Implantable Devices as Orthodontic Anchorage: A Review of Current Treatment Modalities

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ABSTRACT

Recently, there has been a dramatic increase in the use of implantable devices as direct adjuncts to orthodontic treatment. Whereas the use of conventional dental implants has been researched extensively, the body of literature associated with the more recent uses of implantable devices in orthodontics is relatively small. Currently, a limited number of such devices are used to aid in orthodontic treatment. The options include conventional titanium endosseous dental implants, palatal implants, titanium miniscrews (also known as micro- or mini-implants), and mini–bone plates.

Integration of dental implants or implantable devices into contemporary orthodontic practice has the following possible advantages: serving as a means of increasing orthodontic anchorage, virtually eliminating patient compliance issues with regard to wearing of appliances, decreasing overall treatment time, and occasionally permitting orthodontic treatments previously thought to be impossible without surgery.

CLINICAL SIGNIFICANCE

This article is a review of the currently available options for use of implantable devices as sources of temporary skeletal anchorage in orthodontics.

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Over the past 20 years dentistry has seen a dramatic increase in the use of dental implants. What was once an "experimental" or unproven treatment modality is now supported by an extensive research base. The vast majority of dental implant research is centered around the use of endosseous implants for replacement of missing teeth. Recently, the application of implants for use in other specialties has been explored. Previously, the use of dental implants within the specialty of orthodontics was limited to integration of implants into treatment plans strictly to facilitate tooth replacement. The orthodontic treatment that has traditionally been involved in treatment plans including dental implants has been limited to creating space or aligning roots for subsequent placement of implants. The use of dental implants as a direct adjunct to orthodontic treatment has been more limited until recently, but the potential exists for implants to play an important role in enhancing successful treatment outcomes. Integration of dental implants or implantable devices into contemporary orthodontic practice has the following possible advantages: serving as a method of increasing orthodontic anchorage, virtually eliminating patient compliance issues with regard to wearing of appliances, decreasing overall treat-

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ment time, and occasionally permitting orthodontic treatments previously thought to be impossible without surgery.

The practice of clinical orthodontics is largely dependent on the availability of anchorage. Anchorage, by definition, is a body's resistance to displacement. Newton's third law states that for every action there is an equal and opposite reaction. Thus, orthodontic appliances are designed with this law in mind, the goal being to resist unwanted tooth movement. According to Proffit, in treatment planning of orthodontics,

it is simply not possible to consider only the teeth whose movement is desired. Reciprocal effects throughout the dental arches must be carefully analyzed, evaluated, and controlled. An important aspect of treatment is maximizing the tooth movement that is desired, while minimizing undesirable side effects.[1]

In orthodontic movement of teeth, segments of teeth that resist movement and serve as "anchors" are used to pull against other segments that are intended to be moved. Usually, the anchor segment will contain more teeth or teeth with greater root surface area than the segment of teeth that are to be moved. This concept of differential anchorage is important in most orthodontic cases, especially more complex situations. In fact, treatment of certain malocclusions is often limited or defined by the available anchorage. There are numerous ways in which orthodontics has tried to augment anchorage, including auxiliary devices such as headgear, transpalatal arches, and other appliances. Many of these appliances are awkward or uncomfortable for patients, often leading to less than desired levels of compliance. Thus, treatment outcomes can become compromised. Only recently has the concept of using dental implants as sources of anchorage been widely accepted as a successful adjunct to orthodontic treatment.

Dental implants have the ability to aid in anchorage either directly or indirectly. Celenza and Hochman described two different types of anchorage as pertaining to the use of implants in orthodontics.[2] *Direct anchorage* refers to any situation in which forces that originate from the actual implant itself are used to augment anchorage. An example would be a restored dental implant with an orthodontic bracket bonded to the restoration. If conventional orthodontic appliances are used in conjunction with the surrounding teeth and the restored implant, the implant will serve as a stable "anchor." That is, the implant will not respond to the forces generated by the orthodontic wires in the same way that the natural teeth do. The implant simply remains stationary while surrounding teeth move.

The second type of anchorage, as described by Celenza and Hochman, is known as *indirect anchorage*, which refers to a situation in which a dental implant stabilizes multiple teeth, which then serve as an anchor unit. The most common method of achieving indirect anchorage is by placing a dental implant, commonly in the midpalatal or retromolar regions, and then linking the implant to the natural teeth by means of a wire or other rigid fixation device, such as a transpalatal arch. The result is a stable anchorage unit composed of multiple teeth that are tethered together by means of a dental implant that serves as additional anchorage. The high level of stability provided by either approach makes it promising for the practice of orthodontics.

