CAD/CAM-Guided Microscrew Insertion for Horseshoe Distalization Appliances

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An orthodontist needs to establish a comprehensive diagnosis and synthesis of pertinent issues for every patient. Specific treatment objectives are established to address facial, skeletal, dental, and biological needs, leading to the formulation of a biomechanical plan and treatment sequence. Successful treatment will always account for the anchorage required to achieve specific treatment objectives.

Traditional approaches to anchorage include the use of reciprocal forces and intermaxillary elastics. Anchorage can be further reinforced by selectively tipping and torquing individual teeth or using an adjunct such as a transpalatal arch, Quad Helix,* or lower lingual arch. These methods are generally limited by the number and distribution of teeth and their periodontal support. An extraoral traction device such as headgear is heavily dependent on patient compliance. Invariably, some anchorage loss occurs, resulting in undesirable tooth movements—especially when complex anomalies such as cleft lip and palate or hypodontia are present. Anchorage loss can significantly affect the treatment outcome and even result in damage to the patient's biological tissues.[1,2]

Skeletally retained devices are increasingly being used to provide absolute anchorage without unwanted tooth movement. Orthodontic microscrews, composed of a titanium-aluminum-vanadium alloy (titanium grade V) with a machined surface, are now considered a staple of orthodontic treatment. The major advantage of microscrews over fixation plates is their ease of removal.[3] Orthodontic applications for skeletal anchorage include en-masse frontal retraction,[4-6] space closure,[7] space opening,[8] maxillary expansion,[9] intrusion and extrusion of teeth,[10,11] and protrusion of the maxilla.[12,13]

Primary stability and positioning within an area of adequate bone are required for secure microscrew retention.[14-17] In the maxilla, the anterior hard palate is considered the optimal site for microscrew placement because of its superior bone quality, reduced risk of root damage, and lack of interference with tooth movement during treatment.[18-20] In addition, larger-diameter microscrews can be used when needed.[21] Still, the quantity and quality of available bone vary between parts of the palate, as well as from patient to patient.[22]

Using computer-aided design and manufacturing (CAD/CAM), we have developed the horseshoe palatal anchorage plate to optimize microscrew positioning while simplifying the insertion procedure and reducing patient discomfort. The horseshoe appliance facilitates three-dimensional control

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of tooth movement, and the Easy Driver** positioning protocol[23] allows the microscrews to be inserted and the device to be attached in a single appointment. Indications include Class II malocclusions with maxillary dental protrusion and excessive overjet, maxillary distalization requiring vertical control, anterior open bite, and occlusal canting.[24]

Fig. 1 Horseshoe appliance: base arch laser-welded to Beneplate* and palatal arch welded to stainless steel molar bands.**

Appliance Design and Positioning

The horseshoe appliance—a name derived from its distinctive shape—consists of two parts (Fig. 1). A solid base arch is laser-welded to a Beneplate,*** which is extended toward the posterior area of the palate. The base arch is modified by adding an .012" semi-round wire with a terminal eyelet that allows for the attachment of either closed-coil springs or elastomeric chains. The other principal component is a palatal arch welded to stainless steel bands, typically on the maxillary first permanent molars. The anterior part of the arch has bilateral apical extensions with semicircular hooks welded adjacent to the maxillary canines. The orthodontist can control the line of force by varying the point of force application.

The procedure begins with either a direct polyvinyl siloxane impression or a digital scan. The former necessitates the production of a maxillary plaster cast, which is then laser-scanned to produce a digital stereolithographic (STL) file. The digital image of the maxilla is superimposed on a cone-beam computed tomography (CBCT) image (or a lateral cephalogram) to facilitate identification of the optimal microscrew sites (Fig. 2). Virtual planning software is then used to confirm the precise anatomical positions of the microscrews in the anterior hard palate. A surgical insertion guide is produced by rapid prototyping for precise positioning of the microscrews in the mouth.

*Rocky Mountain Orthodontics, Denver, CO; www.rmortho.com.
**Registered trademark of Uniontech Orthodontic Lab, Parma and Milan, Italy; www.uniontech.it.
***PSM North America Inc., Indio, CA; www.psm-na.us.

