jawbone with the intention to create a fix spot for high-anchorage mechanics. As such, it needs to fulfill a number of requirements. It should be simple to insert without major discomfort to the patient and without damaging adjacent anatomical structures. It should remain stable under load at orthodontic force levels and over the intended treatment duration. Finally, it should be easily removable and leave behind a site that heals without complications. This article is intended to provide the basic information on insertion site selection for practitioners attempting to place their own mini-implants. It will aid with the avoidance of anatomical structures and complications and will deliver information vital to securing long-term stability of these little screws.

Selecting an insertion site

Being biomechanically driven, orthodontists usually chose an insertion site based on their treatment goal and their preferred biomechanical approach, accepting the potential anatomical shortcomings of the resulting site. While there is nothing wrong with this approach, there are clearly some implant sites that stand out in terms of anatomical consistency, user friendliness, and performance. The informed mini-implant user should be aware of these favourable sites, and should make every effort to limit themself to these areas that promise a superior outcome.

As orthodontic mini-implants are placed transmucosally and are retained enousseously, at times between the dental roots, they perforate both the hard and soft tissues of the oral cavity. In a normal insertion, they perforate the gingiva, the periosteum, the cortical and canellous bone, and frequently come to lie in close proximity to dental roots (Baumgaertel *et al.*, 2008). This means that there will be both soft and hard tissue interactions with the mini-implant that need to be kept in mind when aiming to place a screw at a certain site. The traditional thought is that attached gingiva is superior to mucosa, as the latter moves around the mini-implant under function, and thicker cortical bone is preferable to thinner cortical bone as it provides superior implant retention. Cancellous bone does not contribute significantly to mini-implant stability and proximity to dental roots increases the likelihood of mini-implant failure (Melsen, 2005; Baumgaertel *et al.*, 2008).

Therefore the traditional approach to selecting a mini-implant site can be summed up that a mini-implant should be placed in attached gingiva, in areas of sufficient cortical bone, and with sufficient clearance to dental roots. While again, there is nothing wrong with this approach, a more nuanced perspective and closer definition of the relevant parameters appears sensible in order to develop a more precise approach to mini-implant site selection.

Hard-tissue anatomical factors

To better understand the impact of hard-tissue anatomical variables, I recently introduced a structured approach, which subdivides these variables into macro-and micro-anatomical factors (Baumgaertel, 2014). The former are true anatomical structures, the latter are aspects of local bone anatomy and can generally only be assessed on three-dimensional (3D) radiographs.

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Marco-anatomical factors

This group of anatomical variables needs to be considered when selecting the implant site to avoid damage and discomfort to the patient. Additionally, proximity to such structures has potential to jeopardize mini-implant success. Table 1 gives an overview of which implant sites carry risk of damage to these structures.

Dental roots

Proximity of the implant to the dental roots has been shown to decrease implant success (Kuroda *et al.*, 2007; Asscherickx *et al.*, 2008; Chen *et al.*, 2008a). It is however interesting to note, that long-term damage to the dental roots is highly unlikely (Kim and Kim, 2011).

Various studies have suggested suitable interradicular implant sites based on 3D imaging of either dry-skulls or live, untreaded patients. (Poggio *et al.*, 2006; Hu *et al.*, 2009; Kim *et al.*, 2009; Monnerat *et al.*, 2009). No common consensus can be found between these studies, resulting in either conflicting or at the very least, confusing recommendations. A major shortcoming of these studies is clearly that root anatomy can be highly variable, rendering averages less useful.

Overall, the majority of mini-implants seem to be placed after the levelling and alignment phase of treatment, at which point root position is under complete control of the clinician and does not necessarily have much relationship to the pre-treatment situation. These anatomical averages should therefore only be used as a general guideline and not considered set in stone. Two sites, however, stand out as presenting so consistently favourable anatomy that they warrant mentioning here: the interdental areas between maxillary first molar and second bicuspid, and between first molar and second molar, when approached from the palate (Poggio *et al.*, 2006). The reason for this should be clear: the maxillary molars have only a single palatal root versus two buccal roots which act as 'spacers'.

