From Planning to Delivery of a Bone-Borne Rapid Maxillary Expander in One Visit

B. GIULIANO MAINO, MD, DDS
EMANUELE PAOLETTO
LUCA LOMBARDO, DDS
GIUSEPPE SICILIANI, DDS

Miniscrews were initially proposed as a means of overcoming problems with dental anchorage due to poor patient compliance or the limits of orthodontic biomechanics.[1,2] More recently, intriguing new applications of miniscrews have been proposed for orthopedic purposes, including boneborne palatal expansion.[3-5] This approach has the advantage of minimizing buccal inclination of the dentition, a risk factor for periodontal damage.[6-8]

In a recent comparison of three different boneborne palatal expanders, Lee and colleagues preferred the one supported by four miniscrews—two in the anterior palate and two in the posterior palate—because less stress was concentrated around the skeletal anchorage and no buccal inclination of the teeth occurred.[9] Since the morphology of the palate varies from person to person,[10-13] however, the anatomy of each patient should be carefully assessed using cone-beam computed tomography (CBCT) to identify the areas with sufficient high-quality bone to withstand the forces generated by expansion.[14]

CBCT improves the accuracy of miniscrew insertion, but may require an additional appointment. We have developed a new protocol in which the location of four miniscrews is planned, an insertion guide is designed, and a Bone-Borne Rapid Maxillary Expander (BBRME) is delivered at the

*International patent pending, 4D Digital Dental Device; 4d.digitaldent.com
**Registered trademark of Dentaurum, Inc., Newtown, PA; www.dentaurum.com.

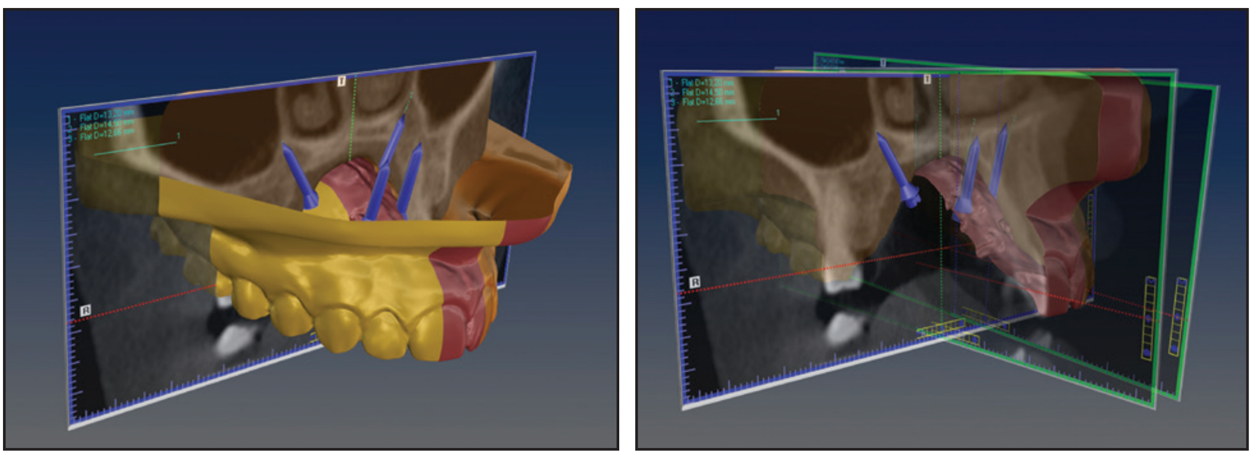

Fig. 1 Miniscrew positions transferred from cone-beam computed tomography (CBCT) images to digital model by superimposition along palatal mucosa.

Dr. Maino

Mr. Paoletto

Dr. Lombardo

Dr. Siciliani

Dr. Maino is a Visiting Professor, Department of Orthodontics, University of Ferrara, Ferrara, Italy, and University of Insubria, Varese, Italy, and in the private practice of orthodontics in Vicenza, Italy. Mr. Paoletto is an Orthodontic Technician, Lab Orthomodul, Thiene, Italy. Dr. Lombardo is an Assistant Researcher and Dr. Siciliani is Chairman, Department of Orthodontics, University of Ferrara, Via Montebello 31, Ferrara 44100, Italy. E-mail Dr. Lombardo at lulombardo@tiscali.it.

same visit, so that the entire procedure is more efficient and more comfortable for the patient.

Miniscrew Insertion

The anatomical structures of the roof of the palate and the dental roots are clearly visible in all three planes of space on a CBCT image of the palatal vault, making it easy to pinpoint the most suitable locations for miniscrew placement. A procedure designed specifically for palatal applications, called the MAPA System,*[14,15] can be used to ensure optimal positioning. The miniscrews should be as long as possible for stability; parallel placement will facilitate fitting of a BBRME. The planned miniscrew positions are transferred from the CBCT images to the digital model by superimposition along the palatal mucosa (Fig. 1).[14,15]

The digital insertion stent, resting on the occlusal surfaces of the posterior teeth, determines the site, depth, and direction of miniscrew application (Fig. 2). To act as a precise guide for miniscrew insertion, the physical stent must be stable, fitting perfectly on the occlusal surfaces, and must be easily removable once the four miniscrews are in place.[14,15] The insertion guide is printed by means of a three-dimensional additive technique (Fig. 3).