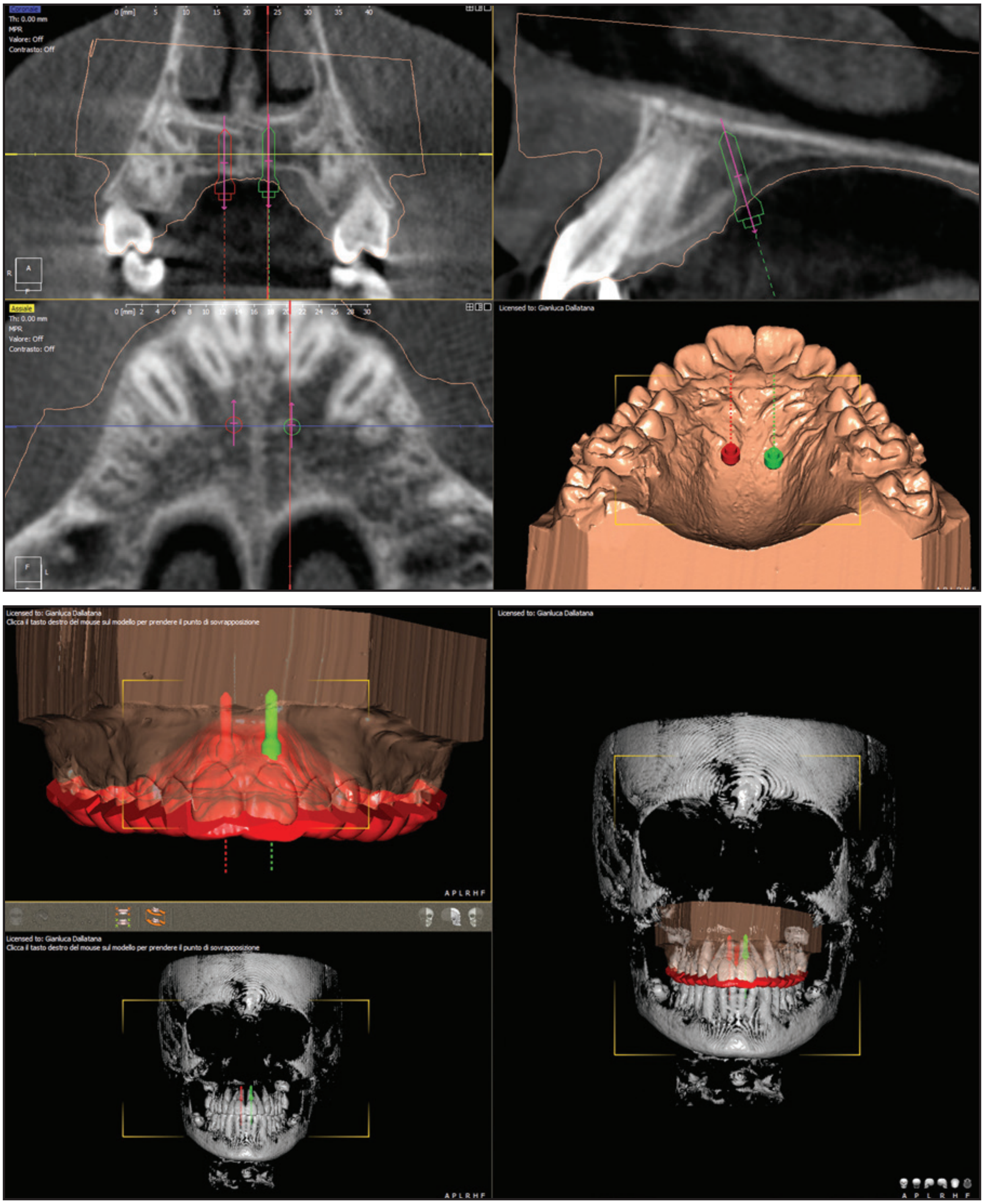

Fig. 2 Virtual planning of microscrew placement.

