Dental implants for orthodontic anchorage

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The purpose of this article is to review and update current concepts involving the use of dental implants for orthodontic anchorage. Topics to be discussed include indications, implant requirements (eg, materials, size, designs of dental implants), surgery and healing time, biomechanics and forces, loading time, implant maintenance, posttreatment considerations, and disadvantages. (Am J Orthod Dentofacial Orthop 2005;127:713-22)

Compared with the past, more patients receive orthodontic treatment because of the demands of esthetics or function. In the Center for Disease Control’s Third National Health and Nutrition Examination Survey (NHANES III), only 35% of adults were considered as having well-aligned mandibular incisors; 15% had severe irregularities that could affect social life or function; about 60% of the entire population might benefit from orthodontic treatment.1 However, not everyone has adequate dentition for orthodontic anchorage, eg, partially edentulous patients and those with congenital dentofacial anomalies.2,3 Therefore, supplementary alternatives have been sought.

In 1960s, Brånemark et al4 noticed the biocompatibility of titanium screws in bone tissue. Light microscopic examinations showed bone-to-implant contact; thus, the concept of “osseointegration” developed.5 After this, many studies were conducted to investigate the application of titanium implants in dentistry. An implant success rate of over 90% has been reported in edentulous patients.6,7 Decades before, the idea of using dental implants to reinforce orthodontic anchorage showed encouraging results.8,9 The purpose of this article is to review and update current concepts of using dental implants for orthodontic anchorage.

DEFINITION OF ORTHODONTIC ANCHORAGE

Orthodontic anchorage is defined as “resistance to unwanted tooth movement.”10 Dentists use appliances to produce desired movements of teeth in the dental arch. According to Newton’s third law of motion, every action has an equal and opposite reaction; this means that, inevitably, other teeth move if the appliance engages them. Anchorage is the resistance to the force provided by other teeth or devices. In orthodontic treatment, reciprocal effects must be evaluated and controlled. The goal is to maximize desired tooth movement and minimize undesirable effects.

HISTORICAL PERSPECTIVE

In 1945, Gainsforth and Higley11 used vitallium screws and stainless steel wires in dog mandibles to apply orthodontic forces. However, the initiation of force resulted in screw loss. In 1969, Linkow8 placed blade implants to anchor rubber bands to retract teeth, but he never presented long-term results.8

In 1964, Brånemark et al4 observed a firm anchorage of titanium to bone with no adverse tissue response. In 1969, they demonstrated that titanium implants were stable over 5 years and osseointegrated in bone under light microscopic view.5 Since then, dental implants have been used to reconstruct human jaws or as abutments for dental prostheses.5,6 The success has been attributed to the material, surgical techniques, and the manner that implants are loaded.

In 1984, Roberts et al9 corroborated the use of implants in orthodontic anchorage. Six to 12 weeks after placing titanium screws in rabbit femurs, a 100-g force was loaded for 4 to 8 weeks by stretching a spring between the screws. All but 1 of 20 implants remained rigid. Titanium implants developed osseous contact, and continuously loaded implants remained stable. The results indicated that titanium implants provided firm osseous anchorage for orthodontics and dentofacial orthopedics.
Table I. Indications and advantages of using dental implants for orthodontic anchorage

<table>
<thead>
<tr>
<th>Indications</th>
<th>Advantages</th>
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<tbody>
<tr>
<td>Intrude/extrude teeth</td>
<td>Reduce complications and facilitate movement</td>
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<tr>
<td></td>
<td>Mini-implants more feasible than conventional</td>
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<td></td>
<td>ones</td>
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<tr>
<td>Close edentulous spaces</td>
<td>Avoid need for prosthesis</td>
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<tr>
<td></td>
<td>Reduce endodontic complications</td>
</tr>
<tr>
<td></td>
<td>Enhance oral hygiene</td>
</tr>
<tr>
<td>Reposition malposed tooth</td>
<td>Improve anchorage</td>
</tr>
<tr>
<td></td>
<td>Reconstruct the edentulous area</td>
</tr>
<tr>
<td>Reinforce anchorage</td>
<td>Maximize anchorage, eg, palatal implant systems</td>
</tr>
<tr>
<td></td>
<td>Improve patient compliance (no headgear, Class II elastics)</td>
</tr>
<tr>
<td>Partial edentulism</td>
<td>Future restorative abutments</td>
</tr>
<tr>
<td>Correct undesirable occlusion</td>
<td>Provide solid anchorage to retract entire arch</td>
</tr>
<tr>
<td></td>
<td>Facilitate localized bonding and treatment</td>
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<tr>
<td>Orthopedic movement</td>
<td>Accelerate sutural distraction (palatal expansion) and bone movement</td>
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</table>