Appliance Fabrication

Stereolithography (STL) is used to obtain a model of the maxillary arch, reproducing the heads of the four miniscrews from the STL file of the digital model. The printed 3D model is then duplicated in a plaster model (Fig. 4), and a Hyrax**-type maxillary expander is constructed

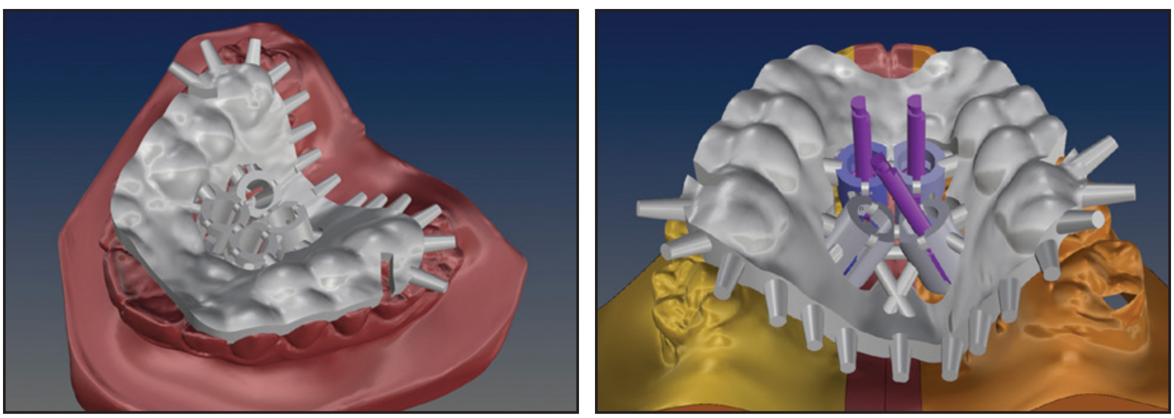

Fig. 2 Digital insertion stent resting on occlusal surfaces of posterior teeth.

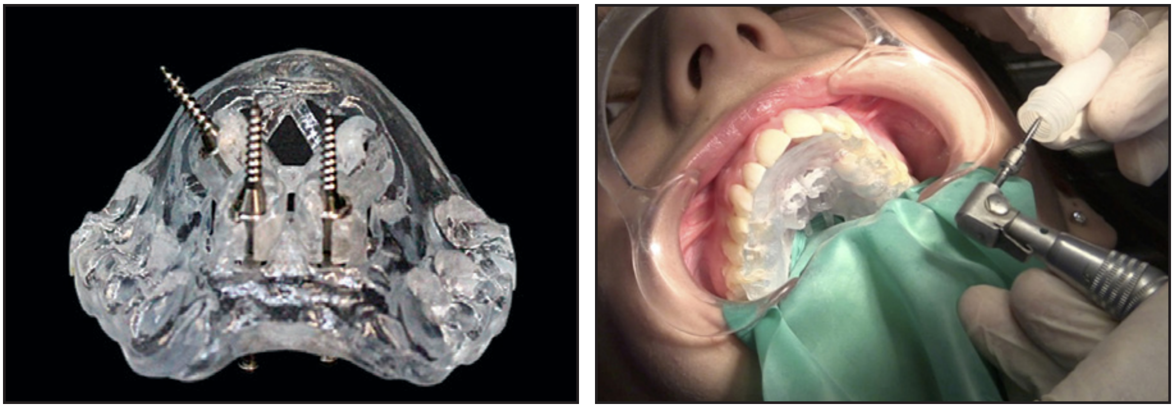

Fig. 3 Three-dimensionally printed insertion guide.

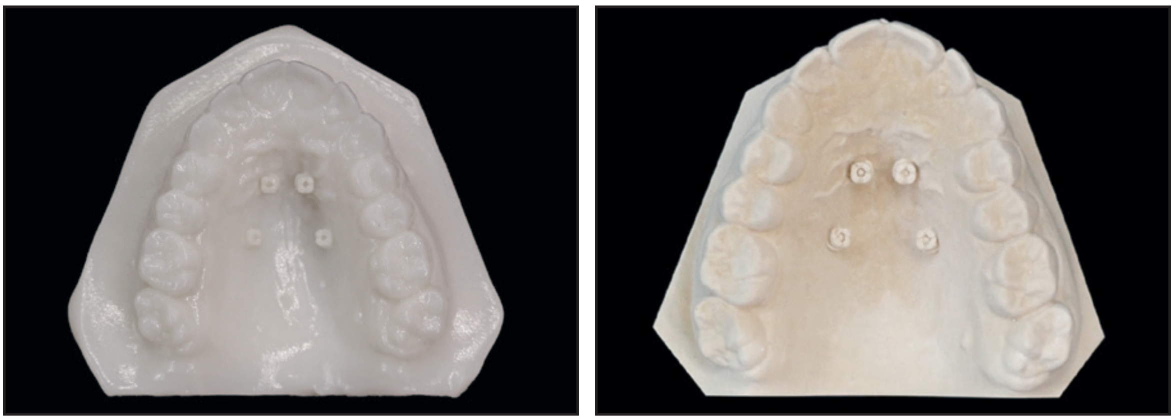

Fig. 4 3D-printed model duplicated in plaster model.

