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Sleep Apnea Treatment with Rapid Maxillary Expansion in Adults and Children - Review of Literature

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Abstract

Sleep apnea treatment with rapid maxillary expansion in adults and children take different approaches to achieve positive outcomes. Obstructive sleep apnea (OSA) is one of the six sleep-related disorders classified in the ICSD-3 by the American Academy of Sleep Medicine (AASM). Its prevalence has been on a steady increase in the past decade, making it a key health concern in a global scale. China, the United States, and Brazil are among the countries with the highest number of people suffering from OSA. There are numerous treatment options for OSA, with CPAP being the preferred option. However, some patients have tolerability issues with CPAP, which reduces its efficacy in correcting OSA hence the need to use alternative treatment methods that use oral appliances, such as Mini-Implant Assisted Rapid Palatal Expansion (MARPE) and mandibular advancement device (MAD), which have gained widespread popularity. MARPE, facilitated with mid-palatal suture cardiopuncture, provides the most effective bone-anchored procedure for lateral osteotomy in the maxillary expansion, and the procedure effectual in adults than other RPE options, such as the tooth-borne in children. Because the narrow maxilla blocks facial development, promote nasal obstruction, nasopharyngeal airways collapse and leads to crowding of teeth because of limited space, MARPE is preferred in young adult with fused suture. The periodontal and oral nature of the treatment options makes the inclusion of dentists in the OSA treatment plans critical.

Keywords: *Obstructive Sleep Apnea (OSA), Dental Sleep Medicine, Obstructive Apneas, Repetitive Hypopneas, Sleep-Disordered Breathing, MARPE, And CPAP*

Abbreviations

MARPE: Mini-Implant Assisted Rapid Palatal Expansion; ICSD-3: International Classification of Sleep Disorders Third Edition; DSM: Dental Sleep Medicine; MAD: Mandibular Advancement Device; CPAP: Continuous Positive Air Pressure; BPAP: Bilevel positive airway pressure; APAP: Automatic Positive Airway Pressure; nEPAP: Nasal Expiratory Positive Airway Pressure; PSG: Polysomnogram; OSA: Obstructive Sleep Apnea; AASM: American Academy of Sleep Medicine; SRBD: Sleep Related Breathing Disorders; BMI: Body Mass Index; ATS: American Thoracic Society; SDB: Sleep-Disordered Breathing; TRD: Tongue Retaining Devices; RPE: Rapid Palatal Expansion

Introduction

The American Academy of Sleep Medicine (AASM) classifies Sleep Related Breathing Disorders (SRBD's) among the six-known sleep disorders recognized in the third edition of International Classification of Sleep Disorders (ICSD-3). In a policy statement concerning the

management of SRBDs, Addy., *et al.* reckon that "sleep-related breathing disorders impact a significant portion of the population, estimating that 23.5 million of United States adults have undiagnosed or untreated OSA-costing billions [2,34]. The condition has increased the risk of health complications, such as hypertension, congestive heart failure, atrial fibrillation, coronary artery disease, stroke, and type 2 diabetes, consequently reducing the quality of life for a significant portion of the population" [2]. Sateia asserts that there are five other sleep related disorders in the ICSD-3 namely insomnia, central disorder of hypersomnolence, parasomnias, rhythm sleep wake disorders, and circadian sleep related movement disorders [44]. SRBD's are classified into four sections namely, central sleep apnea syndromes, OSA, sleep-related hypoxemia, and sleep-related hypoventilation disorders. Frequent collapse or narrowing of the pharyngeal airways during sleep causes OSA.

The clinical diagnosis of OSA subtly differs in pediatric and adult diagnosis. The criterion for adult diagnosis requires either symptoms/signs or associated psychiatric or medical disorders, which combines with five or more critical respiratory events for every hour of sleep during polysomnogram (PSG) [13,44]. The symptoms might include fatigue, snoring, and associated sleepiness, insomnia, observed apnea or subjective nocturnal respiratory disturbance. The psychiatric or medical disorders associated with OSA might include coronary artery disease, hypertension, congestive heart failure, atrial fibrillation, mood disorders, diabetes, or cognitive dysfunction.

