SPECIAL ARTICLE

Orthodontics in 3 millennia. Chapter 15: Skeletal anchorage

Norman Wahl
Sequim, Wash

For many years, orthodontists have searched for a form of anchorage that does not rely on patient cooperation, although the answer already lay in the implants dentists used to replace missing teeth and oral surgeons used to hold bone segments together. Now these divergent lines have come together in the form of stationary anchorage, and titanium is the most biocompatible material. State-of-the-art miniscrews and microscrews—temporary anchorage devices—now permit movements hitherto thought difficult or impossible. This article continues the series last published in April 2007. (Am J Orthod Dentofacial Orthop 2008;134: 707-10)

Attempts to devise implants stemmed from a need to replace missing teeth. The earliest endosseous implant, discovered in Honduras in 1931, was a mandibular fragment of Mayan origin, dating from about AD 600. It consisted of 3 tooth-shaped pieces of shell placed in the sockets of 3 missing mandibular incisors. Radiographs taken in 1970 showed compact bone formation around 2 of the implants, proving that they had been placed before death.[1] In 1784, 5 years before he became president of the United States, George Washington, at age 52, was nearly toothless, so he hired a dentist to transplant 9 teeth into his jaw—having extracted them from the mouths of his slaves.[2] What is probably the earliest reference to an implant in modern literature was described by J. Maggiolo, a dentist at the University of Nancy, in France, in 1809. He forced a metallic tooth root of 18-carat gold into an extraction socket. In 1885, Dr J. M. Younger demonstrated placing a dried tooth into an extraction socket.[1]

Orthodontists have long searched for the perfect anchorage to minimize undesired tooth movements. Headgear, elastics, adjacent teeth, and many appliances have been suggested as anchorage; however, the main drawback was that most relied on patient compliance to be successful.[3] What if the bone itself could be used as the anchorage unit?

Types of implants

Skeletal anchorage, as this concept is called, evolved from 2 lines. One category originated as osseointegrated dental implants, which have a solid scientific base of clinical, biomechanical, and histologic studies.[4] Included in this category are the retromolar implants described by Roberts et al[5] and palatal implants introduced by Wehrbein and Merz.[6] Both are used for *indirect anchorage*, meaning that they are connected to teeth that serve as the anchorage units. When the anchorage is enhanced by using forces that originate from the actual implant, it is called *direct anchorage*. An orthodontic bracket is bonded to the restoration, and then pressure or tension is applied with conventional braces.

The other category developed from surgical mini-implants, which have been used by oral surgeons for decades and are highly predictable. These plates are placed by screws engaging the cortical bone. The most common areas for placement for orthodontic use are in the zygomatic strut in the maxilla and the buccal aspect of the body of the mandible—a particular advantage in treating skeletal open-bite malocclusions.

The classification of implants can also be based on their position, material of construction, and design. (1) The position of the implant can be subperiosteal, transosseous, or endosseous (the most common). (2) Titanium is now the material of choice for implant fabrication. The implant surface can be rough or smooth, and might have an additional hydroxyapatite or titanium spray coating. (3) There appears to be a lack of consensus regarding the best design for an implant, especially how it gains its support from the surrounding bone. The screw design aids loading of the surrounding bone in compression, whereas a smooth, cylindrical design (the typical type) increases implant support when shear forces are exerted on the bone.[7]

Onplants differ from implants, since they adhere only to the outer surface of the bone. An onplant grows and adheres to the cortical plate covering the bone and

Private practice, Eagle Rock, Calif.
Submitted and accepted, April 2008.
0889-5406/$34.00

doi:10.1016/j.ajodo.2008.04.015

provides anchorage by bonding to the surface of a titanium disk with hydroxyapatite.

Evolution of skeletal anchorage

The first implant success was achieved at Harvard University in 1937, with cobalt-chromium-molybdenum alloy (vitallium) implants.[8] The concept of using implants to enhance orthodontic anchorage was first published in 1945 by Gainsforth and Higley,[9] who used vitallium screws to effect tooth movement in dogs. Despite some success, the tooth movement was limited because the implants loosened within 1 month of starting tooth movement. In the 1960s, P. I. Brånemark,[10] a Swedish physician and orthopedic surgeon, found that bone had a high affinity for titanium and coined the term *osseointegration*.