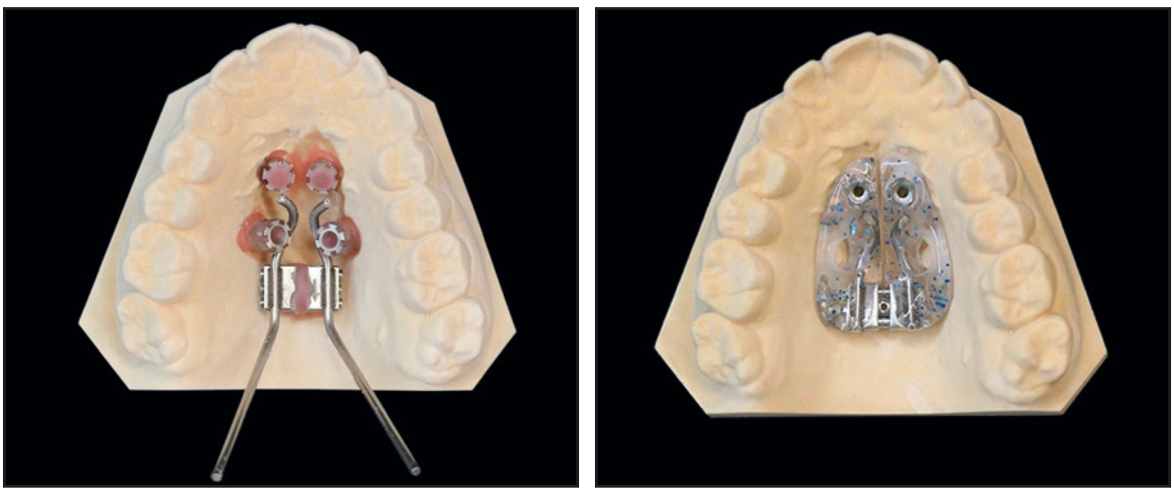

Fig. 5 Two anterior utility abutments fixed to Bone-Borne Rapid Maxillary Expander (BBRME); two holes drilled in acrylic for posterior abutment insertion.

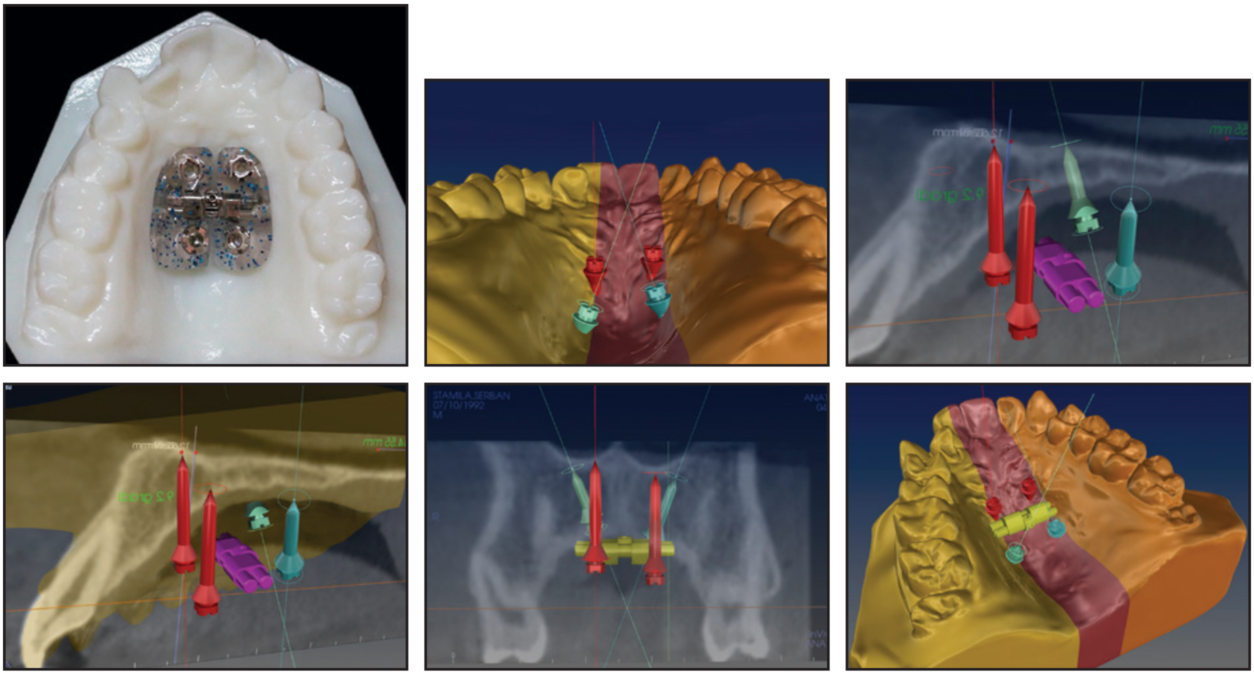

Fig. 6 Depending on patient's anatomical features, rapid palatal expansion screw* can be positioned between anterior and posterior miniscrews, allowing more symmetrical and comfortable opening.**

from an 11mm expansion screw and four utility abutments (metal caps), each 4mm in diameter. The two abutments corresponding to the anterior miniscrews are fixed to the BBRME; two large holes are drilled in the acrylic portion of the device for insertion of the posterior abutments (Fig. 5). Depending on the patient's anatomical features, the rapid palatal expansion screw*** can be positioned distal to the four miniscrews or between the anterior and the posterior screws; the latter placement allows a more symmetrical and comfortable opening (Fig. 6).

