CLINICAL SECTION

A 2-year outcome audit of a versatile orthodontic bone anchor

M. Y. Mommaerts
Division of Maxillo-Facial Surgery, Department of Surgery, General Hospital St. Jan, Bruges, Belgium

M. L. E. Michiels, G. A. De Pauw
Department of Orthodontics, School of Dentistry, University of Ghent, Belgium

This study examined complications leading to, or possibly leading to, treatment failure, related to the use of the orthodontic bone anchor (OBA). The OBA is a potential means of providing absolute anchorage and consists of a base-plate fixed with mono-cortical screws, a neck piercing the soft tissues, and a coronal part with conventional orthodontic hooks, tubes or slots. The investigation took the form of a single centre prospective registry at a supra-regional teaching hospital. Eighteen patients (average age 21 years) had one to four OBAs placed between January 2000 and February 2002. Altogether 35 OBAs were placed. Follow-up took place until April 2004. Reasons for placing the OBAs were noted together with any associated complications during the follow-up period. Twenty-three OBAs have been removed so far, four prematurely (one of them before it was taken into use, due to a change of treatment plan enforced by loss of the contralateral OBA). Nineteen were removed as planned after completion of the intended tooth movements. Common (but minor) complications included granulations, acute gingivitis and gingival recession. Light mobility of the OBA was also noted in some cases, but without clinical repercussions. The OBA can be loaded directly, at the level of the orthodontic archwire or more occlusally. It can be placed at any site at the circumference of the jaws, given good quality and thickness of the bony wall. Conventional biomechanical techniques can be applied. However, the failure rate (premature loss of OBA) of 8.6% is considered high, and has necessitated changes in the hardware and protocol.

Key words: Facial bones, corrective orthodontics, orthotic devices, surgery

Received 4th June 2004; accepted 25th April 2005

Introduction

Missing permanent teeth, loss or absence of anchorage, and non-compliance for extra-oral traction can pose problems during orthodontic treatment. Conventional treatment options consist of compromised orthodontic solutions, segmental osteotomies and prosthodontic implants. Absolute intra-oral anchorage by means of titanium implants has become an attractive treatment option for these cases. Most of the experimental and clinical reports on absolute anchorage in orthodontics deal with endosseous titanium implants provided with modified prosthodontic abutments. From our literature review in 1996, we concluded that the most common problem of using dental implants as anchorage in orthodontic patients is the position and the amount of space available in the dental arch.[1] Three other intra-oral 'implantable' regions were subsequently explored, the palate,[2,3] the ascending ramus[4] and the vertical walls of the alveolar process.[5] The titanium implant systems developed for the first two areas and the miniscrews used for the latter are prone to technical problems. The short palatal implants can be difficult to insert properly and manipulate orthodontically. A specially designed custom-made transpalatal arch is required to splint the anchor teeth before conventional force systems can be installed. It seems sensible to limit their use to adult patients because of the incomplete ossification of the midpalatal suture in the younger patient[6] and the limited bony height in the anterior palate.[7] Horizontal implants in the ascending ramus interfere with the upper dentition when placed above a third molar germ and, as a consequence, tend to dislocate. Furthermore, stability of miniscrews is limited after torsional loading.

We have therefore introduced a versatile type of absolute anchorage in the form of a subperiosteal plate-implant.[8] It is fixed with monocortical screws onto the buccal surface of the maxilla or mandible. Different models accommodate specific anatomical conditions. The 'ortho bone anchor' (OBA) can be placed anywhere on the buccal bony surface, provided the cortex has a minimum

Address for correspondence: Maurice Y. Mommaerts, AZ St Jan av, Ruddershove 10, B-8000 Brugge, Belgium.
Email: maurice.mommaerts@azbrugge.be

