



Distraction Osteogenesis Maxillary Expansion (DOME) and SFOT for Naso-Maxillary Expansion in Obstructive Sleep Apnea (OSA)

Audrey Yoon, Linda Phi, and Stanley Liu

Introduction

Obstructive Sleep Apnea (OSA) has multifactorial etiology including craniofacial risk factors such as narrow maxilla with high arch palate [1, 2]. The maxilla forms the floor of the nasal cavity, so transverse maxillary hypoplasia correlates with a narrow nasal floor. Additionally, individuals with OSA often have a resting tongue position that is more inferiorly positioned [3, 4]. Whether this inferiorly positioned tongue position influences the development of maxillary hypoplasia, or vice versa, remains unknown. Nevertheless, transverse maxillary hypoplasia with inferiorly displaced tongue posture is associated with increased nasal airflow resistance and retroglossal airway narrowing [3, 4]. Nasal obstruction in patients with narrow maxilla and high arch palate may not resolve completely with procedures such as turbinate reduction, septoplasty, and nasal valve reconstruction [5]. In these patients, maxillary expansion has been shown to improve nasal breathing [3, 6].

A. Yoon (✉)

Department of Psychiatry and Behavioral Science, Stanford Center for Sleep Science and Medicine, Stanford University, School of Medicine, Stanford, CA, USA

Sleep Medicine Clinic, Stanford University, Redwood City, CA, USA

Department of Orthodontics, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, CA, USA

UCLA Section of Orthodontics, Los Angeles, CA, USA
e-mail: audrey12@stanford.edu

L. Phi

Department of Orthodontics, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, CA, USA

UCLA Section of Orthodontics, Los Angeles, CA, USA
e-mail: lindaphi@ucla.edu

S. Liu

Division of Sleep Surgery, Department of Otolaryngology-Head & Neck Surgery, School of Medicine, Stanford University, Stanford, CA, USA
e-mail: ycliu@stanford.edu

The treatment modality needed to expand the maxilla and the nasal floor is highly dependent on the patient's growth and developmental stage [7]. Before puberty, the mid-palatal suture has not yet fused. This suture intricately interdigitates after the onset of puberty, making it more difficult to split apart [8].

Rapid Palatal Expansion (RPE)

Rapid palatal expander (RPE) has been shown to be efficacious in pediatric OSA [9]. RPE can predictably expand the maxilla in pediatric patients before pubertal growth spurt is completed, which coincides with the early teenage years [9–11]. The expansion is achieved via orthodontic and orthopedic appliances that apply strong bilateral forces to the dental arch. When the appliance exerts adequate force, there is insufficient time for dental movements to occur [12]; hence, the force is transferred to the mid-palatal suture and circumferential sutures [12]. As the maxilla expands, the nasal floor also widens. A study found that in younger children, transverse expansion with orthopedic appliances is 50% skeletal and 50% dental [13]. The skeletal expansion reduces to 35% skeletal and 65% dental in adolescents when the mid-palatal suture starts to interdigitate [13]. As the suture fuses more intricately, the forces exerted by the RPE will be more concentrated at the level of the dentition rather than the maxillary bone.

With RPE, mid-palatal sutural opening is found to be non-parallel [14]. Looking from the occlusal view, the expansion is triangular in shape with more widening in the incisors, and less widening occurred at the posterior hard palate [14]. From the frontal view, the expansion is pyramidal in shape with more widening on the oral side of the palate, and less on the nasal floor [15]. The palatine process is lowered due to the outward rotation of the hemimaxilla [16].

Miniscrew-Assisted Rapid Palatal Expansion (MARPE)

While conventional tooth-borne or tooth-tissue-borne RPE is effective in skeletally expanding the maxilla in pediatric and pre-pubescent patients, it is less reliable to skeletally expand post-pubescent and adult patients [17]. If RPE is used in this latter age group, it tends to tip the dentition buccally, which may result in periodontal damage [17, 18].