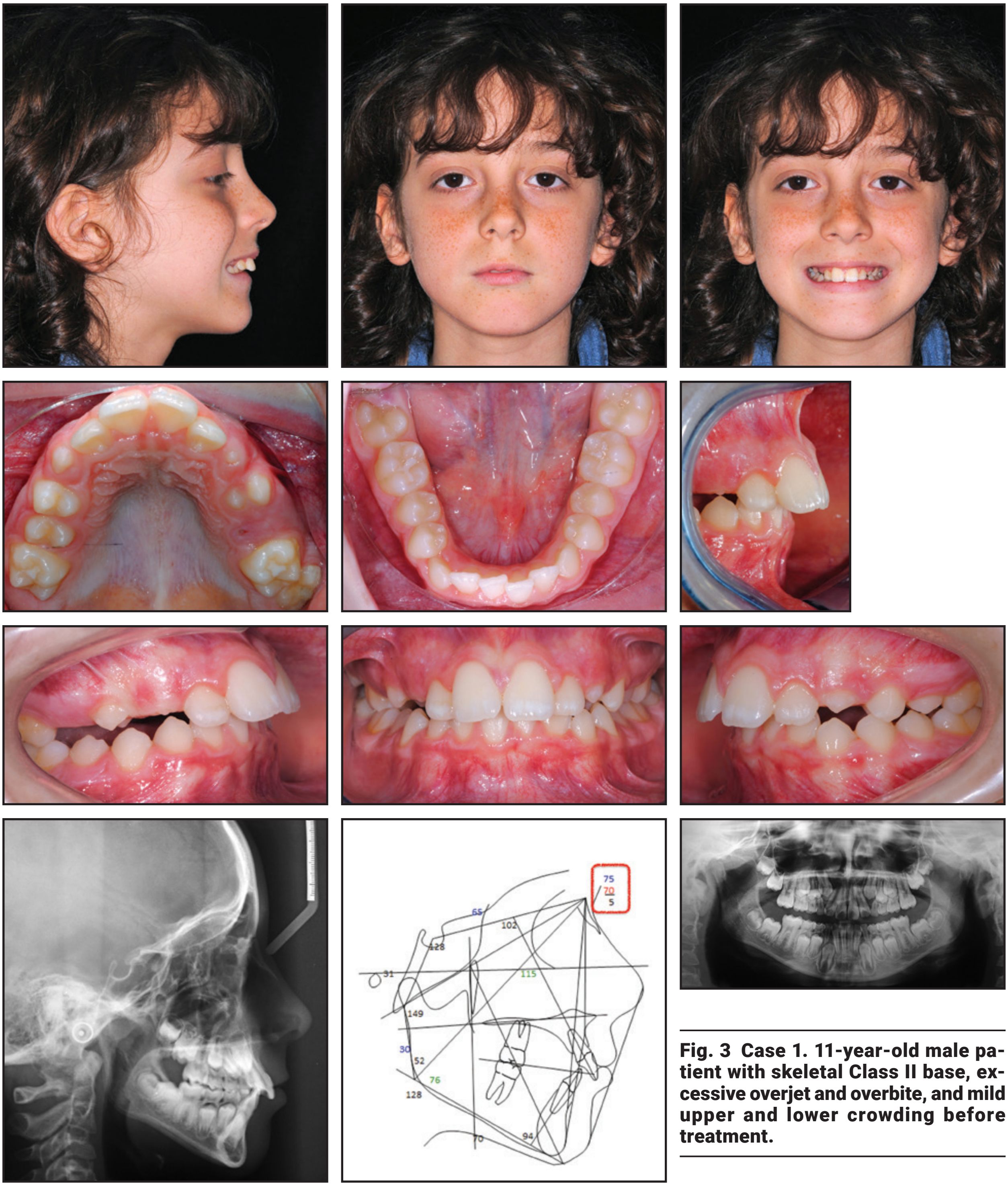

Fig. 3 Case 1. 11-year-old male patient with skeletal Class II base, excessive overjet and overbite, and mild upper and lower crowding before treatment.

Case 1

An 11-year-old male presented with the chief complaints of maxillary incisor protrusion and deep overbite (Fig. 3). His malocclusion was characterized by lip incompetence, a 7mm overjet, and a 50% overbite. He had an end-on molar relationship and a half-unit Class II canine relationship, with mild crowding in both arches and an excessive curve of Spee. The maxillary midline was deviated 2mm to the right.

Cephalometric analysis (Table 1) indicated a skeletal Class II base with an excessive ANB (5°) and Wits appraisal (+2.6mm). A hyperdivergent growth pattern was evidenced by a postero-anterior facial height ratio of 55%. The maxillary and mandibular incisors were normally angulated. The panoramic radiograph confirmed the development of all second and third molars; the maxillary right second molar and both mandibular second molars were partially erupted.

A treatment approach calling for the extraction of multiple premolars was proposed, but was declined by the patient. A plan involving maxillary distalization with a modified horseshoe appliance was accepted. A CAD/CAM procedure was used to plan the positioning of the microscrews and produce the surgical guide (Fig. 2).

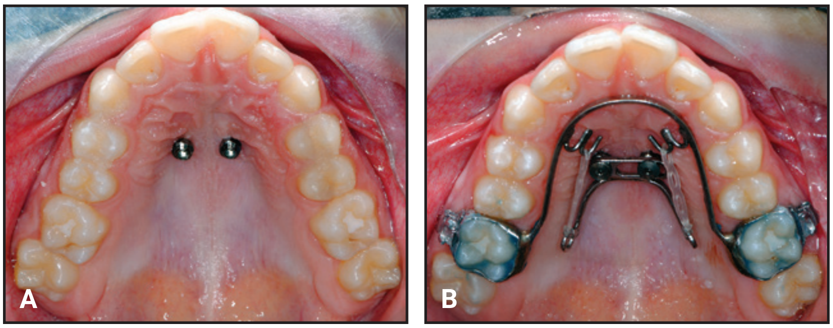

Fig. 4 Case 1. A. Two microscrews* inserted in palate for attachment of horseshoe appliance. B. Two weeks later, elastomeric chains extended from anterior hooks to posterior eyelets for retraction of upper first molars.**