There are numerous situations in which additional anchorage would enhance treatment success. Examples of orthodontic treatment of malocclusions that would particularly benefit from dental implant use are as follows: closing edentulous spaces in first molar extraction sites, midline correction when no posterior teeth are present, retracting and realigning anterior teeth with no posterior teeth present, intruding or extruding teeth, stabilization of teeth with reduced bone support, reestablishing the proper transverse and anterior or posterior position of isolated molar abutments, protraction or retraction of one arch, and perhaps many more applications.[3]

The high level of stability gained from the types of implants placed in retromolar or midpalatal regions is derived largely from the fact that the implants are osseointegrated. Initial concerns about disruption of osseointegration by orthodontic loading were proven to be unfounded by several studies. Roberts and colleagues reported using two-stage conventional titanium implants in the retromolar region to help augment anchorage while protracting molars to close extraction sites.[4] The implants were removed using a trephine following the conclusion of orthodontic treatment and were subsequently histologically analyzed. Roberts and colleagues found that approximately 80% of the endosseous portions of the implants were in direct contact with mature bone. Thus, this case study indicated that a relatively high level of osseointegration was maintained despite loading the implant with orthodontic forces. Another study by Turley and colleagues also pointed to the stability of two-stage titanium implants used for orthodontic traction in dogs.[5] A later study by Wehrbein and colleagues used the Straumann Orthosystem (Straumann Holding AG, Basel, Switzerland) in midpalatal and retromolar areas in humans for anchorage purposes.[6] The implants were subjected to continuous orthodontic loading and were removed and analyzed following treatment. The findings from the histologic evaluation of the implants indicated that they had been well integrated, again despite orthodontic loading. It seems apparent that when subjected to the relatively low continuous forces that are used in orthodontic therapy, implants have little difficulty maintaining osseointegration. Therefore, the question must be raised: is osseointegration desirable or even necessary for orthodontic anchorage? In a review of studies exploring implantable orthodontic anchorage, Favero and colleagues asked a similar question:

> *Some studies have shown that implants loaded early on, although not presenting intimate bone-to-bone contact [osseointegration] because of the formation of a pseudo-peri-implant fibrous ligament, appeared to be sufficiently stable and capable of sustaining the function of anchorage with normal orthodontic forces. Did these represent failures, because osseointegration did not occur, or successes, because the anchorage was achieved anyway?*[7]

It seems that the question does not have a definitive answer, and until specific parameters of success are defined, it would be prudent to use the existing body of research to determine success.

AVAILABLE IMPLANT SYSTEMS

Currently, only a limited number of implantable devices may be used in orthodontic treatment. The options include conventional titanium endosseous dental implants, palatal implants (such as onplants and the Straumann Orthosystem [Andover, MA, USA]), titanium miniscrews (also known as micro- or mini-implants), and mini–bone plates.

Conventional Implants

Conventional titanium endosseous dental implants can be used as sources of absolute or direct anchorage for orthodontic treatment. This approach can be used when edentulous spaces exist within an arch and adjacent or opposing teeth are not positioned ideally. In such cases when the restorative treatment plan involves a dental implant, it may be beneficial to use the implant itself as anchorage for treating concomitant orthodontic problems (Figure 1). In 1991 Higuchi and Slack reported correcting malocclusions in seven adults using Brånemark implants as sources of direct anchorage.[8] Later Schweizer and colleagues reported the use of conventional endosseous implants in orthodontic therapy in 1996.[9] The authors stressed the importance of double use (combined orthodontic and prosthodontic treatment modalities) of the implant system because once the implant has been placed, no movement will occur owing to osseointegration. In 1995 Smalley noted the importance of using a pretreatment diagnostic wax-up to aid in the precise placement of implant(s) prior to orthodontic treatment.[10] This

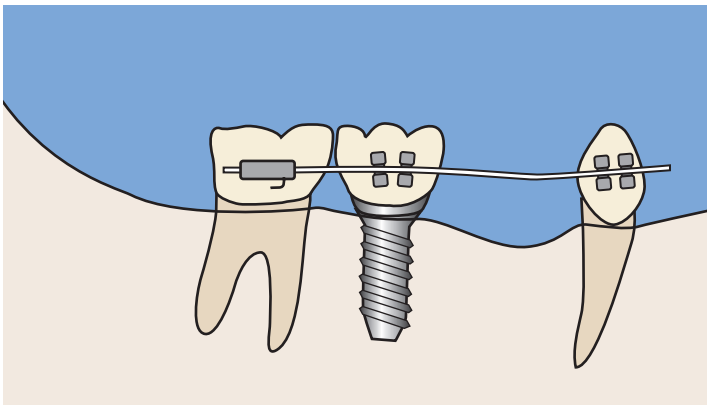


Figure 1. Illustration of a conventional endosseous implant used as a source of direct anchorage.