Case Report

A 16-year-old female presented with a Class II malocclusion, a hyperdivergent face, a gummy smile, an anterior open bite, a narrow maxilla, and a crossbite on the left side (Fig. 7A). Panoramic and cephalometric radiographs confirmed a skeletal Class II malocclusion with hyperdivergence and labially inclined lower incisors (Table 1). The CBCT showed a thin cortical plate in the upper premolar and molar areas; the midpalatal suture seemed to be almost completely closed (Fig. 7B).

The two treatment options were a combined surgical-orthodontic approach or orthodontic treatment using temporary anchorage devices. Preliminary expansion of the upper arch was advised before any orthodontic intervention. To avoid periodontal complications during palatal expansion, we offered the patient a choice of surgically assisted rapid palatal expansion or a BBRME. She opted for the latter approach.

CBCT images were used to plan the virtual insertion of two self-tapping, self-drilling Spider Screw Regular Plus† miniscrews (11mm long, 2mm in diameter) in the paramedian areas at the level of the first premolars (Fig. 8). This miniscrew model is capable of accepting an abutment fixed

***Leone Rapid Micro Expander Screw, Leone, Florence, Italy; www.leone.it.

†Registered trademark of HDC, Sarcedo, Italy. Distributed by Ortho Technology, Inc., Lutz, FL; www.orthotechnology.com.

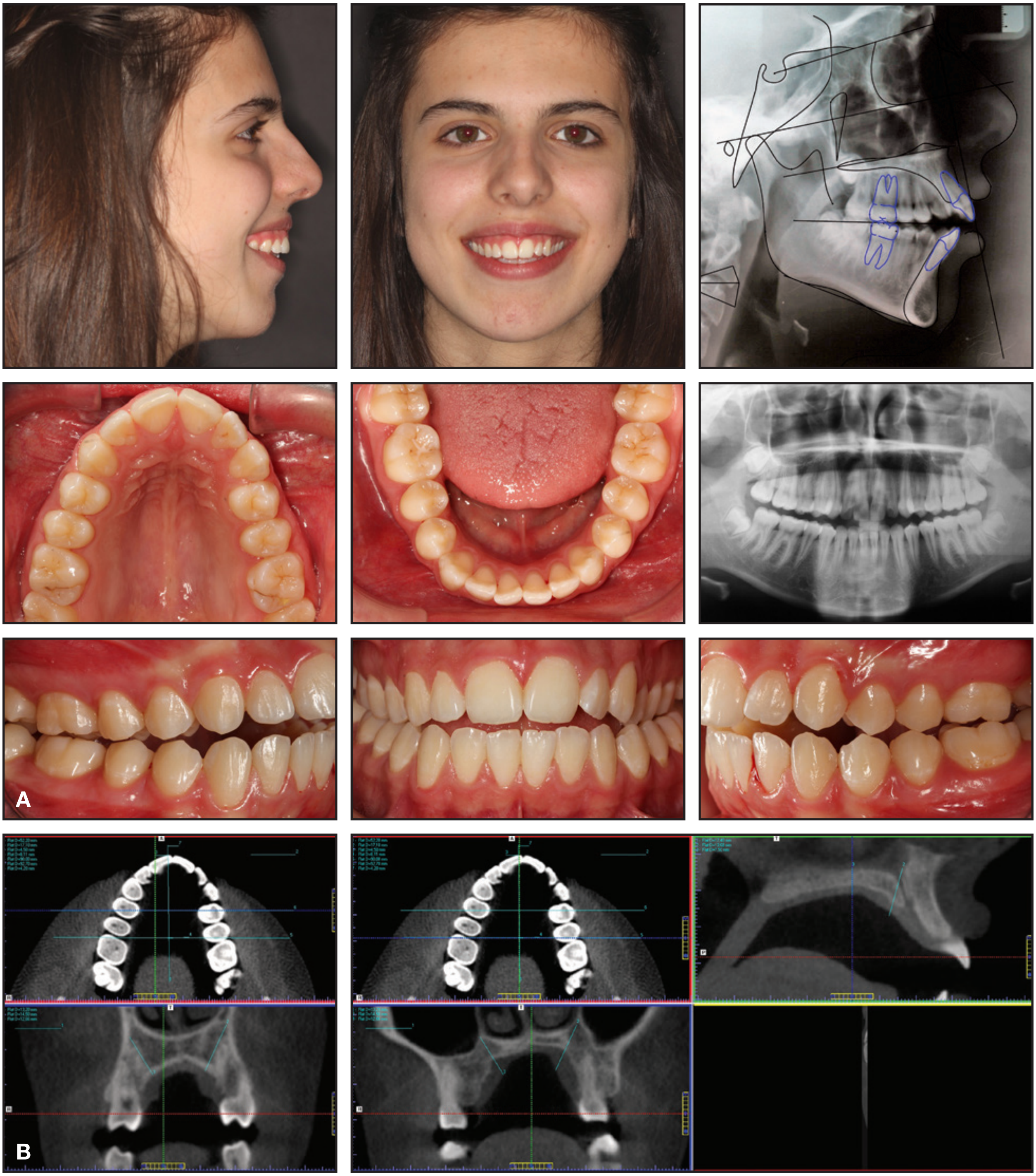

Fig. 7 A. 16-year-old female patient with Class II malocclusion, hyperdivergent face, gummy smile, anterior open bite, narrow maxilla, and crossbite on left side before treatment. B. CBCT showing thin cortical plate, with midpalatal suture almost completely closed.