In contrast, ICSD-3 simplifies the diagnosis criterion for pediatric OSA. For instance, it requires the presence of a single symptom unlike the multiple ones required for an adult diagnosis. Similarly, one obstructive event is enough for a PSG criterion for diagnosis. Numerous researches have studied the disease burden and prevalence of OSA globally. In a literature-based study examining the worldwide prevalence and burden of OSA, Benjafield., *et al.* assert that an estimated 1 billion adults from the ages of 30 to 69 suffer from OSA [5]. However, the scholars trim down the figures to 425 million as those experiencing moderate to severe OSA and who deserve treatment, with China recording the highest number of affected individuals ahead of the United States, Brazil, and India respectively. The cost of diagnosis and treatment of OSA in the USA in 2015 was US $12.4 billion [5]. Due to its socio-economic impacts, OSA is gaining scholarly attention.

Appropriate headings

Discussions

1. Pathophysiology
2. Screening and Physical Examination
3. Treatment Options for OSA
    - Positive Airway Pressure.
    - Oral Appliances.
    - Mandibular Advancement Device (MAD).
    - Mini-Implant Assisted Rapid Palatal Expansion (MARPE).
4. Other Treatment Options for OSA (Positional Therapy, Pharmacologic Treatment, and nEPAP)
5. OSA Implications on Dental Medicine

6. Sleep Apnea Treatment with Rapid Maxillary Expansion in Adults and Children

    - Rapid Palatal Expansion or Rapid Maxillary Expansionin Children
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    - Rapid Maxillary Expansion in Adults
    - Miniscrew-Assisted Rapid Palatal Expansion (MARPE)
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    - Tongue Retaining Devices (TRD).
    - Maxillomandibular Advancement and Hypoglossal Nerve Stimulation
    - Hyoid Suspension/Hyoid Sling Procedure
    - Tongue Reduction Procedures
    - Combination of CPAP and Appliances
    - Surgically Assisted Rapid Palatal Expansion (SARPE) Compared to MARPE

Conclusion

Discussions

Pathophysiology

In a study exploring the high prevalence of sleep-disordered breathing in adults, Peppard., *et al.* note that the apnea and hypopnea incidences of sleep-disordered breathing-(SDB) have considerable harmful health implications, with instantaneous effects encompassing "intermittent hypoxia, fragmented sleep, and exaggerated fluctuations in heart rhythm, blood pressure, and intrathoracic pressure" [2,40]. Recurrent collapse or obstruction of the pharyngeal airways when one sleeps, leading to a reduction (hypopnea) or ultimate cessation (apnea) of airflow in spite of the continuing breathing efforts, causes OSA. Some of its manifestations include cyclic apneas, hypoventilation, and repetitive hypopneas. The upper airway is adapted to performing various functions, such as swallowing, speech, and air passage for breathing due to its anatomical soft tissues, muscles, and bony/rigid support [16]. The airway contains collapsible portions whose frequency and timing of collapse causes OSA. For instance, its portion between the hard palate and the larynx is collapsible, making it susceptible to collapse during inopportune moments, such as during sleep.

Patients vulnerable to OSA have narrow airways with higher chances of collapse. For example, the tongue, jaws, as well as the throat relax during sleep, which narrows the airway and leads to snoring. However, a complete blockage of the airway during sleep denies the brain of oxygen triggering the fight or flight mode in the brain that compels the person to wake up and breathe again. The actions could happen multiple times a night for people with OSA, making it a clinical condition that requires diagnosis and treatment [21,39]. OSA is

clinically viewed as an absolute malfunction of airway anatomy resulting in sleep difficulties, snoring, insomnia, associated sleepiness, or subjective nocturnal respiratory disturbance. Physiologically, the upper airway anatomy and collapsibility are the most critical trait in developing OSA, where the critical passive airway closing pressure-(Pcrit) quantifies the tendency to airway collapsibility. Thus, the physiological traits contributing to the development of OSA should be researched extensively.

