Maxillary skeletal expander with 6 miniscrews and tadlock: A case report

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Miniscrew-assisted rapid palatal expansion (MARPE) devices offer an alternative to orthognathic surgery for postpubertal patients, but a limitation of MARPE is the possible migration of miniscrews during maxillary expansion. This becomes critical when palatal bone is thin at the miniscrew insertion sites, potentially leading to miniscrew failure. In this article, a maxillary skeletal expander (MSE), a particular type of MARPE appliance, was adopted to skeletally expand the maxilla in a postpubertal patient with a thin palatal bone. To reinforce the skeletal anchorage, the MSE was modified by adding 2 lateral miniscrews in the palatal slope between the second premolar and first molar. A virtual model of the MSE with 4 miniscrews was imported into the merged model of the patient's cone-beam computed tomography and maxillary dental arch. Then, a computer-aided design/manufacturing structure with appliance arms, 2 bushings for additional lateral miniscrews, and molar bands was 3-dimensionally designed and manufactured with selective laser melting technology and was laser welded to the MSE body to produce the modified MSE with 6 miniscrews. Because appliance arms tend to slide along the additional lateral miniscrews during maxillary expansion because of the lateral force vector, a steel ligature (the "tadlock") is tied between the miniscrew head and the bushing pin present on the appliance arms to eliminate the problem. The digital workflow to fabricate the MSE with 6 miniscrews and the tadlock mechanism are presented along with the procedure to expand the maxilla in a postpubertal patient with a thin palatal bone. (Am J Orthod Dentofacial Orthop Clin Companion 2025;XX:XX-XX)

Maxillary transverse deficiency (MTD) is a common finding in orthodontics and consists of a skeletal discrepancy between the maxillary and mandibular basal bone width.[1,2] Its diagnosis is based on clinical findings and radiographic examination.[3-5] The most common clinical signs include ≥1 of the following: posterior crossbite, buccally flared posterior teeth, crowding, or large buccal corridors.[1,2,6] Occasionally, the underdevelopment of the maxilla also involves the sagittal dimension, resulting in an insufficient overjet.

In growing patients, tooth-borne rapid palatal expansion is sufficient to achieve a skeletal expansion of the maxilla despite the dental and/or periodontal effects,[7-10] but in nongrowing patients with transverse problems,

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Fig 1. Intraoral photographs: **A,** Pretreatment; **B,** Posttreatment.

miniscrew-assisted rapid palatal expansion (MARPE) may be the best treatment option. The skeletal anchorage with miniscrews ensures an orthopedic effect even after the growth spurt has been reached and helps to minimize unwanted dental side effects.[11,12] The maxillary skeletal expander (MSE) is a specific type of MARPE appliance with unique biomechanical characteristics.[13-15] The stability of miniscrews can be compromised by a lack of sufficient palatal bone thickness. A palatal bone of ≤2 mm can lead to miniscrew failures when a high magnitude of the orthopedic force is required in patients with a high level of resistance (high bone density, heavily interlocked suture, adverse facial pattern, etc.).[16] Thus, 2 additional miniscrews might be necessary to achieve stability during maxillary expansion and protraction.[17]

In this study, we illustrate the digital workflow and rationale for a modified MSE with 6 miniscrews to treat a postpubertal patient with MTD and a thin palatal bone.