wax-up must simulate the position of the teeth following orthodontic treatment, and from this information a surgical stent may be fabricated to aid in the placement of the implant(s). In 1996 Kokich also emphasized the importance of interdisciplinary treatment planning to ensure successful treatment outcomes when using implants as anchors. According to Kokich, "it is impossible to accomplish this type of interdisciplinary treatment without good communication between all members of the team. In most orthodontic patients, interdisciplinary planning is not necessary. However, in the partially edentulous patient, it is mandatory.[11] The Schweizer and colleagues article suggests several specific situations that are ideally suited for using dental implants in this manner, for example, cases in which teeth are supererupted after the loss of opposing teeth. In such cases orthodontic intrusion is required in addition to the prosthodontic replacement of the missing teeth. Once the implant(s) is placed, it can be used for anchorage to achieve intrusion and to obtain adequate occlusal clearance for future restorations. The advantage of this method of treatment is that the definitive restorations can also facilitate orthodontic treatment. The disadvantage of this modality is that implants can be inserted only in edentulous areas with adequate bony support. Also, since this treatment must be coordinated by multiple specialists (including a periodontist or surgeon, a prosthodontist or restorative dentist, and an orthodontist), this option is more complex and perhaps more time consuming.

Palatal Implants

One of the limitations of using implants for orthodontic anchorage is having adequate bone. Conventional root-form implants require adequate thickness of bone for placement, thus limiting their use to edentulous areas. Several authors have reported the midsagittal area of the hard palate as a suitable site for a short implant. Block and Hoffman devised a system that allowed placement of osseointegrated implant anchors in the midpalatal region of the maxilla.[12] In 1989 they designed the Onplant system (Nobel Biocare, Göteborg, Sweden). The device in this system is a thin (2 mm thick and 10 mm in diameter) titanium alloy disk that has a textured side that opposes bone and is coated with a 75 µm layer of hydroxyapatite. The side facing soft tissue is smooth titanium alloy with a threaded hole in the center into which abutments are placed. Original designs of the disks included a sharp (90°) angle at the periphery, but this design was later altered to prevent adverse soft tissue reactions at this margin (Figure 2A).

Onplants are placed subperiosteally on the posterior aspect of the hard palate. A "tunneling" procedure is used to place these anchors. A full-thickness mucoperiosteal incision is made on the anterior aspect of the hard palate, and tunnels are reflected posteriorly. These tunnels allow the onplant to be placed away from the incision, thus reducing the potential for soft tissue reactions that prevent osseointegration. A healing screw is placed, and 10 to 12 weeks are allowed for integration. After this

healing period, a small amount of tissue is removed over the healing screw, which is replaced by an abutment (Figure 2B).

Block and Hoffman conducted two studies using their Onplant system. The first study was performed with mongrel dogs and the second with monkeys. In the canine study, springs were extended from the onplant abutment to the first premolar and activated to exert 11 ounces of force. Measurements of tooth movement were made periodically, and after 5 months the dogs were euthanized. The maxillas were retrieved and sectioned, and osseointegration was assessed. A soft tissue dehiscence developed over one of the onplants at the sharp margin, causing failure of the onplant to integrate. The other onplants did integrate and were loaded with the springs. At the conclusion of the study, measurements indicated that the onplants did not move in relation to the incisors or molars. The premolars attached to the onplant abutment exhibited movement ranging from 4 to 8 mm. Histologic examination showed that bone directly opposed the textured, hydroxyapatite-coated surface. Onplants were also placed in the mandible to examine the shear force required for removal. The results indicated that 160 to 162 pounds of "push-off" force was required to dislodge the onplants from the mandible.

The monkey study examined the effectiveness of the Onplant system to anchor molars during anterior dental retraction. In addition, this study introduced onplants with tapered margins and compared them with the original sharp-margined onplants. Bands were placed on the first molar on one side and the second molar on the contralateral side. The bands were connected to the onplant abutment with either wire or a cast bar. Both premolars were extracted bilaterally, and stainless steel springs were extended from each canine to the ipsilateral first molar. Measurements at the conclusion of this study yielded an average of 1.2 ± 0.2 mm movement of the anchored molars toward the central incisors. The nonanchored molars, however, moved an average of 4.1 ± 1.4 mm toward the central incisors. The canines on both the anchored and nonanchored sides moved an average of 1.9 mm away from the central incisors. Soft tissue dehiscences were observed over the original onplant design but were not observed in the tapered margin design. This study concluded that "the onplant can provide sufficient anchorage to molars to prevent anterior migration in situations requiring maximum anchorage."

