A Three-Dimensional Digital Insertion Guide for Palatal Miniscrew Placement

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Miniscrew anchorage has significantly reduced the need for patient compliance and allowed orthodontic treatment of more types of cases without surgery.[1-4] Despite its increasing popularity, however, miniscrew placement may be dangerous if the clinician lacks adequate information on the anatomy of the insertion area. Various surgical guides based on digital volumetric imaging, such as cone-beam computed tomography (CBCT), have been proposed as aids to allow precise insertion of miniscrews into the interradicular spaces.[5-7]

Numerous studies have demonstrated the suitability of the palate as a skeletal anchorage site,[8-10] and miniscrews placed in the paramedian anterior palate to support various orthodontic appliances have been shown to have excellent survival rates.[11] Although this site is especially safe due to the absence of dental roots, the palate does not present a uniform thickness and can vary from one individual to another.[12,13] It is therefore essential that great care be taken in analyzing the availability of bone for miniscrew insertion to guarantee primary stability and reliable anchorage.[14,15]

This article describes the construction and use of a miniscrew insertion guide designed specifically for palatal applications, called the MAPA System.*[16] It ensures not only that miniscrews are placed at the correct depth in the maxillary bone,

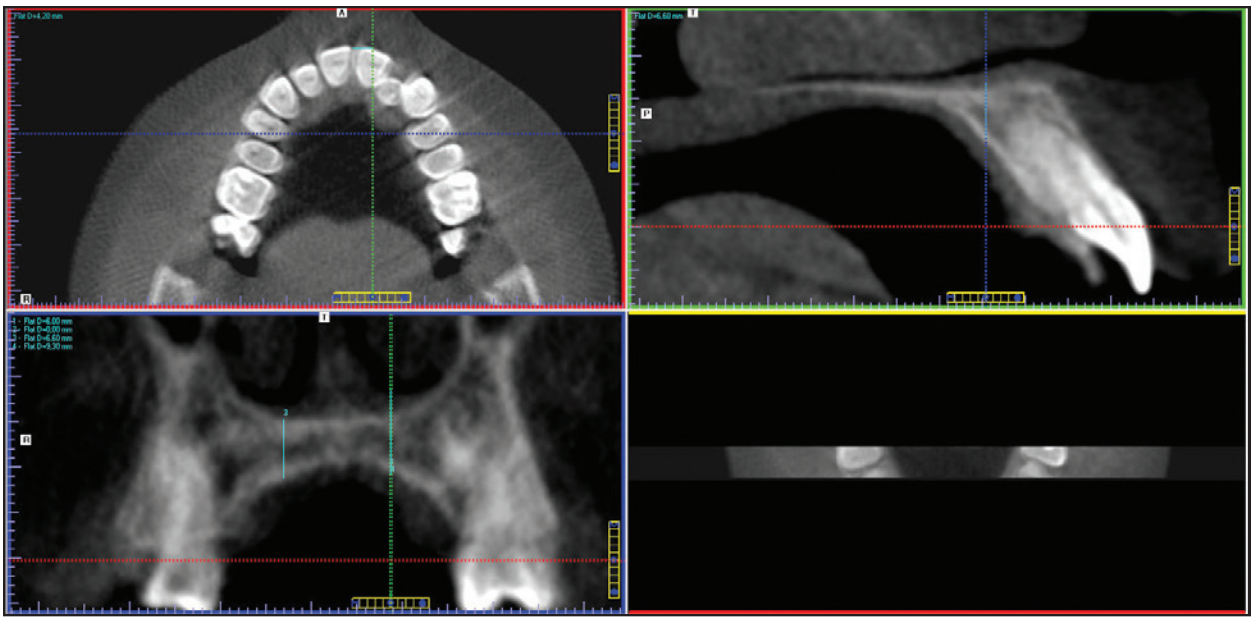

Fig. 1 Cone-beam computed tomography (CBCT) scan used to determine optimal site and direction of miniscrew insertion.

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but also that multiple implants are parallel. It is suitable for placement of miniscrews as anchorage for removable devices or for preformed or customized fixed appliances.

Surgical Guide Fabrication

The optimal site and direction of miniscrew insertion is identified on a CBCT scan (Fig. 1) or lateral cephalogram. The latter requires a thermoplastic polyethylene terephthalate glycol-modified bite registration to be made from the patient's plaster cast, with a series of radiopaque markers inserted along the median palatine raphe (Fig. 2).