CASE REPORT

A postpubertal male patient aged 15 years 4 months was considered in this case report. His growth stage was assessed based on the cervical vertebral maturation stage method and the presence of secondary sexual features. The patient presented with Class I molar relationship, edge-to-edge bite, open bite on his maxillary lateral incisors, mild crowding in both arches, and a posterior crossbite on the left side. The mandibular midline was deviated to the left by 1.5 mm (Fig 1). Cephalometric analysis showed a Class I brachyfacial skeletal pattern, as well as

Table. Cephalometric analysis

Measurement	*Norm*[†]	*Pretreatment*	*Posttreatment*
SNA (°)	82.0 ± 3.5	86.4	87.6
SNB (°)	80.0 ± 3.0	85.7	85.0
ANB (°)	2.0 ± 2.0	0.8	2.6
SN-MP (°)	32.9 ± 5.2	23.7	25.5
FMA (°)	26.0 ± 4.5	19.0	20.8
U1-NA (mm)	4.3 ± 2.7	3.7	3.6
U1-SN (°)	102.0 ± 5.5	110.7	110.9
L1-NB (mm)	4.0 ± 1.8	6.3	5.5
L1-MP (°)	95.0 ± 7.0	100.7	100.1
UL/E-plane (mm)	−6.0 ± 2.0	−3.9	−4.5
LL/E-plane (mm)	−2.0 ± 2.0	0.1	−1.1

[†]Values are presented as mean ± standard deviation.

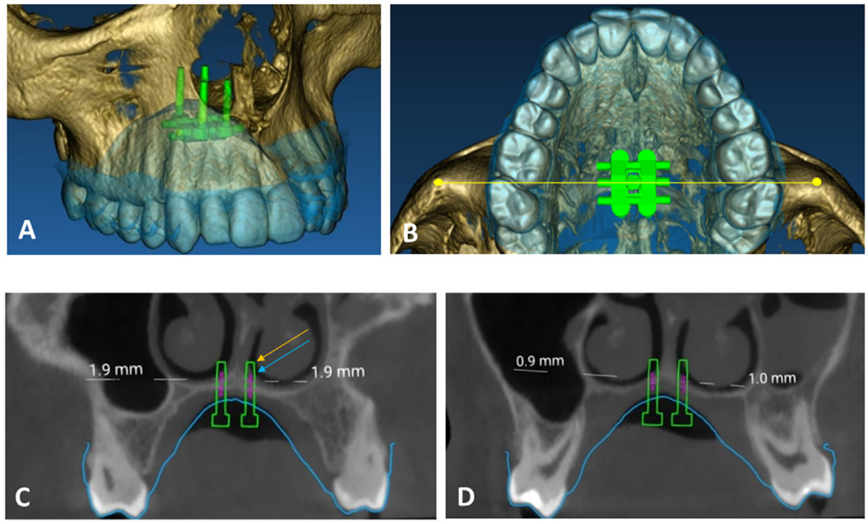

Fig 2. Digital planning of the MSE position by means of an MSE virtual model complete with miniscrews on the integrated model of the patient's CBCT and digital dental arch: **A,** Three-fourth view; **B,** Occlusal view, showing the MSE jackscrew perpendicular to the midpalatal suture and in close proximity to the bizygomatic line (*yellow*) that connects the most lateral points of the right and left zygomaticomaxillary sutures; **C** and **D,** Measurement of the palatal bone thickness at the anterior and posterior miniscrew levels, respectively. The *cylinder* that represents the miniscrews has a length of 13 mm (*orange*), whereas the *notch* (*light blue*) represents a miniscrew length of 11 mm. The miniscrew length was selected to achieve bicortical anchorage.

proclined maxillary and mandibular incisors (Table). The patient had a large tongue (macroglossia), which, by producing excessive pressure on the maxillary and mandibular incisors, might have contributed to their proclination. The overall Bolton analysis revealed a mandibular excess of 4.5 mm.

Two treatment alternatives were suggested to the patient. The first would use MSE, followed by a fixed orthodontic appliance, and the second involved a surgically assisted palatal expansion when the patient was older, followed by fixed orthodontic treatment. The surgical alternative was considered too invasive by the patient's parents and was rejected; therefore, MSE combined with a fixed appliance was chosen as the treatment plan. Interproximal reduction (IPR) in the mandibular arch was planned to relieve crowding and improve the Bolton discrepancy. Because of the macroglossia, the possibility of extractions or en-masse retraction of the mandibular arch with skeletal anchorage was excluded because of the high likelihood of relapse of the mandibular incisor inclination.