In fact, it appears reasonable to actively diverge roots at implant sites to allow insertions with sufficient clearance. Other authors prefer to use stents or surgical guides to reduce the probably of root contact. Morea has reported excellent results in a pilot study, but the increased cost of this latter approach must be kept in mind (Morea *et al.*, 2011).

Table 1 Insertion sites and anatomical structures at risk for damage.

Implant site	Anatomical structure at risk
Maxillary buccal alveolar process	• Dental roots • maxillary sinus
Palatal alveolar process	• Dental roots • Maxillary sinus • Greater palatine vein, artery, nerve
Palate	• Nasal cavity • Incisive vein, artery, nerve
Mandibular buccal alveolar process	• Dental roots • Inferior alveolar vein, artery nerve
Mandibular retromolar region	• Inferior alveolar vein, artery, nerve
Infrazygomatic crest	• Maxillary sinus • Dental roots

Nerves and blood vessels

Although not hard-tissues, nerves and blood vessels fit this category well as they both travel within the maxilla and mandible.

It is clear that both nerves and larger blood vessels should be avoided. Fortunately, these structures are rather consistent in their course, and in the mandible they are even easily identified on a plain film radiograph and hence easily avoidable. Maxillary structures are less easy to image and would require a 3D method to precisely identify their course, but again, they are easily avoided clinically due to their very consistent course.

Sinuses and the nasal cavity

It is currently accepted that maxillary insertions carry the risk of creating oral-antral perforations at certain sites (Baumgaertel, 2009; Baumgaertel and Hans, 2009b; Baumgaertel, 2011). As may be obvious, such perforations can carry various risks, including infection, and therefore should be avoided (Kravitz and Kusnoto, 2007). Some authors advocate retaining the mini-implant in the proximal and the distal cortex as they have found bicortical anchorage to deliver better screw retention *in vitro* (Brettin *et al.*, 2008). In the majority of cases, a diligent risk–benefit assessment does not appear to support such an approach in areas where the distal cortex forms the boundary of the sinus or other midfacial cavities. Maxillary insertions should therefore only take place in areas with sufficient bone depth, such as the anterior palate and the maxillary alveolar process (Baumgaertel, 2009; Baumgaertel, 2011).

Micro-anatomical factors

To better understand the relevance of these microanatomical factors, we need to revisit what was said in the introductory remarks of this article regarding implant stability: it should be able to withstand mechanical load at orthodontic force levels and should remain stable over the intended period of time. This obviously requires good short-term, or primary stability, but also good long-term, or secondary stability.

Primary stability

Primary stability is defined as the stability the implant has immediately after the insertion and is a result of mechanical retention of the implant shank in the bone (Martinez *et al.*, 2001). While both implant design and insertion technique can have an impact on primary stability, it is the micro-anatomical factors that deliver the baseline for the expected stability at any given insertion site, namely the quantity and quality of the bone.

As Dalstra and co-workers have demonstrated, it is mainly the cortical bone that is responsible for the mechanical retention of the screw (Dalstra *et al.*, 2004). It is therefore reasonable to presume that the thickness of this layer of bone will determine the primary stability of the implant. Simply stated: that thick cortical bone will deliver greater primary stability than thin cortical bone (Wilmes *et al.*, 2006).

The quality, or density, of the local bone is becoming an increasing focus of research in the field of orthodontic mini-implants. In traditional implant dentistry, this factor has long found consideration in the planning of dental implants (Matteson *et al.*, 1996). But also for orthodontic mini-implants, it has been demonstrated that increased cortical bone density may have a positive effect on primary stability (Marquezan *et al.*, 2012). However, the same authors did not find any beneficial effects of increased overall bone density at an insertion site (Marquezan *et al.*, 2011). Therefore, to date, we are still unsure if bone density is an important factor for mini-implant success and how it should be factored into the planning and placing of an orthodontic mini-implant.

Secondary stability

Long-term, or secondary stability is defined as the stability of an implant long past the initial loading period during which intense bone remodelling can be observed. It is the result of 'positive remodelling', which constitutes bone formation at the bone/implant interface (O'Sullivan *et al.*, 2004; Wilmes *et al.*, 2006).