INDICATIONS

In orthodontic treatment, anchorage control is essential for success.10 Dental implants, due to the stability in bone, can serve as firm anchorage. They have been applied in the following situations (Table I, Fig 1).

Intrude/extrude teeth. It is difficult to intrude or extrude teeth, particularly molars. Implant anchorage greatly facilitates these movements. However, conventional implants are 3.5 to 5.5 mm in diameter and 7 to 15 mm long; these dimensions create limitations for usage. Therefore, mini-implants (1.2 mm in diameter, 6 mm in length), which can be placed between roots or apical to a tooth, are more feasible.12 Pure intrusion or extrusion cannot be achieved. If the implant is at the facial side for intrusion, only intrusion plus protrusion can be accomplished. Also, care should be taken not to involve the periodontal ligament* and prevent postoperative peri-implant mucositis, which is often observed when an implant is placed in mobile mucosa. Mini-implants are too small to cause irreversible damage. Removal of these implants should result in uneventful healing.

Close edentulous spaces. Missing first molars or congenital missing teeth are common. Because of reduced anchorage, implants in retromolar areas have been used to translate teeth into edentulous areas.13,14 Titanium screws were placed to protract molars and close the spaces of congenital missing premolars.15 This treatment is superior to others when adjacent teeth are intact or have large pulp chambers, making preparation undesirable. Plaque control is more complicated with fixed partial dentures, which increase the risk of caries and endodontic or periodontal disease. The soft tissue around implants should be cared for during treatment. If the translated tooth is tipped, it should be uprighted to prevent a mesial angular bony defect. Tight contact points are preferred to minimize food impaction and future caries or periodontal tissue breakdown.

Reposition malposed teeth. Preprosthetic corrections of tilted abutments are not unusual. Adequate anchorage for tooth movement is often impossible when there are several missing teeth. Realignment of molars by using the remaining teeth is complicated because of limited support. Implants facilitate uprighting the abutment teeth at the end of a long edentulous ridge.16-18 If carefully planned, dental implants used to upright teeth can be restored as implant-supported prostheses in edentulous areas.19

Reinforce anchorage. Palatal implants have been developed to reinforce anchorage.20-23 An endosseous orthodontic implant anchor system (Orthosystem, Straumann, Waldenburg, Switzerland) was designed and used in Angle Class II malocclusion patients in whom extraction of maxillary first premolars and retraction of anterior teeth were planned. Implants were placed in anterior palatal areas and attached to posterior teeth. Maximum anchorage was achieved without compliance-dependent aids (headgear, elastics). When palatal implants were used to reinforce anchorage, they showed no mobility, and they did not cause soft tissue complications, posterior teeth movement, or retraction of anterior teeth.21-23 This application in molar distalization successfully stabilizes teeth against rotational movement.24

Treat partial edentulism. Treatment is complicated in patients with malocclusion and many missing and periodontally compromised teeth. Fortunately, implants in edentulous areas to provide orthodontic anchorage and later serve as prosthetic abutments have been considered a proper interdisciplinary approach (Figs 2 and 3).2,16,25-28 To improve lip profile, anterior teeth can be repositioned with implants at the ramus or tuberosity. Implants are particularly helpful when many posterior teeth are missing and the teeth must be moved in 1 direction.29 Transitional implants have been applied in these situations. The relatively low cost,
user-friendly protocol, immediate loading potential, and adaptability to orthodontic mechanics make them worth further investigation.30 The benefit of implants is that when several teeth are missing, the reciprocal effects of conventional methods can be minimized.