The MSE position was digitally planned on the integrated model of the patient's cone-beam computed tomography (CBCT) and digital dental arch (Fig 2, A and B).[18] Because the palatal bone thickness was <2 mm (Fig 2, C and D), 2 additional miniscrews (1.8 mm diameter and 11 or 13 mm length, depending on bone thickness at the insertion site) were added to the original MSE (Fig 3).

A virtual model of the bushings with a miniscrew inside was created and imported in the same software used to digitally plan the MSE position (Real Guide software; 3Diemme, Figino Serenza, Italy) (Fig 3, *A*).[17] The 2 additional miniscrews were virtually positioned on the palatal side of the alveolar process, between the second premolar and first molar (Fig 3, *B* and *C*). The bushings were then merged with the virtual appliance arms and molar bands to form a 1-piece structure (Fig 3, *D*) that was then 3-dimensional (3D) printed with the selective laser melting technique (Fig 4, *A*).[19]

The computer-aided design/manufacturing (CAD-CAM) structure was then placed over the body of the MSE appliance and laser welded to it (Fig 4, *B*). The connection between the right and left arms was cut and removed. The appliance was then polished (Fig 4, *C*), sterilized, and delivered to the patient. After cementing the molar bands, all 6 miniscrews were inserted. For the 2 additional lateral miniscrews, a 0.011-in steel ligature (tadlock) was tied from the miniscrew head to a pin present on the bushing (Fig 4, *D*) to avoid any sliding of the appliance arms along the lateral miniscrews (Figs 5 and 6). The miniscrew head was then covered with flowable composite material to prevent tongue irritation (see Video, available at www.ajodo.org [multimedia files "MSE with 6 miniscrews and Tadlock]).

The MSE was activated twice daily (0.13 mm expansion per activation) until the desired transverse dimension of the maxilla was obtained (a total of 7 mm of activation) (Fig 7, A). A CBCT was obtained immediately after the expansion, showing a split of 5.02 mm at the anterior nasal spine and 4.16 mm at the posterior nasal spine (Fig 7, B). At the same time, no contact of the lateral miniscrews with the adjacent dental roots was observed (Fig 7, C).

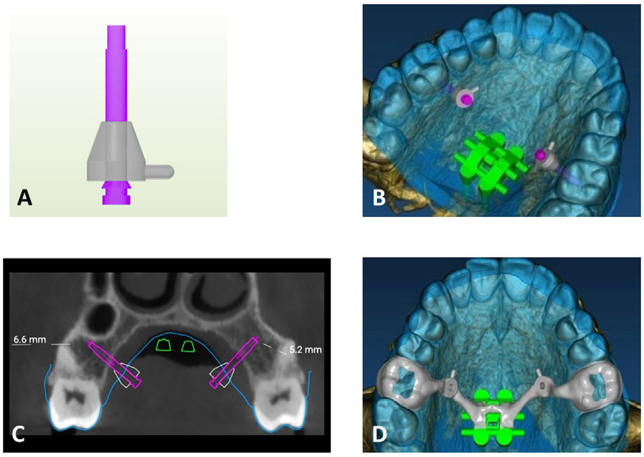

Fig 3. Digital planning for 2 additional lateral miniscrews for the MSE: **A,** Virtual model of bushing (*gray*) and miniscrew (*purple*); **B,** Two additional bushings and miniscrews were positioned on a merged model of the patient's CBCT and digital dental arches; **C,** Measurement of bone thickness for additional lateral miniscrews on the palatal slopes; **D,** CAD-CAM structure incorporating molar bands, arms, and bushings in *gray* and MSE body in *green*.

