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CLINICAL SECTION

Combined cephalometric and stent planning for palatal implants

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Several aspects of palatal implant usage are technique sensitive. In particular, problems during the insertion stage may compromise implant osseo-integration, or its subsequent ease of handling and effectiveness. This paper describes a systematic approach to combined cephalometric and model planning, and subsequent stent fabrication for Orthosystem® palatal implants. The authors recommend this protocol in order to optimize three-dimensional control of implant positioning, and to both simplify and standardize the insertion stage.

Key words: Orthodontic anchorage, Orthosystem®, implant stent, palatal implant

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Introduction

Implant-assisted orthodontics has been suggested as a credible alternative to conventional anchorage especially headgear.[1–3] However, as palatal implant techniques have evolved it has become clear that implant positioning is one of several key factors affecting successful integration and usage.[4,5] Optimal three-dimensional positioning provides the maximum bone depth yet the minimum risk of perforation of adjacent structures, including the incisor roots (Figure 1). In particular, the degree of inclination of the implant (towards the anterior nasal spine) influences the ease of access for surgical instruments, and the chances of a conflict between the path of insertion of the implant and molar bands (where they are used as attachments for the transpalatal arch). The original 'orthodontic' implants were actually endosseous fixtures used in restorative dentistry. During the 1990s, collaboration between the Straumann Institute and University of Aachen produced a customized orthodontic anchorage implant called the Orthosystem®.[6,7] Initially, it was not deemed necessary to use a surgical stent during implant placement, but it now appears to be highly beneficial for the transfer of positional information from the planning process to the insertion stage.[4,5] This is especially important when the planning and insertion stages are performed by different clinicians. For palatal implants this requires a customized design so that the stent provides precise guidance for the surgical instruments and, hence, implant positioning.

Three recent papers have proposed the use of removable stents for this purpose.[5,8,9] Two of these introduced the use of a vacuum-formed stent,[8,9] whilst the most recent paper illustrated a modified removable appliance design. A lateral cephalograph with a radiographic template *in situ* was required in all three techniques (in addition to the normal pretreatment cephalograph). Tosun *et al.*[8] described a stent with a metal cylinder integrated at the insertion site. Whilst the cylinder provided both positional and inclination information it had two potential disadvantages. Access for external irrigation of the drill would be restricted, although the implant system used by Tosun *et al.*[8] also used internal irrigation. Secondly, the cylinder is suitable for the use of narrow uniformly-shaped surgical pilot drills only, rather than a range of instruments (trephine, profile drills and inserting device) as used in the Orthosystem. Furthermore, this method requires superimposition of a hand tracing of the maxillary outline onto a sectioned maxillary model. This aspect is limited by magnification errors and the need for division of the plaster model.

Two techniques have been described for the Orthosystem.[5,9] Martin *et al.*[9] placed a 2.2 mm diameter metal rod into a vacuum-formed template at an arbitrary 90° to the palatal incline. A cephalometric radiograph with the template *in situ* was used to assess the bone and soft tissue depths at the proposed insertion site. In turn, this helped the authors to select the most appropriate Orthosystem implant in terms of its body and neck length, respectively. It appears that additional radiographs would be required if the template rod location needed to be altered. Then a vacuum-formed stent was made over a 5 mm diameter metal rod placed

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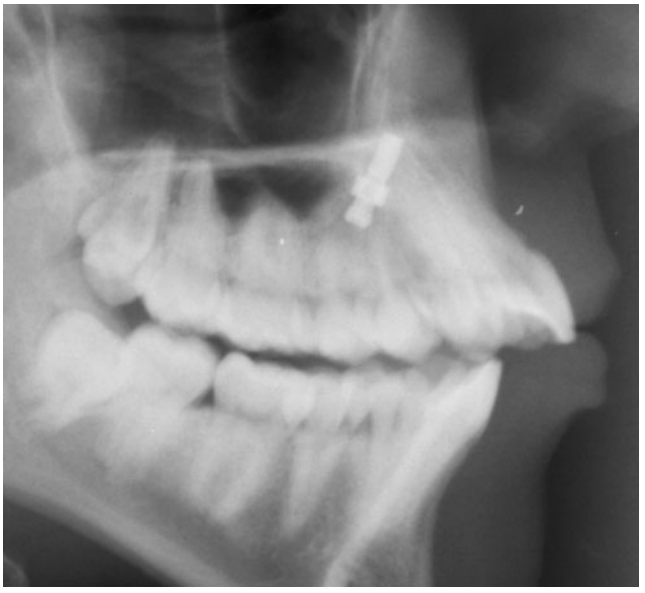

Figure 1 A lateral cephalograph showing a 6 mm intra-osseous depth implant inserted in the anterior palatal triangle of bone

in the planned implant site, thereby creating a hole for the mucosal trephine. This would provide simple topographical information on the insertion site, but the antero-posterior (AP) and lateral drill inclination would not be controlled. In addition, access for external irrigation of the implant site would be limited.