DOI 10.1179/146531205225021060

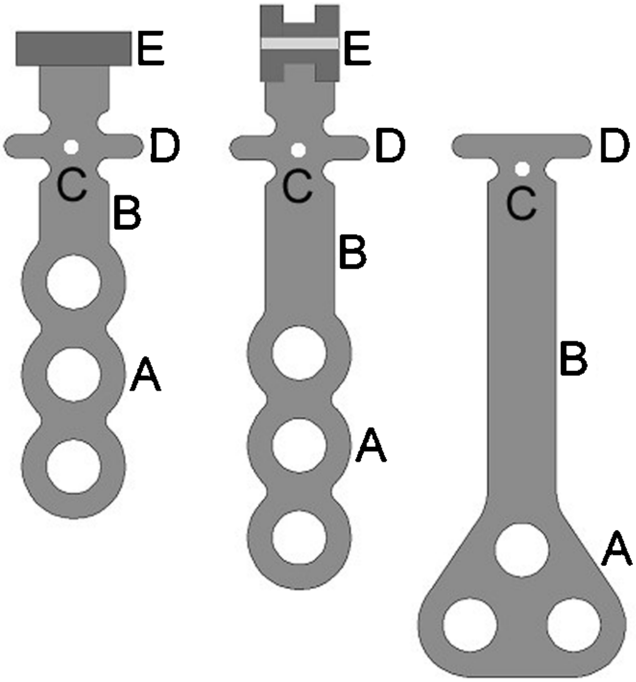

Figure 1 Basic design of an ortho bone anchor. (A) Malleable base-plate to be fixed to the bone surface with monocortical screws. (B) A malleable neck that pierces the gingiva or mucous membrane. (C) Small holes for ligatures. (D) Hooks for rubber bands. (E) The coronal part can bear a tube (variants for the molar region, for tension and compression springs) or a bracket-like slot (variants for the pre-molar and front region, for vertical and transversal movements), or it can be absent (when only elastic traction is required)

thickness to hold the screws. The OBA has hooks, tubes or slots for application of forces by rubber bands, tension or compression springs, or orthodontic archwires. Known biomechanical principles can be applied.

Aim

This is a Phase I clinical trial with the use of OBAs of original design, in order to implement appropriate technical design and/or surgical protocol changes. The results represent a 2-year audit of outcomes and complications to date.

Design and technique

The basic design consists of a base-plate for apical fixation onto the bony surface, a neck that pierces the gingiva or the mucous membrane, and a coronal part for application of force transduction tools (Figure 1). The components are made of commercially pure titanium (Grade 2). The base-plate is 0.6 mm thick and is, to a certain extent, malleable in the antero-posterior (AP) direction in order to accommodate the curvatures of the

Figure 2 Hockey-stick incision with horizontal leg in the attached gingiva. Care should be taken to avoid frenulum insertions

bony surface. It is fixed with monocortical screws of 2.3 mm diameter and 5–7 mm length to penetrate the thick cortical bone of the mandible, the zygomatic buttress or the piriform aperture. The screws have been used clinically for more than 8 years with facial distraction devices and osteosynthesis plates.[9] Their biomechanical properties are essential for proper fixation of the base-plate. The form of the base-plate is rectangular or triangular (Figure 1A). The neck is wider than it is thick, again to allow pliability in the AP direction. This is important to accommodate the orthodontic appliances on the teeth, allow application of the force systems, protect the soft tissues of the cheek, allow mastication, comfort and oral hygiene, and to resist forces that are applied mainly in the sagittal plane. The neck is short in variants used in the retromolar area and extra long in the tree-stem-shaped variants that allow tooth migration along the OBA. The coronal part has hooks for elastic bands or chains. There are also types provided with bracket-like slots, for use in the premolar or frontal region, and with tubes, for use in the molar and retromolar region (Figure 1E). The surface of the OBAs used in the study is machine-polished.

The OBA can easily be placed under local anaesthesia infiltration. In the mandible, care should be taken to place the OBA in between the roots, except for the extra-long tree stem-shaped model.[10] The coronal horizontal leg of the hockey-stick incision is preferably placed in the attached gingiva, unless the resulting cuff would be very narrow (Figure 2). The antero-posterior and vertical position of the coronal part is dictated by orthodontic mechanics. The orthodontist usually prefers a tube or a slot at the level he or she is used to working with, i.e. close to the mid-buccal tooth surface, but sometimes a higher position is required. In the maxilla, sagittal pull, and traction or vertical pull (intrusion) can be applied when the OBA is fixed in the piriform aperture or zygomatic buttress. Again, care should be taken to avoid root damage. This is done by checking the width of the alveolus, knowing the thickness of the buccal cortical plate, and the length of the roots and their relationship to the buccal cortical plate. Surgical experience in osteosynthesis for fractures or corrective osteotomies is extremely important in helping to establish this.