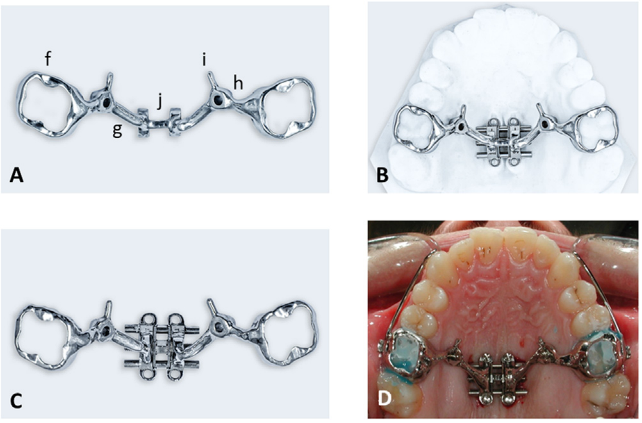

Fig 4. Laboratory work for customized CAD-CAM MSE manufacturing: **A,** CAD-CAM structure with molar bands (*f*), arms (*g*), bushing for additional lateral miniscrews (*h*), pin for the steel ligature (*i*), and connection between the right and left arms (*j*); **B,** CAD-CAM structure placed over the MSE body before laser welding; **C,** Appliance after laser welding of the CAD-CAM structure to the MSE body and removal of the connection between the right and left arms; **D,** Appliance after delivery in the oral cavity.

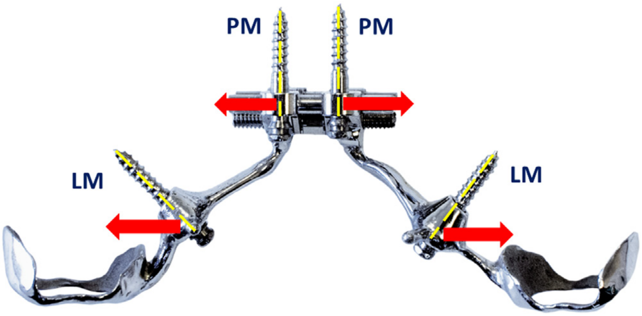

Fig 5. Image of CAD-CAM modified MSE appliance with 6 miniscrews, frontal view. The expansion force vector acts perpendicular to the long axis of the original PM and in an oblique fashion on the additional LM. *Red*, expansion force vector; *yellow*, miniscrew long axis. *PM,* paramedian MSE miniscrews; *LM,* lateral miniscrews.

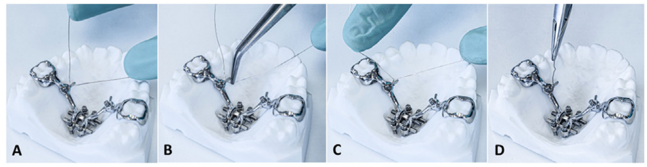

Fig 6. Tadlock mechanism for additional lateral miniscrews. After the miniscrews were inserted in the lateral bushings, a 0.011-in steel ligature was used to tie the miniscrew head to the pin present in the bushing: **A,** Two tight knots were tied around the miniscrew head; **B,** With the help of tweezers, the steel ligature was turned around the bushing pin; **C,** Two more tight knots were tied; **D,** The steel ligature was twisted with a Mathieu plier. Afterward, the steel ligature was cut, and the end was twisted behind the bushing pin to prevent it from poking the patient's tongue. Finally, flow composite material was placed above the miniscrew head and bushing and was light-cured.