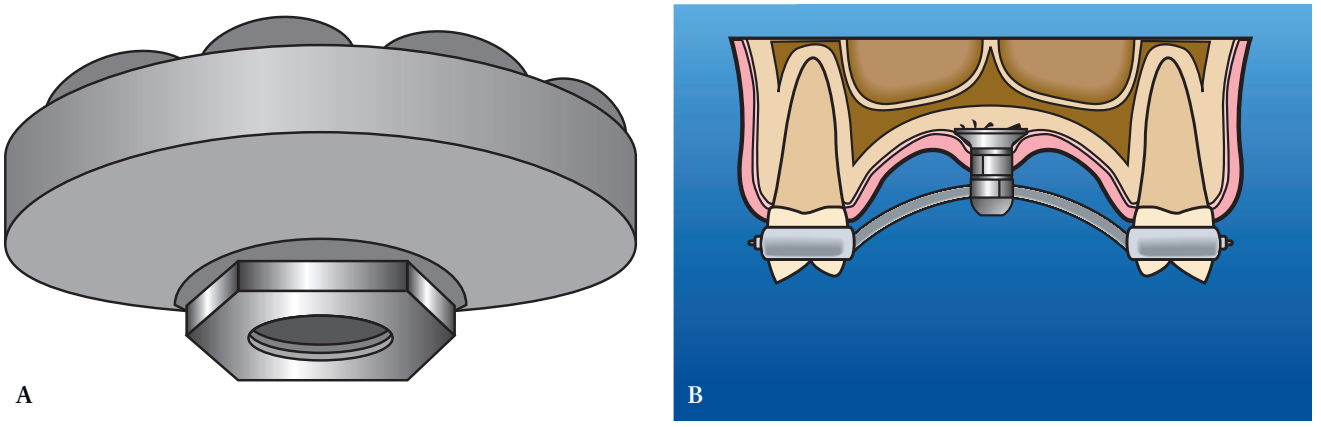


Figure 2. A, *Illustration of an onplant (Nobel Biocare, Göteborg, Sweden) as described by Block and Hoffman.* B, *Diagram of placement of the onplant connected to a transpalatal arch.*

In addition to requiring less bone depth for placement compared with endosseous implants, onplants can be loaded after a shorter healing period. The onplant system cuts this healing period approximately in half. Despite these advantages, one area of concern with this system is removal of the onplant. Block and Hoffman described using osteotomes for removal of the devices.[12] Although this technique is obviously atraumatic to a euthanized dog, performing it on a human could be uncomfortable to the patient. Removal of the onplant also requires removal of a large portion of soft tissue, which could be uncomfortable postoperatively for a patient.

Like Block and Hoffman, Straumann has devised an implant system that can be placed in areas of decreased bone thickness.[13] In 1996 Wehrbein and colleagues described this system in a pilot study.[14] The Straumann Orthosystem incorporates screw-type endosseous implants that can be placed in the palate and subjected to orthodontic force without migration or loss of osseointegration. In addition to the median palate, the Orthosystem implant can be placed in retromolar positions owing to its design. The self-tapping Orthosystem implant itself has a diameter of 3.3 mm and is available in 4.0 and 6.0 mm lengths. A 4.0 mm diameter implant is also available for use when drilling errors have occurred.

The surface of the Orthosystem implant is Straumann's sand-blasted, large-grit, acid-etched surface (Figure 3).

Lateral cephalometric analysis is required prior to placement to determine the ideal site for placement and the appropriate length of implant. Under palatal local anesthesia, the palatal mucosa at the implant site is removed. The site is prepared using a series of drills rotated at no more than 750 rpm under saline irrigation. The implant is hand-turned as far as possible, and a ratchet is used to tighten the implant into its final position. A healing cap or healing screw is placed for the next 10 to 12 weeks, after which time the impression is made. The impression is sent to a laboratory for fabrication of the prescribed orthodontic appliance. After completion of orthodontic treatment, the implant is removed by drilling down two-thirds of the implant length with the exploration trephine and pulling out the implant with extraction forceps and gentle rotation.[13] Currently, use of this system is approved by the US Food and Drug Administration (FDA) for midpalatal placement in adults only owing to concerns about the effects on the midpalatal suture in younger patients (Figure 4).