Screening and physical examination

Dentists can screen OSA through medical techniques and general examination processes for anatomical abnormalities. Earlier screening helps in establishing a patient's daytime and nocturnal OSA signs/symptoms, such as snoring, sleeping, as well as gasping to ascertain the presence of SRBD. In addition, other popular screening questionnaires, such as "STOP-BANG, Berlin, and Epworth Sleepiness Scale (ESS), have acquired worldwide usage" [52]. The subjective items include "tiredness, snoring, high blood pressure, and observed apnea whereas the demographic items include age, gender, neck circumference, and body mass index (BMI)" [56]. A "Yes" answer to atleast three of the items indicates a high risk for OSA. The scholars also simplified how the Berlin Questionnaire (BG) works. BQ consists of three sections on snoring, sleepiness, and daytime fatigue, and finally anthropometric measures and medical history, such as BMI and hypertension. A score of two or more in the three categories indicates high risk for OSA.Unlike the BQ, the ESS has eight items to assess daytime sleepiness. It uses a four-point Likert response format with a score ranging from zero to 24 [30]. A score of 11 or more indicates a high affinity for daytime sleepiness hence high likelihood for OSA. Even though these questionnaires are critical in examining OSA, there should not completely replace the need for an objective OSA test since they only help highlight those at risk of the disorder [49]. In OSA, a positive airway pressure is used to phenotype patients' pathophysiologic traits (PTs); the patient should be in a supine position as well as the stage-2 non-rapid eye movement sleep (NREM). Thus, the patient's daytime and nocturnal symptoms, such as snoring, disturbed sleeping, or gasping, can unveil the likelihood of OSA.

In a study investigating the screening, treatment, as well as management of patients with SRBDs, Levine., *et al.* note that a physical examination by a qualified dentist is vital in accurate diagnosis of OSA at the preliminary stages. In the process, a dentist records vital signs indicating the condition, such as neck perimeter, BMI, as well as blood pressure levels [30]. Thorough and systemic physical examination, with descriptive assessments and visual presentation of craniofacial complexes in the posterior airways and pharyngeal wall, is recommended. Besides, dentists are expected to assess major structures, such as uvula, palatine tonsils, and soft palate, to ascertain the level of infection. In the same way, the nose of the patient should be closely checked for any form of deviation, obstruction incidence, and/or valvular collapse. Observation of any patency with the pharyngeal and nasal airways calls for immediate referral to the ENT clinic [32]. The authors further offer critical insights critical in the examination that hold clues to a possibility of OSA. For example, assessment of the occlusal positioning as well as the size of the tongue size substantially indicates oropharyngeal crowding. The surface texture, shape, color, and tonicity of the tongue also offer valuable clues.

In addition, soft and hard tissues of the oral cavity should be examined. The area consists of the teeth, the hard palate tissues, gingiva, alveolar processes, as well as frenal attachments. The dentist should identify the location as well as the teeth numbers besides their morphological integrity to determine the patient's standing to oral appliances [24]. A periodontal examination can guide dentists in the selection of appropriate appliance. Similarly, some dentists use radiographic imaging foe oral appliance therapy candidacy, often to assess the level of damage to the soft tissue and skeletal presentations. Levine., *et al.* takes note of the close association of the SRBDs and temporomandibular disorders [30]. Therefore, it is critical for the dentists to focus temporomandibular joint section that includes the temporalis, masseter, associated superficial muscles, and sternocleidomastoid muscles. The examination also focuses on the protrusive areas, lateral deviations, and anomalous movements.