TABLE 1
CEPHALOMETRIC ANALYSIS

	Norm	Pretreatment
SNA	82.0° ± 3.5°	79.5°
SNB	80.0° ± 3.0°	74.1°
ANB	2.0° ± 2.4°	5.4°
Maxillary skeletal (A-N perp.)	0.0mm ± 3.1mm	–9.8mm
Mandibular skeletal (Pg-N perp.)	–4.0mm ± 5.3mm	–45.5mm
Wits appraisal	0.0mm ± 1.0mm	+6.7mm
FMA (MP-FH)	26.0° ± 5.0°	32.5°
MP-SN	33.0° ± 6.0°	38.0°
Palatal-mandibular angle	28.0° ± 6.0°	31.0°
Palatal-occlusal plane (PP-OP)	10.0° ± 4.0°	11.5°
Mandibular-occlusal plane	11.4° ± 5.0°	19.5°
Maxillary-occlusal plane (MxOP-N perp.)	95.6° ± 1.8°	103.0°
U1 protrusion (U1-APo)	6.0mm ± 2.2mm	22.7mm
L1 protrusion (L1-APo)	2.0mm ± 2.3mm	12.0mm
U1-Palatal plane	110.0° ± 5.0°	111.4°
U1-Occlusal plane	54.0° ± 7.0°	57.1°
L1-Occlusal plane	72.0° ± 5.0°	53.4°
IMPA	95.0° ± 7.0°	107.2°

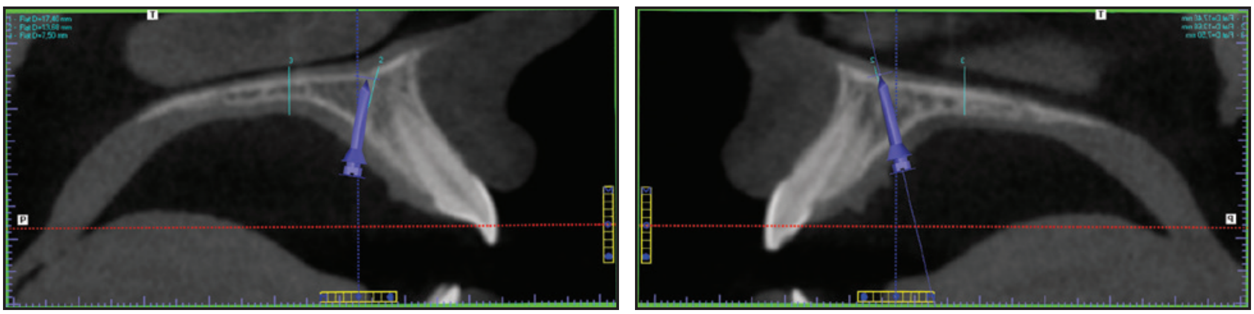

Fig. 8 Virtual insertion of two Spider Screw Regular Plus† miniscrews (11mm long, 2mm in diameter) in paramedian areas at level of first premolars.

with a microscrew. Two similar miniscrews were then virtually inserted between the second premolars and first molars on each side, with a divergent inclination to maximize bony support (Fig. 9). The insertion guide and BBRME were designed as described previously.

With the patient under local anesthesia, the four miniscrews were each mounted on a low-speed contra-angle handpiece (50rpm) and directed through the custom-designed guide sleeves of the insertion stent, precisely positioning them in the palate (Fig. 10A). The BBRME was attached immediately by connecting it to the ante-

†Registered trademark of HDC, Sarcedo, Italy. Distributed by Ortho Technology, Inc., Lutz, FL; www.orthotechnology.com.

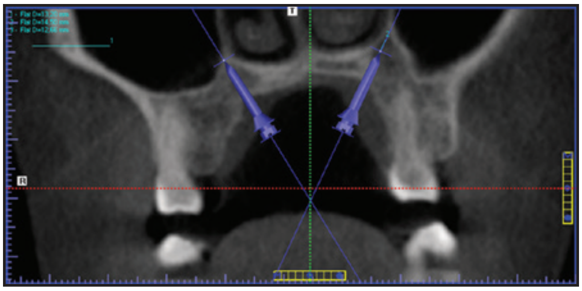

Fig. 9 Virtual insertion of two miniscrews between second premolars and first molars on each side, with divergent inclination to maximize bony support.

rior miniscrews through two abutments embedded in the acrylic and fixed by microscrews (Fig. 10B). The two posterior abutments were attached to the posterior miniscrews through predrilled holes in the acrylic portion of the appliance. These two abutments were then affixed to the body of the BBRME using a small amount of flowable light-cured composite.