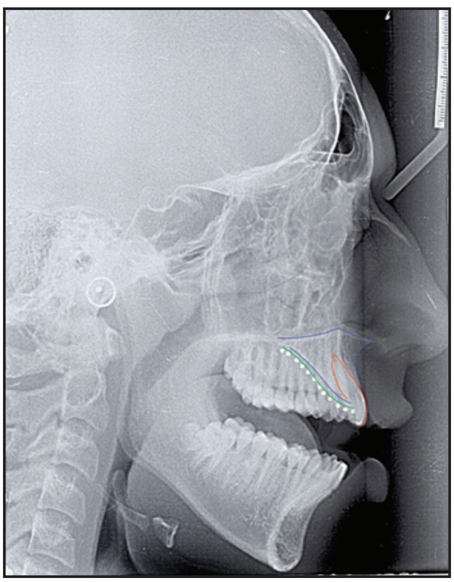

Fig. 2 Lateral cephalogram showing radiopaque markers inserted on thermoplastic bite registration along median palatine raphe.

According to Kim and colleagues, palatal thicknesses measured from lateral cephalograms are comparable to those measured on CBCT scans taken about 5mm from the midsagittal plane.[17]

After scanning, a digital model (stereolithography file) of the upper arch is superimposed onto the CBCT scan (Fig. 3A) or the lateral cephalogram (Fig. 3B), using eXam Vision** and Rhinoceros*** software, to identify the best antero-

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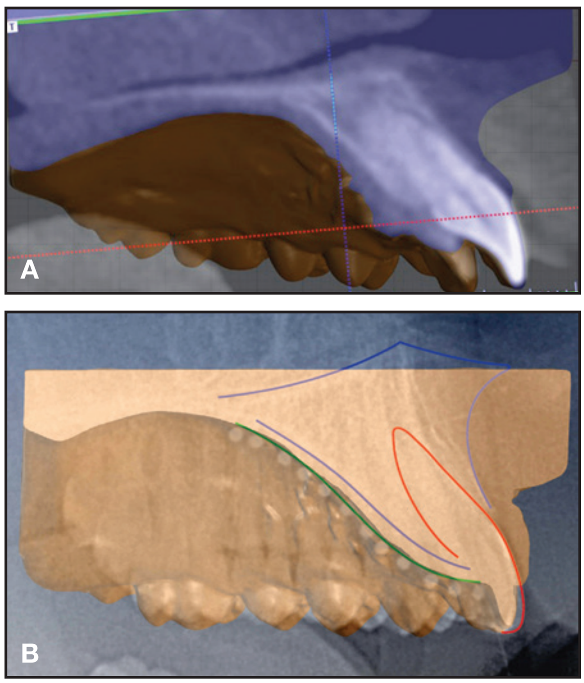

Fig. 3 Superimposition of digital model on CBCT (A) and lateral cephalogram (B).

posterior miniscrew placement sites based on the width and thickness of the palatal vault (Fig. 4). The same software is then used to design a virtual surgical guide that will fit the morphology of the palate and the teeth in the buccal and posterior segments of the upper arch.

Two cylindrical guides are designed to replicate the angle of insertion and prevent the screws from penetrating beyond the required depth in the central portion of the palate. The cylindrical guides are virtually joined to the template by transparent resin bridges (Fig. 5), and the entire assembly is produced using a three-dimensional printer.†[16]

After guiding the miniscrew insertion, the bridges can be quickly and easily removed with a dental bur (Fig. 6).[9] As demonstrated by the following case reports, palatal miniscrews positioned in this manner are useful in resolving various clinical problems.

†DigitalWax 020D, registered trademark of DWS Systems, Zanè, Italy; www.dwssystems.com.