MARPE is a technique that utilizes miniscrews (also referred to as mini-implants or temporary anchorage devices) with RPE, resulting in a bone-borne appliance that is capable of providing greater force to split the mid-palatal and circumferential sutures [19, 20]. The miniscrews are inserted paramedian to the mid-palatal suture line, beneath the nasal floor. Compared to RPE, the additional anchorage from the implants provides the advantage of minimizing dentoalveolar tipping while maximizing skeletal expansion [19, 20]. This allows the concentration of forces to be at the level of the suture rather than at the dentition. A randomized controlled trial demonstrated that the nasal airflow following expansion was significantly higher in miniscrew assisted palatal expanders compared to the tooth-anchored expander [21]. Also skeletal expansion with MARPE is more predictable than RPE for post-pubescent individuals and young adults. Studies have shown that in cases where the sutural split was successful, the opening is typically parallel from a coronal view [22].

Prior to the advent of miniscrews, surgically assisted rapid palatal expansion (SARPE) was used to skeletally correct transverse maxillary hypoplasia in adults. [23] Utilizing the implants in MARPE, the maxilla can be expanded in teenagers and young adults without the need for general anesthesia and invasive osteotomies. However, it is important to note that a successful sutural split with MARPE may not always be predictable, especially in older adults [24]. Some osteotomies may still be needed in conjunction with MARPE for more predictable results, which will be dis-

cussed in the next section. An orthodontist commonly delivers the MARPE chairside under local anesthesia [24], with minimal bleeding, swelling, pain, and discomfort as compared to SARPE [25].

Numerous MARPE designs are available to expand the maxilla and nasal floor, including bar-type, multiple miniscrew-supported expander (no teeth banded), acrylic base reinforced with miniscrews, hybrid design with molar bands and multiple miniscrews, and customized “specific to patient” design [24]. The number of implants in the MARPE design is based on the provider’s preference, typically 2, 4, or 6 implants.

Distraction Osteogenesis Maxillary Expansion (DOME) (Figs. 1 and 2)

Before MARPE was developed, SARPE was utilized to correct a maxillary transverse discrepancy for adults. SARPE combines the conventional RPE with Le Fort I osteotomy with or without bilateral pterygoid plate disjunction and lateral nasal wall osteotomy [23]. The mid-palatal sutural opening for SARPE is similar in shape to the conventional RPE. It is triangular in shape from an occlusal view, with more expansion occurring at the incisors. It is pyramidal from the frontal view, with more expansion occurring at the oral surface [26].

Utilizing MARPE with site-specific osteotomies, distraction osteogenesis maxillary expansion (DOME) was developed for OSA patients whose mid-palatal suture may not predictably expand with MARPE alone [27]. As mentioned previously, MARPE is most predictable in teenagers and young adults. Well-designed osteotomies in conjunction with MARPE are more effective and predictable in the adult OSA population [24, 27]. Originally conceived by Liu, Yoon, and Guillemineault, conventional DOME techniques and minimally invasive nasal endoscopic (MINE) DOME techniques will be discussed below.