The expander was activated under a protocol of three quarter-turns per day to determine whether the BBRME would show immediate results; if not, surgically assisted rapid palatal expansion would be required. After six days of activation, a

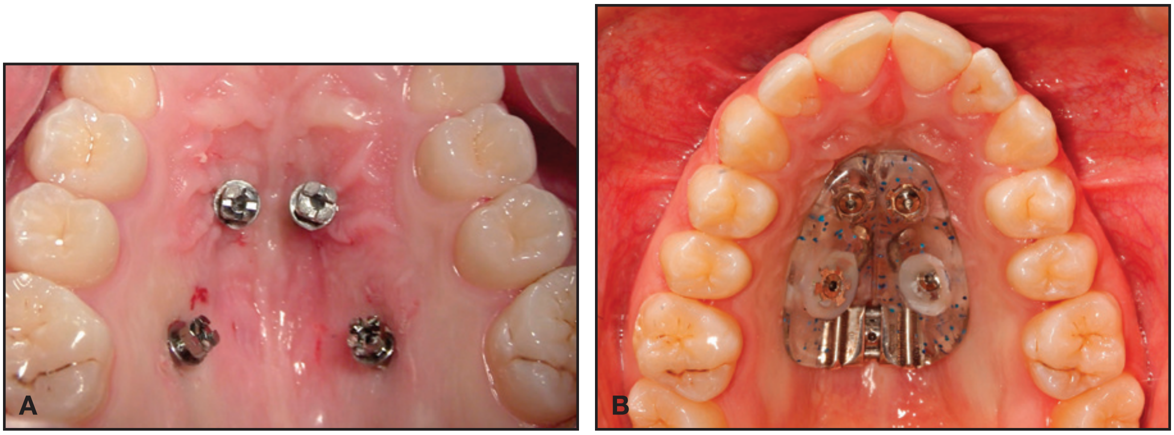

Fig. 10 A. Miniscrews inserted. B. BBRME in place.

Fig. 11 Activation complete after 14 days of expansion.

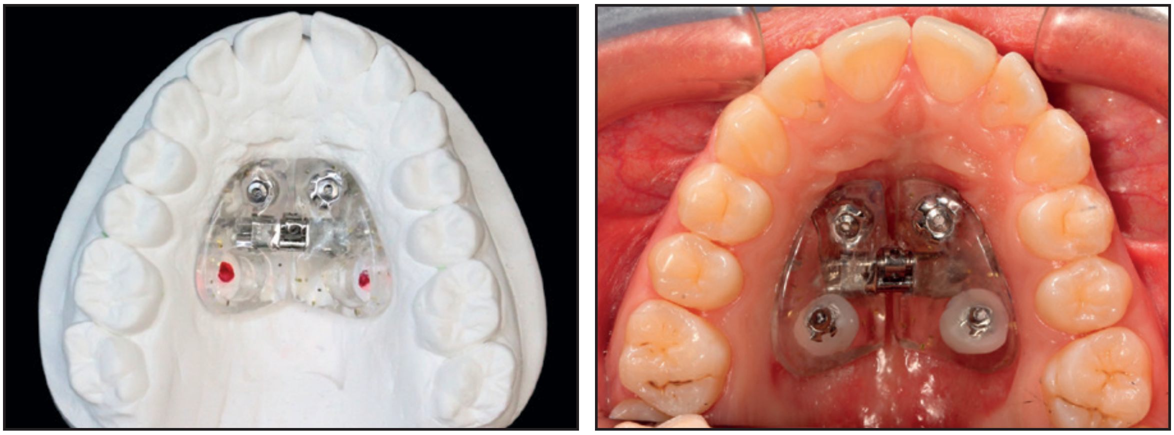

Fig. 12 New BBRME constructed using impression taken over four miniscrews.

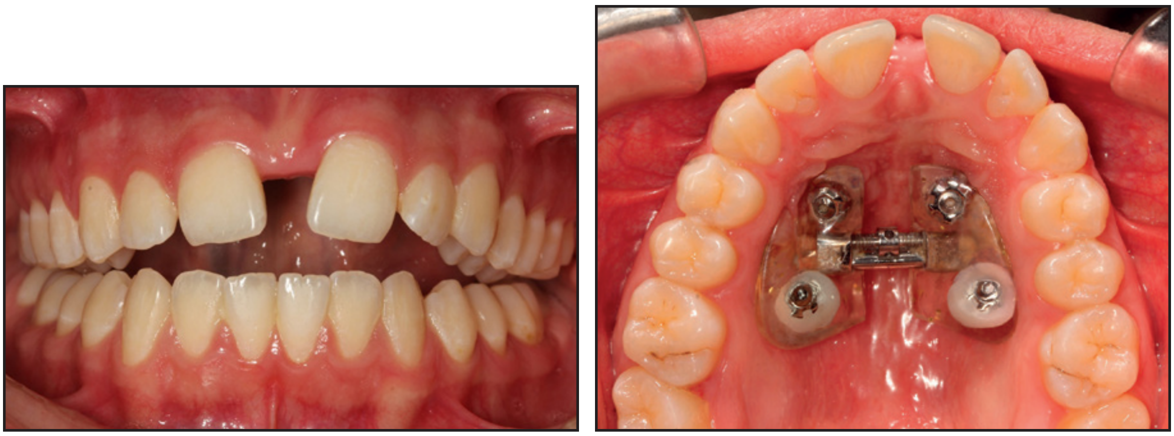

Fig. 13 Overcorrection of transverse diameter achieved after 12 days of additional expansion.

small diastema had appeared. Activation was completed in 14 days (Fig. 11). Because the transverse dimension had not been completely corrected, however, a new BBRME was constructed from an impression taken over the four miniscrews after the first device was removed (Fig. 12).