In 1969, Linkow[11] described the endosseous blade implant for orthodontic anchorage but did not report on its long-term stability. Vitreous carbon implants had a failure rate of 67% with orthodontic loading, and attempts at using bioglass-coated ceramic implants for orthodontic anchorage were almost as disappointing. Although all those materials were compatible with bone, none showed consistent long-term attachment of bone to the implant interface, meaning that they did not achieve true osseointegration.[7]

After Adell et al[12] reported successful osseointegration of implants in bone, there was a surge of interest in implants for orthodontic anchorage. However, the superiority of this material was reinforced by comparison with the disappointing results in the experiments of Sherman,[13] using vitreous carbon implants in dogs, and the use of bioglass-coated ceramic implants in the maxillae of 3 pigtail monkeys by Turley et al.[14] The failures were attributed to mobility and inflammation.

Smith[15] studied the effects of loading bioglass-coated aluminum-oxide implants in monkeys and reported no significant movement of the implants during force application. He described the interface between the bioglass implants and the surrounding tissue as fusion or ankylosis, despite observing intervening areas of connective tissue.

In 1984, Roberts et al[16] evaluated the effect of orthodontic-level forces on titanium implants in rabbit femurs. Nineteen of 20 implants remained stable after subjection to 100 g of force for 4 to 8 weeks. In the first clinical report of skeletal anchorage in a human, Creekmore and Eklund[17] intruded the maxillary central incisors of a patient using elastic thread and anchorage from a vitallium screw placed below the anterior nasal spine. Shapiro and Kokich[18] emphasized the importance of implant positioning and proper case indications and implant requirements when implants were used for prosthodontic restorations. They also emphasized the need for adequate oral hygiene to maintain the implant.

In a foreshadowing of distraction osteogenesis, Smalley et al[19] demonstrated the separation of facial sutures in growing monkeys, using osseointegrated implants as anchorage with external protraction forces of 600 g, but it was not until 1997 that Kanomi[20] described a mini-implant specifically designed for orthodontic use. Costa et al[21] described a 2-mm titanium miniscrew with a special bracket-like head that could be used for either direct or indirect anchorage. The screws were placed manually with a screwdriver directly through the mucosa without a flap and were loaded immediately. In contrast to osseointegrated implants, these devices are smaller in diameter, have smooth surfaces, and are designed to be loaded shortly after placement.

Roberts[22] used conventional, 2-stage titanium implants in the retromolar region to help reinforce anchorage while successfully closing first-molar extraction sites in the mandible. In another study, Turley et al[23] used tantalum markers and bone labeling dyes in dogs to illustrate the stability of 2-stage implants for orthodontic or orthopedic traction. This study also showed that 1-stage implants were less successful in this role. In the late 1990s, the introduction of miniscrews for immediate loading virtually revolutionized our approach to skeletal anchorage. Kanomi,[20] Costa et al,[21] Lee et al,[24] and Park et al[25] showed the use of titanium miniscrews for immediate loading as an alternative anchorage system and discussed possible placement sites. Freudenthaler et al[26] placed 12 titanium bicortical screws horizontally as anchorage for mandibular molar protraction in 8 patients. Park et al[27] reported molar uprighting with microimplant anchorage. More recently, Maino et al[28] introduced the spider screw for skeletal anchorage for prerestorative treatment in adults.

In 1995, Block and Hoffman[29] introduced the onplant to provide orthodontic anchorage. This is a thin titanium alloy disk (2 mm high, 10 mm in diameter), textured and coated with hydroxyapatite on 1 side and with an internal thread on the other. They found that an onplant could provide absolute anchorage for tooth movement in dogs and monkeys. Southard et al[30] used a small vitallium bone screw to depress an entire anterior maxillary dentition without untoward sequelae.

Other recent highlights in the evolution of skeletal anchorage include the following.

- Wehrbein et al[31] described the midsagittal area of the palate as a placement site for implant anchorage in orthodontic treatment of the maxilla using 3.3-mm diameter implants. First-premolar extraction sites were closed in 9 months with no movement of the implant and only 0.5 mm of mesial movement of the implant-supported second premolars. The incisors and the canines were retracted by 8 mm.