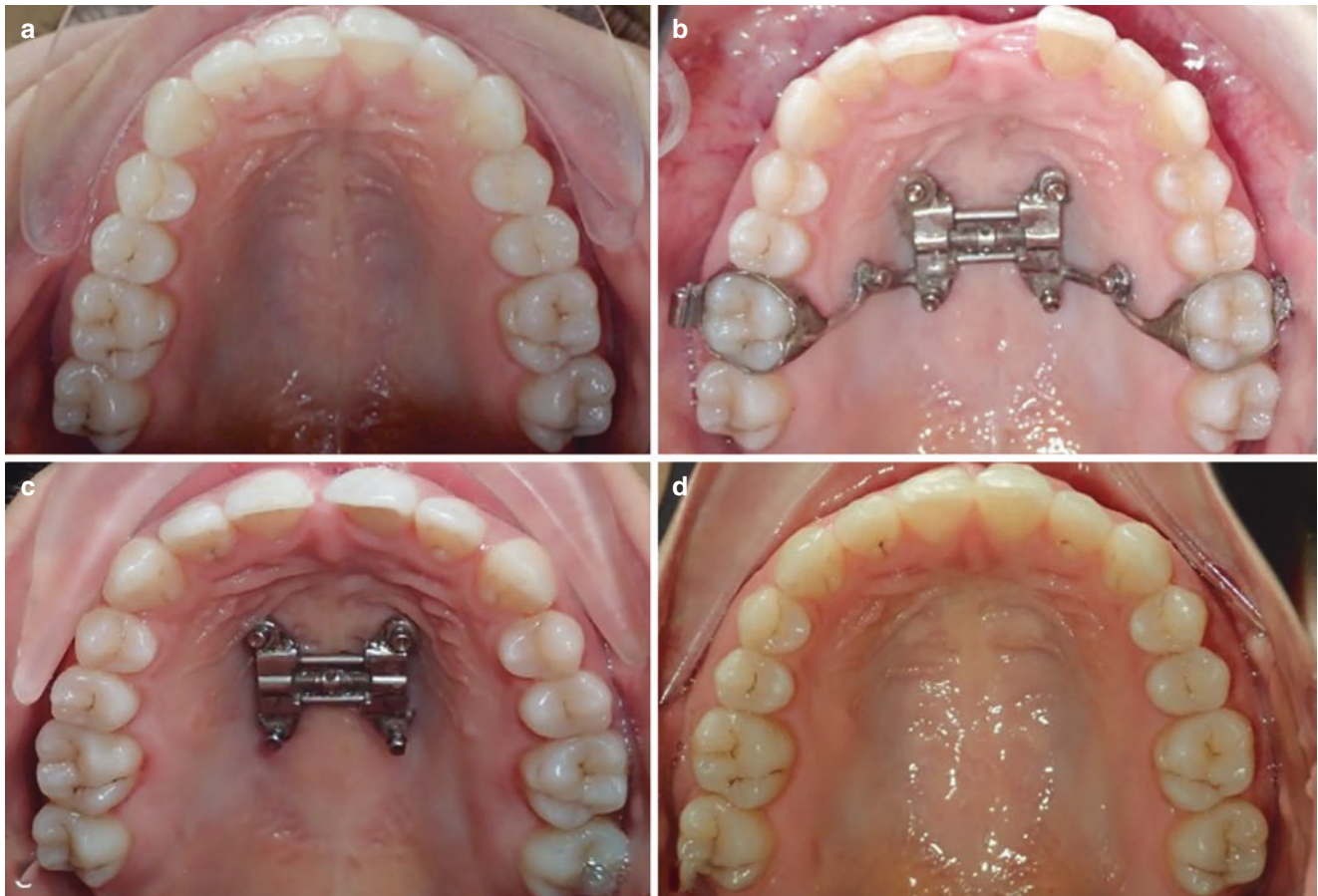


Fig. 1 DOME Expansion Occlusal View. (a) Initial Pre-DOME: Patient presented high arch palate with nasal obstruction and sleep apnea. (b) Post-DOME expansion: Custom DOME expander design with 6 mini-screws. 8 mm jackscrew level expansion achieved with expansion velocity 0.25 mm a day after DOME surgery. (c) Post-

DOME consolidation stage: Palatal width and nasal floor are maintained using jackscrew base with 4 mini-screws. Closing spaces and arch coordination with aligner therapy treatment. (d) Final Post-Orthodontic treatment: Patient's nasal breathing and sleep apnea were improved