Alternatively, Tinsley *et al.*[5] used two 6 mm metal tubes in an acrylic radiographic template and they also orientated these markers perpendicular to the anterior palatal curvature. A lateral cephalograph was taken with this template in place and the implant position was then planned relative to these tubes, although the authors did not provide precise details on their determination of the implant location and inclination. Subsequently, this technique involved conversion of the radiographic template into a surgical stent featuring a 6 mm diameter hole to locate the insertion site. No detail was provided on the transfer of prescription information from the radiographic to the model stage. A 10 mm length of 0.7 mm steel wire was embedded in the stent 'at the appropriate angle' to provide a visual reference plane for the surgeon when angling the profile drill. However, the authors did not comment on the operator's ability to visually align the profile drill with this guide wire. Finally, neither of these proposed Orthosystem stents provides guidance for the lateral angulation of the implant (i.e. tipping of the implant towards the buccal teeth on either side) nor controls the range of movement of the profile drill.[5,9] This would potentially result in creation of an excessive implant bed width, as noted by Tinsley *et al.*,[5] whereby a wider (4 mm) diameter implant had to be inserted in 20% of cases.

Since 2002 we have independently developed a systematic planning and surgical stent technique that is not affected by these limitations and provides full three-dimensional guidance at the surgical stage. This technique has been used in the planning and insertion of 14 consecutive palatal implants. Although two of these failed to integrate, the planned implant position had been successfully replicated (as seen on the post-operative radiograph) and the failures were probably caused by the bone over-heating. This paper describes the key aspects of this implant planning and stent fabrication in order to simplify the surgical stage and provide optimal insertion of Orthosystem palatal implants.

Cephalometric planning

A recent standard lateral cephalograph is used to determine each patient's ideal AP implant position and inclination. The relevant area of bone is roughly triangular in shape and is bordered by the nasal floor superiorly, the oral cavity infero-posteriorly, and the central incisor roots and incisive canal anteriorly (Figure 1). Although Orthosystem implants are available with 4 mm intra-osseous lengths, it is advised that the 6 mm format is used whenever possible in order to maximize the prospects of both primary stability and osseo-integration.[4] Fortunately, a cephalometric study of Orthosystem clinical cases and dried skulls has indicated that there is at least 2 mm extra bone depth present in the sagittal area of the palate than indicated on a lateral cephalograph.[10] Conversely, a recent radiographic study of the palatal depth relative to the incisive canal found a mean of only 4.3 mm bone depth in the anterior palate area.[11] These measurements however were taken perpendicular to the palatal contour and, hence, at a more anterior inclination (towards the incisive canal) than recommended. It is the authors' experience that the available bone depth in the mid-palatal area seldom necessitates the use of the smaller 4 mm implant.

Anterior positioning in the sagittal plane potentially provides the greatest bone depth, but may place the implant tip too close to the incisive canal or central incisor roots. In this respect, it is important to consider both the pretreatment and the planned final incisor positions. Conversely, posterior positioning reduces the available bone depth for primary stability and osseo-integration, and also increases the risk of nasal floor perforation. In the authors' first 14 cases planned using