It is still unknown if any latency time (healing of soft tissues, osseointegration) has to be allowed for, or if it needs to be adjusted to the anatomic area or in relation to the magnitude of the forces to be applied. In this study, a latency period of at least 3 weeks was allowed for all indications.

Orthodontic indications

The OBA can be used in a variety of situations as shown but at the end of treatment it is removed.

Sagittal movement of teeth

Common indications include missing permanent teeth within the lateral segments, retroclination of the lower front-teeth and non-compliance with a facial protraction mask. Distalization of the upper molars, non-compliance with headgear and closure of extraction spaces in the treatment of dental Class II malocclusion are others. In the mandible, the ideal places are between the canines and first premolar teeth, between the first and second molars, and in the retro-molar region when the third molar is absent. In the maxilla, the ideal places are at the piriform aperture, between the canine and first premolar and at the infra-zygomatic crest. Forces are generated by coils and elastic bands or chains.

Vertical movement of teeth

Indications are for the treatment of infraposition of a single tooth and bite opening. The ideal place for the OBA is next to the problem area or at the infra-zygomatic crest. Forces are generated by orthodontic archwires or elastic bands.

Transverse movement of teeth

Indications are dental cross-bites of single or multiple teeth. The ideal place for the OBA is near the problem area. Forces are generated by orthodontic archwires.

Registry design, subjects and methods

The study protocol was approved by the ethics committee of the GH St Jan (OG 065). The study design was a prospective registry of a consecutive series of patients treated by one surgeon and five orthodontists. The setting was a supra-regional teaching hospital. Eighteen patients received one to four OBAs. The group comprised 10 males and eight females, with an average age of 21 years (minimum age 10 years, maximum age 45 years). Informed consent was obtained from all patients. The most common indication was protrusion of the front teeth with missing molars (seven patients). Next was closure of an extraction space or spacing due to developmental absence of a tooth in the premolar/molar area (six patients). Protrusion of an aligned lower arch in deep bite Class II malocclusions with prominent chin (whilst avoiding extra-oral traction and an orthognathic procedure) was undertaken in three patients, whilst two had a deep bite and a reversed maxillary curve of Spee. The upper front teeth were intruded to facilitate placement of the orthodontic appliance on the lower front teeth. Altogether, 35 OBAs were placed between January 2000 and February 2002. 50% (17) were provided with a tube, 16% (six) with a bracket and 34% (12) with only elastic hooks.

Radiographic and clinical follow-up was carried out with registration of problems regarding mobility and peri-implant condition. The time of removal and the reason were recorded. The difficulties regarding tooth displacement encountered by the orthodontists were not recorded. Thus, an opinion regarding treatment satisfaction, from a patient's and orthodontist's point of view, cannot be given.

Results

The results are summarized in Table 1. Thirty-five OBAs were placed in the study period. Twenty-three OBAs have been removed so far, four prematurely, 19 after completion of the intended tooth movements. The 19 removed after completion of tooth movement were in place on average 456 days (SD 266) . Twelve OBAs are still in use, (average period in place of 651 days; SD 161) at the time of writing the manuscript (April, 2004). In one patient, the two OBAs distal to the last mandibular molar were clinically mobile and the soft tissues acutely inflamed 3 weeks post-operatively. The orthopantomogram showed extensive bone loss around the fixation plates and they had to be removed. In another patient, also with bilateral OBAs in the retromolar area, one failed after 3 weeks, due to an acute inflammation. The

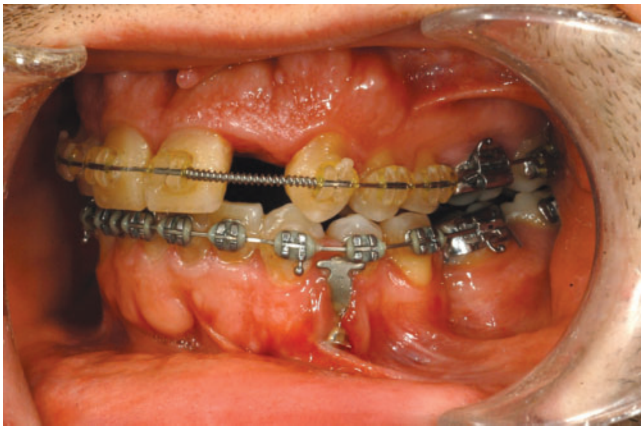

Figure 3 Left occlusal view of 42-year-old male patient, treated with OBA for closure of the 'extraction space' of an extracted left lower first molar. The OBA has been in place during 831 days. The neck was left straight instead of bent in a bayonet shape, and this caused the gingival recession and exposure of an osteosynthesis screw