It is unrealistic to expect such positive remodelling and overall good healing if the implant were to lack good primary stability (i.e. present with mobility after the insertion). Unfortunately, however, high primary stability does not necessarily translate to good secondary stability (Baumgaertel, 2010). It appears that the most effective way to ensure a predictable transition from primary to secondary stability is to control the insertion torque (Motoyoshi *et al.*, 2006).

Managing insertion torque

Insertion torque serves as a proxy measure for bone compression and hence, is a popular measurement for primary stability (Wilmes *et al.*, 2006). It can be measured with various gauges (Pauls *et al.*, 2013). While low values usually indicate poor bone-to-implant contact and hence reduced mechanical retention, high values typically point to excellent primary stability, due to substantial compression of the bone. This latter aspect may explain why primary stability may not translate to high secondary stability. It has long been demonstrated that excessive compression of the bone carries the risk of substantial damage in terms of microfractures and compression osteonecrosis, which usually will result in resorptive remodeling, as opposed to the depositional positive healing required (Soltesz *et al.*, 1982; Huiskes and Nunamaker, 1984; Ueda *et al.*, 1991). Therefore, it comes as no surprise that the optimum result should be expected at medium torque levels, where primary stability is sufficient to avoid mobility of the screw, but where the compression is at physiologic levels, allowing for adaptive, depository remodelling and good secondary stability (Motoyoshi *et al.*, 2006).

One should be cognizant of the cortical bone thickness at a given insertion site, either through the use of 3D imaging techniques or at least by consulting anatomical averages that have been previously published (Baumgaertel, 2009; Baumgaertel and Hans, 2009a; Baumgaertel, 2011). This will allow the selection of the most adequate implant site or deliver information on how the site should be treated prior to the insertion. The author has designed an insertion protocol based on this information that is still in use to date and delivers above average placement outcomes (Baumgaertel, 2010).

Soft-tissue anatomical considerations

The theoretical advantages of mini-implant insertions in attached gingiva have been outlined above. There is no doubt that it is favourable if the implant is surrounded by gingiva that lacks mobility, and this paper will not argue with that fact (Atrzi *et al.*, 1993; Baumgaertel *et al.*, 2008). I will, however, attempt clarification that attached gingiva is not the only favourable soft-tissue option, and that others exist that will expand the number of possible insertion sites. Also, it is important to note that this discussion really only applies to insertions in the buccal alveolus and the infra-zygomatic crest, as all other sites come with only attached gingiva.

Multiple studies have researched the impact of mucosal quality on the success rates of orthodontic mini-implants, however, without reaching a unanimous conclusion (Cheng *et al.*, 2004; Park *et al.*, 2006; Chen *et al.*, 2008b; Lim *et al.*, 2009; Vivatttanatipa *et al.*, 2009). A reasonable explanation for this lack of consensus may be the varying mobility of the mucosa at different heights. The mucosa is attached at the mucogingival junction (MGJ), where it has no mobility, making the regions coronal to the MGJ suitable for insertions of mini-implants. As the mobility increases with distance to the MGJ, side effects should also increase, reaching their maximum at maximum distances, in the depth of the vestibule.

In a recent study, differences were observed between 'high mucosal' mini-implants and those placed at the MGJ (Vivatttanatipa *et al.*, 2009). Most studies, however, have neglected to differentiate between the area that can be referred to as 'limited-mobility mucosa' directly apical to the MGJ and the highly mobile mucosa located even further apically (Baumgaertel and Tran, 2012). As mobility is minimal in the limited-mobility mucosa, the expected side effects are negligible. But insertions at this level come with other advantages: buccal bone at this level is typically thicker further coronal and hence will provide better primary stability as outlined above (Wilmes *et al.*, 2006; Baumgaertel and Hans, 2009a). Targeting the attached gingiva can also be misleading as it is similar in appearance to the free gingiva, which can lead to insertions that are located too close to the crest of the alveolar bone. Lastly, as dental roots diverge in apical direction, limited-mobility mucosa insertions will on average have greater clearance from the roots as insertions in attached gingival (Kim *et al.*, 2009).

Tissue thickness should ideally be minimal; however, thicker attached tissue can be compensated for by choosing longer implants.

Summary

Orthodontic mini-implants offer so many advantages, they are here to stay. Considering the impact of hard and soft tissues will produce higher success rates and a better clinical experience.