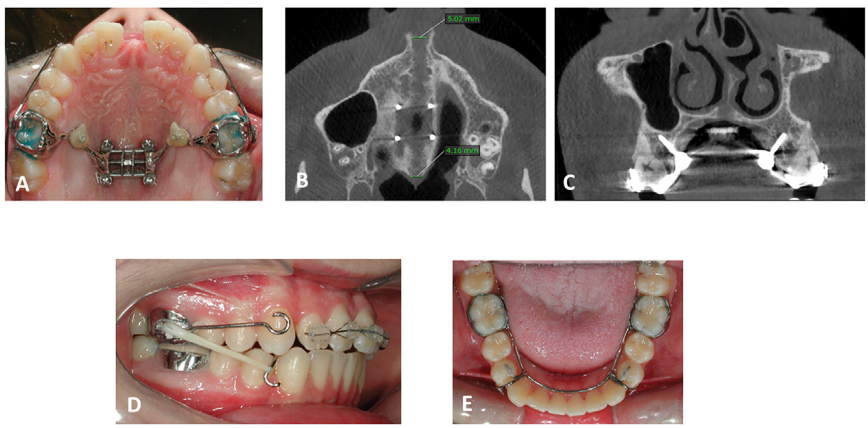

Fig 7. Records after maxillary expansion: **A,** After the expansion of the maxillary arch with MSE; **B,** Axial section for the CBCT at the palate; **C,** Coronal section of the CBCT with additional lateral miniscrews; **D,** Use of Class III elastics during the daytime; **E,** A modified mandibular lingual arch with hooks for Class III elastics. Cantarella et al[17] was originally published by and used with permission from Dove Medical Press Ltd.

To increase the patient's overjet, a facemask was delivered immediately after the expansion was completed. Maxillary protraction was performed using extraoral elastics (3/8-in, 16 oz) worn at night, whereas Class III intraoral elastics (3/16-in, 6 oz) from the maxillary molar bands to a modified lingual arch cemented in the mandibular arch were used during the day until a slight Class II molar and canine relationship was achieved (Fig 7, D and E). During this phase, which lasted for just 3 months, brackets were placed on the maxillary incisors, and the midline diastema was closed with an orthodontic archwire (0.016 × 0.022-in nickel-titanium and then 0.016 × 0.022-in stainless steel) and an elastomeric chain (Fig 7, D).

After the facemask and Class III elastics were discontinued, the MSE arms and additional lateral miniscrews were removed, whereas the MSE body with the 4 paramedian miniscrews was left in place for 8 additional months for skeletal retention of the maxillary expansion. A complete fixed orthodontic appliance with a 0.022-in slot and McLaughlin Bennett MB 5.0 prescription was placed (Fig 8). Then, 0.016-in, 0.019 × 0.025-in nickel-titanium, and 0.019 × 0.025-in stainless steel archwires were used for dental alignment, occlusal finishing and detailing. IPR

Fig 8. Intraoral photographs taken after 11 months of fixed orthodontic treatment.

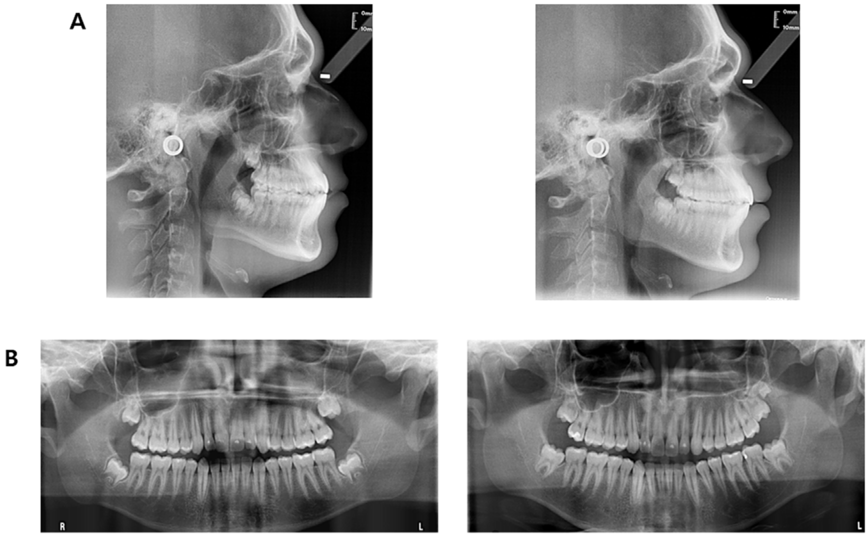

Fig 9. Radiographic records: **A,** Lateral cephalograms (pretreatment and posttreatment); **B,** Panoramic radiographs (pretreatment and posttreatment).