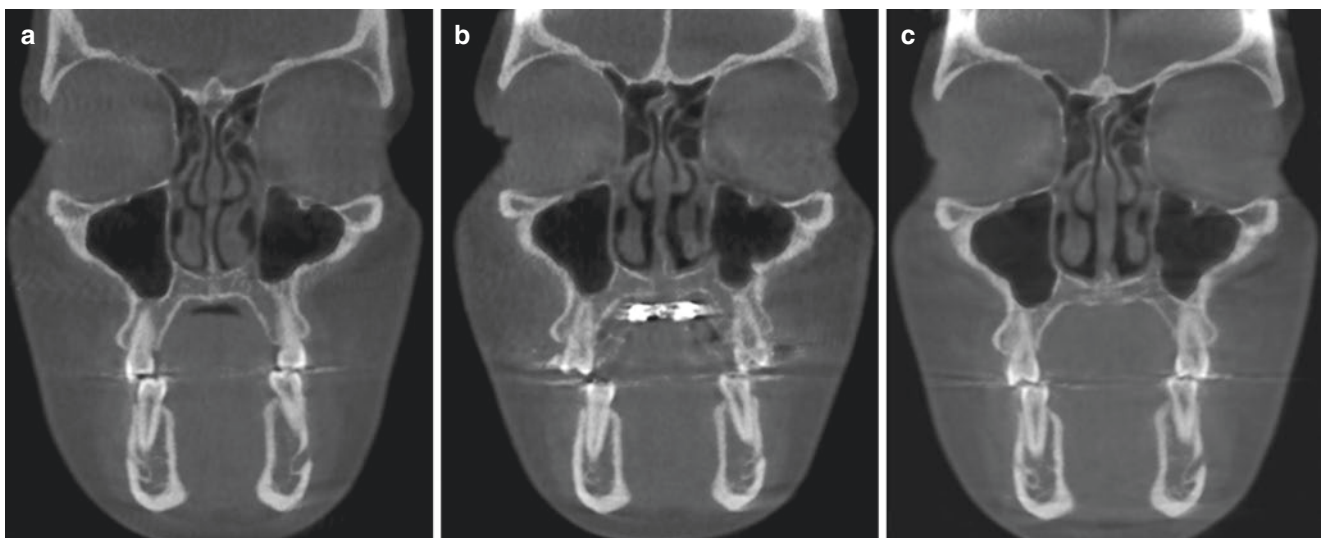


Fig. 2 DOME expansion cone beam CT: Coronal View at second pre-molar level. (a) Initial Pre-DOME: Patient presented high arch palate with nasal obstruction and sleep apnea. (b) Post-DOME expansion:

Nasal floor and palatal width were expanded by 8 mm. (c) Final Post-Orthodontic treatment: Patient's nasal passage was developed with wide nasal floor

Conventional DOME

During the treatment planning process for DOME, a 3D cone-beam computed tomography (CBCT) radiograph is essential to visualize the anatomical structures involved [24]. These anatomical structures typically include the following areas: (1) the palatal bone to assess its thickness to avoid implant loosening or perforation through the maxillary sinus, (2) location of the maxillary roots to avoid root damage during the osteotomy; (3) piriform aperture; (4) naso-maxillary buttress, and (5) zygomaticomaxillary buttress.

Once the palatal bone density, thickness, sutural location, and sutural fusion status are assessed, miniscrew location and length are determined for MARPE design and placement. Optimally, they are placed paramedian to the mid-palatal suture in an area with sufficient bone thickness. The selected screw length should have bicortical bone engagement without creating an oroantral fistula or damaging the root of adjacent teeth. Typically, the orthodontist delivers the MARPE and the corresponding miniscrews in preparation for DOME [24].

After the MARPE is delivered, surgery involves limited osteotomy at the Le Fort I level without pterygomaxillary disjunction [28]. Some auxiliary osteotomy may be needed at the maxillary midline using a piezo-electric saw and osteotome wedges to open the mid-palatal suture. The expander screw is turned to ensure that the maxillary expansion is symmetric with easy separation as the maxillary diastema develops [27]. Patients with mild to moderate OSA can be discharged on the same day as the surgery. Patients with severe OSA or those with co-morbidities are recommended to stay overnight for precautionary monitoring [24].