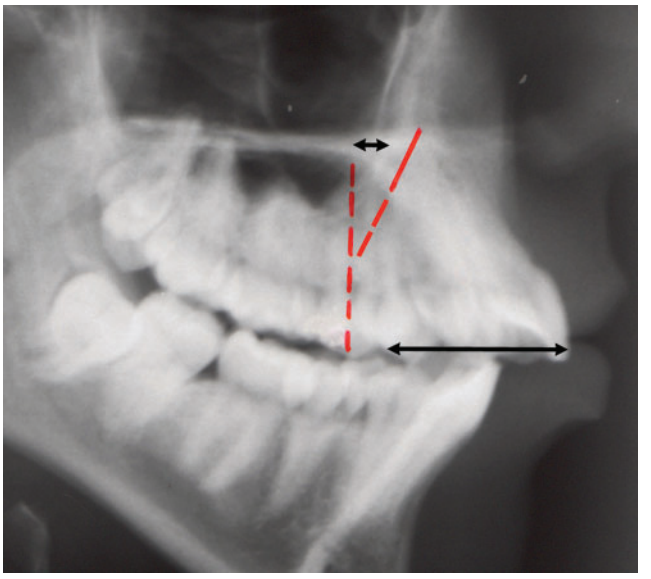

Figure 2 The pretreatment cephalograph with its original planning lines. The dashed red line through the long axes of the upper second premolars represents the vertical plane. The optimal implant position (solid red line) is at 23° to the vertical plane and it crosses the cortical plate at the level of the first premolars. This insertion point can be measured relative to the vertical plane and the most labial incisor (black arrows)

this technique the level of the upper first and second premolars provided the most appropriate AP site for implant entry through the palatal cortical plate (Figure 2).

A balance is struck between the AP position and the inclination of the implant's insertion towards the anterior nasal spine. Implant inclination affects both the access for surgical instruments at the insertion and explantation stages, and the path of insertion of the transpalatal arch (TPA).[4] This is a particular problem where molar/premolar bands are used as the TPA lateral attachments.[5] Clinical results have led the authors to conclude that an inclination of 20–30° to the vertical plane is suitable for palatal implant cases (Figure 2). This provides sufficient inclination for adequate (greater than 6 mm) bone depth yet, in combination with some freedom during the fitting of the TPA, it avoids a conflict between the path of insertion of molar bands and the TPA onto the implant head. This freedom in the TPA components is temporary, since once the cover cap is fully secured there is no slack and, hence, no effect on anchorage. Interestingly, this 20–30° vector is broadly consistent with the 60° inclination to the palatal plane originally recommended for the Orthosystem,[6,7] but since it is derived from a vertical plane it is unaffected by variations in the shape of the palate. This vertical plane is based on the long axes of clinically upright upper premolars, since these are readily identifiable on both the lateral cephalograph and dental models. Hence, both the implant's AP insertion point and inclination may be related to the premolar vertical plane in terms of linear and angular measurements respectively (Figure 2). The use of reference planes and angles also avoids discrepancies between the cephalograph and working model due to radiographic magnification error.

Model planning

Once the implant's optimal AP position and inclination have been determined radiographically then this information is transferred to a working model of the maxillary dentition and palate. This model should be cast in dental stone and trimmed to ensure that its base is approximately perpendicular to the long axes of the premolars. Although implants may be placed in parasagittal sites the technique described here has been used to place implants in the midline location only. Whilst implants may vary in their AP position and inclination we plan them to be upright in the transverse plane (i.e. not tipped laterally towards the buccal teeth), especially to avoid problems with instrument access and TPA placement. The model planning stage proceeds as follows:

- The radiographic AP insertion point (Figure 2) is transferred to the working model by marking it in the palatal midline at the planned distance from the premolar vertical plane using a permanent marker pen. However, the radiographic entry point will have been directly on the cortical plate surface whilst the model includes the palatal mucosa depth (which will not have been discernible radiographically). Therefore, to avoid the implant being more anteriorly placed than its planned position one needs to allow for the depth of the mid-sagittal mucosa. In the authors' experience the AP location on the model should be approximately 2 mm more posterior than the radiographic position in order to allow for the estimated soft tissue thickness and place the implant at the correct position on the cortical plate.
- The model is mounted on an adjustable model table, which is set horizontally level (at zero degrees inclination). A 1.6 mm hole is drilled, using a vertical pillar drill, in the center of the premolar teeth identified in the radiographic plan. These holes are orientated in order that the technician can insert 1.6 mm diameter metal rods down the long axes of the model teeth (Figure 3). These rods correspond to the vertical plane on the planning radiograph.