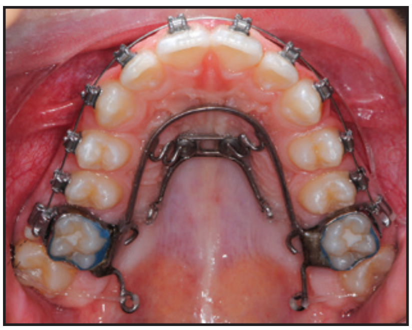

Fig. 5 Case 1. After six months of treatment, distal extension lever arms added to palatal arch and palatal hooks welded to first molar bands for upper second molar intrusion without unwanted first molar extrusion.

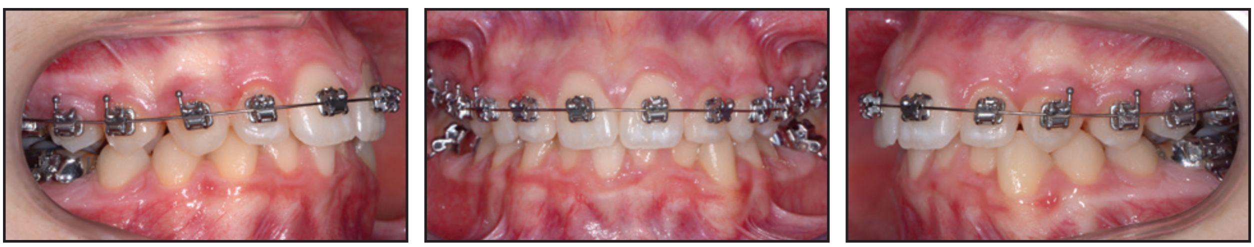

TABLE 1
CASE 1 CEPHALOMETRIC ANALYSIS

	Pretreatment	Post-Treatment
Saddle angle	128°	128°
Articular angle	149°	146°
Gonial angle	128°	123°
Upper	52°	45°
Lower	76°	78°
Posterior cranial base	30mm	32mm
Anterior cranial base	65mm	66mm
Ramal height	31mm	37mm
Mandibular body length	70mm	82mm
Postero-anterior facial height	55%	57%

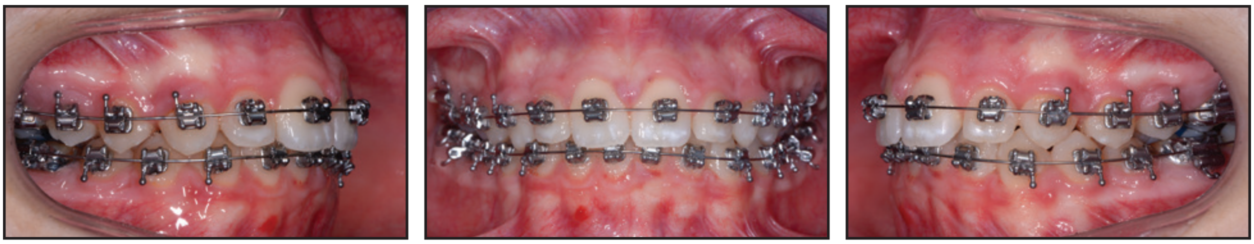

Fig. 6 Case 1. After 14 months of treatment.

The two palatal microscrews*** (9mm in length, 2mm in diameter) and the appliance were inserted in a single visit, using the Easy Driver protocol (Fig. 4). About two weeks later, elastomeric chains were attached between the two components of the horseshoe appliance and the superior hooks (stirrups) in the palate for bodily distalization of the maxillary first permanent molars. A Dynamometer† can be used to measure the level of force; our usual procedure is to apply about 150g per side.

After six months, the maxillary molars had been distalized into a super-Class I relationship. Preadjusted fixed appliances were then bonded in the upper arch to reduce the overjet and allow guided drift of the buccal segments.

To assist with alignment of the buccally flared maxillary second molars, the palatal arch was modified with the addition of two distal extension lever arms, and two more hooks were welded to the palatal surfaces of the first molar bands (Fig. 5). Elastomeric chains were attached between the lever arms and buccal tubes on the second molars, crossing over the occlusal surfaces, to reposition the second molars with proper torque. Additional elastomeric chains between the lever arms and the first molar hooks prevented unwanted extrusion of the first molars during this second molar intrusion.

