

IMPLANTS



IMPLANTS AS ABSOLUTE ANCHORAGE

Kitichai Rungcharassaeng, DDS, MS; Joseph Y.K. Kan, DDS, MS;
and Joseph M. Caruso, DDS, MS

ABSTRACT

Anchorage control is essential for successful orthodontic treatment. Each tooth has its own anchorage potential as well as propensity to move when force is applied. When teeth are used as anchorage, the untoward movements of the anchoring units may result in the prolonged treatment time, and unpredictable or less-than-ideal outcome. To maximize tooth-related anchorage, techniques such as differential torque, placing roots into the cortex of the bone, the use of various intraoral devices and/or extraoral appliances have been implemented.

Implants, as they are in direct contact with bone, do not possess a periodontal ligament. As a result, they do not move when orthodontic/orthopedic force is applied, and therefore can be used as “absolute anchorage.” This article describes different types of implants that have been used as orthodontic anchorage. Their clinical applications and limitations are also discussed.

One of the most important determinants in successful orthodontic treatment is optimal anchorage control. Nevertheless, due to Newton's third law, teeth that are used as anchoring units also have the same propensity to mobilize as the teeth intended to be moved (moving unit) during orthodontic force application. As movements of the anchoring units are inevitable, orthodontic anchorage is traditionally categorized into maximum, moderate and minimum anchorage, depending on the amount of anticipated movement of the anchoring unit during orthodontic/orthopedic force application.¹ Of the three types of anchorage, maximum



Authors / Kitichai Rungcharassaeng, DDS, MS, is associate professor, Department of Restorative Dentistry; resident, Department of Orthodontics, Loma Linda University School of Dentistry.

Joseph M. Caruso, DDS, MS, associate professor and chair/program director, Department of Orthodontics, Loma Linda University School of Dentistry.

Guest editor / Joseph Y.K. Kan, DDS, MS, associate professor, Department of Restorative Dentistry, Loma Linda University School of Dentistry.

anchorage is usually most desirable and, at the same time, the most difficult one to achieve. Extraoral devices have been implemented to enhance the stability of the anchoring unit. Nonetheless, they are esthetically objectionable, cumbersome and, most important of all, require a patient's compliance.

Absolute anchorage is the term used to describe the anchoring unit that remains stationary under orthodontic forces. The dental elements that may provide such anchorage are generally limited to ankylosed teeth.² However, they are, more often than not, in undesirable positions and should be moved. Therefore, their use as orthodontic anchorage is very limited. Nevertheless, with the advent of the osseointegrated implants, the possibility of functional absolute anchorage is realized.

Implants and Osseointegration

Osseointegration is defined as the direct connection between living bone and load-carrying implant at light microscopic level.³ Classical requirements to achieve osseointegration include aseptic and atraumatic surgery, primary implant stability, complete tissue coverage and nonloaded healing period of three to six months.³ Besides, the implant should be made of a bioinert (e.g. titanium, carbon) or bioactive (e.g. hydroxyapatite) and not biotolerant (e.g. stainless-steel, chrome-cobalt alloy) material. The clinical applications of implant-supported prostheses have been well documented and generally high success rates have been reported.⁴

Immediate Loading and Endosseous Implants

While the osseointegration technique had been strictly followed throughout the 1970s and most of the 1980s, toward the end of the 1980s,

some of the classical guidelines had been challenged, especially the nonloaded healing period. In 1986, Babbush et al. reported a technique of immediately loaded implant bar overdenture and achieved a cumulative implant success rate of 88 percent up to eight years of function.⁵ Since then, numerous studies regarding immediately loaded implants have been published and the rationale established.

The key to the success of immediately loaded implants is achieving primary implant stability and maintaining it until osseointegration is complete. Therefore, the rate and magnitude of osseointegration achieved are also of consequence. Primary implant stability and the rate and magnitude of osseointegration are influenced by the following factors:⁶

Bone Quality

Lekholm and Zarb classified bone quality into four types: Type I, II, III and IV, where Type I is the densest (consisting mainly of cortical bone) and Type IV is the least dense bone (loosely packed trabecular bone with thin cortical bone).⁷ Studies have shown that significantly higher implant failure rates were observed when implants were placed in Type IV bone as compared with those placed in Type I – III bone.⁴ This is mainly due to the fact that implant-bone interface is much less in Type IV bone, which leads to poor primary implant stability.