Taking hard- and soft-tissue variables into consideration, no better insertion region exists than the anterior palate. Here, soft-tissue is all attached gingiva, bone depth is favourable for short to medium length mini-screws and cortical bone thickness will deliver, on average, good primary and secondary stability. From this area, plenty of biomechanical options exist to manage a wide range of clinical situations (Baumgaertel, 2008).

A site that on average should be ruled out for anatomical reasons is the infra-zygomatic crest. Here, sinus perforations are to be expected and the soft-tissue is extremely mobile, leading to various side effects: first and foremost, discomfort to the patient.

Both buccal and palatal insertions into the alveolar process will be successful, so long as inter-radicular distance and cortical bone thickness are respected.

The mandibular retromolar region presents with great anatomical variability and thick soft-tissue. However, ruling it out would mean missing out on opportunities for molar uprighting and mandibular full-arch retraction.

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References

Artzi Z, Tal H, Moses O, Kozlovsky A. Mucosal considerations for osseointegrated implants. *J Prosth Dent* 1993; **70**: 427–432.

Asscherickx K, Vande Vannet B, Wehrbein H, Sabzevar MM. Success rate of miniscrews relative to their position to adjacent roots. *Eur J Orthod* 2008; **30**: 330–335.

Baumgaertel S. Maxillary molar movement with a new treatment auxiliary and palatal miniscrew anchorage. *J Clin Orthod* 2008; **42**: 587–589.

Baumgaertel S. Quantitative investigation of palatal bone depth and cortical bone thickness for mini-implant insertion in adults. *Am J Orthod Dentofacial Orthop* 2009; **136**: 104–108.

Baumgaertel S. Pre-drilling of the implant site — is it necessary for orthodontic mini-implants? *Am J Orthod Dentofacial Orthop* 2010; **137**: 825–829.

Baumgaertel S. Cortical bone thickness and bone depth of the posterior palatal alveolar process for mini-implant insertion in adults. *Am J Orthod Dentofacial Orthop* 2011; **140**: 806–811.

Baumgaertel S, Hans MG. Investigation of buccal cortical bone thickness for mini-implant placement. *Am J Orthod Dentofacial Orthop* 2009a; **136**: 230–235.

Baumgaertel S, Hans MG. Assessment of infrazygomatic bone depth for mini-screw insertion. *Clin Oral Impl Res* 2009b; **20**: 638–642.

Baumgaertel S, Razavi MR, Hans MG. Mini-implant anchorage for the orthodontic practitioner. *Am J Orthod Dentofacial Orthop* 2008; **133**: 621–627.

Baumgaertel S, Tran TT. Mini-implant site selection – the mucosal fallacy. *J Clin Orthod* 2012; **46**(7): 434–436.

Baumgaertel S. Planning and placing temporary anchorage devices with the aide of cone beam computed tomography imaging. In Kapila S, (ed). Cone Beam Computed Tomography in Orthodontics: Indications, Insights, and Innovations. Chichester: Wiley, 2014, 411–425.

Brettin BT, Grosland NM, Qian F, Southard KA, Stuntz TD, Morgan TA, *et al.* Bicortical vs monocortical orthodontic skeletal anchorage. *Am J Orthod Dentofacial Orthop* 2008; **134**: 625–635.

Chen YH, Chang HH, Chen YJ, Lee D, Chiang HH, Yao CC. Root contact during insertion of miniscrews for orthodontic anchorage increases the failure rate: an animal study. *Clin Oral Implants Res* 2008a; **19**: 99–106.

Chen YJ, Chang HH, Lin HY, Lai EH, Hung HC, Yao, CC. Stability of miniplates and miniscrews used for orthodontic anchorage: experience with 492 temporary anchorage devices. *Clin Oral Impl Res* 2008b; **19**: 1188–1196.

Cheng SJ, Tseng IY, Lee JJ, Kok SH. A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. *Int J Oral Maxillofac Implant* 2004; **19**: 100–106.

Dalstra M, Cattaneo PM, Melsen B. Load transfer of miniscrews for orthodontic anchorage. *Orthodontics* 2004; **1**: 53–62.

Huiskes R, Nunamaker D. Local stresses and bone adaptation around orthopedic implants. *Calcif Tissue Int* 1984; **36**(Suppl. 1): 110–117.