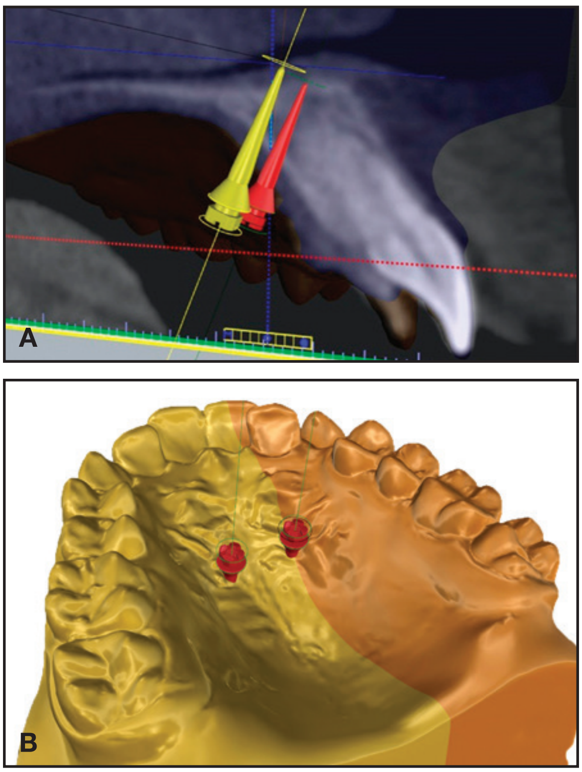

Fig. 4 A. Sagittal plane of CBCT scan, showing miniscrew passing through ideal insertion point. B. Stereolithographic (STL) model with ideal miniscrew insertion sites.

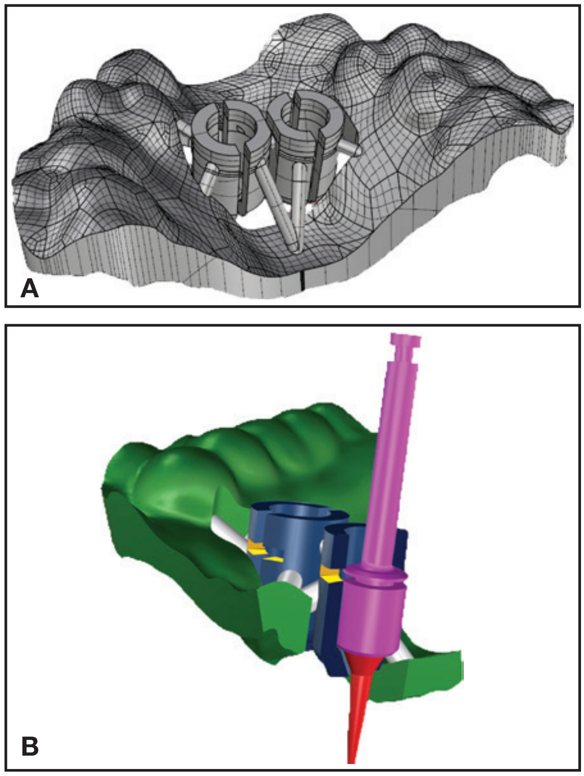

Fig. 5 A. Connection bridges between cylindrical guides and template body. B. Section of insertion guide combining STL files of miniscrew and pick-up driver.

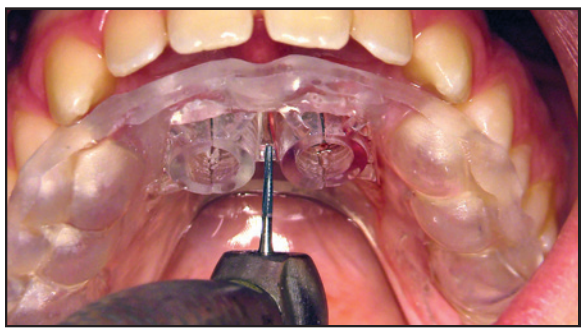

Fig. 6 Cylindrical guide removed with dental bur after miniscrew insertion.

Case 1

A 7-year-old female presented with a complaint about the unsightly appearance of her teeth. Extraoral evaluation showed a slightly prognathic mandibular profile with an asymmetrical position of the mandible (Fig. 7). The patient was in the mixed dentition, exhibiting a Class III malocclusion with a crossbite on the right side and the mandible also deviating toward the right. The upper


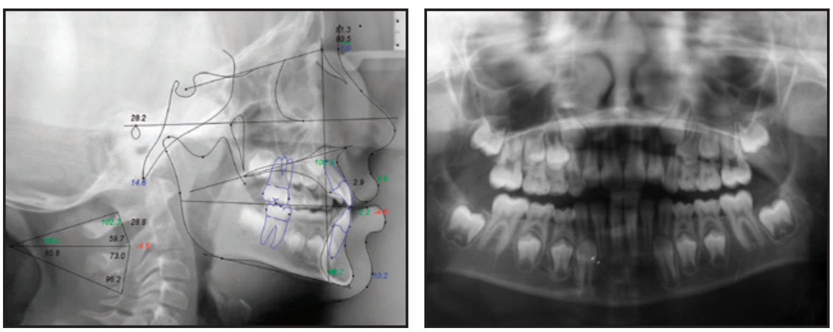

Fig. 7 Case 1. 7-year-old female patient with skeletal Class III malocclusion before treatment.