Two months later, when the overjet had been

***PSM North America Inc., Indio, CA; www.psm-na.us.
†Haag-Streit Diagnostics, Köniz, Switzerland; www.haag-streit.com.

Fig. 7 Case 1. Patient after 20 months of treatment. (Radiographs taken after 17 months of treatment.)

significantly reduced and the buccal relationship was Class I, the lower arch was bonded. Both arches were started on .014" Sentalloy‡ archwires, followed by upper .020" Sentalloy and then upper and lower .020" × .020" BioForce‡ archwires (Fig. 6).

Active treatment was completed in 20 months (Fig. 7). A vacuformed retainer was delivered for the upper arch, and a 3-3 lingual retainer was bonded in the lower arch.

The patient's profile was improved, and a satisfactory buccal occlusal relationship was obtained. Cephalometric analysis (Table 1) confirmed the correction of the skeletal malocclusion (ANB = 3°, Wits appraisal = −1.7mm) without any associated increase in the vertical dimension, notwithstanding the nonextraction approach.

‡Registered trademark of Dentsply Sirona, York, PA; www.dentsplysirona.com.

TABLE 2
CASE 2 CEPHALOMETRIC ANALYSIS

	Pretreatment	Post-Treatment
Saddle angle	126°	127°
Articular angle	139°	138°
Gonial angle	127°	125°
Upper	56°	56°
Lower	71°	69°
Posterior cranial base	34mm	34mm
Anterior cranial base	72mm	67mm
Ramal height	44mm	42mm
Mandibular body length	80mm	75mm
Postero-anterior facial height	55%	57%

Case 2

A 13-year-old female presented with the chief complaint of incisor malalignment (Fig. 8). Clinical examination noted bilateral end-on Class II molar and canine relationships, with mild arch-length discrepancies in both arches.

Cephalometric analysis revealed a skeletal Class II base with mandibular retrognathia (Table 2). The mandibular incisors were proclined, and the maxillary incisors had normal angulations. The panoramic radiograph confirmed the development of all second and third molars.

A treatment plan involving multiple premolar extractions was recommended, but was declined by the patient. An alternative proposal for maxillary distalization with a modified horseshoe appliance was accepted.

A CBCT scan was matched with a digital impression using Easy Driver software (Fig. 9). Virtual planning allowed optimal positioning of the microscrews in accordance with the patient's individual anatomical variations, considering the quantity of bone available in the anterior maxilla and the relative root positions of the maxillary incisors. The 3D-printed surgical guide replicated the planned positions of the palatal microscrews (9mm in length, 2mm in diameter) at a depth of 6.8mm and closely parallel to each other.

After the fit of the surgical template was verified, the microscrews were inserted with the Easy Driver protocol, and the horseshoe appliance was attached at the same visit (Fig. 10). Two weeks later, the palatal arch was connected to the Beneplate extension with elastomeric chains. The point of force application was at the most apical hook, facilitating a line of force that could achieve bodily movement of the maxillary dentition with minimal tipping.

The patient underwent planned extraction of the maxillary third molars about two weeks later. After five months of treatment, the maxillary molars were distalized enough to allow alignment of all teeth without concomitant anterior flaring (Fig. 11). As in Case 1, to enable 3rd-order correction of the buccally flared maxillary second molars, the appliances were modified with two distal extension lever arms and two additional palatal hooks on the first molar bands (Fig. 12). Lingual buttons were bonded to the second molars for attachment of elastomeric chains to torque the second molars, using the orthodontic archwire as a rotation hinge.

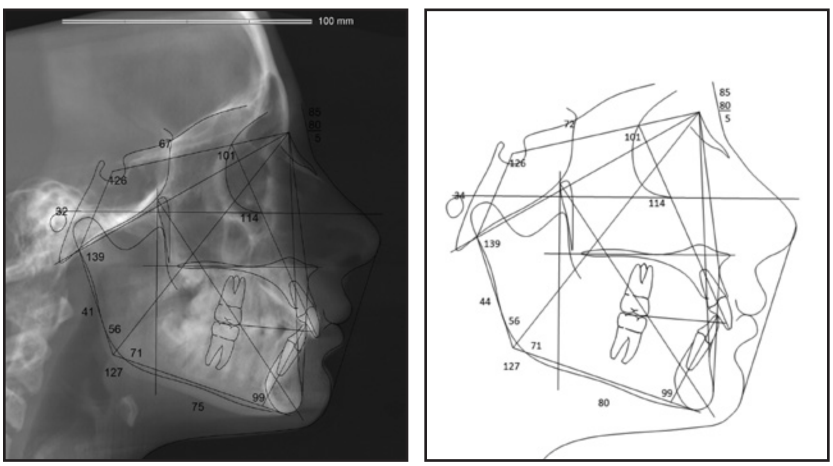

Fig. 8 Case 2. 13-year-old female patient with end-on Class II molar and canine relationships, skeletal Class II base with mandibular retrognathia, and mild arch-length discrepancy before treatment.