Correct undesirable occlusion. Correcting Class III anterior crossbite with conventional methods is not always satisfactory. Retracting the entire mandibular arch with dental implants is possible.29 Localized crossbite can be treated by bonding implants and teeth to avoid full-mouth treatment.31 Protracting maxillary arches can be achieved by using implant anchorage.12 A patient with anterior open bite, bilateral crossbite, and missing mandibular anterior teeth was reported. Three implants, placed in the edentulous area to improve anchorage, later served as abutments for fixed
Figure 1. Continued
Fig 2. This 58-year-old man had many missing teeth, deep bite, and generalized spacing. Due to reduced anchorage source in mandibular arch, dental implants were placed first. After 3 to 4 months, implants at teeth 21 and 31 were used as orthodontic anchorage units to move mandibular incisors to right; later, all implants were used as abutments for fixed prosthesis. A, Initial panoramic radiograph. B, Initial mandibular occlusal view. C, Panoramic radiograph midtreatment. D, Mandibular occlusal view during treatment. E, Mandibular occlusal view after treatment. Space between teeth 26 and 27 was closed without changing angulation and position of teeth 27, 28, and 29. Teeth 17 and 18 were extracted. F, Mandibular occlusal view posttreatment. Implants used for orthodontic anchorage became abutments of fixed prosthesis.

Fig 3. During treatment, 5 dental implants were placed; 2 were used as anchorage to move mandibular incisors to right (dotted line, initial; gray, treatment completed).
partial denture. Open bite correction is significantly enhanced by permitting intrusive forces to be applied posteriorly.\(^3\,\,^2\) Patients with compromised occlusions benefit tremendously if implants are used to provide rigid and superior anchorage.

**Provide orthopedic anchorage.** Palatal implants can be used to elicit palatal expansion. This applies to partially edentulous patients or children with congenital diseases that result in facial developmental defects or missing teeth.\(^3\) Implants in congenital anomalies can promote orthodontic and orthopedic therapy and accelerate jaw movement by sutural distraction.

**IMPLANTS AS ANCHORS FOR ORTHOPEDIC APPLICATIONS**

In orthopedic treatment, it is common to use appliances to move bones or influence bone growth; ie, posterior directed headgears are placed to correct Class II malocclusions by limiting forward growth of the maxilla. Anterior directed distractors are used to treat maxillary hypoplasia. Palatal expansion devices are used to treat maxillary constrictions. In each case, the forces are transmitted to the bones by a tooth; this implies skeletal as well as dental effects. In some patients, tooth movement is desirable, but, in others, it compromises the outcome. Tooth splinting or controlling force vectors can minimize undesirable movement, but it cannot be avoided. Skeletal movement can be accomplished by using teeth as anchorage, but dental side effects often limit the amount of movement. Implants can overcome the limitations by guiding forces directly to the bones.

Facial skeletal movement by implant anchorage has also been evaluated.\(^3\) Titanium implants were placed in maxillary, zygomatic, frontal, and occipital bones in monkeys. After 4 months, the implants were exposed, and the abutments placed and connected with extraoral tractors. A 600-g force was applied until 8 mm of maxillary displacement occurred. All implants remained stable over 12 to 18 weeks. The findings also showed the possibility of controlling the direction of protraction. This study provided promising results, but further evaluations are needed to determine the practicability in humans.

To evaluate the application of implants in sutural expansion, animal studies have been conducted.\(^3\,\,^4\,\,^5\) Two titanium implants were placed on either side of the midnasal suture in 18 rabbits, which were divided into an unloaded control group and 2 test groups. After 8 weeks, each test group was loaded with a force of 1 newton (N) or 3 N. All implants remained stable for 12 weeks. Low loads applied to implants assist expansion across unfused sutures. The amount of expansion was positively correlated to the force. More woven bone formation was observed at sutural margins in loaded groups.\(^3\) Moreover, bone volume, turnover rate, and new bone formation were higher within 1 mm of the implant. This might be due to the increased stress and strain adjacent to the implant.\(^3\) These studies indicate no detrimental effects of loading on implants to expand sutures.