Figure 3. The Orthosystem implant (courtesy of Straumann, Basel, Switzerland).

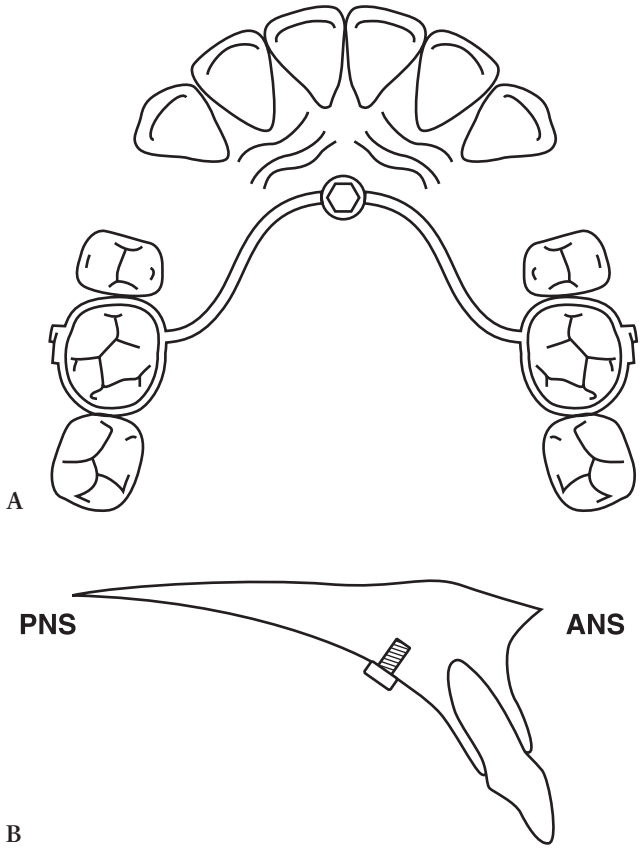


Figure 4. A, *Illustration of a midpalatal implant connected to a transpalatal arch.* B, *Illustration of placement location for a midpalatal implant.*

In 1998 Wehrbein and colleagues published a study examining bone-to-implant contact of implants following orthodontic loading in patients.[6] In this study, four patients were treated for Class II malocclusion using Straumann Orthosystem implants for anchorage instead of conventional extraoral anchorage aids. Orthosystem implants were placed in the midpalatal area of the maxilla and the retromolar areas of the mandible. Midpalatal implants were used to anchor the posterior teeth for anterior dental retraction after premolar extraction. In one patient, the midpalatal implant was used for both anterior and posterior anchorage in premolar mesialization. The retromolar implants were used for bilateral molar distalization.

After completion of orthodontic treatment, the implants were removed in a bony core using a trephine. These cores were then preserved and sectioned through the implant to examine the bone-to-implant contact. Midpalatal implants were found to have a mean bone-to-implant contact of 79.3%, whereas the retromolar implants exhibited contact of 68%. This study concluded that "the data of the present histological report indicate that orthodontic implants are well integrated into the host bone even following long periods of orthodontic loading in humans."[6]

According to Wehrbein and colleagues, the advantages of the Orthosystem are that it can be placed in areas that conventional implants cannot, soft tissue irritation is minimal, and anchorage is stable owing to sound osseointegration.[14] The disadvantages are that the placement process requires a surgeon, loading is not typically done immediately, and removal of the device often requires the use of a trephine owing to the extent of osseointegration.

Miniscrews

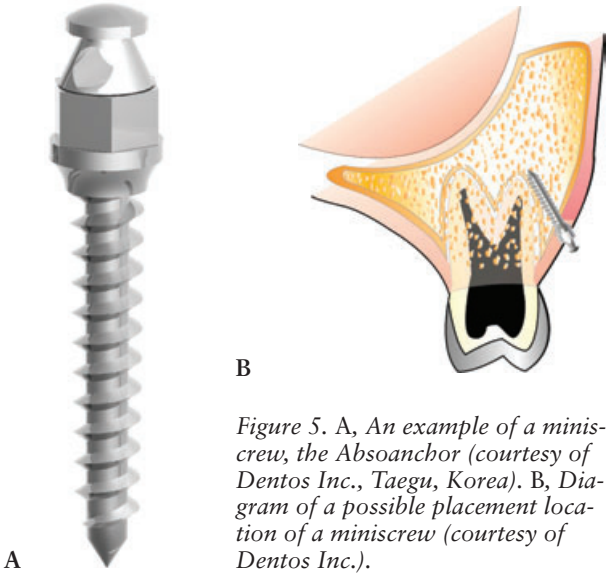
An alternative approach to achieving anchorage is the use of titanium miniscrews. These devices are very small and can be placed in areas where other implantable devices cannot. For example, some miniscrews are so small that they can actually be placed in bone between the roots of individual teeth. The screws themselves are similar or identical to those used for osteotomy fixation following orthognathic surgery. These mini-

