Mini-implant anchorage for the orthodontic practitioner

Sebastian Baumgaertel,[a] Mohammad R. Razavi,[b] and Mark G. Hans[c]
Cleveland, Ohio

Mini-implant–enhanced anchorage has become a popular concept in orthodontics over the past years. Although these systems are routinely used in university settings, there is some reservation because of lack of information in private practices. This article will introduce the concept of mini-implant anchorage to the orthodontic practitioner. (Am J Orthod Dentofacial Orthop 2008;133:621-7)

Orthodontic anchorage is defined as resistance to undesired tooth movement. In the anteroposterior dimension, 3 anchorage situations are traditionally defined by the ratio of incisor retraction to molar protraction. While moderate anchorage entails reciprocal space closure, maximum anchorage means that most of the space is closed by retraction of the incisors, and minimum anchorage means that most of the space is closed by protraction of the buccal segments. Absolute anchorage, when the anchorage units remain completely stationary, is sometimes desirable but is usually unattainable with traditional orthodontic mechanics. The exception is the presence of ankylosed teeth in the anchorage unit. Under these special circumstances, forces applied to those teeth are completely transferred to the surrounding skeletal structures. This situation is sometimes called skeletal anchorage and, by the above definition, could also be called absolute anchorage.

Understanding each patient's anchorage requirements is of paramount importance and ensures high-quality care. Unexpected or unintended anchorage loss frequently results in a compromised finish. Traditionally, high-anchorage situations require excellent patient compliance with extraoral traction devices. This dependency on patient compliance greatly increases the risk for failure.

Therefore, over the past 60 years, methods have been developed to create absolute skeletal anchorage and thus widen the scope of orthodontics. In 1945, Gainsforth and Higley[1] used vitallium screws in mongrel dogs to create absolute anchorage for tooth movement. Linkow[2,3] suggested implants for anchorage purposes and described the use of an endosseous blade implant for retraction of anterior teeth in 1969. In 1983, Creekmore and Eklund[4] performed maxillary incisor intrusion with the help of a titanium osteosynthesis screw. Roberts et al[5] investigated the effects of immediate and delayed loading of dental implants in rabbits in 1984. In 1988, Turley et al[6] used endosseous implants to investigate the influence of absolute anchorage on tooth movement in dogs. Shortly thereafter, Roberts et al[7] reported on applying these principles for molar movement in an adult patient. With the invention of the onplant in 1995, Block and Hoffman[8] introduced the palate as an anchorage device location, and, in 1996, Wehrbein et al[9] used the palate as an implant site. Kanomi[10] used a 1.2-mm diameter mini-implant in 1997. After that, many reports were published on orthodontic absolute anchorage systems, reflecting their increasing popularity and importance. Some of these involved screws only, and some used screws in conjunction with miniplates.[11,12]

The recent increase in popularity of skeletal anchorage in the United States has led to the introduction of many new systems. American orthodontists can choose from many systems and components to achieve absolute anchorage. The intent of this article is to give the clinician the information necessary to understand mini-implant anchorage systems as well as an overview of currently available systems approved by the Food and Drug Administration with active distributors in the United States (Table).

INDICATIONS

Defining specific indications where orthodontic mini-implants can successfully be used has 2 potential benefits. First, using mini-implants appropriately will

From the Department of Orthodontics, School of Dental Medicine, Case Western Reserve University, Cleveland, Ohio.
[a]Assistant clinical professor.
[b]Assistant clinical professor; head, Section Orthodontics, Department of Plastic Surgery, Section Dentistry, Cleveland Clinic Foundation, Cleveland, Ohio.
[c]Professor and chairman.
Reprint requests to: Sebastian Baumgaertel, Case Western Reserve University, School of Dental Medicine, Department of Orthodontics, 10900 Euclid Ave, Cleveland, OH 4410; e-mail, sxb155@case.edu.
Submitted, November 2006; revised and accepted, March 2007.
0889-5406/$34.00

doi:10.1016/j.ajodo.2007.03.022

Table. Currently available systems approved by the Food and Drug Administration with distributors in the United States