and lower incisors were in an edge-to-edge relationship. There was no crowding in the maxillary arch, but some interdental spacing in the mandibular arch. Panoramic and lateral cephalometric radiographs indicated a skeletal Class III tendency, hypodivergence, lingual inclination of the upper incisors, and normal inclination of the lower incisors (Table 1).

Orthopedic treatment was planned to expand and protract the maxilla with anchorage from palatal miniscrews. A CBCT scan of the upper jaw was superimposed on a digital model of the upper arch to identify ideal insertion sites for two 7mm Spider Screw Regular Plus‡ miniscrews (Fig. 8). A 3D surgical guide was designed (Fig. 9) and printed as described above for precise placement of the palatal miniscrews. A hybrid rapid palatal expander was then constructed and bonded in place, using both skeletal and dental anchorage (Fig. 10).

The maxilla was expanded according to Liou,[18] and the patient was subsequently instructed to wear a Delaire facial mask for 12-14 hours per

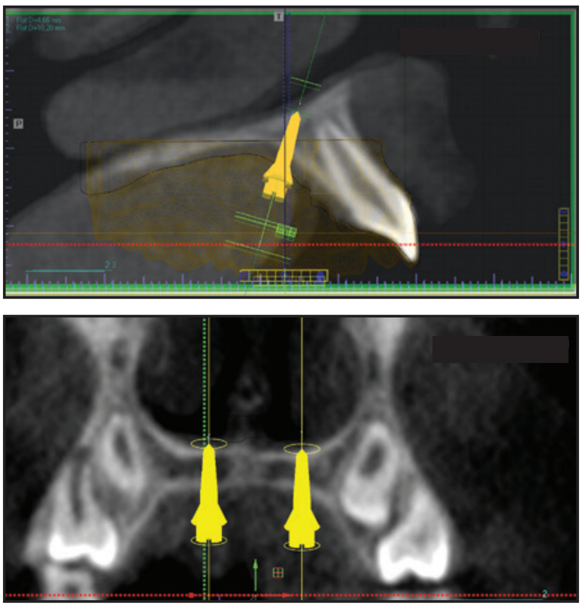

Fig. 8 Case 1. CBCT scan superimposed on digital model of upper arch to identify ideal palatal insertion sites for two 7mm Spider Screw Regular Plus‡ miniscrews.

‡Registered trademark of HDC, Sarcedo, Italy. Distributed by Ortho Technology, Inc., Lutz, FL; www.orthotechnology.com.
††Registered trademark of TheraMon, Pforzheim, Germany. Distributed by Forestadent, Pforzheim, Germany; www.forestadent.com.

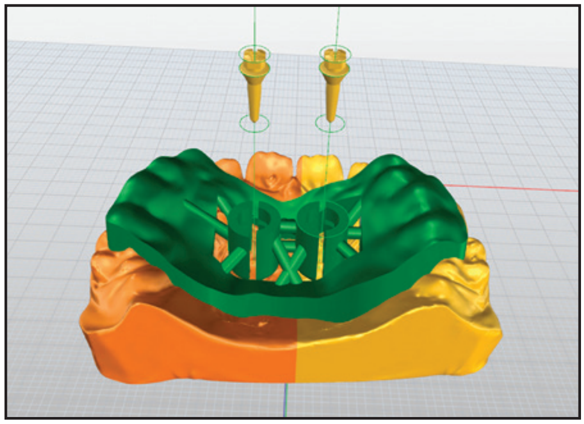

Fig. 9 Case 1. Three-dimensional surgical guide design.

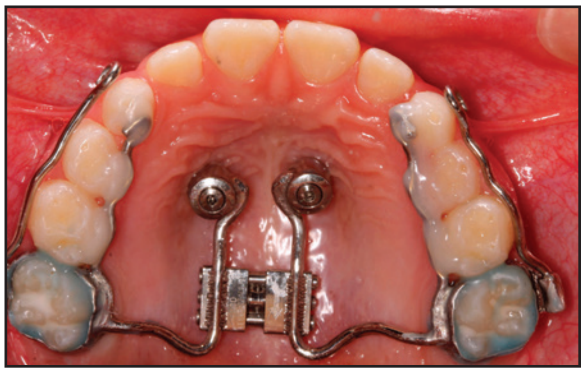

Fig. 10 Case 1. Hybrid rapid palatal expander with miniscrew anchorage.