Several congenital facial anomalies and developmental defects present anchorage challenges. Case reports using dental implants for orthopedic movement and acceleration of jaw movement by sutural distraction have been reported.\(^3\,\,^2\,\,^0\) Nonetheless, the optimal load, which has not been determined yet, for sutural expansion is the lowest above the woven bone threshold that effectively separates it. Therefore, further studies are needed to determine the optimal load.

**IMPLANT CRITERIA**

**Implant materials.** The material must be nontoxic and biocompatible, possess excellent mechanical properties, and provide resistance to stress, strain, and corrosion. Commonly used materials can be divided into 3 categories: biotolerant (stainless steel, chromium-cobalt alloy), bioinert (titanium, carbon), and bioactive (hydroxyapatite, ceramic oxidized aluminum). Because of titanium’s characteristics (no allergic and immunological reactions and no neoplasm formation), it is considered an ideal material and is widely used. Bone grows along the titanium oxide surface, which is formed after contact with air or tissue fluid. However, pure titanium has less fatigue strength than titanium alloys. A titanium alloy—titanium-6 aluminum-4 vanadium—is used to overcome this disadvantage.\(^3\,\,^6\)

**Implant sizes.** Implant fixtures must achieve primary stability and withstand mechanical forces. The maximum load is proportional to the total bone-implant contact surface. Factors that determine the contact area are length, diameter, shape, and surface design (rough vs smooth surface, thread configuration). The ideal fixture size for orthodontic anchorage remains to be determined. Various sizes of implants, from “mini-implants” (6 mm long, 1.2 mm in diameter) to standard dental implants (6-15 mm long, 3-5 mm in diameter), have proved to effectively improve anchorage.\(^12\,\,^13\,\,^2\,\,^6\) Therefore, the dimension of implants should be congruent with the bone available at the surgical site and the treatment plan.

**Implant shape.** This determines the bone-implant contact area available for stress transfer and initial stability. The design must limit surgical trauma and allow good primary stability. It is difficult to identify the “perfect” implant shape. The most commonly used
Question: Will the implant be used as prosthetic abutment?  
Yes: Standard healing protocol, loading after 3-6 months  
No: Immediate or delayed loading, check initial stability

Question: Is the anchorage mechanism direct or indirect?  
Direct: Immediate or delayed loading  
Indirect: Immediate or delayed loading

Question: What is the primary stability of the implant achieved at the time of surgery?  
Yes: Immediate or delayed loading  
No: Retrieve and replace

Question: Is the implant stable postoperatively (at the time of orthodontic loading)?  
Yes: Immediate or delayed loading  
No: Immediate or delayed loading, check initial stability

Is the implant stable postoperatively (at the time of orthodontic loading)?  
Yes: Immediate or delayed loading  
No: Retrieve and replace

Fig 4. Factors to consider before loading an implant.

PALATAL IMPLANTS

In 1995, a 2-stage hydroxyapatite-coated titanium subperiosteal implant (Onplant, Nobel Biocare, Göteborg, Sweden) was developed. This system has several characteristics: disc shaped, 10 mm in diameter, 2 mm thick, coated with hydroxyapatite on the side against bone, and smooth titanium facing soft tissue with a threaded hole where abutments will be placed. Surgical procedures include a full-thickness mucoperiosteal incision followed by a subperiosteal tunnel and fixation of the disc to the prepared site. After biointegration with tissue, the disc is exposed by punch technique (removal of a patch of tissue at the center). A ball-shaped abutment is connected, to which orthodontic devices will be attached. Onplants have been shown, in animal models, to provide sufficient anchorage to move and anchor teeth. However, their efficiency remains to be determined. Several drawbacks need to be addressed. Primary stability often cannot be achieved by mechanical retention. Placement might be greatly limited by anatomical structures, eg, the torus. Clinical assessment of integration is not easy, except by cephalometry. Further long-term research is needed for future applications.