System	*Lomas*	*Tomas*	*Ortho Implant*
Manufacturer	Mondeal, Tuttlingen, Germany	Dentaurum, Ispringen, Germany	Imtec, Ardmore, Okla
US distributor	GAC/Dentsply, Bohemia, NY	Dentaurum, Newtown, PA	3M Unitek, Monrovia, Calif
Screw shape	Cylindrical	Cylindrical	Conical
Screw type (thread)	Self-drilling Self-tapping	Self-tapping Self-drilling	Self-drilling Self-tapping
Diameter (mm)	1.5 2.0 2.3	1.6	1.8
Length (mm)	7 9 11	6 8 10	6 8 10
Screw head	Rectangular, .018 × .025-in and .022 × .025-in tube and slot	Hexagonal, .022-in universal cross slot and patented undercut	Hexagonal, O-ball & .030-in hole, O-cap
Packaging	Sterile	Sterile	Sterile
System components	Autoclavable tray Pilot drill Ø 1.0 and 1.5 mm Torque wrench Socket driver handle Socket blade Finger socket driver Hand piece socket	Teflon tray Tissue punch Locator Round drill Ø 1.0 mm Standard pilot drill Ø 1.2 mm Pilot drill Ø 1.1 mm Applicator wheel Torque ratchet Driver	MDI tray Tissue punch Pilot drill Ø 1.1 mm O-driver O-cap Mucosa marker Optional: #2 round bur Ratchet wrench with adapters

lead to improved treatment results. Second, not using them when traditional mechanics could lead to equally satisfying results prevents overtreatment. However, because of the versatility of mini-implant–enhanced mechanics, some situations that could be resolved with traditional mechanics might be treated in a shorter time or at least with a more predictable outcome. In these situations, mini-implant anchorage might be indicated if the patient's desires can be better addressed and the benefits outweigh the risks. Since many orthodontic treatment planning decisions are based on decades of dogma, a clinician who is interested in using mini-implants needs to adopt a new treatment-planning paradigm. The following treatment objectives might benefit from mini-implants.

Corrections in the anteroposterior dimension[13-16]

1. Because anchorage considerations are of no concern, the choice between first or second premolars can be made by solely considering tooth anatomy, and periodontal and restorative status (Fig 1).
2. Adults with full-step Class II malocclusion and severe overjet having extraction of the maxillary first or second premolars and retraction of the maxillary anterior teeth could benefit. Absolute anchorage might be indicated because anchorage loss is unfavorable in this situation, and treatment time will be reduced because of en-masse retraction.
3. Severely bimaxillary protrusive patients with chief complaint of unpleasant profile or lip incompetence and unwillingness to wear headgear could use mini-implants after 4 premolar extractions because these allow for maximum retraction with maximum impact on profile.
4. Patients who need canine substitution because of lateral incisor agenesis might benefit. Absolute anchorage allows for protraction of the posterior segments, thus making canine substitution an option even in a Class I molar relationship, a traditional contraindication for canine substitution.
5. Mini-implants could be used for protraction of posterior segments, in general, for extraction space closure, or for tooth agenesis or tooth loss if prosthetic replacement is not desired. This is also possible in extraction sites with collapsed alveolar

Table. Continued

Dual Top	*Spider Screw*	*Ortho Anchor*	*AbsoAnchor*
Jeil Medical, Seoul, South Korea	HDC Italy, Sarcedo, Italy	KLS Martin, Tuttlingen, Germany	Dentos, Daugu, South Korea
Rocky Mountain Orthodontics, Denver, Colo	Ortho Technology, Tampa, Fla	KLS Martin, Jacksonville, Fla	Great Lakes Orthodontics, Tawanda, NY
Cylindrical	Cylindrical K1-conical	Cylindrical	Cylindrical, conical
Self-drilling Self-tapping	Self-tapping K1 – Self-drilling & Self-tapping	Self-tapping	Self-drilling Self-tapping
1.4 1.6 2.0	1.5, 2.0 K1: 1.5	1.5 2.0	1.2-1.8
6 8 10	Ø2 mm: 7, 9, 11 Ø1.5 mm & K1: 6.5, 8,10	6 8	4-10 12
Hexagonal, button, .022-in cross slot	Octagonal, .022-in cross slot, .022 × .025-in tube, 2 round tubes	.035-in single slot and .035-in hole	Hexagonal, small, long, circle, fixation, bracket, or no head
Nonsterile	Nonsterile	Nonsterile	Nonsterile
Screwdriver body Hex driver shaft Cross driver shaft Pilot drill Screw block	Cross handle & pick-up handle driver shafts Hand driver Contra angle cross driver & pick-up driver Pilot drill Ø 1.1 × 5 mm Ø 1.2 × 10 mm Ø 1.5 × 7, 9, 11 mm	Screwdriver handle Screwdriver blade Right-angle blade Pilot drill Ø 1.1 mm Optional: OrthoAnchor container Soft-tissue punch Rose burr	Long hand driver B & tip S Short hand driver S Pilot drill 25/1.0 mm Pilot drill 31/1.0 mm Round bur 21 mm Regular case Optional: Long hand driver B-TG and tip L Short hand driver L Engine drivers S & L Pilot drill 24/1.0 mm

ridges when the patient can benefit from the osteogenic potential of orthodontic tooth movement.