Twelve days after activation of the second BBRME, sufficient overcorrection of the transverse diameter had been achieved (Fig. 13). During the last 10 days of activation, expansion was hindered by resistance from the bony support. This common problem was resolved by using a modified dental probe to overcome the resistance of the palate when opening the screw.

CBCT performed after expansion demonstrated the skeletal effects of the appliance (Fig. 14). The upper first-molar diameter increased by about .6cm at the level of the crowns and mesiolabial root apices (Table 2). The thickness of the maxilla (measured at the level of the root apices) increased by .48cm at the molars and .7cm at the first premolars.

Discussion

Using the teeth as anchorage for rapid palatal expansion presents two major problems in adult patients: the risk of creating large areas of root

TABLE 2
SKELETAL EFFECTS OF BONEBORNE RAPID MAXILLARY EXPANDER

	Pretreatment	Post-Treatment	Difference
Upper first-molar diameter (crowns)	5.26cm	5.85cm	+0.59cm
Upper first-molar diameter (apices)	5.06cm	5.64cm	+0.58cm
Upper first-premolar diameter (crowns)	4.00cm	4.75cm	+0.75cm
Upper first-premolar diameter (apices)	3.57cm	4.28cm	+0.71cm
Alveolar bone (first-molar apices)	5.98cm	6.46cm	+0.48cm
Alveolar bone (first-premolar apices)	3.35cm	4.05cm	+0.70cm

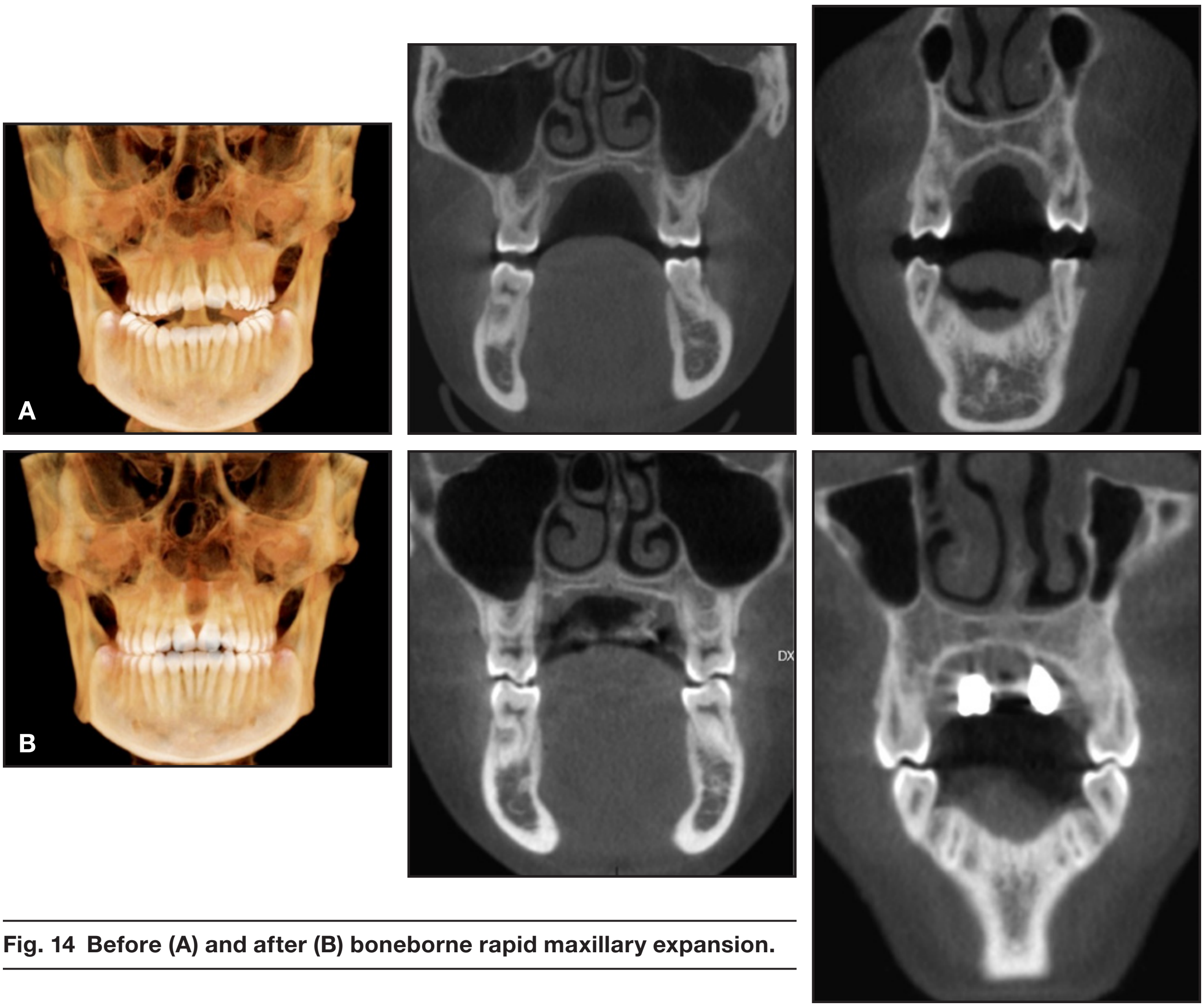

Fig. 14 Before (A) and after (B) boneborne rapid maxillary expansion.

resorption and an even greater danger of causing severe bone fenestration.[16,17] Because adults generally require the use of greater forces to open the palatine suture,[18] surgically assisted expansion is often prescribed. This is an invasive procedure, however, that is unpopular with patients.