screws are unique because unlike restorative endosseous implants they do not require osseointegration. Instead, these devices rely on mechanical retention to maintain rigidity, which also makes their removal relatively simple and noninvasive. They may be loaded immediately, but biomechanical factors must be taken into consideration owing to the increased chance of loosening associated with the lack of integration and torquing or rotational forces that may occur under loading. Kanomi published one of the preliminary reports of this technique in which he referred to the devices as mini-implants.[15] Although he referred to the devices by a different name, his results were essentially similar to those of other case reports on the use of miniscrews, such as the one published by Costa and colleagues.[16] Their article is a case report in which the authors observed 14 patients with 16 screws. The titanium screws that they used were manufactured by a company called Cizeta (Rome, Italy) and had a diameter of 2 mm and a length of 9 mm. The placement technique involved inserting the screws under local anesthesia directly through mucosa without a mucoperiosteal flap. The screws were placed in several different locations depending on the desired treatment and available bone. They were reported to be useful in both the maxilla and the mandible, specifically, on the inferior surface of the anterior nasal spine, midpalatal suture, infrazygomatic crest of the maxilla, retromolar area of the mandible, and mandibular symphysis and within edentulous areas of the alveolar process. After taking into account what tooth movements were desired, the location was decided upon, and the screws were placed with specific angulations to accommodate existing anatomy and deliver forces in the desired directions. Prior to insertion of the screws, a 1.5 mm diameter hole was drilled into the bone with a slow-speed handpiece using irrigation. The miniscrews were inserted by hand with a screwdriver. To apply the desired force, the heads of the screws were joined to the dental arch or tooth with a wire. In cases involving one-dimensional force, the head of the screw was placed so that mucosa would cover it and the attached wire would emerge from the mucosa. In cases that involved the use of multidimensional forces, the heads of the screws were kept above the mucosa so that edgewise wires could be inserted into the specially designed head of the screw. In this article, the miniscrews were loaded immediately, and after treatment they were removed under local anesthesia using the same screwdriver that was used during initial placement.

In 2000 Melsen and Costa reported the use of a similar device called the Aarhus Achorage screw, which is manufactured by Medicon (Tuttlingen, Germany).[17] This system uses a self-drilling titanium screw, and the surgical process and clinical applications are not unlike the previously mentioned systems. This system is FDA approved.

In 2003 Kyung and colleagues reported the development of a microimplant for orthodontic anchorage.[18] This implant is a small titanium screw known as the Absoanchor and is manufactured by a Korean company called Dentos Inc. (Taegu, Korea). According to Kyung and Dentos, the Absoanchor is a particularly attractive member of the family of mini-implants because it "has been designed specifically for orthodontic use and has a button-like head with a small hole that accepts ligatures and elastomers. The Absoanchor's small diameter allows its insertion into many areas of the maxilla and mandible previously unavailable—even between roots of adjacent teeth" (Figure 5).[18]

The stated advantages of miniscrews for use in orthodontic treatment are primarily the ease of insertion and removal. Compared with other systems the surgical procedure for placing and removing miniscrews is very simple and noninvasive. This can allow the procedures to be performed by an orthodontist, thereby eliminating the need for a surgical referral. Additional advantages are that loading can occur immediately, which has the potential to shorten



A B

Figure 5. A, *An example of a miniscrew, the Absoanchor (courtesy of Dentos Inc., Taegu, Korea).* B, *Diagram of a possible placement location of a miniscrew (courtesy of Dentos Inc.).*

treatment time, and local soft tissue irritation is reported to be limited compared with other transmucosal types of anchorage and, when present, is easily controlled with local application of chlorhexidine. The stated disadvantages of the miniscrews as used in the Costa and colleagues article were the potential for infection or local soft tissue irritation, the potential for maxillary sinus perforation, infringement upon tooth roots, especially when placed in the infrazygomatic crest region, and, perhaps most importantly, loosening of the miniscrew.[16] During the trial reported by Costa and colleagues 2 of the 16 screws were loosened and lost prior to the completion of treatment. Loosening is suggested to be a problem only when the screws are loaded in a manner that results in a force that is oriented in a direction that unscrews the screw. If the screw is loaded such that the force is oriented in the direction that tightens the screw, then loosening does not occur as quickly. This supposition helps reinforce the conjecture that lateral shearing forces are more detrimental to the stability of implantable devices than are other forces. Miyawaki and colleagues retrospectively examined the success rates of titanium screws placed for orthodontic anchorage in the buccal alveolar bone in the posterior region.[19] They concluded that a screw diameter of 1.0 mm or less, inflammation of periimplant tissue, and a high mandibular plane angle were associated with the mobility (failure) of the screws. Interestingly, they detected no association between the success rate and length of the screw. Miniscrews are available from manufacturers other than those mentioned in this article, but, in general, the same advantages and disadvantages exist for all of them.