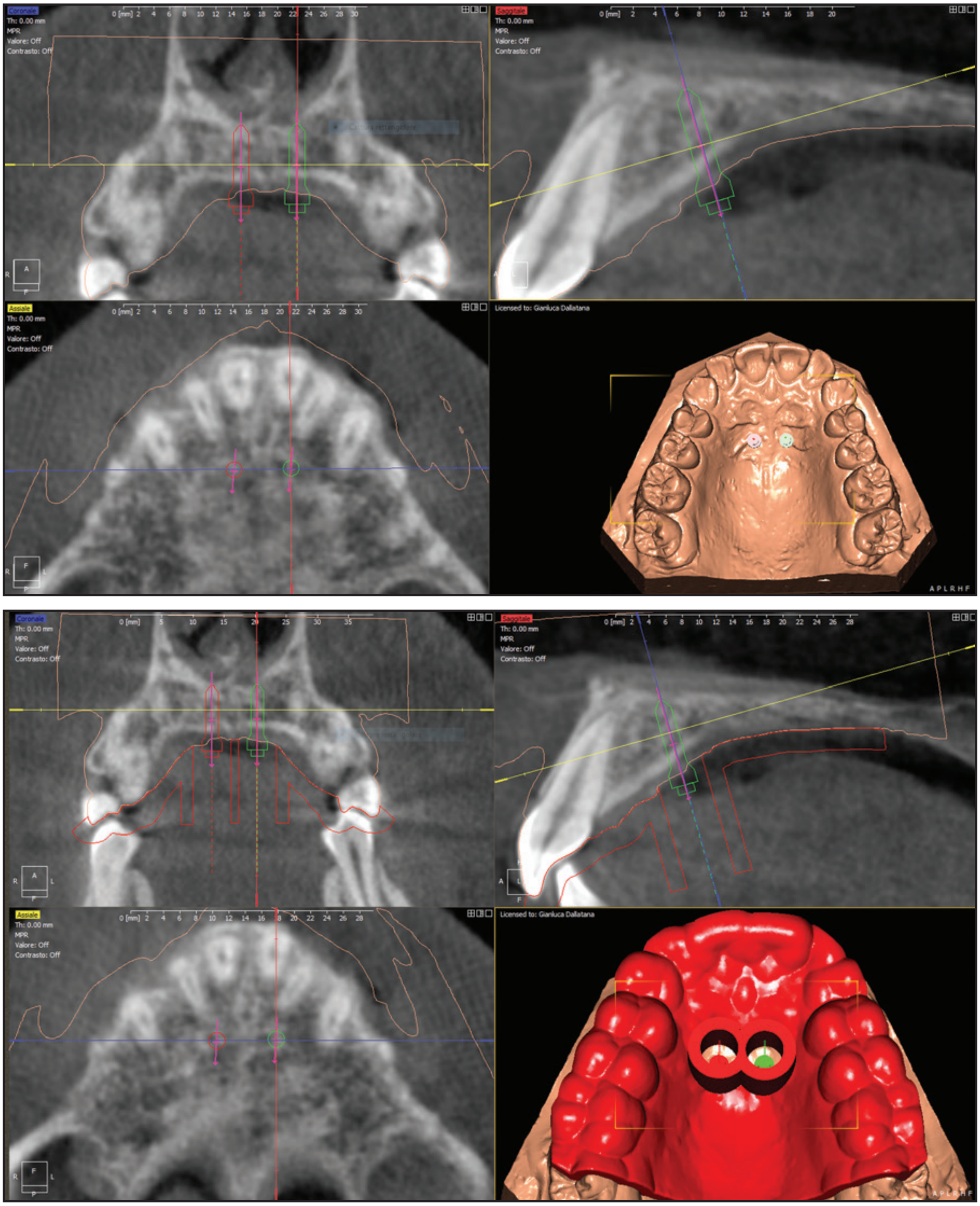

Fig. 9 Case 2. Virtual planning for placement of microscrews and creation of three-dimensional surgical guide.