OBA on the other side posed no clinical problems, but remained unloaded and was subsequently removed. In the first patient with this complication, heavy orthodontic forces were already applied after only 1 week. In the second patient, orthodontic force had never been applied. The cause of these failures still remains unknown (mastication trauma?). In one patient, acute gingivitis around one OBA occurred 6 months after placement, and was cured with irrigation (aqueous chlorhexidine solution), cleansing and antibiotics (penicillin). Light mobility of the OBA, where movement of the plate was possible at its bony interface, but limited by the screws was noted five times at various sites, without clinical repercussions. Six OBAs had been fixed with two osteosynthesis screws instead of three. In one of the six cases, the lower screw loosened and this resulted in rotation of the OBA. The orthodontist continued treatment by blocking the OBA with a lower molar to form one unit of resistance. Granulations were noted more frequently, but were of lesser concern to the patient. Chronic inflammation around the exit port did not correlate with premature loss or with significant morbidity. Gingival recessions of variable magnitude were noticed when the necks were exiting the soft tissues tangentially to the bony and gingival surface (Figure 3). Each time, the surrounding tissues were inflamed. Occasionally, the upper screw became visible, and it had to be removed in two patients because of loosening and irritation. In the course of the study, it became obvious that the neck had to be bent into a bayonet shape to reduce the circumference of the exit point and for cleansing the posterior part of the neck (Figure 4). The screw head was lowered to prevent it from piercing the tissues.

Table 1 Summary table of demographic, locations of OBAs and complications

Sex	10 male, 8 female
Age	21 years (min. 10, Max. 45)
Indications	
Protrusion and tipping of front teeth with missing anchor teeth	7
Closure of diastemas, uprighting premolars and molars	6
Protrusion of aligned lower teeth	3
Intrusion of upper front teeth	2
OBA type	
With tube	17
With brackets	6
With elastic hooks	12
Complications	
Premature removal	4 (3 retromolar because of loosening)
Light mobility	5
Chronic inflammation	Periodically and variable number
Acute gingivitis	1
Recessions (straight OBAs)	10

Table 1. Key: OBA = orthodontic bone anchor

Figure 4 Implant neck bent to a bayonet shape to reduce complications

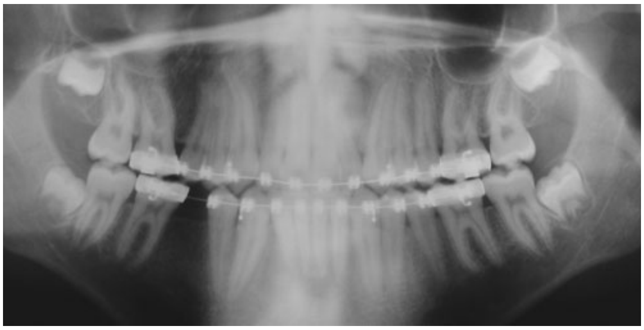

Figure 5 Case report. Orthopantomogram before insertion of OBA. The second right lower premolar is missing. Asymmetric agenesis is a typical indication for absolute anchorage

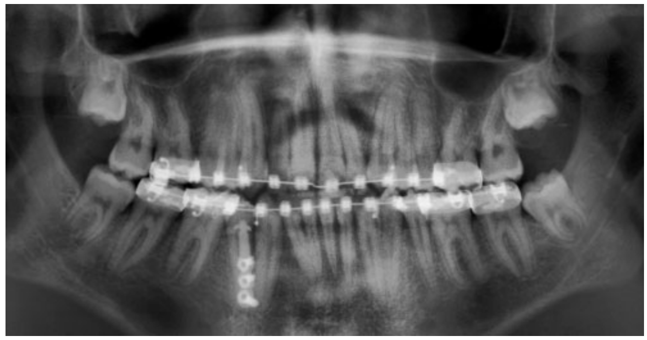

Figure 6 Case report. Orthopantomogram 2 years later. The extraction space has been closed by active mesialisation of the first and second lower right molars, and by passive mesialisation of the third molar. The monocortical screws do not touch the canine root. (Orthodontic treatment by N. Lammens)