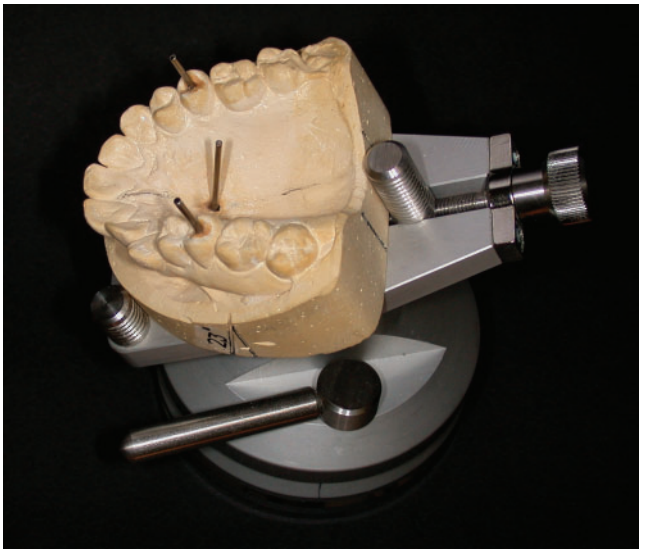

Figure 3 The working model mounted on an adjustable table and tilted by 23° to the vertical plane (which is represented by the premolar rods). The implant rod enters the model at the distal level of the first premolars

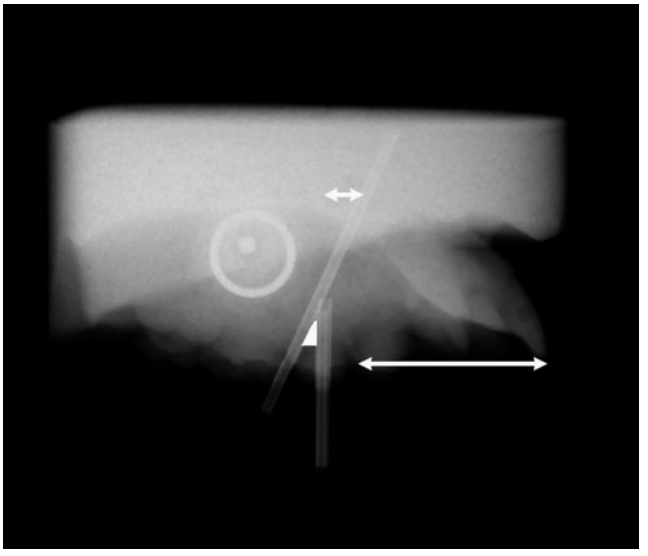

Figure 4 Cephalometric radiograph of the premolar and implant rods inserted in the working model (shown in Figure 3). The implant rod inclination (indicated by the white triangle) is measured relative to the vertical rods. The white arrows indicate the AP linear measurements from the insertion point (through the model surface) to the vertical plane and most prominent incisor

- The adjustable table is altered to the prescribed (20–30°) implant inclination using a magnetic angle finder (an engineering tool which indicates the tilt of a metallic object: supplied by www.kennedy-tools.co.uk).
- The model is placed on the adjustable table under the pillar drill and a 1.6 mm hole is drilled through the implant site. A metal rod is then inserted into this hole and secured using ribbon wax to represent the implant position (Figure 3).
- The model is radiographed in a cephalostat by placing it on a horizontal platform within the machine. This produces a lateral cephalograph showing the provisional implant location and inclination relative to the vertical plane (premolar pins) (Figure 4). The prescription details are checked by comparison with the original radiographic position. This involves measurement of the sagittal distance and angle between the premolar vertical plane and the implant position in both the planning and model radiographs (Figures 2 and 4). Again, the working model AP linear measurement must be corrected by 2 mm to allow for the thickness of the palatal mucosa, which will be included in its radiograph (Figure 4). Any discrepancies may be corrected by repositioning the metal rod that represents the implant and re-radiographing the model as necessary. Unlike previously published stent techniques[5,8,9] this would not involve repeat exposure of the patient.

Fabrication of the stent

The crucial component of the surgical stent is its central guide channel, which dictates the prescribed insertion site and inclination (in both sagittal and transverse planes) by providing three-dimensional control for the surgical instruments. There are two alternatives for the baseplate design: either a vacuum-formed or modified upper removable appliance (with premolar and molar Adams clasps for retention). The choice depends largely on clinical preferences and whether a fixed appliance is already *in situ*. The authors use a modified vacuum design for the majority of cases given its simplicity and reliable retention, and therefore its fabrication is described in detail here. The stent is constructed as follows:

- The metal rods are removed from the working model and the holes filled with high melting point wax. A separator is applied to the model and then a 0.75 mm baseplate blank is vacuum-adapted to the model.
- After trimming the baseplate edges, an acrylic block is built up between the canines and first molars to approximately 1 cm depth.
- The model is reseated on the angled table set at the prescribed implant inclination and positioned under the vertical pillar drill.
- A 3 mm pilot drill is used to make a cylindrical channel through both the central block and baseplate. The drill bit creates this channel at the prescribed angle since the model has been tilted on the angled table.