Hu KS, Kang MK, Kim TW, Kim KH, Kim HJ. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. *Angle Orthod* 2009; **79**: 37–45.

Kim SH, Yoon HG, Choi YS, Hwang EH, Kook YA, Nelson G. Evaluation of interdental space of the maxillary posterior area for orthodontic mini-implants with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2009; **135**: 635–641.

Kim H, Kim TW. Histologic evaluation of root-surface healing after root contact or approximation during placement of mini-implants. *Am J Orthod Dentofacial Orthop* 2011; **139**: 752–760.

Kravitz ND, Kusnoto B. Risks and complications of orthodontic miniscrews. *Am J Orthod Dentofacial Orthop* 2007; **131**(4 Suppl): S43–S51.

Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T. Root proximity is a major factor for screw failure in orthodontic anchorage. *Am J Orthod Dentofacial Orthop* 2007; **131**(4 Suppl): S68–s73.

Lim HJ, Eun CS, Cho JH, Lee KH, Hwang HS. Factors associated with initial stability of miniscrews for orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2009; **136**: 236–242.

Martinez H, Davarpanah M, Missika P, Celletti R, Lazzara R. Optimal implant stabilization in low density bone. *Clin Oral Implants Res* 2001; **12**: 423–432.

Marquezan M, Souza MM, Araújo MT, Nojima LI, Nojima Mda C. Is miniscrew primary stability influenced by bone density? *Braz Oral Res* 2011; **25**: 427–432.

Marquezan M, Lau TC, Mattos CT, Cunha AC, Nojima LI, Sant'Anna EF, *et al*. Bone mineral density. *Angle Orthod* 2012; **82**: 62–66.

Matteson SR, Deahl ST, Alder ME, Nummikoski PV. Advanced imaging methods. *Crit Rev Oral Biol Med* 1996; **7**: 346–395.

Melsen B. Mini-implants: where are we? *J Clin Orthod* 2005; **39**: 539–547.

Monnerat C, Restle L, Mucha JN. Tomographic mapping of mandibular interradicular spaces for placement of orthodontic mini-implants. *Am J Orthod Dentofacial Orthop* 2009; **135**: 428.e1–428.e9.

Morea C, Hayek JE, Oleskovicz C, Dominguez GC, Chilvarquer I. Precise insertion of orthodontic miniscrews with a stereolithographic surgical guide based on cone beam computed tomography data: a pilot study. *Int J Oral Maxillofac Implants* 2011; **26**: 860–865.

Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N. Recommended placement torque when tightening an orthodontic mini-implant. *Clin Oral Implants Res* 2006; **17**: 109–114.

O'Sullivan D, Sennerby L, Meredith N. Influence of implant taper on the primary and secondary stability of osseointegrated titanium implants. *Clin Oral Impl Res* 2004; **15**: 474–480.

Park, HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. *Am J Orthod Dentofac Orthop* 2006; **130**: 18–25.

Pauls A, Nienkemper M, Drescher D. Accuracy of torque-limiting devices for mini-implant removal: an *in vitro* study. *J Orofac Orthop* 2013; **74**: 205–216.

Poggio PM, Incorvati C, Velo S, Carano A. 'Safe zones': a guide for miniscrew positioning in the maxillary and mandibular arch. *Angle Orthod* 2006; **76**(2): 191–197.

Soltesz U, Siegele D, Riedmüller J, Schultz P. Stress concentration and bone resorption in the jaw for dental implants with shoulders. In Lee AJC, Albrektsson T, Branemark PI, (ed). Clinical Applications of Biomaterials. Chichester: Wiley & Sons, 1982. pp. 115–122.

Ueda M, Matsuki M, Jacobsson M, Tjellstrom A. The relationship between insertion torque and removal torque analyzed in fresh temporal bone. *Int J Oral Maxillofac Implants* 1991; **6**: 442–447.

Viwattanatipa N, Thanakitcharu S, Uttraravichien A, Pitiphat W. Survival analyses of surgical miniscrews as orthodontic anchorage. *Am J Orthod Dentofac Orthop* 2009; **136**: 29–36.

Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters affecting primary stability of orthodontic mini-implants. *J Orofac Orthop* 2006; **67**: 162–174.