6. Patients who need molar distalization for correction of Angle Class II malocclusion and relief of crowding would also benefit.

Corrections in the vertical dimension[4,13,17-20]

1. Anterior open bites can be corrected with intrusion of the maxillary posterior segments in patients with posterior maxillary excess (Fig 2).
2. Mini-implants can be used for vertical control of mandibular posterior segments in high-angle patients.
3. Anterior open bites can be corrected by a combination of the above.
4. Maxillary incisors can be intruded in patients with deep bite and excessive gingival display.
5. Mandibular incisors can be intruded in patients with deep bite and deep curve of Spee.
6. Deep bites can be resolved by a combination of the above.
7. Canted occlusal planes can be resolved.

Preprosthetic orthodontics, single tooth movement, and mutilated dentition[21,22]

1. Mini-implants can be used for molar uprighting, space management, and single-tooth intrusion in patients with extruded antagonists.
2. Desirable anchorage situations can be predictably achieved in patients with mutilated dentition.

IMPLANT SITE SELECTION

Selecting the proper implant site can be an important factor in the overall success of this treatment approach. Five factors are important in determining an adequate site for implantation.

1. Indication, system used, and required mechanics. When placing an orthodontic mini-implant, the treatment objective and how long the implant will remain in situ are of paramount importance. Mechanics should be as simple and fail-safe as possible, but the future tooth movement must be anticipated to avoid any interference with the implant.

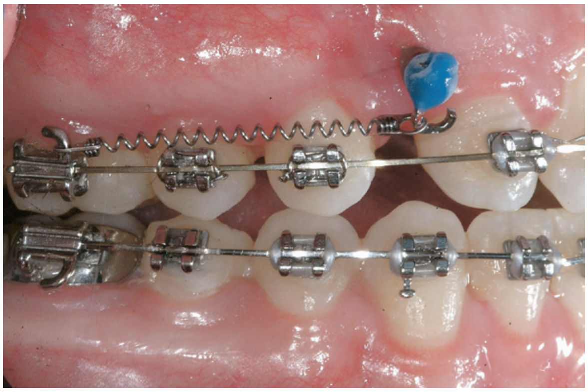

Fig 1. Correction in the anteroposterior plane of space: molar protraction.

Fig 2. Correction in the vertical plane of space: molar intrusion.

2. Placement in attached gingiva, clear of the frenulum. The implant site should ideally provide sufficient attached gingiva for placement of the mini-implant. This prevents patient discomfort, tissue overgrowth, and microjiggling that can lead to long-term implant failure.
3. Sufficient interradicular distance. The implant must be placed where roots are wide enough apart so that no damage is inflicted. Periapical radiographs or 3-dimensional cone-beam computed tomography are essential tools for evaluating potential implant sites. If the preferred implant site is obstructed by root proximity, some preparatory root uprighting might be necessary.
4. Avoiding other anatomical structures. Other anatomical structures can interfere with the placement of an orthodontic mini-implant: eg, inferior alveolar nerve, artery, vein, mental foramen, maxillary sinus, and nasal cavity. Again, 3-dimensional digital imaging can help evaluate the anatomical relationships.[23]
5. Adequate cortical bone thickness. Cortical bone thickness is an important factor in mini-implant stability.[24] Placing the implant in areas of favorable bone thickness ensures better primary stability and long-term success.

PLACEMENT PROTOCOL

Placement protocols can differ, depending on the various systems. The most common steps involved in the placement of mini-implants are described. Clinicians should consult the manufacturer to optimize this protocol for the mini-implant system they are using.

Generally, topical anesthetic is sufficient for painless placement of mini-implants. A brief review of the anatomy will illustrate this. During placement, an implant penetrates several layers of tissue, some of which are innervated. The superficial layer—the gingival tissue—is strongly innervated, but topical anesthetic is effective for desensitizing the neural input from this tissue. The second layer is the periosteum, which also is highly innervated. Topical anesthetic can reduce painful stimuli originating in this tissue if sufficient time is allowed for diffusion of the medication to the periosteal layer. The third layer is the cortical plate of either the maxilla or the mandible; this is not highly innervated and thus does not require anesthetic. The fourth layer is the cancellous bone of the jaw. Bone is not well innervated and does not require anesthetic.