Miniplates

A further approach to the use of implantable devices in conjunction with orthodontic treatment has been the use of titanium miniplates. Miniplates are frequently used in orthognathic surgery for osteotomy fixation or in the fixation of fractures. An early case report by Sherwood and colleagues described two adult patients referred for orthodontic treatment of supererupted molars.[20] The extruded teeth were in contact with the opposing alveolar ridge. Without orthodontic intervention the supererupted teeth would need to be reduced occlusally by a considerable amount, which would have required endodontic therapy and subsequent restoration. The implant placement involved a surgical procedure with a 1.5 cm incision under local anesthesia in the buccal vestibule adjacent to the extruded molars. A full-thickness mucoperiosteal flap was reflected, and bone was exposed. An L-shaped titanium Leibinger (Stryker Leibinger GmbH & Co. KG, Freiburg, Germany) miniplate was contoured over the exposed bone and fixed with two self-tapping screws of 3 mm length. The last loop of the miniplate was allowed to project through the vestibular wound adjacent to the supraerupted molars. The incision was closed via sutures, and soft

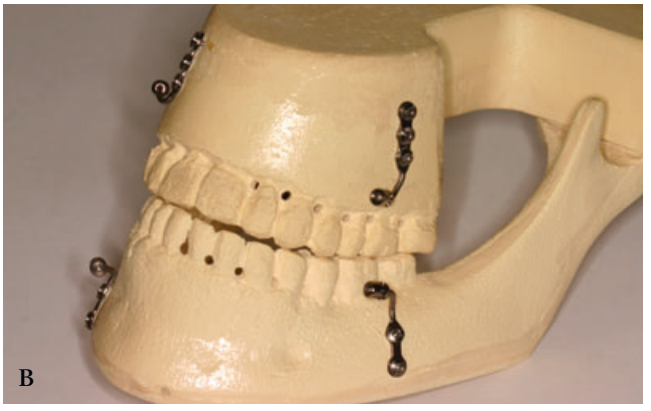
tissue was allowed to heal around the exposed loop for 2 months. During healing the other teeth were orthodontically leveled, excluding the extruded molars. Elastic threads were attached to the exposed loop of the miniplate and tied tightly over the buccal tube of the extruded molar, which was now banded. New elastics were applied and activated every month. This process was continued until the molars were at the plane of occlusion of the adjacent teeth. This process took approximately 6.5 months, and afterward the molars were ligated to the miniplate loops for retention.

In another case report by Chung and colleagues the investigators used the miniplate system by Martin Medizin Technik (Gebruder Martin GmbH & Co KG, Tuttlingen, Germany), but they soldered a round 0.036-inch tube with a hook to one end of the miniplate.[21] The authors called this device the C-tube, and it was designed to use the tube with a hook instead of an exposed loop or rectangular slot to minimize torque forces (Figure 6). This specific report involved the treatment of a 10-year-old female with severe crowding and a Class II skeletal discrepancy. The surgical process was similar to that described by Sherwood and colleagues. One C-tube was placed in each quadrant. In the maxilla they were placed between the second premolars and first molars and in the mandible between the first and second molars. The C-tubes were placed so that the tube end protruded through the mucosa. The authors reported good results in retraction of anterior teeth and leveling of the occlusal plane following connection of C-tubes to the rest of the arches via rectangular wires. This case was cut short owing to the patient moving away, but the results nevertheless seem to indicate a potential method of achieving skeletal anchorage.

In 2002 De Clerck and colleagues introduced and reported success in the treatment of Class II malocclusion using the Zygoma Anchorage System.[22] The authors adapted a Surgitec zygoma anchor miniplate (Surgitec, Bruges, Belgium) secured with three screws that had a round extension arm carrying an attachment mechanism (Figure 7). These devices were placed in the inferior surface of the zygomaticomaxillary buttress. The surgical procedure for placement was similar to that discussed for the other miniplate systems; however, in this case the devices were loaded immediately after placement. The tooth movements reported in this case were retraction and intrusion for correction of Class II malocclusion. The specific points addressed by De Clerck and colleagues were the design of the extension arm, the exit of the extension arm at the mucogingival junction, and the versatility of the attachment apparatus.