Following the osteotomy, the MARPE is activated by turning the axial screw. On average, a total of 8–12 mm of maxillary skeletal expansion is helpful to mitigate OSA, with an expansion rate of 0.125–0.25 mm per day [24]. However, the amount of skeletal expansion needed for OSA improvement has not yet been established. Oftentimes, the mandibular dentition are more lingually inclined to compensate for a narrow maxilla. As a result, it is important to take into consideration the amount of mandibular dental uprighting possible when deciding the amount of maxillary expansion. Also important are the width of the palatal and nasal floor [24]; the initial CBCT is beneficial in evaluating these measurements and comparing them to the mandibular skeletal transverse dimension.

With conventional DOME, the diastema increases as MARPE is activated. 8–12 mm expansion of the nasal floor with proper DOME techniques translates to approximately 10–14 mm of diastema formation [24]. Once expansion is

completed, orthodontic treatment commences to close this diastema, upright the mandibular dentition, and coordinate the arches. Although 3 months is the typical time frame for the consolidation period in typical craniofacial distraction osteogenesis, it is recommended that this period is longer for DOME to maximize bone mineralization and minimize relapse. The recommended DOME consolidation period is 6–8 months after the expansion is completed [27].

Minimally Invasive Nasal Endoscopic (MINE) DOME

Although DOME already utilizes minimally invasive osteotomy, founders of the DOME technique have continued to innovate and further reduce morbidity, including prolonged V2 paresthesia and nasolabial alterations. The minimally invasive nasal endoscopic (MINE) DOME was developed to avoid large sublabial incisions with midface degloving for the Le Fort I level osteotomy, which may cause considerable facial edema, CN V2 hypoesthesia, abnormal upper lip mobility, and nasal flaring.

Similar to conventional DOME, the orthodontist first places the mini-screw assisted expander. Rather than incising an intraoral flap across the maxilla to access the Le Fort I osteotomy, an incision is made transnasally, parallel to the piriform rim at the inferior turbinate level, and towards the anterior maxilla. An endoscope is inserted into this pocket for better visualization of anatomical structures. An ultrasonic aspirator is used under endoscopic guidance to create the Le Fort I osteotomy. In the study evaluating the post-operative effects of MINE DOME, there was a significant reduction in morbidity utilizing a nasal endoscopic approach compared to the classic degloving technique, since a surgical incision of the facial musculature is avoided.

Currently, our team is customizing the MARPE for optimal implant and expander success. Additionally, the Le Fort I osteotomy is modified and customized based on the desired patterns of expansion. For example, if a large diastema from the DOME or MINE DOME expansion is contraindicated, then the piriform area is left intact. If more posterior expansion is warranted, pterygomaxillary disjunction can be performed.

Difference Between SFOT and DOME

SFOT and DOME can both be used to expand the maxilla in adults, but their characteristics and indications are different. Table 1 differentiates these expansion techniques.

Table 1 Characteristics of surgical expansion technique: SFOT and DOME [29, 30]

Characteristics	SFOT	DOME
Method	Regional accelerated phenomenon	Distraction osteogenesis at the nasal floor/maxillary roof
Type of movement	Dentoalveolar expansion	Mainly skeletal expansion
Expansion area	Expand maxillary arch width Increase intraoral cavity volume Increase alveolar bone volume	Expand maxillary arch width Expand nasal floor width Increase intraoral cavity volume Increase nasal cavity volume
Benefit to airway	Slight increase in intraoral volume	Improve nasal obstruction Increase intraoral volume Create more tongue space
Surgery	Corticotomies	Osteotomies designed based on patient need, target areas are the vertical maxillary buttresses and midpalatal suture
Bone grafting	Extensive	Optional, if necessary
Average activation interval	Slow expansion Biweekly	Rapid expansion Daily (jackscrew activation; 0.1–0.25 mm per day)
Indications	Accelerated tooth movement Shorter treatment time Mild to moderate arch development Mild to moderate transverse discrepancy Exposed tooth root due to gum recession	Nasal obstruction Moderate to severe arch development Moderate to severe transverse discrepancy Sleep disordered breathing Avoid segmental surgery

Combination of SFOT and DOME

In many cases of hypoplastic nasomaxillary complex, lower teeth are lingually tilted to compensate for maxillary constriction. To establish the efficacy of DOME surgery by achieving the greatest possible skeletal expansion for the airway, it would be optimal to expand the mandibular width. A limitation to the amount of maxillary expansion is mandibular alveolar basal bone width. Gingival recession and bone loss over prominences of dental roots are found in the adult OSA population. Alveolar bone loss and gingival recession limit orthodontic movement buccally. Uprighting teeth over basal alveolar bone to normal inclination may create further bone and gingival attachment loss.