This approach offers the clinician another important aid aside from not having to give an injection. Because all other innervated structures inside the bone have not been blocked by anesthetic allows the patient to provide the clinician important feedback. If the clinician comes close to sensitive structures, such as the alveolar socket of a tooth, the nerve canal, or the maxillary sinus, the patient senses pain and can alert the doctor before the implant penetrates these sensitive structures, thus preventing potentially irreversible damage.

After correct identification of the implant site and topical anesthesia, a self-drilling or a self-tapping implant must be placed into the bone by clockwise rotation with the system-specific driver or a torque wrench if torque control is desired. Only rarely is a soft-tissue punch or perforation of the cortical plate necessary.

Some self-tapping systems require a pilot hole. After correct identification of the implant site and topical anesthesia, the soft tissues covering the bone (gingiva and periosteum) at the implant site should be excised with a soft-tissue biopsy punch. This ensures a clean soft-tissue margin surrounding the implant. An initial perforation of the cortical plate with a round bur

Fig 3. Buccal mini-implant immediately after placement.

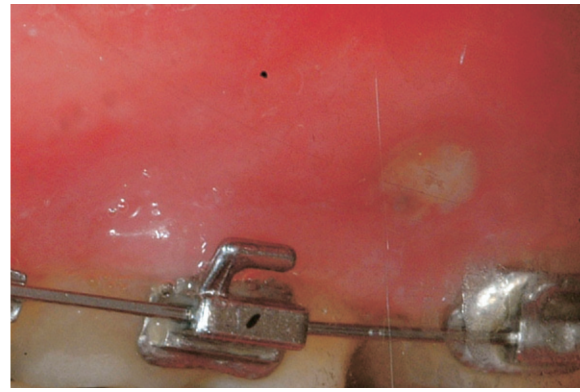

Fig 4. Residual wound 24 hours after mini-implant removal.

as indicated by the manufacturer is then necessary because pilot drills are usually not designed to cut through cortical bone. This design element protects the roots of the teeth. After perforation of the cortical plate, the pilot drill is used to create a channel though the bone with a smaller diameter than the implant. The drill should be either an implant hand piece or a slow-speed hand piece with torque reduction to allow for drilling at approximately 800 rpm. All steps that include drilling require constant irrigation with sterile saline solution. The implant can then be rotated manually in a clockwise direction with an applicator and a torque wrench or a driver. Figure 3 shows a buccal mini-implant (TOMAS Pin, Dentaurum, Newtown, Pa) immediately after placement.

Removal generally does not require anesthesia. The manual applicator or the driver is used to derotate the implant in a counterclockwise direction. Figure 4 shows the residual wound 24 hours after implant removal.

Self-tapping vs self-drilling

Self-tapping mini-implant systems have a noncutting tip and therefore require a pilot hole of the same length as the implant. It is not necessary, however, to tap a thread into the bone as in some dental implant systems because mini-implants have a self-tapping thread. The difference of self-drilling systems is that the screws have a cutting tip that makes drilling a pilot hole unnecessary.

Both modalities of implant placement seem to have advantages and disadvantages. Whereas, generally, self-tapping systems are considered slightly more invasive, they have distinct advantages when it comes to perforating the cortical bone. To drill a self-drilling screw through the cortical bone, relatively high pressure could be necessary. This can cause compression of the bone, leading to patient discomfort, resorption, and subsequent failure. With the application of high pressure, the clinician might also lose some tactile sensitivity and deviate from the ideal path of placement. The resistance encountered when drilling a self-drilling implant through the cortical bone can ultimately increase the risk for fracture of the implant. On the other hand, once the pilot hole is drilled, the self-tapping implant is placed without difficulty and with minimal tissue damage. Deviation from the ideal path of placement is not possible because the implant follows the pilot hole.

However, in areas with thin cortical bone, such as in the posterior maxilla, a pilot hole might not be necessary. Here, self-drilling systems show their strength: a relatively uncomplicated placement without the drill and with less procedure time. This might have psychological advantages because patients and doctors alike seem to prefer a drill-free system. In addition, self-drilling systems seem to have greater primary stability.[25]

The ideal combination appears to be a self-drilling mini-implant system with perforation of only the cortical bone but without a true pilot hole extending into the bone the entire length of the implant. This combines the advantages of both systems and is user friendly.