Fig. 11 Case 1. TheraMon†† microsensor embedded in foam of facemask support frame.

TABLE 1
CASE 1 CEPHALOMETRIC ANALYSIS

	Norm	Pretreatment	Post-Treatment
SNA	82.0°	81.3°	84.6°
SNB	80.0°	80.5°	80.9°
ANB	2.0°	0.9°	3.7°
Wits appraisal	0.0mm	–4.6mm	+0.9mm
FMA (MP-FH)	26.0°	14.6°	18.8°
MP-SN	33.0°	29.2°	31.2°
Palatal-mandibular angle	28.0°	28.8°	21.3°
U1-Palatal plane	110.0°	102.3°	112.3°
U1-Occlusal plane	54.0°	59.7°	64.4°
L1-Occlusal plane	72.0°	73.0°	76.1°
IMPA	95.0°	96.2°	85.8°



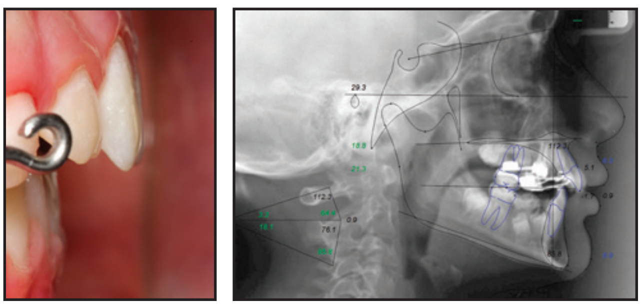

Fig. 12 Case 1. Patient after seven months of facemask treatment.

day. Patient compliance was verified by the TheraMon†† system, in which a microsensor is embedded into the foam of the support frame to identify temperature changes that are then transformed into wear-time information[19-22] (Fig. 11).

††Registered trademark of TheraMon, Pforzheim, Germany. Distributed by Forestadent, Pforzheim, Germany; www.forestadent.com.


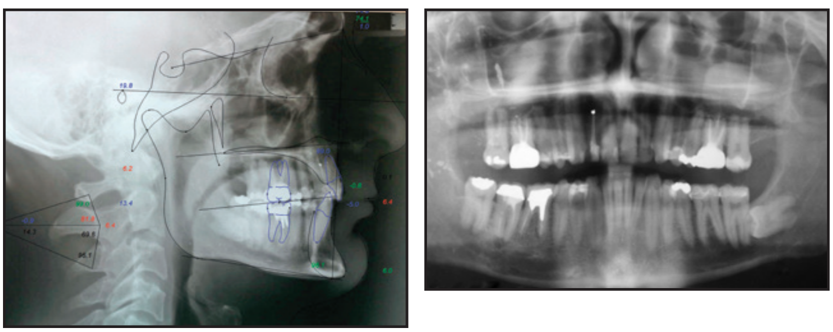

Fig. 13 Case 2. 39-year-old male patient with Class II tendency before treatment.

After seven months of treatment, the patient's face was more symmetrical and the profile was notably improved, with greater projection of the upper lip (Fig. 12). Intraoral photographs demonstrated the expansion of the maxilla and overcorrection of the Class III malocclusion, with a corresponding increase in overjet. Cephalometric analysis indicated a greater protrusion of the maxilla, a marked increase in ANB, and a slight lingual inclination of the upper and lower incisors (Table 1).

Case 2

A 39-year-old male presented with the chief complaint of dental crowding. Clinical examination showed facial symmetry with insufficient exposure of the upper incisors, a retrusive lower lip, and a pronounced chin (Fig. 13). Both arches were contracted with slight crowding. The patient had a Class II relationship on the left side and a Class I relationship with an edge-to-edge tendency on the right. The panoramic radiograph revealed a lack of upper third molars and an ectopic lower right third molar; cephalometric analysis confirmed the Class II tendency and hypodivergence, showing retroclined upper incisors and a normal lower-incisor inclination (Table 2).