Bone Quantity

The quantity of available bone determines the dimension of the implant to be placed. The increase in diameter and/or length of the implant results in the increase in the potential implant-bone contact area (magnitude of osseointegration).⁸



Figure 1. Osseointegrated implants (Nos. 3 and 14) are used as absolute anchorage in a partially edentulous patient who otherwise would not be able to benefit from orthodontic treatment due to inadequate anchorage.

Implant Surface

The surface of endosseous implants may be smooth (machined-surface) or rough (treated-surface). It has been shown that a significantly higher rate and magnitude of osseointegration were achieved with implants that had surface treatment when compared to machined-surface implants.⁹

Implant Geometry

Screw-shaped implants have been shown to provide the strongest immediate mechanical retention after placement.¹⁰

Prosthetic and Orthodontic Forces

There are substantial differences in both direction and magnitude of prosthetic and orthodontic forces. While prosthetic forces are multidirectional, interrupted heavy forces (estimated in kilograms), orthodontic forces generally are unidirectional, continuous and much lighter (from 20 to a few hundred grams).¹¹ Since endosseous implants have been successfully immediately loaded with prosthetic forces, it is logical to believe that it would be able to withstand orthodontic forces immediately or very soon after placement, without hav-

ing to wait for complete healing of the bone. Roberts et al. demonstrated in an animal (dog) study that implants with less than 10 percent direct bone-implant contact could resist a continuous load of 3 N (~300g) for 13 weeks while maintaining clinical rigidity.¹²

Endosseous Implant as Orthodontic Anchorage

The use of endosseous implants as orthodontic anchorage has been extensively studied as they are viewed as an excellent alternative to traditional orthodontic anchorage methodologies (Figure 1). Animal and human studies utilizing osseointegrated implants as orthodontic anchorage to perform different types of orthodontic tooth movements (tipping, torquing, rotation, intrusion, extrusion, uprighting, and bodily movements) under different levels of force (orthodontic vs. orthopedic) have been reported.¹¹⁻¹⁴ Various anatomic sites have been used for implant location (retromolar, media/paramedian palatal regions, edentulous sites) and a wide range of healing time (four to 36 weeks) has been observed. In all studies, desired orthodontic movements were achieved and osseointegration maintained until the end of the treatment.

Endosseous implants are suitable as orthodontic anchorage due to the following features:

- **Direct bone-implant contact:** There is no PDL between bone and implant, therefore the implant does not respond to the orthodontic force (no apposition and resorption).¹³ Its immobility makes it an ideal absolute anchoring unit, as lack of reciprocal movement during orthodontic treatment would likely reduce the total treatment time.

- Though similar in their unresponsiveness toward orthodontic force, unlike an ankylosed tooth, an implant

can be placed in a position that will provide optimal mechanical anchorage and not be in the way of tooth movement.¹¹ This is made possible by the availability of implants of variable sizes.

- The possibility of immediate or early loading of implant for orthodontic tooth movement minimizes the waiting bone-healing period and thus does not significantly increase the total treatment time.

- Intraoral location of implants make it appealing to patients who otherwise would need anchorage from esthetically challenged extraoral devices. Furthermore, patient compliance is not required with implant-borne anchoring unit.

Endosseous Implants — A Perfect Absolute Anchorage?

Nevertheless, the use of endosseous implants as orthodontic anchorage has still been limited due to the following reasons:

- It involves additional surgical procedures and entails significant additional cost. While it has been shown that implant success rates are comparable when they are performed in a sterile or clean condition, aseptic surgery is still recommended for the osseointegration technique.¹⁵ Due to its technique-sensitive nature that requires special setup, implant surgery should be referred to and performed by a specialist.

- When the implant is placed in the edentulous site, it is likely to be used for the final prosthesis and does not need to be removed. However, when the implant is placed in a nonrestorative location (e.g. mid-palate, retromolar region), it must be removed at the end of the treatment. Since the implant has been osseointegrated, the implant removal usually entails removal of surrounding bone (with trephine burs or

high-speed carbide bur) and thus can be more traumatic than the implant insertion. Multiple surgeries can also be objectionable to some patients.

- In partially edentulous patients, the implant(s) may be placed in the planned edentulous site(s) to be used for the final prosthesis as well as not to interfere with the programmed orthodontic movement. However, this requires an interdisciplinary approach that demands a very accurate prosthetic setup, precise implant placement, and errorless orthodontic execution. Any minute mistake may result in an esthetically compromised situation that warrants implant removal during the course or at the end of the treatment.