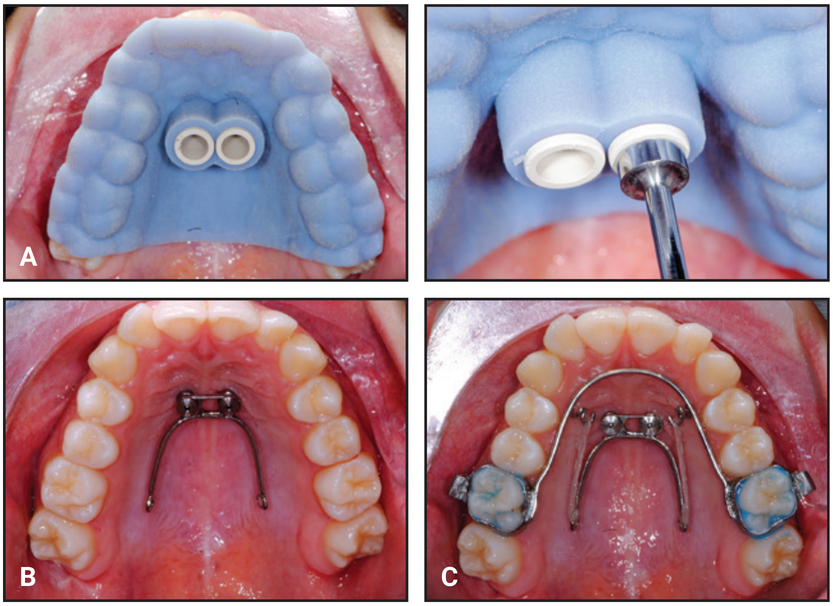

Fig. 10 Case 2. A. Surgical guide and microscrew insertion. B. Horseshoe appliance mounted on microscrews. C. Two weeks later, elastomeric chains attached between hooks on palatal arch and eyelets on horseshoe appliance.

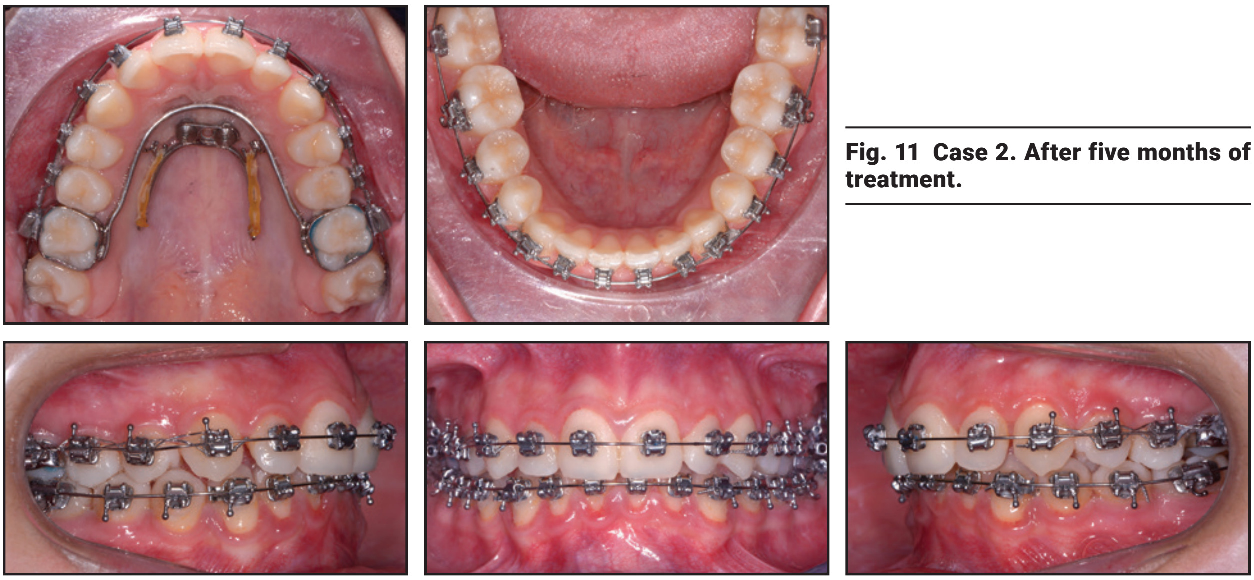

Fig. 11 Case 2. After five months of treatment.

Fig. 12 Case 2. After 10 months of treatment, distal extension lever arms added to palatal arch and palatal hooks welded to first molar bands for upper second molar intrusion without unwanted first molar extrusion; lingual buttons bonded to second molars for torquing.

Total active treatment time was 20 months (Fig. 13). A vacuformed retainer was delivered for the upper arch, and a 3-3 lingual retainer was bonded in the lower arch. The patient was satisfied with the final occlusion and facial profile. Post-treatment cephalometric analysis demonstrated maxillary molar distalization and favorable positioning of both the maxillary and mandibular incisors (Table 2).