The patient declined surgical-orthodontic treatment and, instead, selected nonextraction treatment involving distalization of the upper molars to correct the dental Class II malocclusion. To distalize the molars without loss of anchorage, two 7mm Spider Screw Regular Plus miniscrews were positioned in the palate. Insertion was simulated on a CBCT scan of the upper jaw, upon which a digital model of the upper arch was superimposed at the level of the median palatine raphe (Fig. 14). This setup was used to design a virtual insertion guide (Fig. 15A), which was then 3D-printed to position the miniscrews on the upper cast (Fig. 15B). An acrylic button with metal arms was constructed around the miniscrews, with the arms welded to the screw heads (Fig. 16). For distalization, elastic chains were stretched between the arms and metal buttons bonded to the lingual surfaces of the upper molars and premolars.

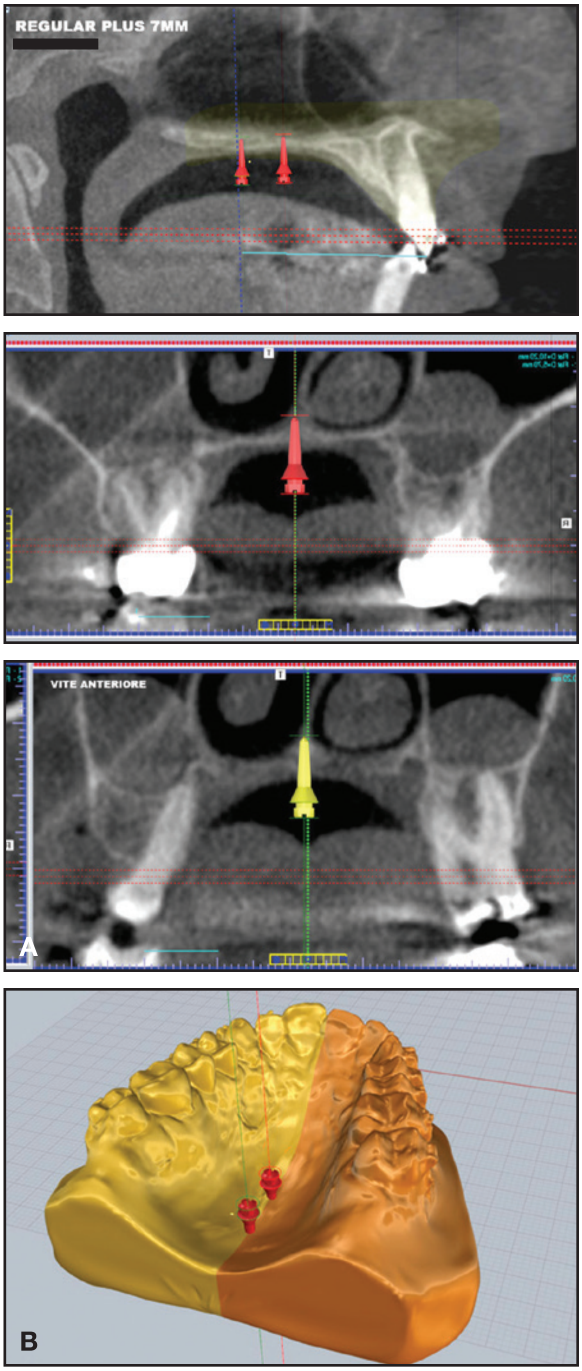

Fig. 14 Case 2. A. CBCT scan superimposed on digital model of upper arch to identify ideal palatal insertion sites for two 7mm Spider Screw Regular Plus miniscrews. B. Miniscrew positions on STL upper model.