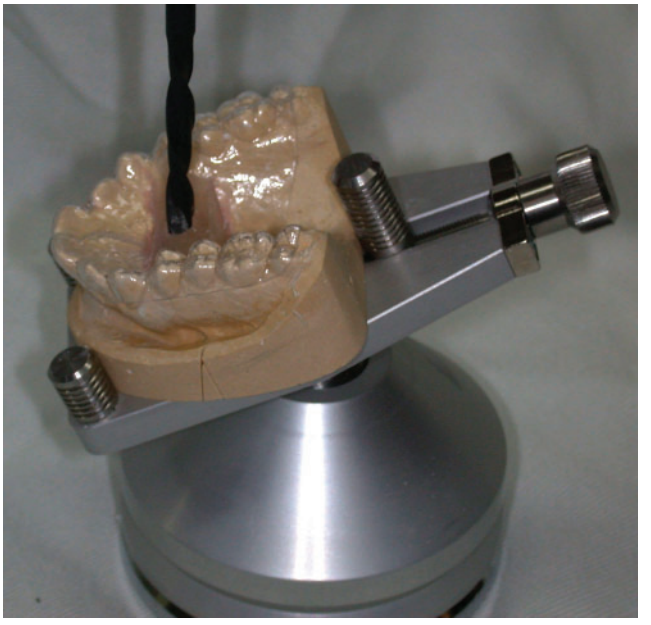

Figure 5 The working model on the adjustable table tilted at the prescribed angle (23° in this case). This means that the 5.6 mm diameter vertical pillar drill will create a channel through the central acrylic block at the correct inclination to the vertical plane

- The pilot channel is enlarged by the use of a drill bit, which corresponds to the 5.6 mm (7/32 inch) mid-shaft diameter of the implant profile drill (Figure 5).
- The stent is removed from the model and acrylic relieved from along the anterior aspect of the cylindrical channel to convert it into an approximately one-third open cylinder. The channel is also trimmed around the fitting surface (Figure 6). These modifications provide open access anteriorly for an unobstructed view of the drill and for its direct irrigation, especially at the insertion point. However, this does not detract from the positive guidance for the surgical instruments within the guide channel.

Conclusions

- The cephalometric planning described here enables the orthodontist to determine the optimal AP position and inclination for palatal implants.
- The planned implant position is easily transferred to a mounted working model using the premolar vertical reference plane. The depth of palatal mucosa on the model causes a discrepancy between the insertion point on the model and cephalograph, but a 2 mm correction is made for this.
- This planning technique reduces radiation exposure by utilizing the existing pretreatment cephalograph and a radiograph of the working model, rather than