A comprehensive dental assessment would encompass angle classification, overjet and overbite, and recording any figures, structures or occurrences that deviate from the norm. There should also be documentation of crossbites, midlines, crowding and intra-arch spacing, and interproximal and occlusal contacts for reference. When anticipating the use of use of OA, dentists should acquire extraoral and intra-oral photographs to justify the pre-management dental condition [30]. A fulfillment of all these mentioned tests and examinations should provide the necessary information concerning the presence of OSA and the most favorable treatment option.

Treatment options for OSA

According to Levine., *et al.* Continuous positive airway pressure (CPAP) remain the immediate or the first-line treatment for many OSA patients, although the long-term compliance with CPAP therapy is often a challenge [30]. The choice for treatment depends on various factors, such as the patient's tolerability of the treatment option, their age, ease or comfort of using the appliance, and state of health among other reasons. Some other treatment options include "positional therapy, nasal expiratory positive airway pressure (nEPAP), oral pressure therapy, oral appliances, hypoglossal nerve stimulation, surgeries, pharmacologic treatments, and weight loss and exercise" [1]. Some treatment options, such as the oral appliances like mandibular advancement device, provide a perfect alternative for patients who are non-tolerant to CPAP, BPAP and APAP. Thus, the treatment of OSA should be anchored on the screening results and other physiological factors differing from one patient to the next.

Positive airway pressure

According to the American Thoracic Society (ATS), PAP refers to the continuous positive airway pressure and includes numerous strategies [4]. The organization lists various types of positive airway pressure, such as continuous positive air pressure (CPAP), automatic positive airway pressure, and the Bilevel positive airway pressure (BPAP). The machines/treatment option uses air pressure to open and ventilate the upper airways during sleep. The unhindered breathing due to the open upper airway facilitates free movement of air into the lungs preventing snoring or constantly waking up at night due to obstruction of the airway. According to Calik (in a study exploring the treatment options for obstructive sleep apnea), CPAP is the "is the current gold standard treatment for OSA, as it pneumatically stabilizes the upper airway" [10]. CPAP treatment involves the use of a mask covering the patient's nose and mouth and providing pressured air to keep the upper airway open during sleep facilitating an uninterrupted sleep. The machine does not breathe for the patient but instead facilitates breathing by opening up the airway while the patient independently inhales and exhales [10,42] Thus, the positive airway pressure facilitates free movement of air into the lungs preventing snoring or constantly waking up at night due to obstruction.

Even though CPAP, BPAP, and APAP operate in a more or less similar manner, there are slight variations in their operations. The APAP machines send air through a thin tubular passage mounted in a patient's nose and mouth during sleep. However, unlike CPAP that facilitates ventilation by opening the airway using thoracic and alveolar pressure, the BPAP machine delivers "an exhalation (Exhalation positive airway pressure or EPAP) and inhalation pressure (Inhalation positive airway pressure or IPAP)" [10]. In addition, the BPAP machine monitors the patient's effort during exhalation and inhalation and delivers/induces breathing if the patient fails to breathe for a set/programmed period. The programmed timing for breathing acts as a 'back-up rate" that monitors adherence to the recommended breathes per minute (BPM). The recommendation for a CPAP or BPAP machine by the physician or dentists depends on various factors due to the difference in how they operate [9]. For instance, CPAP is often the most recommended for OSA whereas BPAP is best suited to correct COPD, complex sleep apnea and central sleep apnea [13,45]. BPAP helps reduce the expiration strain that is often associated with CPAP and which makes it intolerable for some patient [4]. Another form of PAP treatment is the automatic positive airway pressure (APAP). According to Calik, APAP consists of software that automatically regulates the amount of air the patient breathes during sleep based on need [10]. The machine automatically raises the air pressure if it detects a slight narrowing of the airway during sleep to ensure it remains open and does not hinder breathing.