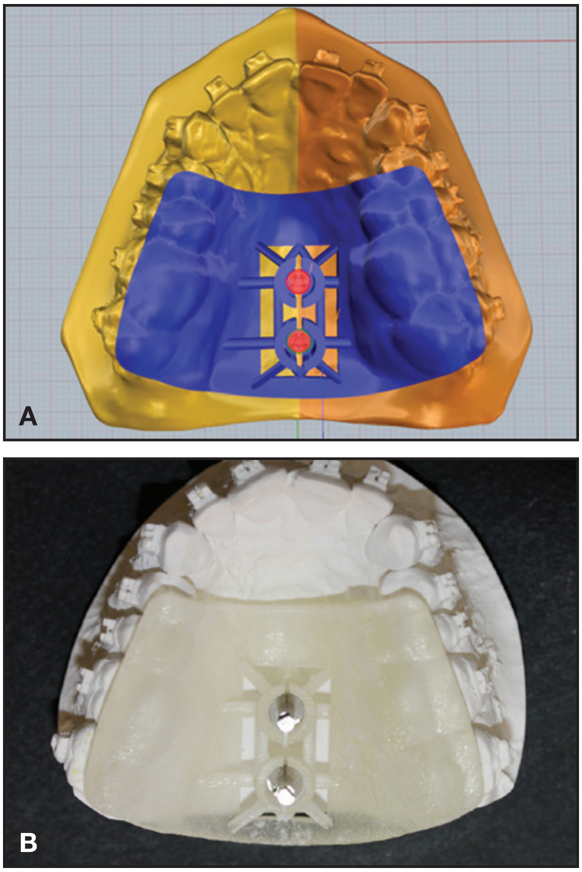

Fig. 15 Case 2. A. 3D surgical guide design. B. 3D surgical guide printed and positioned on upper cast.

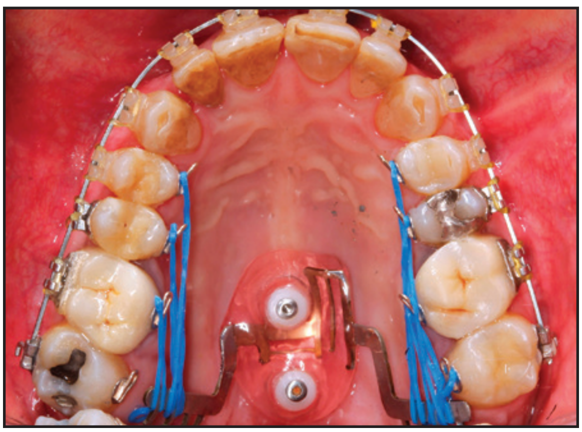

Fig. 16 Case 2. Acrylic button with metal arms constructed around miniscrews.

After seven months of treatment, a full Class I relationship was achieved on both sides (Fig. 17). Spaces were left distal to the lateral incisors to enable the placement of composite restorations that would correct the Bolton discrepancy. After the finishing procedure, the upper and lower appliances were debonded (Fig. 18, Table 2).

Fig. 17 Case 2. After seven months of treatment, showing fixed appliances used for finishing phase.

TABLE 2
CASE 2 CEPHALOMETRIC ANALYSIS

	Norm	Pretreatment	Post-Treatment
SNA	82.0	74.9°	76.4°
SNB	80.0	74.1°	75.4°
ANB	2.0°	0.8°	0.9°
Wits appraisal	0.0mm	+6.4mm	+6.0mm
FMA (MP-FH)	26.0°	6.2°	9.5°
MP-SN	33.0°	21.4°	22.3°
Palatal-mandibular angle	28.0°	13.4°	14.5°
U1-Palatal plane	110.0°	99.0°	103.7
U1-Occlusal plane	54.0°	81.8°	72.2 °
L1-Occlusal plane	72.0°	69.6°	66.4°
IMPA	95.0°	96.1°	103.2°

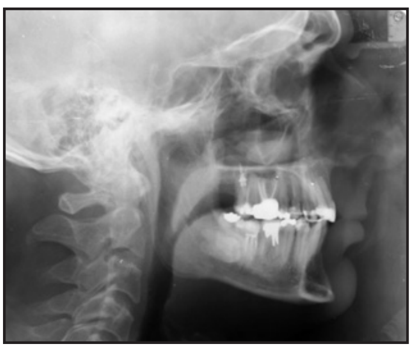

Fig. 18 Case 2. After 13 months of treatment, showing composite restorations of upper lateral incisors.

Discussion

Although miniscrew insertion has become a common procedure and anatomical studies have reduced the associated risks,[12-15,17] a digitally designed 3D guide like the one described here can help the orthodontist avoid any damage to anatomical structures while reducing patient discomfort. Using a standard lateral cephalogram to construct the surgical guide can lower the cost and the radiation exposure. In most patients, the cephalometric radiograph, combined with digital intraoral scans of the dental arches, will suffice to calculate the correct positions of the miniscrews. CBCT is generally needed only in cases involving impacted teeth, unerupted upper incisors, or extremely narrow maxillas, in which the benefits of more precise and reliable placement of miniscrews may outweigh the increased expense and radiation exposure associated with the technique.

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