The apparent advantages for using a miniplate system as declared by the above authors are as follows: a long history of biocompatibility, a variety of shapes and sizes, a minimally invasive surgical procedure, and little risk of damaging nerves or tooth roots. This approach is indicated by various authors as being valuable in aiding patients needing intrusion of individual or groups of teeth, correction of severe crowding, correction of skeletal Class II malocclusion, and management of an anterior open bite.[23] The disadvantages are that placement of miniplates is more invasive than the placement of miniscrews and requires a surgeon for the procedure. In the reports of miniplate use as temporary skeletal anchorage, patients experience loosening of the plates secondary to inflammation or excessive shearing or torsional forces from the archwire.

Figure 6. The C-tube miniplate (KLS Martin, Tuttlingen, Germany).



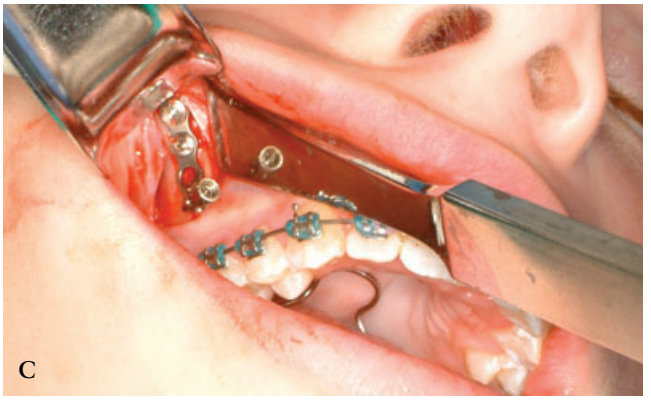


Figure 7. A, *Surgitec bone anchor miniplate (Surgitec, Bruges, Belgium).* B, *Possible placement locations of miniplates. C, Surgical placement of a miniplate in the zygomatic buttress region.*

CONCLUSIONS

It seems apparent that dental implants or implantable devices can play a valuable part in augmenting anchorage for orthodontic movement of teeth. However, the question must be asked: why is this approach better than other auxiliary treatment methods or appliances? One of the most important answers is that most traditional methods of anchorage rely on patient cooperation and compliance:

Clinical experience suggests that there is a threshold for force duration in humans in the 4-8 hour range [per day], and that increasingly effective tooth movement is produced if force is maintained for longer durations…Continuous forces, produced by fixed appliances that are not affected by what the patient does, produce more tooth movement than removable appliances unless the removable appliance is present almost all the time.[1]

The reality is that many patients, especially adolescents, do not show optimum compliance, that is, they do not wear their appliances or head gear all of the time. The social implications of doing so make this understandable, but the result is a delivery of force that is unquestionably more discontinuous than using an implant. The result of using implantable devices is that patient compliance issues are virtually eliminated and force is delivered continuously throughout the day.

With compliance eliminated as a factor in treatment it seems logical that treatment times would be decreased. In the currently available literature there are few data in this area, and most reports are purely anecdotal. However, logic would suggest that the use of implantable devices could significantly increase the speed of orthodontic treatment in certain circumstances.

In conclusion, the incorporation of dental implants into dental treatment plans has had a tremendous impact on virtually the entire field

of dentistry. With the increased interest in the area of implantology has come a great deal of credible research exploring the use of dental implants. Indeed, evidence-based dentistry is the basis for sound clinical decision making and treatment-planning modalities. Whereas the conventional use of dental implants has been studied for some time now, the use of implants and implantable devices as described in this article is relatively new by comparison. Therefore, the literature is limited in clinical trials and other more rigorous evaluation methods. At this time the body of research associated with this subject is composed largely of case reports and a few small time-limited trials in animals. There is no doubt that this area will continue to be explored and researched and will probably become an indispensable part of contemporary orthodontic therapy in the future. Purely as a matter of opinion, it seems that the extent to which the use of implants or implantable devices is accepted by the field of orthodontics on a broad basis will depend on a few specific factors. It seems that the devices themselves will continue to evolve but will probably move in a direction that supports the best combination of ease of placement (able to be placed by orthodontist), least invasive procedure, and best physical design properties to deliver optimum mechanical forces. Perhaps the use of dental implants will prove to be as useful to the field of orthodontics as it has been for other areas of dentistry.

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