- Since osseointegrated implants are in a state of ankylosis, they do not follow the development of the adjacent structures.¹⁶ Implants placed in the edentulous sites of a growing patient will result in vertical tissue discrepancies that are virtually incorrigible at the end of growth. Therefore, their use in partially edentulous situations is essentially limited to nongrowing patients.

Alternatives to Endosseous Implants

To cope with the limitations of endosseous implants as orthodontic anchorage, several alternatives, collectively termed temporary anchorage devices, have been advocated. These devices can be placed transosteally, subperiosteally, or endosteally and can be fixed to bone either biochemically (osseointegrated) or mechanically (cortically stabilized).¹⁷ They can be used as indirect absolute anchorage when connected to the anchoring teeth or direct absolute anchorage when connected to the moving unit, and as the name implies, these devices are to be removed after use.

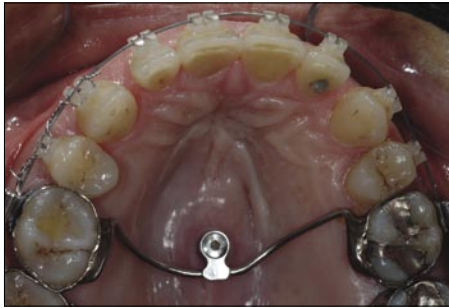


Figure 2. An onplant (Nobel Biocare, Yorba Linda, Calif.) is used to assist anchorage provided by the transpalatal bar.



Figure 3. Skeletal anchorage system consists of titanium miniplate and monocortical screws (Leibinger Micro Implants, Portage, Mich.).



Figure 4. Dual-top anchor orthodontic miniscrews (RMO, Denver, Colo.) are designed for orthodontic procedures.



Figure 5. Osteotomy fixation screws (ACE Surgical Supply, Inc., Brockton, Mass.) are made of titanium alloy and therefore can also be used as absolute anchorage.

Onplant

Onplant (Nobel Biocare, Yorba Linda, Calif.) is a thin titanium alloy (6Al4V) disk, textured and coated with hydroxyapatite on one surface and a threaded hole on the opposite side. It is to be inserted subperiosteally with the HA-coated side against bone for osseointegration. Since onplant is placed "on" the bone surface and not into the bone, it can be used in growing patients without affecting the skeletal development. The abutment is designed to receive up to 0.051-inch wire and thus does not significantly alter the routine orthodontic practice. Block and Hoffman had demonstrated in their animal studies that after 10 weeks of healing in dogs and 12 weeks in monkeys, the onplants

were able to withstand 11 ounces (~300 g) of force for five months in dogs, and 250 g of force for six months in monkeys.¹⁸ They found that orthodontic movement of the teeth was achieved without any movement of the onplants. Histologic examination also showed a direct contact between bone and the HA-coated surface of the onplants. They concluded that onplants could provide absolute anchorage for orthodontic tooth movement.

Onplants are usually placed in the mid-palatal region with the transpalatal bar incorporated to the abutment (Figure 2). Gunduz et al. reported a high patient acceptance rate of palatal implants.¹⁹ Most patients got used to their implants in about two weeks

and 75 percent of the patients found the orthodontic construction between the anchor teeth and the implant less comfortable than the implant itself. Furthermore, the removal of onplant does not involve bone removal and therefore not as traumatic as osseointegrated implant removal.

Since onplant is placed on the bone, there is minimal initial direct contact between bone and onplant and the initial stability of the onplant is of soft tissue origin (subperiosteal tunnels) and not hard tissue origin. Therefore, for nonplants to be used as orthodontic anchorage, a complete surface integration between the bone and HA-coated surface must be achieved, an additional healing period of five to six months is required. An animal (rabbit) study using recombinant human bone morphogenetic protein-2 (rhBMP-2) and dentin matrix protein-1 (DMP-1) in conjunction with onplants has been carried out in an attempt to reduce the waiting period before orthodontic force application.²⁰ After six weeks of healing, histological and histomorphometric results demonstrated significant more bone formation at the bone-onplant interface in the rhBMP-2 group when compared to DMP-1 group and control (onplant only). Mechanically, rhBMP-2 group also withstood significantly higher tensile force (3.4-5 kg) than DMP-1 group and control (0-1.3 kg). However, Roberts postulated the rate of bone remodeling in rabbits is ~three times faster than humans.²¹ Six weeks of healing in rabbits might be equivalent to 18 weeks in humans and clinical application of this result is, therefore, questionable. Furthermore, publications regarding onplant application are scarce and limited to case reports and animal studies.^{18,20,21} Well-controlled human studies are needed before its clinical application can be in the mainstream.