Oral appliances

Oral appliances function to prevent collapse of the upper airway through various strategies, such as raising the soft palate to facilitate increased airflow, advancing the mandible or stabilizing the tongue. All these strategies facilitate free flow of air by ensuring the airways remain open; the mandible advancement helps alleviate OSA. Sutherland., *et al.* asserts that the use of oral appliances is the second most widespread treatment option for OSA after CPAP [47]. The author notes that "oral appliances cover the lower and upper dental arches and have a configuration that ensures the lower jaw is held forward in a more protruded position" [47]. She further admits that the action of advancing the mandible reduces the likelihood of airway collapsibility and increases the pharyngeal airway space. The efficacy and success of oral appliances vary among individuals. However, it remains the best alternative for people with tolerability issues for CPAP [4]. Various factors contribute to the variations in success of oral appliances, such as differences in treatment protocols and devices, obesity, and upper airway and craniofacial features of the patient. Examples of an oral appliance in widespread use include the mandibular advancement device (MAD), mandibular repositioning appliances, mandibular advancement splints, and tongue retaining devices.

Mandibular advancement device (MAD)

The two versions of MAD namely adjustable advancement and fixed advancement are popular in the management of OSA by ensuring the upper airways remain open during sleep. MAD conducts an inferior and anterior jaw movement producing anatomical variations in the upper airways creating more space in the pharyngeal area. The movement fixes, aligns, and stabilizes the hyoid bone and the jaw securing these structures from poster rotation during decubitus hence prevent airway blockage [28]. The device functions by ventrally displacing the soft palate increasing the capacity of the lateral walls within the velopharyngeal area to drastically reduce or eliminate snoring. MAD's trigger changes in the pharyngeal pressure that enables normalization of the physiological properties of the upper airways. The change in anatomical relationship (mandibular advancement and rotation) triggers a neurosensorial stimulation increase that in turn reduces the collapsibility likelihood by increasing the motor muscular tone. The positional change of the hyoid bone that pushes it forward alters the suprahyoid musculature that facilitates an increase in permeability and volume of the upper airway. The treatment has a 90% to 100% success rate among patients with OSA particularly in reducing or eliminating snoring [54]. However, MAD is not effective among some patients such as those with scarce mandibular advancement/deficient protrusive, those with periodontal or dental problems, and those with temporomandibular disorders.

Mini-implant assisted rapid palatal expansion (MARPE)

It is often called the Mini-screw assisted rapid palatal expansion, which is a non-extraction and non-surgical treatment option for OSA that expands the upper jaw called the maxilla. The size of the maxilla directly affects the airflow. For instance, a narrow maxilla hinders facial development, causes nasal obstruction, and leads to crowded teeth due to the limited space. MARPE is most effective among young people whose suture is fused. It includes a deliberate effort to expand the maxillary bone and create more room to allow for free flow of air during inhalation and exhalation by increasing the volume of the oral and nasal cavity [6]. The process includes the placement of a custom-designed maxillary expander with mini-screws within the mid-palatal suture. Due to the use of the expander for a period ranging four to six months during which the new bone forms, the suture often splits creating a gap between the front teeth. The dentists can help close the gap and guarantee a stable bite through orthodontic treatment [30]. MARPE is an effective non-surgical treatment option for OSA particularly for youths due to its simple maxillary bone expansion.

Oral pressure therapy

According to Calik, oral therapy pressure includes the application of negative pressure on the upper airway to prevent retro-palatal collapse [10]. The therapy involves the use of the oral pressure therapy device to apply gentle suction superiorly and anteriorly to displace

the soft palate and the tongue and facilitate breathing using the nasopharyngeal airway. OPT has a 25% to 37% success rate, which is low compared to other available treatment options for OSA. The low success rate is due to the therapy's focus on pressure application on the upper airway to prevent retro-palatal collapse with zero focus on the collapse of other levels [28]. The therapy helps marginally; reduces the AHI but fails to make a considerable impact due to the relatively high AHI arising from the collapse in other levels and positional apneas. Oral tissue irritation, dry mouth, and dental discomfort constitute the therapy's side effects.