Less invasive options that protect the periodontium by exploiting skeletal anchorage are now available.[6-8] The greatest advantage of the BBRME is its complete bone-to-bone support, which avoids adverse periodontal effects from bone resorption of the upper molars. Because conventional miniscrews may be incapable of completely withstanding the forces transmitted by a boneborne expander, the device should be anchored by more miniscrews than are needed for purely dental movements. The miniscrews should be as wide and long as possible to ensure optimal bony support. Moreover, the location and direction of miniscrew insertion must be carefully planned to provide the most favorable positions in terms of biomechanics. Precise digital planning by means of CBCT and guided insertion are essential.

The MAPA System enables accurate and reliable insertion of multiple miniscrews at the same appointment as the BBRME is placed, thus going directly from planning to delivery without the need for new impressions. Using digitally designed boneborne anchorage, this protocol makes rapid palatal expansion a valid alternative to surgical approaches in adult patients.

REFERENCES

1. Melsen, B.: Mini-implants: Where are we? J. Clin. Orthod. 39:539-547, 2005.
2. Cozzani, M.; Zallio, F.; Lombardo, L.; and Gracco, A.: Efficiency of the distal screw in the distal movement of maxillary molars, World J. Orthod. 11:341-345, 2010.
3. Lee, K.J.; Park, Y.C.; Park, J.Y.; and Hwang, W.S.: Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism, Am. J. Orthod. 137:830-839, 2010.
4. Kim, K.B. and Helmkamp, M.E.: Miniscrew implant-supported rapid maxillary expansion, J. Clin. Orthod. 46:608-612, 2012.
5. MacGinnis, M.; Chu, H.; Youssef, G.; Wu, K.W.; Machado, A.W.; and Moon, W.: The effects of micro-implant assisted rapid palatal expansion (MARPE) on the nasomaxillary complex—A finite element method (FEM) analysis, Prog. Orthod. 15:52, 2014.
6. Seo, Y.J.; Chung, K.R.; Kim, S.H.; and Nelson, G.: Camouflage treatment of skeletal Class III malocclusion with asymmetry using a bone-borne rapid palatal expander, Angle Orthod. 85:322-334, 2015.
7. Lin, L.; Ahn, H.W.; Kim, S.J.; Moon, S.C.; Kim, S.H.; and Nelson, G.: Tooth-borne vs. bone-borne rapid-maxillary-expanders in late adolescence, Angle Orthod. 85:253-262, 2015.
8. Seo, Y.J.; Lin, L.; Kim, S.H.; Chung, K.R.; and Nelson, G.: Strategic camouflage treatment of skeletal Class III malocclusion (mandibular prognathism) using bone-borne rapid maxillary expansion and mandibular anterior subapical osteotomy, Am. J. Orthod. 149:114-126, 2016.
9. Lee, H.K.; Bayome, M.; Ahn, C.S.; Kim, S.H.; Kim, K.B.; Mo, S.S.; and Kook, Y.A.: Stress distribution and displacement by different bone-borne palatal expanders with micro-implants: A three-dimensional finite-element analysis, Eur. J. Orthod. 36:531-540, 2014.
10. Bernhart, T.; Vollgruber, A.; Gahleitner, A.; Dörtbudak, O.; and Haas, R.: Alternative to the median region of the palate for placement of an orthodontic implant, Clin. Oral Implants Res. 11:595-601, 2000.
11. Werhbain, H.; Merz, B.R.; and Diedrich, P.: Palatal bone support for orthodontic implant anchorage—Clinical and radiological study, Eur. J. Orthod. 21:65-70, 1999.
12. Gracco, A.; Lombardo, L.; Cozzani, M.; and Siciliani, G.: Quantitative cone-beam computed tomography evaluation of palatal bone thickness for orthodontic miniscrew placement, Am. J. Orthod. 134:361-369, 2008.
13. Winsauer, H.; Vlachojannis, C.; Bumann, A.; Vlachojannis, J.; and Chrubasik S.: Paramedian vertical palatal bone height for mini-implant insertion: A systematic review, Eur. J. Orthod. 36:541-549, 2014.
14. Maino, B.G.; Paoletto, E.; Lombardo, L.; and Siciliani, G.: MAPA: A new high-precision 3D method of palatal miniscrew placement, Eur. J. Clin. Orthod. 3:41-477, 2015.
15. Maino, B.G.; Paoletto, E.; Lombardo, L.; and Siciliani, G.: A three-dimensional digital insertion guide for palatal miniscrew placement, J. Clin. Orthod. 50:12-22, 2016.
16. Garib, D.G.; Henriques, J.F.; Janson, G.; de Freitas, M.R.; and Fernandes, A.Y.: Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: A computed tomography evaluation, Am. J. Orthod. 129:749-758, 2006.
17. Pangrazio-Kulbersh, V.; Jezdimir, B.; de Deus Haughey, M.; Kulbersh, R.; Wine, P.; and Kaczynski, R.: CBCT assessment of alveolar buccal bone level after RME, Angle Orthod. 83:110-116, 2013.
18. Zimring, J.F. and Isaacson, R.J.: Forces produced by rapid maxillary expansion: 3. Forces present during retention, Angle Orthod. 35:178-186, 1965.