SFOT is a valuable procedure for these patients to allow safe teeth movement when maximizing the amount of skel-

etal expansion. Therefore, to achieve maximum benefit from DOME surgery, SFOT can be planned concurrently for the mandibular arch. SFOT can also be performed with DOME on the maxillary arch, which can facilitate teeth movement, repair preexisting alveolar dehiscences over root prominences, and reduce the likelihood of new dehiscence formation [31]. Ensuring adequate bone support for the roots of all dentition will allow long-term stability for the expanded airway [32].

References

- Guilleminault C, Partinen M, Hollman K, Powell N, Stoohs R. Familial aggregates in obstructive sleep apnea syndrome. *Chest*. 1995;107(6):1545–51.
- Johal A, Conaghan C. Maxillary morphology in obstructive sleep apnea: a cephalometric and model study. *Angle Orthod*. 2004;74(5):648–56.
- Zambon CE, Cecchetti MM, Utumi ER, et al. Orthodontic measurements and nasal respiratory function after surgically assisted rapid maxillary expansion: an acoustic rhinometry and rhinomanometry study. *Int J Oral Maxillofac Surg*. 2012;41(9):1120–6.
- Cistulli PA, Richards GN, Palmisano RG, Unger G, Berthon-Jones M, Sullivan CE. Influence of maxillary constriction on nasal resistance and sleep apnea severity in patients with Marfan's syndrome. *Chest*. 1996;110(5):1184–8.
- Williams R, Patel V, Chen Y-F, et al. The upper airway nasal complex: structural contribution to persistent nasal obstruction. *Otolaryngol Head Neck Surg*. 2019;161(1):171–7.
- Gray LP. Results of 310 cases of rapid maxillary expansion selected for medical reasons. *J Laryngol Otol*. 1975;89(6):601–14.
- Persson M, Thilander B. Palatal suture closure in man from 15 to 35 years of age. *Am J Orthod*. 1977;72(1):42–52.
- Melsen B. Palatal growth studied on human autopsy material. A histologic microradiographic study. *Am J Orthod*. 1975;68(1):42–54.
- Cistulli PA, Palmisano RG, Poole MD. Treatment of obstructive sleep apnea syndrome by rapid maxillary expansion. *Sleep*. 1998;21(8):831–5.
- Pirelli P, Saponara M, Guilleminault C. Rapid maxillary expansion (Rme) for pediatric obstructive sleep apnea: a 12-year follow-up. *Sleep Med*. 2015;16(8):933–5.
- Villa MP, Rizzoli A, Miano S, Malagola C. Efficacy of rapid maxillary expansion in children with obstructive sleep apnea syndrome: 36 months of follow-up. *Sleep Breath*. 2011;15(2):179–84.
- Agarwal A, Mathur R. Maxillary expansion. *Int J Clin Pediatr Dent*. 2010;3(3):139–46.
- Krebs A. Midpalatal suture expansion studies by the implant method over a seven-year period. *Rep Congr Eur Orthod Soc*. 1964;40:131–42.
- Inoue N, Oyama K, Ishiguro K, Azuma M, Ozaki T. Radiographic observation of rapid expansion of human maxilla. *Bull Tokyo Med Dent Univ*. 1970;17(3):249–61.
- Bishara SE, Staley RN. Maxillary expansion: clinical implications. *Am J Orthod Dentofac Orthop*. 1987;91(1):3–14.
- Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *Angle Orthod*. 1961;31(2):73–90.