Case report

The malocclusion of a male patient aged 16 years 6 months with a missing lower right second premolar, was treated with fixed orthodontic appliances (Figure 5). After placement of the OBA, a medium–light force (Chuck elastics, 3M, Minnesota) was applied on a 0.016-inch Australian wire with toe-in and tip-back. After banding the second molar a 0.016 × 0.016-inch nitinol archwire was used and elastics were immediately applied to keep the space closed. The OBA was also used to apply a vertical elastic so that no open bite was created. Space closure took over 2 years. It has been reported that this is because the trailing roots are engaged by the relatively dense bone formed by the leading (mesial) roots and that the rate of mandibular molar transition is inversely related to the apparent radiographic density of the resisting alveolar bone (Figure 6).[11] Coil spring also seemed to be more effective in providing a continuous, low force over a long period of time.

Discussion

This study has shown that bone plates provided with conventional orthodontic slots and placed on the outer jaw surfaces can be used with an acceptable failure rate for orthodontic anchorage with conventional mechanics, such as springs and elastic bands. However, it may be possible to further reduce the failure rate of 8.6%. Most orthodontic treatments require the use of intra- and/or extra-oral means to help maintain the anchorage of teeth. Their use may result in undesirable tooth movements. Some also require excellent co-operation, have an injury risk and can be cumbersome to wear especially by adults.

The use of intra-oral dental implants, which initially can be used as an orthodontic anchor, and thereafter as an abutment for crown or bridge, constitute an elegant treatment option. To ensure success when using these endosseous implants as anchors to move teeth several factors need to be considered and interdisciplinary planning is essential.[11] Positioning of the implant requires a pre-treatment diagnostic wax set-up[12,13] and the appropriate time for placing the implant has to be determined because implants do not erupt.[14,15] Importantly, there needs to be an edentulous area and sufficient bone in the alveolar ridge to place the implant. These conditions limit the use of dental implants as a means of obtaining absolute anchorage in orthodontic patients. Absolute anchorage is also more frequently needed in patients not requiring prosthodontic rehabilitation. Consequently, the need for orthodontic implant anchors, used during, but removed after orthodontic treatment, was identified. The use of dental implants in the mandible for that purpose is described by Roberts and co-workers.[16–19] Others recommend the use of palatal implants as anchorage for tooth movements in the maxilla.[2,3,20,21] Both of these systems use teeth in the dental arch for indirect anchorage. The presence of the third molar and interferences with the upper dentition pose problems for the mandibular implants, whilst the lack of vertical thickness of the anterior palate poses problems for the maxillary implants.[7] Also, as reported by Tinsley *et al.* (2004), the associated transpalatal arches can be awkward and time-consuming to fit.[22]

The OBA-system is not a cylindrical implant, but an abutment plate fixed with monocortical screws, giving more flexibility in the location of the implant. Depending on the desired three-dimensional tooth movement and the biomechanical aspects in each individual, the OBA-system can be inserted anteriorly or posteriorly in the dental arch of the maxilla or mandible. In contrast to the other implant anchors, the OBA-system can serve not only as an indirect anchor, but can be loaded directly. Direct loading has the advantage that only the teeth that need orthodontic correction are involved in the initial stage of treatment. Moreover, the use of the OBA-system is independent of toothless areas in the dental arch, and so can be used in non-extraction treatments.