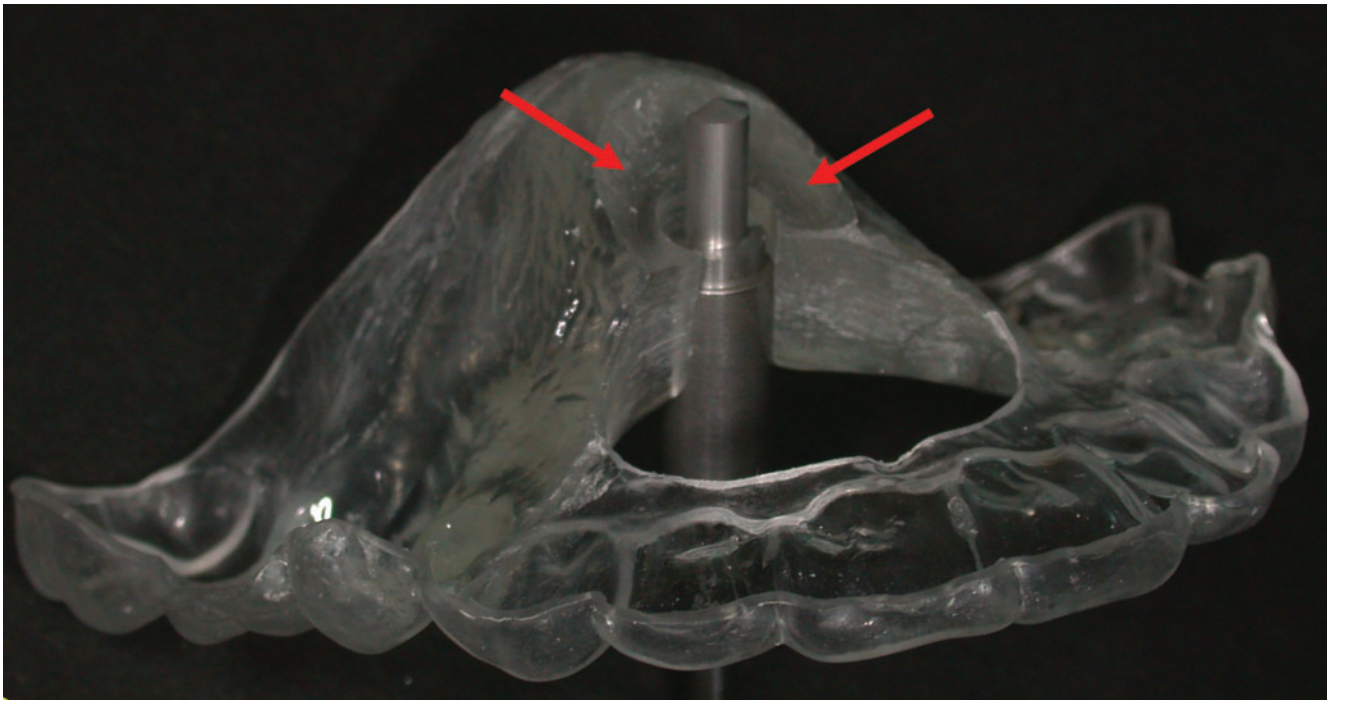

Figure 6 A profile drill is shown fitting into the guide channel within the vacuum-formed stent. The open anterior side of this channel and the surrounding relief of the fitting surface (arrows) provide space for direct vision and external irrigation of the instruments

additional ones of the patient with a radiographic template.

- The surgical stent transfers the prescribed implant location to the surgical stage through precise control of the surgical instruments. This is especially valuable where the planning and insertion stages are performed by different clinicians.
- Although this planning and stent technique has been devised for use with Orthosystem implants the principles may be adapted to other palatal implant systems.

References

1. Bantleon H, Bernhart T, Crismani AG, Zachrisson U. Stable orthodontic anchorage with palatal osseointegrated implants. *Wld J Orthod* 2002; **3**: 109–16.
2. Favero L, Brollo P, Bressan E. Orthodontic anchorage with specific fixtures: related study analysis. *Am J Orthod Dentofac Orthop* 2002; **122**: 84–94.
3. Wehrbein H, Feifel H, Diedrich P. Palatal implant anchorage reinforcement of posterior teeth: a prospective study. *Am J Orthod Dentofac Orthop* 1999; **116**: 678–86.
4. Cousley RRJ. Critical aspects in the use of orthodontic palatal implants. *Am J Orthod Dentofac Orthop* in press.
5. Tinsley D, O'Dwyer JJ, Benson PE, Doyle PT, Sandler J. Orthodontic palatal implants: clinical technique. *J Orthod* 2004; **31**: 3–8.
6. Wehrbein H, Glatzmaier J, Mundwiler U, Diedrich P. The Orthosystem—a new implant system for orthodontic anchorage in the palate. *J Orofac Orthop* 1996; **57**: 142–53.
7. Wehrbein H, Merz BR, Diedrich P, Glatzmaier J. The use of palatal implants for orthodontic anchorage. Design and clinical application of the Orthosystem. *Clin Oral Implants Res* 1996; **7**: 410–16.
8. Tosun T, Keles A, Erverdi N. Method for the placement of palatal implants. *Int J Oral Maxillofac Implants* 2002; **17**: 95–100.
9. Martin W, Heffernan M, Ruskin J. Template fabrication for a midpalatal orthodontic implant: technical note. *Int J Oral Maxillofac Implants* 2002; **17**: 720–2.
10. Wehrbein H, Merz BR, Diedrich P. Palatal bone support for orthodontic implant anchorage—a clinical and radiological study. *Eur J Orthod* 1999; **21**: 65–70.
11. Henriksen B, Bavitz B, Kelly B, Harn SD. Evaluation of bone thickness in the anterior hard palate relative to midsagittal orthodontic implants. *Int J Oral Maxillofac Implants* 2003; **18**: 578–81.