Discussion

Orthodontists are increasingly using digital platforms for treatment planning. The Easy Driver protocol was designed to promote safe and accurate microscrew positioning. Further advantages include ease of application, avoidance of damage to the roots or neuromuscular bundles, and lack of interference with planned orthodontic movement and natural growth. The digital planning and guided insertion process ensure parallelism between multiple microscrews, eliminating the wobbling effect that can lead to loosening.

With this protocol, the microscrews and the horseshoe palatal anchorage plate can be fitted in a single clinical session. The horseshoe appliance is retained with fixation screws and can be removed for modifications without compromising the palatal microscrews. It provides absolute anchorage for en-masse distalization of the maxillary arch. By modifying the line of force and point of force application, the vertical dimension can be controlled even in hyperdivergent patients.

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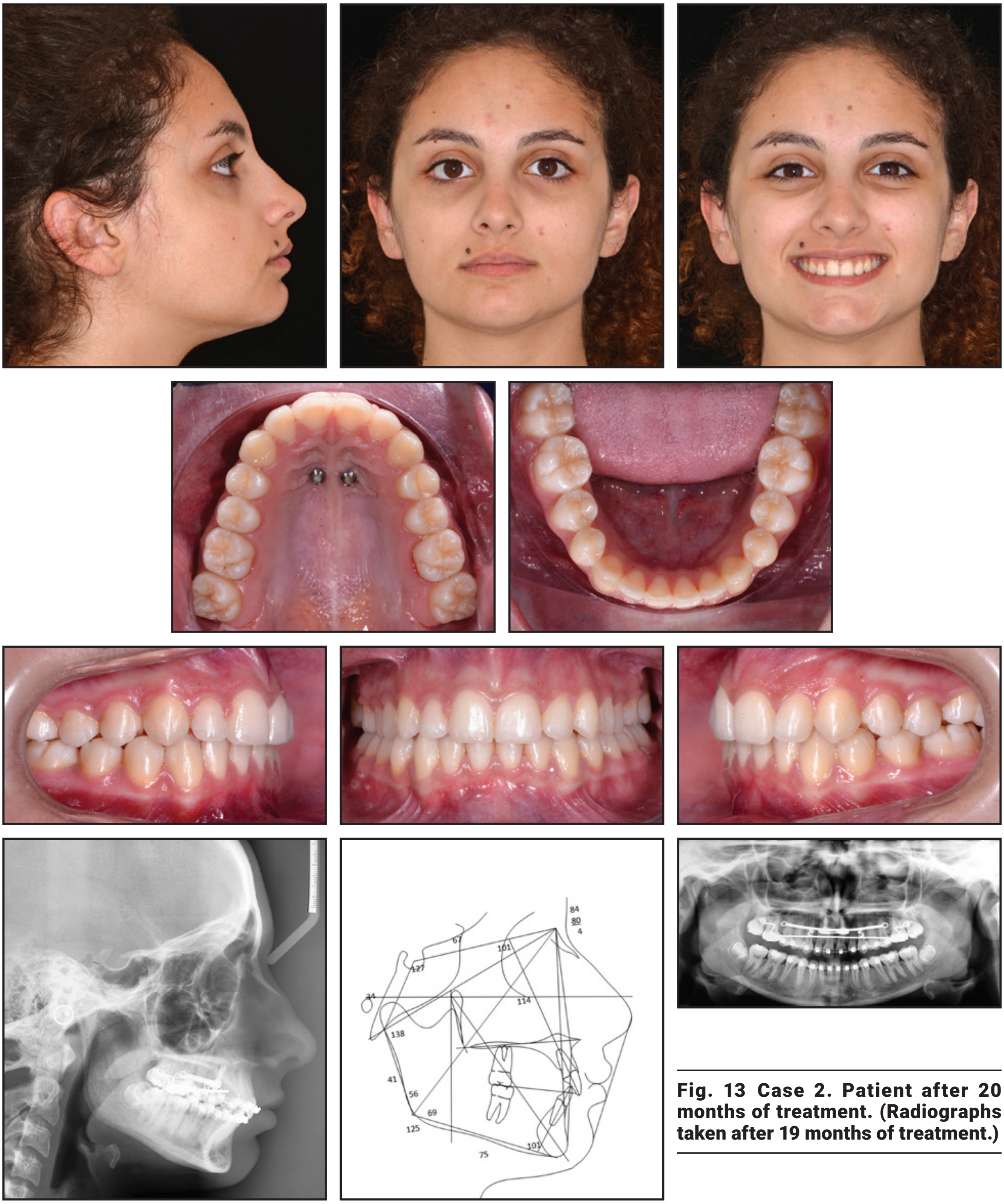

Fig. 13 Case 2. Patient after 20 months of treatment. (Radiographs taken after 19 months of treatment.)

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