OBA is a more versatile tool than other endosseous implants, palatal implants, onplants or horizontal implants in the ascending ramus. They can be placed around the entire jaw circumference and do not need special abutments. On the contrary, standard tubes, hooks and slots enable the orthodontist to apply conventional fixed appliance mechanics. The latter cannot be achieved with miniscrews, which are also prone to loosening when a moment is created. Small shaft diameter and thin buccal alveolar bone are two factors associated with increased incidence of premature loss of miniscrews.[23] Bicortical screws[24] should provide more stability than miniscrews, but the possibility of root damage comes into play. Liou *et al*.[25] used 17 mm long titanium screws of 2 mm diameter in the zygomatic buttress area. The authors do not mention if they aimed for bicortical fixation. In 44% of a total of 32 bilaterally placed screws, considerable extrusion and/or tipping was demonstrated after a 9-month follow-up period. This prompted the authors to state that mini screws do not provide predicable stationary anchorage, but that they remained clinically stable. A cephalometric appraisal of OBA movement was not included in this pilot study.

The series of our study is too small to provide full evidence-based conclusions. The failure rate of 8.6% needs consideration however. Cheng *et al*.[26] lost 11% of 140 mini-implants (48 trauma-plates and 92 freestanding mini-screws), of which four were before orthodontic loading and six after loading of less than 1 month. We have the impression that forces of higher magnitude (mastication, orthopaedic), applied soon after placement are responsible for dislocating the base-plate and loosening the fixation screws. One way to prevent patients from chewing heavily on the OBA is to place it after an initial phase of orthodontic alignment, below the archwire or attached to it. Another way is to increase surface roughness of the plate, since motion appears under smooth plates under relatively low physiological loads.[9,27,28] Consequently, the manufacturer was requested to sandblast and etch the base-plate.[29]

In the pilot study presented, tipping, uprighting, intrusion of front teeth, mesialization and distalization of molars, premolars, canines and incisors was undertaken, but not measured. Intrusion of molar teeth[30] and extrusion of front teeth was not performed. Furthermore, more detailed follow-up will be required to fully establish the value of the OBA.

Conclusion

This study shows that a bone plate with orthodontic slot can be used in many situations where anchorage is missing or unreliable. Because of its unique design, the OBA can be loaded at the level of the orthodontic archwire or at a higher level when indicated. It can be placed at any site at the circumference of the jaws, given good quality and thickness of the bony wall. Conventional biomechanical techniques apply. However, the failure rate of 8.6% (four OBAs lost prematurely) is high. Changes in the hardware were introduced in February 2002, and included roughening of the base plate and reduction in the height of the screw heads. Bending the neck in a bayonet shape was also introduced as a change in surgical protocol and placing the OBA after an initial phase of orthodontic alignment as a change in treatment protocol. A prospective multi-centre registry of complications with the new type of OBA is envisaged.

Acknowledgements

The authors wish to thank Mr T. Billiet for his design suggestions and the Surgi-Tec company for the production of the prototypes.

References

1. Michiels G, Mommaerts M, De Pauw G, *et al*. Osseointegrated implants as orthodontic anchorage. A literature review. *Belg Tijdschr Tandheelkd* 1996; **51:** 205–16.
2. Triaca A, Antonini M, Wintermantel E. Ein neues Titan-Flachschrauben-Implantat zur orthodontischen Verankerung am anterioren Gaumen. *Inf Orthod Kieferorthop* 1992; **24:** 252–7.
3. Wehrbein H, Glatzmaier J, Mundwiller U, *et al*. The Orthosystem—a new implant system for orthodontic anchorage in the palate. *Fortsch Kieferorthop* 1996; **57:** 143–53.
4. Mommaerts MY. Horizontal anchorage in the ascending ramus-a technical note. *Int J Adult Orthod Orthognath Surg* 1998; **13:** 59–65.
5. Costa A, Raffaini M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. *Int J Adult Orthod Orthognath Surg* 1998; **13:** 201–9.
6. Schlegel KA, Kinner F, Schlegel KD. The anatomic basis for palatal implants in orthodontics. *Int J Adult Orthod Orthognath Surg* 2002; **17:** 133–9.
7. Henriksen B, Bavitz B, Kelly B, *et al*. Evaluation of bone thickness in the anterior hard palate related to midsagittal orthodontic implants. *Int J Oral Maxillofac Implants* 2003; **18:** 578–81.