Skeletal Anchorage System

The skeletal anchorage system consists of titanium miniplates and monocortical screws (**Figure 3**) that are temporarily placed in either the maxilla or the mandible, or both, as absolute anchorage units. Since the anchor plates work as the onplant and screws function as the implant, SAS enables the rigid anchorage that results from the osseointegration effects in both the anchor plates and screws.²² Furthermore, because all portions of the anchor plates and screws are placed outside the maxillary and mandibular dentition, the SAS does not interfere with the tooth movement.²² The miniplates are available in various shapes and sizes, and are easily adaptable to most bony surfaces (e.g. buccal plate, zygomatic process, retromolar etc.). They also can be used for a variety of anchorage purposes (molar intrusion, molar distalization etc.). The surgery is simple, minimally invasive, and appropriate to an office setting.²³ While orthodontic force could be applied immediately after placement, it is advisable to wait until the wound is healed.²³ Healing periods of four to seven days up to three months have been reported.²³ The disadvantages of this technique include the necessity of flap reflection, mild infection, and the discomfort associated with the placement, maintenance, and removal of the plates.²⁴

Mini-implants, Microscrews, Pinplants

Mini-implants have recently been introduced as simpler absolute anchorage alternatives to endosseous implants and onplants in orthodontics.^{17,25-30} This group of implants includes titanium implants that are 2.5 mm or less in diameter.¹⁷ They can be implants made especially for orthodontic procedures



Figure 6. A mini-implant (Ortho Implant, Imtec Corp., Ardmore, Okla.) is used as direct absolute anchorage when it is connected to the moving unit (No. 6).



Figure 7. When a mini-implant (AnchorPlus, Myung Sung, Seoul, Korea) is connected to the anchoring unit (No. 14), it is considered as indirect absolute anchorage.



Figure 8. A mini-implant (Ortho Implant, Imtec Corp.) can be used as direct and indirect absolute anchorages at the same time when it is connected to both the moving unit (No. 30) and anchoring unit (No. 27).

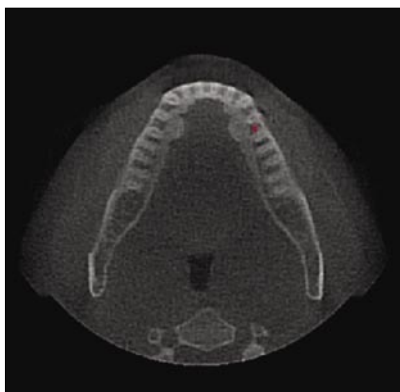


Figure 9a.

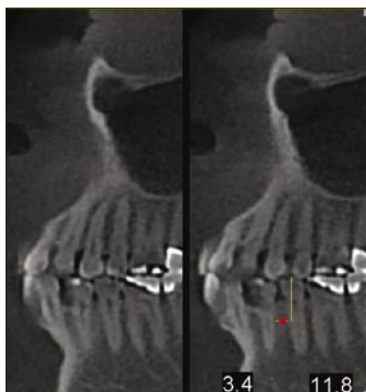


Figure 9b.



Figure 9c.

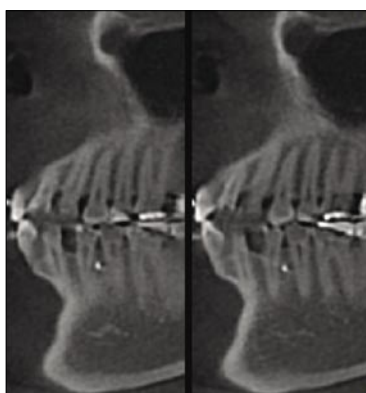


Figure 9d.

Figure 9. Cone-beam computed tomography (Newtom 3G, Aperio Services LLC, Sarasota, Fla.) provides 3-D views essential in treatment planning the mini-implant position. a) Preoperative axial view; b) preoperative sagittal view. Red dots signify predetermined mini-implant position. Accurate mini-implant placement was achieved as shown in c). Postoperative axial view, and d) postoperative sagittal view.

(Figure 4) or simple osteotomy fixation screws (Figure 5). The main advantage of mini-implants is their small size (as small as 1.0 in diameter and as short as 4 mm) and the size variety.²⁵ This significantly increases the potential sites for implant placement especially the inter-radicular/pararadicular regions. The surgical placement of a mini-implant is also much simpler than endosseous implants, onplants and miniplates, and can be easily performed in orthodontic settings by orthodontists. The additional cost involved is therefore much less than other absolute anchorage systems.