- Melsen et al[32] introduced zygomatic ligatures as anchorage in partially edentulous patients for intrusion and retraction of the maxillary incisors.
- Park[33] described a skeletal cortical anchorage system using titanium microscrew implants. Six months of applied force resulted in 1.5-mm of distalization of the maxillary posterior teeth.
- Sugawara[34] and Umemori et al[35] treated open-bite patients with molar intrusion using a miniplate skeletal anchorage system. L-shaped miniplates implanted in the buccal vestibule were connected to the archwire in the molar area by elastic thread.
- Park et al[25] showed that microscrews only 1.2 mm in diameter could be placed between the roots of teeth to retract the 6 anterior teeth en masse and intrude the mandibular molars at the same time.
- Lee et al[24] showed that microimplants can provide reliable and absolute anchorage for lingual orthodontic treatment and conventional labial treatment.
- Janssens et al[36] reported on the use of an onplant for palatal anchorage to successfully extrude the unerupted horizontal maxillary first molars in a 12-year-old white girl with tooth aplasia and cleft of the secondary palate. Deguchi et al,[37] using small titanium screws in dogs, found that a 3-week healing period is sufficient before loading the screws with an orthodontic force.

Capabilities and limitations

Although endosseous implants and onplants have been used successfully for orthodontic anchorage, their clinical applications are still limited in edentulous or retromolar areas because of their size and complicated fixture designs. Other disadvantages include a long waiting period (2-6 months) for bone healing and osseointegration, comprehensive clinical and laboratory work, difficult removal after treatment, and high cost. Furthermore, dental implants are troublesome for patients because of the severity of surgery, the discomfort of the initial healing, and the difficulty of oral hygiene.

Another limitation has been the direction of force application—eg, when a dental implant is placed on the alveolar ridge and is too large for horizontal orthodontic traction. Titanium microimplants, however, have several advantages over surgical miniplates. Their surgical procedure for placement is simpler and costs less. Even the maximum magnitude of orthodontic force application on them is less than that for surgical miniplates.[38]

Miniplates and miniscrews (now called *temporary anchorage devices,* or *TADs)* have recently been introduced as simpler alternatives to endosseous implants and onplants in orthodontics. Their advantages include smaller size, greater number of implant sites and indications, simpler surgical placement (only local anesthetic or sometimes only topical) and orthodontic connection, immediate loading, no need for laboratory work, easier removal after treatment, and lower cost.[3] However, since osseointegration is not required, minor loss of anchorage can occur. A final important consideration is the need for precise placement between the roots of adjacent teeth.[14]

A disadvantage of miniplates as anchorage is that a full-thickness flap is required for their placement, and the plates must be retrieved after treatment. Miniplates have advantages over other implant options, since they do not move, they have a low profile, and the attachment for clinical use can be easily accessed for adjustment by the orthodontist.[39]

Using TADs, orthodontists can now (1) retract and realign anterior teeth without posterior support, (2) close edentulous spaces in first-molar extraction sites, (3) correct midlines in patients with missing posterior teeth, (4) reestablish proper transverse anteroposterior positions of isolated molar abutments, (5) intrude or extrude teeth, (6) protract or retract an arch, (7) stabilize teeth with reduced bone support, and (8) apply orthopedic traction.[7]

Movements of teeth that were previously thought difficult—if not impossible—might now be feasible by using TADs as anchorage. These tiny adjuncts offer orthodontists an exciting new horizon for patients and doctors alike.[39]

The author thanks Patrick J. Turley for his review and suggestions.

REFERENCES

1. Ring ME. A thousand years of dental implants: a definitive history. Part 1. Compend Contin Educ Dent 1995;16:1060-9.
2. Boser U. The sorry legacy of the founders. US News and World Report 2004;136(1):52.
3. Liou EJW, Pai BCJ, Lin JCY. Do miniscrews remain stationary under orthodontic forces? Am J Orthod Dentofacial Orthop 2004;126:42-7.
4. Matthews DC. Osseointegrated implants: their application in orthodontics. J Can Dent Assoc 1993;59:454.
5. Roberts WE, Helm FR, Marshal KJ, Gongloff RK. Rigid endosseous implants for orthodontic and orthopaedic anchorage. Angle Orthod 1989;59:247-56.
6. Wehrbein H, Merz BR. Aspects of the use of endosseous palatal implants in orthodontic therapy. J Esth Dent 1998;10:315-24.
7. Ismail SFH, Johal AS. The role of implants in orthodontics. J Orthod 2002;29:239-45.