was performed on the mandibular incisors to relieve crowding. After fixed orthodontic treatment, Class I canine and molar relationships were present, with optimal overjet and overbite; the left lateral crossbite was solved with proper torque of the posterior teeth (Fig 1, *B*).

The posttreatment lateral cephalogram showed a Class I skeletal relationship (ANB, 2.6°). The lateral cephalometric superimpositions showed that the maxilla had moved forward and downward with treatment. The mandible showed a residual sagittal growth between pretreatment and posttreatment (Figs 9and 10; Table).

DISCUSSION

The introduction of MARPE has helped MTD treatment in 2 ways: by limiting the dental and periodontal side effects of the classic tooth-borne expanders and by extending the age limit of treatment.[8,11,20,21]

In this case report, the posterior crossbite was solved using MSE, a specific type of MARPE appliance. Incisor overjet was increased by a combination of protraction forces delivered to the MSE molar bands from the facemask and Class III elastics, mandibular posterior rotation, and IPR in the mandibular arch. Given the patient's age, there was only a limited potential for residual maxillary growth, but even if this was just a small amount, the growth could have contributed to the maxillary advancement. The increase in ANB angle after treatment was small (1.8°) because the required amount of dental correction in the sagittal plane was small, and protraction mechanics were applied for just a short time. The

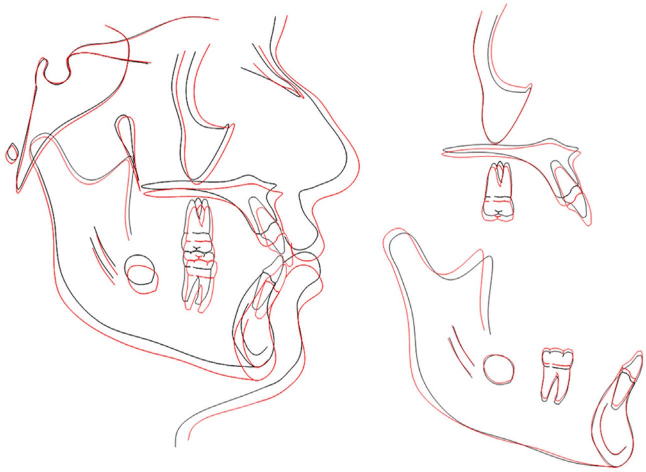

Fig 10. Lateral headfilm with overall superimposition, maxillary superimposition, and mandibular superimposition. *Black,* pretreatment; *red*, posttreatment.

Fig 11. Facial photographs: **A,** Pretreatment; **B,** Posttreatment.

increase in overjet, in turn, allowed the extrusion of maxillary and mandibular incisors and the correction of the anterior open bite at the level of the lateral incisors. The molars showed some extrusion after treatment as compensation for the posterior mandibular rotation. Overall, the treatment improved the convexity of the facial profile and maxillary incisor display while smiling (Figs 1, 8, 10, and 11; Table).

In a finite element model study,[22] it was shown that the concentration of expansion force with MSE is mainly on the maxillary bone instead of on maxillary teeth, which explains the limited dental side effects. In fact, in this case report, the proper torque of the posterior teeth was present after treatment. Furthermore, when a tooth-borne expansion is combined with a facemask or Class III elastics protraction, an unwanted maxillary incisor proclination occurs. Such proclination was avoided in this case report because of the skeletal anchorage (Figs 9 and 10; Table).