The orthodontic load is usually applied to the mini-implant immediately or very early after placement.²⁶ A waiting period is not necessary because its primary stability is generally sufficient to sustain normal orthodontic loading. Even though it has been shown histologically that premature loading would result in the fibrous tissue interposition at the bone-implant contact, this did not compromise the clinical stability of the mini-implants. Furthermore, it has been suggested that this phenomenon is favorable because it would facilitate implant removal at the end of the treatment.²⁶ The implant removal entails

unscrewing the implant with minimal use of an anesthetic agent.

A mini-implant can be used as direct and/or indirect absolute anchorage at the same time or at different point of time (Figures 6-8). To use the mini-implant efficiently, a thorough understanding of orthodontic mechanics associated to mini-implants is essential. To be used as direct absolute anchorage, the line of action of the force has to pass through the mini-implant.²⁷ When the line of action of the force does not pass through the mini-implant, a moment of force is generated resulting in shearing force.



Figure 10. When the PDL is violated, the patient usually develops pain on percussion or mastication.

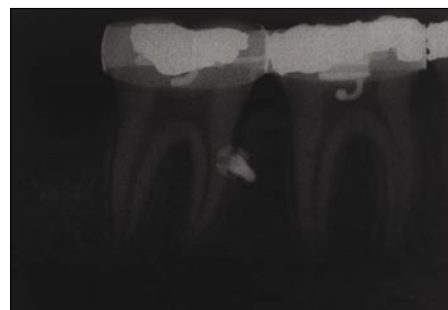


Figure 11. The mini-implant that invades vital structure should be removed as soon as possible and a new mini-implant can be placed immediately.

Since the mini-implant is only mechanically fixed to bone via cortical stabilization and is not osseointegrated, the shearing force may be detrimental to the mini-implant leading to its failure. In such a situation, the mini-implant should be tied to the anchoring unit and used as indirect absolute anchorage.²⁷ The treatment plan should be established to maximize the use of the mini-implant and avoid its untimely removal and/or replacement.

Since mini-implants are small, the planned implant sites can sometimes be very close to vital structures e.g. neurovascular bundles, sinuses and root of tooth etc. Care must be taken not to violate those structures and axial tomography (Figures 9a-d) is recommended during implant site planning. Mini-implants that invade periodontal ligament usually results in pain on percussion or mastication, whereas when the root is violated, the patient will develop sensitivity to hot and cold.²⁸ The mini-implant should be removed as soon as the symptoms develop (Figures 10-11). Once removed, the symptoms generally subside and pulpal damage is unlikely.²⁷⁻²⁹ In addition, Fabbroni et al. showed that the incidence of clinically significant damage of teeth that had been impinged by transalveolar screws was very low.³⁰

Small diameter, while providing versatility in implant location, increases the risk of implant fracture during implant removal if the achieved osseointegration level exceeds the implant mechanical strength. Since osseointegration is not required for orthodontic anchorage, the mini-implant surface should be machined (smooth) and not treated (rough). While data regarding optimal implant diameter is lacking, a minimum of 1.5 mm diameter has been recommended.^{17,25-30}

Conclusions

Incorporating implants to orthodontic treatment is an exciting venue and is inevitable. However, to achieve successful outcomes, a thorough understanding of each type of implant, its indications and limitations is essential in the decision making. When an interdisciplinary approach is warranted, comprehensive diagnosis and treatment planning must be established through effective communication followed by meticulous execution. **CDA**