In 1996, a 1-stage endosseous orthodontic implant for palatal anchorage was presented (Orthosystem, Straumann). This system has a diameter of 3.3 mm and endosseous length of 4 or 6 mm. The self-tapping design provides good initial stability with fewer procedures and less instrumentation during surgery. The implant surface was treated with sand blasting, acid etching, and heat to create 2 levels of roughness that improve the mechanical retention and osseointegration. The transmucosal neck, with a diameter of 4.2 mm, is a smooth cylinder. Neck heights of 2.5 and 4.5 mm are available to accommodate different mucosal thicknesses. A groove above the transmucosal part can hold a transpalatal bar (square wire, 0.032 × 0.032 in, stainless steel), which can be clamped by a cover and screwed tightly to the implant. Many studies have demonstrated its success in maxillary tooth retraction and stabilization of anchor teeth. The Graz implant-supported pendulum and the flange fixture (Branemark, Nobel Biocare) have also been developed by using a similar concept. Biodegradable implants have also been applied, but more studies are required to evaluate their efficacy.

The midsagittal area has relatively low vertical bone height, and complete ossification of the suture is rare before 23 years of age. For most adults, osseointegration is uneventful. However, the paramedian region might be more optimal for adolescents to avoid connective tissue of the suture and interaction of its growth.

SURGERY AND HEALING TIME

The surgical protocol is similar to standard implant surgery. Placement must be aseptic, atraumatic, and precise to ensure success.

How long should we wait before loading? So far, the literature does not provide a justifiable answer. To discuss this, several issues should be addressed (Fig 4). If implants are planned for future prosthetic abutments, a standard healing protocol should be followed. Direct orthodontic forces generate less stress on implants due to limited force imposed (< 3N, about 300 g). The stress is far less for indirect anchorage because implants are used to stabilize teeth. During surgery, assessment of bone quality and initial implant stability are important. With dense bone and satisfactory stability, immediate loading might be feasible. Threaded implants provide superior mechanical interlock as compared with cylindrical designs. Thus, waiting time should be longer for nonthreaded implants. Complete osseointegration is favorable but not essen-
tial for effective orthodontic anchorage implants. However, stable mechanical retention or partial osseointegration is required, and implants should not be overloaded during healing. The loading regimen should be evaluated individually.

**BIOMECHANICS, FORCES, AND LOADING TIME**

Implants should not only fulfill primary stability, but also withstand the stress and strain applied. There are substantial differences between orthodontic and occlusal forces. Orthodontic loads are continuous, horizontal, and usually 20 to 300 g. Occlusal loads are discontinuous, vertical, and sometimes up to several kilograms. Thus, to discuss the maximal load, we need to evaluate the design of the fixtures, the biomechanical requirements, the anatomic limitations, and the degree of osseointegration. The applied forces and waiting period reported in the literatures are summarized in Table II.9,47-58 Although diverse amounts of force were used, the results all showed favorable implant stability.

**IMPLANT MAINTENANCE**

After surgery, the surrounding soft tissues must be maintained to ensure longevity of the implant. Plaque accumulation near the gingival margin can cause periimplantitis. Prolonged inflammation leads to breakdown of bone around implants and peri-implantitis; this, without proper management, can lead to implant failure. Therefore, patients must be instructed to follow daily plaque control at home and have periodic professional care, similar to regular periodontal maintenance.