8. Bike WS. Clinical implant dentistry to be added to DDS program. UIC College of Dentistry 2005;spring/summer:22-4.
9. Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities in basal bone. Am J Orthod Oral Surg 1945;31:406-17.
10. Brånemark PI, Adell R, Breine U, et al. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J Plast Reconstr Surg 1969;3:81-100.
11. Linkow LI. The endosseous blade implant and its use in orthodontics. Int J Orthod 1969;18:149-54.
12. Adell R, Hansson BO, Brånemark PI, Breine U. Intra-osseous anchorage of dental prostheses. II. Review of clinical approaches. Scand J Plast Reconstr Surg 1970;4:19-34.
13. Sherman JA. Bone reaction to orthodontic forces on vitreous carbon dental implants. Am J Orthod 1978;74:79-87.
14. Turley PK, Shapiro PA, Moffett BC. The loading of bioglass coated aluminium oxide implants to produce sutural expansion of the maxillary complex in the pigtail monkey Macaca nemestrina. Arch Oral Biol 1980;25:459-69.
15. Smith JR. Bone dynamics associated with the controlled loading of bioglass-coated aluminum oxide endosteal implants. Am J Orthod 1979;76:618-36.
16. Roberts WE, Smith RK, Zilberman Y, Mozsary PG, Smith RS. Ossesous adaptation to continuous loading of rigid endosseous implants. Am J Orthod 1984;86:95-111.
17. Creekmore TD, Ecklund MK. The possibilities of skeletal anchorage. J Clin Orthod 1983;17:266-9.
18. Shapiro PA, Kokich VG. Uses of implants in orthodontics. Dent Clin North Am 1988;32:539-40.
19. Smalley WM, Shapiro PA, Hohl VG, Branemark P-I. Osseointegrated implants for maxillofacial protraction in monkeys. Am J Orthod Dentofacial Orthop 1988;94:285-95.
20. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod 1997;31:763-7.
21. Costa A, Raffaini M, Melsen B. Microscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthod Orthognathic Surg 1998;13:201-9.
22. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod 1990;60:135-51.
23. Turley PK, Kean C, Schur J, et al. Orthodontic force application to titanium endosseous implants. Angle Orthod 1988;58:151-62.
24. Lee JS, Park HS, Kyung HM. Micro-implant anchorage for lingual treatment of a skeletal class II malocclusion. J Clin Orthod 2001;35:643-7.
25. Park HS, Bae SM, Kyung HM, Sung JH. Micro-implant anchorage for treatment of skeletal Class I bialveolar protrusion. J Clin Orthod 2001;35:417-22.
26. Freudenthaler JW, Bantleon H-P, Haas R. Bicortical titanium screws for critical orthodontic anchorage in the mandible: a preliminary report on clinical applications. Clin Oral Implants Res 2001;12:358-63.
27. Park HS, Kyung HM, Sung JH. Simple method of molar uprighting with micro-implant anchorage. J Clin Orthod 2002;36:592-6.
28. Maino BG, Bednar J, Pagin P, Mura P. The Spider screw for skeletal anchorage. J Clin Orthod 2003;37:90-7.
29. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontics. Am J Orthod Dentofacial Orthop 1995;107:251-8.
30. Southard TE, Buckley MJ, Spivey JD, Krizan KE, Casko JS. Intrusion anchorage potential of teeth versus rigid endosseous implants: a clinical and radiographic evaluation. Am J Orthod Dentofacial Orthop 1995;107:115-20.
31. Wehrbein H, Merz BR, Diedrich P, Glatzmaier J. The use of palatal implants for orthodontic anchorage. Clin Oral Implant Res 1996;7:410-7.
32. Melsen B, Petersen JK, Costa A. Zygoma ligatures: an alternative form of maxillary anchorage. J Clin Orthod 1998;32:154-8.
33. Park HS. The skeletal cortical anchorage using titanium microscrew implants. Korea J Orthod 1999;29:699-706.
34. Sugawara J. Dr. Junji Sugawara on the skeletal anchorage system. Interview by Dr. Larry W. White. J Clin Orthod 1999;33:689-96.
35. Umemori M, Sugawara J, Mitani H, Nagasaka H, Kawamura H. Skeletal anchorage system for open-bite correction. Am J Orthod Dentofacial Orthop 1999;115:166-74.
36. Janssens F, Swennen G, Dujardin T, Glineur R, Malavez C. Use of an onplant as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2002;122:566-70.
37. Deguchi T, Takano-Yamamoto T, Kanomi R, Hartsfield JK Jr, Roberts WE, Garetto LP. The use of small titanium screws for orthodontic anchorage. J Dent Res 2003;82:377-81.
38. Sung JH. History of skeletal anchorage and development of microimplants for orthodontic anchorage. Unpublished manuscript; via e-mail; December 26, 2005.
39. Eitzen C. Implant anchorage in orthodontics. In: Technology spotlight. Available at: http://www.dentalcompare.com/spotlight.asp? spotlighted=8. Accessed December 25, 2006.