- References** / 1. Gianelly A, Goldman H, Biologic basis of orthodontics. Philadelphia, Lea and Febiger, 1971.
2. Kokich VG, Shapiro PA, et al, Ankylosed teeth as abutments for maxillary protraction: A case report. *Am J Orthod* 88:303-7, 1985.
3. Branemark PI, Osseointegration and its experimental background. *J Prosthet Dent* 50:399-410, 1983.
4. Goodacre CJ, Kan JYK, Rungcharassaeng K, Clinical complications of osseointegrated implants. *J Prosthet Dent* 81:537-52, 1999.
5. Babbush CA, Kent JN, Misiek DJ, Titanium plasma-sprayed (TPS) screw implants for the reconstruction of the edentulous mandible. *J Oral Maxillofac Surg* 44:274-82, 1986.
6. Rungcharassaeng K, Kan JYK, Immediately loaded mandibular implant bar overdenture: A surgical and prosthodontic rationale. *Int J Periodontics Restorative Dent* 20:71-9, 2000.
7. Lekholm U, Zarb GA, Patient selection and preparation. In Branemark PI, Zarb GA, Albrektsson T: Tissue-integrated protheses, osseointegration in clinical dentistry. *Quintessenz* Berlin, 1985.
8. Ivanoff CJ, Sennerby L, et al, Influence of implant diameters on the integration of screw implants. An experimental study in rabbits. *Int J Oral Maxillofac Surg* 26:141-8, 1997.
9. Wennerberg A, Ektessabi A, et al, A one-year follow-up of implants of differing surface roughness placed in rabbit bone. *Int J Oral Maxillofac Implants* 12:486-94, 1997.
10. Brunski JB, Biomechanical factors affecting the bone-dental implant interface: Review paper. *Clin Mater* 10:153-201, 1992.
11. Celenza F, Implant-enhanced tooth movement: Indirect absolute anchorage. *Int J Periodontics Restorative Dent* 23:533-41, 2003.
12. Roberts WE, Helm FR, et al, Rigid endosseous implants for orthodontic and orthopedic anchorage. *Angle Orthod* 59:247-56, 1989.
13. Roberts WE, Arbuckle GR, Analoui M, Rate of mesial translation of mandibular molars using implant-anchored mechanics. *Angle Orthod* 66:331-8, 1996.
14. Higuchi KW, Slack JM, The use of titanium fixtures for intraoral anchorage to facilitate orthodontic tooth movement. *Int J Oral Maxillofac Implants* 6:338-44, 1991.
15. Scharf DR, Tarnow DP, Success rates of

osseointegration for implants placed under sterile versus clean conditions. *J Periodontol* 64:954-6, 1993.

16. Odman J, Grondahl K, et al, The effect of osseointegrated implants on the dentoalveolar development. A clinical and radiographic study in growing pigs. *Eur J Orthod* 13:279-86, 1991.

17. Cope JB, Temporary anchorage devices in orthodontics: A paradigm shift. *Semin Orthod* 11:3-9, 2005.

18. Block M, Hoffman DR. A new device for absolute anchorage for orthodontics. *Am J Orthod Dentofacial Orthop* 107:251-8, 1995.

19. Gunduz E, Schneider-Del Savio TT, et al, Acceptance rate of palatal implants: A questionnaire study. *Am J Orthod Dentofacial Orthop* 126:623-6, 2004.

20. Hassan AH, Evans CA, et al, Use of bone morphogenetic protein-2 and dentin matrix protein-1 to enhance the osteointegration of the Onplant system. *Connect Tissue Res* 44:30-41, 2003.

21. Roberts WE, Turley PK, et al, Implants: Bone physiology and metabolism. *J Calif Dent Assoc* 15:54-61, 1987.

22. Sugawara J, Daimaruya T, et al, Distal movement of mandibular molars in adult patient with the skeletal anchorage system. *Am J Orthod Dentofacial Orthop* 125:130-8, 2004.

23. Umemori M, Sugawara J, et al, Skeletal anchorage system for open-bite correction. *Am J Orthod Dentofacial Orthop* 115:166-74, 1999.

24. Sugawara J, Dr. Junji Sugawara on the skeletal anchorage system. Interview by Dr. Larry W. White. *J Clin Orthod* 33:689-96, 1999.

25. Ohmae M, Saito S, Morohashi T, et al, A clinical and histological evaluation of titanium mini-implants as anchors for orthodontic intrusion in the beagle dog. *Am J Orthod Dentofacial Orthop* 119:489-97, 2001.

26. Costa A, Raffaini M, Melsen B, Miniscrews as orthodontic anchorage: A preliminary report. *Int J Adult Orthod Orthognath Surg* 13:201-9, 1998.

27. Melsen B, Verna C, Miniscrew implants: the Aarhus anchorage system. *Semin Orthod* 11:24-31, 2005.

28. Maino BG, Mura P, Bednar J, Miniscrew implants: the spider screw anchorage system. *Semin Orthod* 11:40-6, 2005.

29. Herman R, Cope JB, Miniscrew implants: Imtec mini ortho implants. *Semin Orthod* 11:32-9, 2005.

30. Fabbroni G, Aabed S, et al, Transalveolar screws and the incidence of dental damage: A prospective study. *Int J Oral Maxillofac Surg* 33:442-6, 2004.

To request a printed copy of this article, please contact / Kitichai Rungcharassaeng, DDS, MS, Loma Linda University School of Dentistry, Loma Linda, Calif., 92350.