POTENTIAL COMPLICATIONS

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.[24,26,27] 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 (Table).[28] 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 (Table). 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.

CONCLUSIONS

Orthodontic mini-implants are a powerful aid for the orthodontic practitioner in resolving challenging malocclusions. A wide selection of implants is available in the United States and more systems are expected to be introduced to the market. One should select a versatile system that allows for a wide variety of mechanical applications. Various indications were illustrated, with the placement process discussed and potential complications listed. Mini-implant enhanced mechanics can become a routine application in the modern orthodontic office.

REFERENCES

1. Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities in basal bone. Am J Orthod Oral Surg 1945;31:406-17.
2. Linkow LI. The endosseous blade implant and its use in orthodontics. Int J Orthod 1969;7:149-54.
3. Linkow LI. Implanto-orthodontics. J Clin Orthod 1970;4:685-90.
4. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. J Clin Orthod 1983;17:266-9.
5. Roberts WE, Smith RK, Zilberman Y, Mozsary PG, Smith RS. Osseous adaptation to continuous loading of rigid endosseous implants. Am J Orthod 1984;86:95-111.
6. Turley PK, Kean C, Schur J, Stefanac J, Gray J, Hennes J, et al. Orthodontic force application to titanium endosseous implants. Angle Orthod 1988;58:151-62.
7. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod 1990;60:135-52.
8. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontics. Am J Orthod Dentofacial Orthop 1995;107:251-8.
9. Wehrbein H, Glatzmaier J, Mundwiller U, Diedrich P. The orthosystem—a new implant system for orthodontic anchorage in the palate. J Orofac Orthop 1996;57:142-53.
10. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod 1997;31:763-7.
11. Costa A, Raffaini M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthod Orthognath Surg 1998;13:201-9.
12. Sugawara J. Dr. Junji Sugawara on the skeletal anchorage system. Interview by Dr. Larry W. White. J Clin Orthod 1999;33:689-96.
13. Park HS, Kwon TG. Sliding mechanics with microscrew implant anchorage. Angle Orthod 2004;74:703-10.
14. Gelgor IE, Buyukyilmaz T, Karaman AI, Dolanmaz D, Kalayci A. Intraosseous screw-supported upper molar distalization. Angle Orthod 2004;74:838-50.
15. Herman RJ, Currier GF, Miyake A. Mini-implant anchorage for maxillary canine retraction: a pilot study. Am J Orthod Dentofacial Orthop 2006;130:228-35.
16. Chung KR, Cho JH, Kim SH, Kook YA, Cozzani M. Unusual extraction treatment in Class II Division 1 using C-orthodontic mini-implants. Angle Orthod 2007;77:155-66.
17. Kuroda S, Katayama A, Takano-Yamamoto T. Severe anterior open-bite case treated using titanium screw anchorage. Angle Orthod 2004;74:558-67.
18. Erverdi N, Keles A, Nanda R. The use of skeletal anchorage in open bite treatment: a cephalometric evaluation. Angle Orthod 2004;74:381-90.
19. Ohnishi H, Yagi T, Yasuda Y, Takada K. A mini-implant for orthodontic anchorage in a deep overbite case. Angle Orthod 2005;75:444-52.
20. Jeon YJ, Kim YH, Son WS, Hans MG. Correction of a canted occlusal plane with miniscrews in a patient with facial asymmetry. Am J Orthod Dentofacial Orthop 2006;130:244-52.
21. Giancotti A, Arcuri C, Barlattani A. Treatment of ectopic mandibular second molar with titanium miniscrews. Am J Orthod Dentofacial Orthop 2004;126:113-7.

22. Yao CC, Wu CB, Wu HY, Kok SH, Chang HF, Chen YJ. Intrusion of the overerupted upper left first and second molars by mini-implants with partial-fixed orthodontic appliances: a case report. Angle Orthod 2004;74:550-7.
23. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop 2006;129:611-8.
24. Tseng YC, Hsieh CH, Chen CH, Shen YS, Huang IY, Chen CM. The application of mini-implants for orthodontic anchorage. Int J Oral Maxillofac Surg 2006;35:704-7.
25. Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters affecting primary stability of orthodontic mini-implants. J Orofac Orthop 2006;6:162-74.
26. 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 Implants 2004;19:100-6.
27. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2006;130:18-25.
28. Maino BG, Mura P, Bednar J. Miniscrew implants: the spider screw anchorage system. Semin Orthod 2005;11:40-6.