**POSTTREATMENT CONSIDERATIONS**

After orthodontic therapy, the implants can be used as abutments for dental prostheses. Thus, it is important to discuss the treatment plan with the restorative dentist in advance. When implants are used for anchorage, the

### Table II. Orthodontic anchorage on implants: orthodontic forces applied and waiting time before loading

<table>
<thead>
<tr>
<th>Authors/year</th>
<th>Animal</th>
<th>Implant design</th>
<th>Applied force/time (weeks)</th>
<th>Delay time (weeks)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray et al, 1983</td>
<td>Rabbit femurs</td>
<td>Bioglass-coated &amp; Vitallium</td>
<td>60, 120, 180g/4</td>
<td>4</td>
<td>No implant movement.</td>
</tr>
<tr>
<td>Roberts et al, 1984</td>
<td>Rabbit femurs</td>
<td>Titanium, acid-etched</td>
<td>100g/4-8</td>
<td>6-12</td>
<td>6 weeks healing gave rigid anchorage.</td>
</tr>
<tr>
<td>Roberts et al, 1989</td>
<td>Rabbits, dogs</td>
<td>Titanium, acid-etched</td>
<td>3N (&gt;300g)/13</td>
<td>6-7</td>
<td>Ortho anchor implant need &lt;10% bone-to-implant contact.</td>
</tr>
<tr>
<td>Linder-Aronson et al, 1990</td>
<td>Monkey jaws</td>
<td>Titanium (Biodes)</td>
<td>60g/8</td>
<td>8</td>
<td>Rigid implant can be ortho anchorage.</td>
</tr>
<tr>
<td>Wehrbein et al, 1993</td>
<td>Dog jaws</td>
<td>Titanium (Brånemark)</td>
<td>2N/26</td>
<td>25</td>
<td>No crestal bone loss but subperiosteal bone apposition, no implant dislocation.</td>
</tr>
<tr>
<td>Majzoub et al, 1999</td>
<td>Rabbit calvaria</td>
<td>Titanium</td>
<td>150g/8</td>
<td>2</td>
<td>Implants can be used for ortho anchor in early healing phase.</td>
</tr>
<tr>
<td>Saito et al, 2000</td>
<td>Dog jaws</td>
<td>Titanium (Brånemark)</td>
<td>200g/24, 28,32</td>
<td>18</td>
<td>Implants remained rigid. No difference between test and control.</td>
</tr>
<tr>
<td>Daimaruya et al, 2001</td>
<td>Dog jaws</td>
<td>Titanium sandblasted miniplate</td>
<td>Intrusion, 100-150g/16-28</td>
<td>12</td>
<td>Degree of osseointegration is independent of loading, which influenced turnover and density of bone; unloaded control also kept bone.</td>
</tr>
<tr>
<td>Melser and Lang, 2001</td>
<td>Monkey jaws</td>
<td>TPS (ITI)</td>
<td>100, 200, 300 cN/11</td>
<td>12</td>
<td>Implants remained stable. Peri-implant bone at loaded implants was equal to or slightly greater than unloaded ones.</td>
</tr>
<tr>
<td>Ohmae et al, 2001</td>
<td>Dog jaws</td>
<td>Titanium mini-implant</td>
<td>150g/12-18</td>
<td>6</td>
<td>All implants remained stable. Peri-implant bone at loaded implants was equal to or slightly greater than unloaded ones.</td>
</tr>
<tr>
<td>Trisi and Rebaudi, 2002</td>
<td>Human</td>
<td>Titanium (Bioggini, Ormco)</td>
<td>80-120g/8-48</td>
<td>8</td>
<td>All implants remained stable and osseointegrated. Bone remodeling around implants was observed.</td>
</tr>
<tr>
<td>Deguchi et al, 2003</td>
<td>Dog jaws</td>
<td>Small titanium screw (Stryker)</td>
<td>200-300g/12</td>
<td>3, 6, 12</td>
<td>3-week healing period was sufficient for orthodontic loading in dogs.</td>
</tr>
<tr>
<td>Akin-Nergiz et al, 1998 (orthopedic force)</td>
<td>Dog jaws</td>
<td>Titanium (ITI)</td>
<td>2 N/12 W ⇒ 5N/24</td>
<td>12</td>
<td>Implants had no displacement for any force level. PD was not increased.</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Currently, dental implants have become predictable and reliable adjuncts for oral rehabilitation. Osseointegration can be used to provide rigid orthodontic or orthopedic anchorage. Although initial results are encouraging, the risks and benefits must be thoroughly evaluated. Further investigations are needed to standardize the treatment protocol.

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