In this case report, MSE was chosen because of the patient's limited growth potential and because a crossbite was present in the posterior region of the maxilla (Fig 1, *A*). MSE consists of a central jackscrew and 4 paramedian miniscrews positioned in the posterior region of the palate.[13,14] This posterior position of the appliance, together with the bicortical engagement of the miniscrews, helps split the midpalatal suture with a parallel pattern and loosens the circummaxillary sutures.[14,15,23-25]

Recently, digital workflows for palatal miniscrew insertions have been described. Insertion sites with greater bone thickness are identified in the patient's CBCT, and a surgical guide is then 3D printed and used by the orthodontist during miniscrew positioning. An expansion device is then connected to miniscrew heads with fixation screws.[26,27] In this study, a different digital workflow was applied. A virtual model of the MSE appliance, complete with 4 miniscrews, was created and imported into the combined model of the patient's CBCT and maxillary dental arch (Fig 2, A and B).[18] Then, MSE was virtually moved to locate the position for optimal biomechanics. Ideally, the expansion force vector should be perpendicular to the midpalatal suture to deliver symmetrical force vectors to maxillary halves and be located at the bizygomatic line that connects the most lateral points of right and left zygomaticomaxillary sutures (Fig 2, *B*) to generate a force vector close to the center of resistance of the maxilla.[18] Furthermore, the appliance body should be located ≤2 mm from the palatal mucosa to avoid excessive leverage on miniscrews during active maxillary expansion. The length of the miniscrews was also selected at this stage: miniscrews should penetrate 1 mm into the nasal cavity to ensure firm bicortical anchorage through the cortical bone layers of the palatal vault and nasal floor. Finally, palatal bone thickness at the miniscrew insertion sites was checked (Fig 2, C and D).

Recent studies have shown that miniscrews tend to migrate through the maxillary bone under orthopedic forces.[28,29] This becomes a critical issue when a palatal bone is <2 mm thick in patients with relatively high resistance, leading to MSE failure.[16] In this case report, this severely brachycephalic patient with potentially high resistance against expansion had a palatal bone thickness of <2 mm, and to reinforce the skeletal anchorage, 2 additional miniscrews were used (Fig 3).[17] A CAD-CAM structure was produced with selective laser melting technology, a novel additive manufacturing method to 3D print metal parts through heating and melting a metal powder using a laser beam.[19] The CAD-CAM structure included 2 bushings for the additional lateral miniscrews and was then laser welded to the MSE body (Figs 3 and 4). The posterior location of the 2 additional miniscrews near the maxillary center of resistance[18] was chosen to produce posterior expansion and, consequently, a larger disarticulation of posterior circummaxillary sutures.[15] The material used for the CAD-CAM structure was a cobalt-chromium alloy, which presents high rigidity (modulus of elasticity of 205 GPa) for secure delivery of the expansion force to the skeletal structures.

Indications for MSE with 6 miniscrews include an insufficient palatal bone thickness, usually <2 mm as in this case report, but can also be an increased midface resistance to expansion as in older patients with advanced skeletal maturation,[30] a higher bone density or thickness of the zygomatic buttress bones,[25] or a higher interdigitation of the circummaxillary sutures.[10,31,32] In contrast, 2 mm palatal bone may be a sufficient thickness in an opposite situation when a patient presents with weak resistance (younger patients with patent sutures, low density or thin zygomatic buttress bones, etc.). Patients with a higher level of resistance require a thicker palatal bone for anchorage, and each case should be evaluated individually.