8. Mommaerts MY, Correia P, Abeloos JVS, *et al*. Experiência Clínica Inicial com o 'Ortho Bone Anchor - OBA' (Ancoragem Ortodôntica Óssea). Relatório Preliminar. *Rev Port Estomat Med Dent Cir Maxillofac* 2001; **42:** 131–5.
9. Black GV. *Descriptive Anatomy of the Human Teeth*, 4th edn. Philadelphia: SS White Dental Manufacturing Co., 1897.
10. Kokich VG. Managing complex orthodontic problems: the use of implants for anchorage. *Semin Orthod* 1996; **2:** 153–60.
11. Smalley W, Blanco A. Implants for tooth movement: a fabrication and placement technique for provisional restorations. *J Esthet Dent* 1995; **7:** 150–4.
12. Smalley W. Implants for orthodontic tooth movement. Determining implant location and orientation. *J Esthet Dent* 1995; **7:** 62–72.
13. Ödman J, Gröndahl K, Lekholm U, *et al*. The effect of osseointegrated implants on the dentoalveolar development. A clinical and radiographic study in growing pigs. *Eur J Orthod* 1991; **13:** 279–86.
14. Thilander B, Ödman J, Gröndahl K, *et al*. Aspects on osseointegrated implants inserted in growing jaws. A biometric and radiographic study in the young pig. *Eur J Orthod* 1992; **14:** 99–109.
15. Roberts WE, Arbuckle GR, Analoui M. Rate of mesial translation of mandibular molars using implant-anchored mechanics. *Angle Orthod* 1996; **66:** 331–8.
16. Roberts WE, Helm FR, Marshall KJ, *et al*. Rigid endosseous implants for orthodontic and orthopedic anchorage. *Angle Orthod* 1989; **59:** 247–56.
17. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. *Angle Orthod* 1990; **60:** 135–52.
18. Roberts WE, Nelson CL, Goodacre CJ. Rigid implant anchorage to close a mandibular first molar extraction site. *J Clin Orthod* 1994; **28:** 693–704.
19. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontists. *Am J Orthod Dentofac Orthop* 1995; **107:** 251–8.
20. Glatzmeier J, Wehrbein H, Diedrich P. Die Entwicklung eines resorbierbaren Implantatsystems zur orthodontischen Verankerung. Das BIOS-Implantatsystem. *Fortschr Kieferorthop* 1995; **56:** 175–81.
21. Tinsley D, O'Dwyer JJ, Benson PE, *et al*. Orthodontic palatal implants: clinical technique. *J Orthod* 2004; **3**: 3–8.
22. Miyawaki S, Koyama I, Inoue M, *et al*. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofac Orthop* 2003; **124:** 373–8.
23. Freudenthaler JW, Haas R, Bantleon HP. Bicortical titanium screws for critical orthodontic anchorage in the mandible: a preliminary report on clinical applications. *Clin Oral Implants Res* 2001; **12:** 358–63.
24. Liou EJ, Pai BC, Lin JC. Do miniscrews remain stationary under orthodontic forces? *Am J Orthod Dentofac Orthop* 2004; **126:** 42–7.
25. Cheng SJ, Tseng IY, Lee JJ, *et al*. A prospective study of risk factors associated with failure of mini-implants used for orthodontic anchorage. *Int J Oral Maxillofac Implants* 2004; **19:** 100–6.
26. Mommaerts M. A novel osteosynthesis design for routine corrective facial surgery. *J Craniofac Surg* 2002; **13:** 584–94.
27. Cordey J, Mikuschka-Galgoczy E, Blümlein H, *et al*. Importance de la friction plaque-os pour l'ancrage des plaques d'ostéosynthèse. Détermination du coefficient de friction metal-os chez l'animal '*in vivo*'. *Helv Chir Acta* 1979; **46:** 183–7.
28. Cordey J, Borgeaud M, Perren SM. Force transfer between the plate and the bone: relative importance of the bending stiffness of the screws friction between plate and bone. *Injury* 2000; **31 Suppl 3:** C21–8.
29. Li D, Liu B, Han Y, *et al*. Effects of a modified sandblasting surface treatment on topographic and chemical properties of titanium surface. *Implant Dent* 2001; **10:** 59–64.
30. Sherwood KH, Burch JG, Thompson WJ. Closing anterior open bites by intruding molars with titanium miniplate anchorage. *Am J Orthod Dentofac Orthop* 2002; **122:** 593–600.