17. Lee SC, Park JH, Bayome M, Kim KB, Araujo EA, Kook Y-A. Effect of bone-borne rapid maxillary expanders with and without surgical assistance on the craniofacial structures using finite element analysis. *Am J Orthod Dentofac Orthop.* 2014;145(5):638–48.
18. Landes CA, Laudemann K, Schübel F, et al. Comparison of tooth- and bone-borne devices in surgically assisted rapid maxillary expansion by three-dimensional computed tomography monitoring: transverse dental and skeletal maxillary expansion, segmental inclination, dental tipping, and vestibular bone resorption. *J Craniofac Surg.* 2009;20(4):1132–41.
19. Mosleh MI, Kaddah MA, Abd ElSayed FA, ElSayed HS. Comparison of transverse changes during maxillary expansion with 4-point bone-borne and tooth-borne maxillary expanders. *Am J Orthod Dentofac Orthop.* 2015;148(4):599–607.
20. Deeb W, Hansen L, Hotan T, Hietschold V, Harzer W, Tausche E. Changes in nasal volume after surgically assisted bone-borne rapid maxillary expansion. *Am J Orthod Dentofac Orthop.* 2010;137(6):782–9.
21. Bazargani F, Magnuson A, Ludwig B. Effects on nasal airflow and resistance using two different RME appliances: a randomized controlled trial. *Eur J Orthod.* 2018;40(3):281–4.
22. de Oliveira CB, Ayub P, Ledra IM, et al. Microimplant assisted rapid palatal expansion vs surgically assisted rapid palatal expansion for maxillary transverse discrepancy treatment. *Am J Orthod Dentofac Orthop.* 2021;159(6):733–42.
23. Suri L, Taneja P. Surgically assisted rapid palatal expansion: a literature review. *Am J Orthod Dentofac Orthop.* 2008;133(2):290–302.
24. Yoon AJ-S, Liu SY-C, Guilleminault C. Miniscrew-assisted maxillary expansion techniques for treatment of obstructive sleep apnea. In: Kim KB, Movahed R, Malhotra RK, Stanley JJ, editors. *Management of obstructive sleep apnea: an evidence-based, multidisciplinary textbook.* Cham: Springer; 2021. p. 293–304.
25. Zong C, Tang B, Hua F, He H, Ngan P. Skeletal and dentoalveolar changes in the transverse dimension using microimplant-assisted rapid palatal expansion (MARPE) appliances. *Semin Orthod.* 2019;25(1):46–59.
26. Goldenberg DC, Alonso N, Goldenberg FC, et al. Using computed tomography to evaluate maxillary changes after surgically assisted rapid palatal expansion. *J Craniofac Surg.* 2007;18(2):302–11.
27. Liu, S. Y. C., Guilleminault, C., & Yoon, A. J. S. (2019). Distraction osteogenesis maxillary expansion (DOME) for adult obstructive sleep apnea patients. In: *Sleep apnea and snoring: surgical and non-surgical therapy.* Amsterdam: Elsevier; 2019. p. 344–7.
28. Yoon A, Guilleminault C, Zaghi S, Liu SY-C. Distraction osteogenesis maxillary expansion (Dome) for adult obstructive sleep apnea patients with narrow maxilla and nasal floor. *Sleep Med.* 2020;65:172–6.
29. Ferris BG, Mead J, Opie LH. Partitioning of respiratory flow resistance in man. *J Appl Physiol.* 1964;19:653–8.
30. Abdelwahab M, Patel PN. Conventional resection versus preservation of the nasal dorsum and ligaments: an anatomic perspective and review of the literature. *Facial Plast Surg Clin North Am.* 2021;29(1):15–28.
31. Amit G, JPS K, Pankaj B, Suchinder S, Parul B. Periodontally accelerated osteogenic orthodontics (Paoo) - a review. *J Clin Exp Dent.* 2012;4(5):e292–6.
32. Mandelaris GA, Huang I, Relle R, Vence BS, DeGroot BS. Surgically facilitated orthodontic therapy (Sfot): diagnosis and indications in interdisciplinary dentofacial therapy involving tooth movement. *Clin Adv Periodontics.* 2020;10(4):204–12.