An important clinical aspect to consider when using a modified MSE with 6 miniscrews is the risk that lateral bushings and arms migrate toward the palatal mucosa during expansion, potentially resulting in tissue impingement. With the 4 original paramedian MSE miniscrews, the direction of force during expansion is perpendicular to the long axis of the miniscrews, which prevents the vertical movement of the MSE body toward the palatal mucosa (Fig 5). This is not the case with the lateral bushings, which, having an oblique inclination, can slide along the axis of the lateral miniscrews and be pushed toward the mucosa of the palatal slope during a maxillary expansion (Fig 5). A tadlock mechanism was used to avoid such an occurrence in the present case. It consisted of a 0.011-in steel ligature tied from the miniscrew head to a pin present on the bushing (Figs 4, *D* and 6) after all 6 miniscrews were inserted. A flow composite material was placed on top to prevent tongue irritation from the 0.011-in steel ligature. During active maxillary expansion, the tadlock kept the bushing locked to the lateral miniscrew head. Detailed domestic oral hygiene instructions, including the use of an oral irrigator, were given to the patient after MSE delivery to avoid tissue irritation during treatment time. No tissue inflammation or discomfort was experienced by the patient during the treatment.

The modified MSE was cemented in the oral cavity and served as a guide for inserting the miniscrews. With this digital workflow,[17,18] the clinicians did not need any surgical guide, and the possibility of misfitting was reduced, contrary to what might have happened if the miniscrews had been inserted first and requiring the appliance to be passively fitted afterward, especially if multiple miniscrews were used. The safety of the procedure was confirmed by the posttreatment CBCT, which showed the additional lateral miniscrews were away from the adjacent roots of the second premolar and first molar.

Maxillary protraction can be achieved with Class III elastics, which are attached to maxillary and mandibular miniplates like in the bone-anchored maxillary protraction (BAMP) technique.[33] BAMP protocol needs reduced patient compliance because a facemask is not used. In addition, the mandible is minimally postrotated, and the mandibular incisors tend to decompensate and procline.[33] When facemask is used in association with miniplates, like in the bone-anchored facemask technique, incisor retroclination and mandibular postrotation are larger than in the traditional BAMP protocol.[34]

The protocol presented in this article uses a facemask at night and Class III elastics during the day. Class III elastics are attached to the MSE molar bands in the maxilla and a modified mandibular lingual arch in the mandible (Fig 7, D and E). Because intraoral elastics are used in a discontinuous way (daytime only), the distalization of the mandibular dental arch is minimized, even if miniscrews are not used in the mandible. The incisor mandibular plane angle was reduced with treatment by only 0.6° (Table). The FMA (Frankfurt mandibular plane angle) was increased by 1.8°, which was beneficial because the patient presented a brachyfacial pattern before treatment. In addition, because the patient presented a posterior crossbite at the level of the molars, a posterior rather than anterior maxillary expansion was required. MSE was used for this purpose and then was exploited as an anchor for maxillary protraction.

Further investigations with longitudinal design are needed and encouraged to enhance the understanding of the subject.

CONCLUSIONS

This case report shows the successful treatment of an adolescent with MTD, open bite and a thin palatal bone, treated with a modified MSE followed by comprehensive fixed orthodontic treatment. Good skeletal anchorage significantly contributed to the orthopedic effect of the maxillary expansion and avoided unwanted dental side effects. The MSE was modified by adding 2 lateral miniscrews in the lateral slope of the palate for a total of 6 miniscrews, which enabled treatment even though the palatal bone thickness was <2 mm. A tadlock mechanism on the additional lateral miniscrews avoided the risk of the appliance arms sliding along them during active maxillary expansion.

CONFLICT OF INTEREST

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

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AUTHOR CREDIT STATEMENT

Daniele Cantarella contributed to investigation, original manuscript preparation, and manuscript review and editing; Jae Hyun Park contributed to supervision and manuscript review and editing; Lorena Karanxha contributed to investigation and original manuscript preparation; Giovanni Evangelista Mancini contributed to investigation and manuscript review and editing; Massimo Del Fabbro contributed to investigation and manuscript review and editing; Alberto Caprioglio contributed to manuscript review and editing; and Won Moon contributed to investigation and manuscript review and editing.

STATEMENT OF INFORMED CONSENT

Informed consent was obtained by the patient included in the study.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.xaor.2025.03.003.

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