Other treatment options for osa (positional therapy, pharmacologic treatment, and nEPAP)

Even though qualified dentists can conduct various OSA treatment options on patients such as CPAP, oral appliances such as MAD, MARPE, and oral pressure therapy, there are numerous other treatment options for the condition. CPAP is an effective treatment for OSA. A general physician conducts the remaining alternative treatment options for OSA, such as positional therapy, pharmacologic treatment, nEPAP, hypoglossal nerve stimulation, and weight loss. These alternatives seldom require dental or periodontal services hence the need for a general physician either alone or in collaboration with a dentists [30]. Scholars assert that a person's sleeping position could contribute to OSA hence the recommendation for positional therapy.

Lying in the supine position has numerous disadvantages that make an individual susceptible to OSA. Sleeping in the supine position increases the patient's apnea-hypopnea index (AHI) compared to when one is the lateral position. Studies indicate that an estimated 60% of OSA patients typically sleep in the supine position, making it a key contributory factor [17,28]. Calik further asserts that "a drug-induced sleep endoscopy research demonstrated that the upper airway collapses at multiple levels when in the supine position as opposed to a single level sleeping in the lateral position" [10]. Therefore, it is recommended that OSA patients sleep in the lateral position as opposed to the supine position to lower the likelihood of airway collapse and increase passive airway anatomy. Positional therapy includes the use of a device worn by the patient during sleep and which notifies the patient when they slip into supine position so that they maintain sleep in the lateral position hence considerably decrease AHI [19]. Even though compliance to the therapy is relatively low among most people, it is a good alternative for patients who are intolerant to the use CPAP.

nEPAP is also treatment option for OSA that includes attaching a single-use device to the nostril using an adhesive thereby resulting in an airtight seal. The mechanical valve contained in the device results in a high resistance during expiration as opposed to during inspiration. nEPAP focus on the expiration; prevents upper airway collapse often happens at the end of the respiratory phase due to phasic activation or lack of positive pressure in the upper airway. Calik summarizes the pharmacologic treatment options for OSA. He classifies the drugs according to their role in alleviating OSA. For instance, acetazolamide, progestogens, and theophylline help alleviate OSA by increasing the ventilatory drive while cholinergic and serotonergic drugs expand the upper airways tone [10]. The treatment option for OSA should be pegged on a patient's physiological and pharmacological features.

OSA implications on dental medicine

Contemporary researches about the OSA pathophysiology unveil new ideas about the heterogeneity of the disease. For instance, recent studies on OSA's phenotyping have pathophysiological frameworks discerning the disease at the patient level. It has also exposed the critical role of qualified dentists and physicians in the screening, diagnosis, examination, and treatment of OSA. Dental sleep medicine is an area that requires collaboration between physicians and dentists due to its overlapping nature and numerous treatment options that range from oral appliances, invasive and non-invasive machines like CPAP, pharmacologic treatment, surgeries, and numerous other therapies like positional therapy [29].

The American Academy of Dental Sleep Medicine and European Respiratory Society underscores the need for collaboration between physicians and qualified dentists in the diagnosis and treatment of DSM. They assert that the training of dentists to practice DSM helps re-

duce the public health burden of SRBD. The academy proposes the use of questionnaires like the STOP-BANG, Berlin and Epworth Sleepiness Scale designed to collect critical information from the patient that helps the dentists determine the risk, presence, or absence of OSA. The inclusion of dentists in DSM arises from the nature and treatment options for OSA, most of which extensively involve the periodontal and oral cavity. The dental/periodontal nature of these treatment options underscore the importance of incorporating dentists to collaborate with physicians in the diagnosis and treatment of OSA. For instance, MARPE and MAD involve the placement of an oral appliance in the mouth. The placement of such appliances should be done by a dentist since that is their area of expertise hence understands it better than general physicians [25]. Some of the oral appliances, such as MARPE, distort the arrangement of the teeth by creating a gap between the two front teeth as the bone expands. Dentists should close the gap through orthodontic treatment.

Sleep apnea treatment with rapid maxillary expansion in adults and children

Brunetto., *et al.* describes OSA as the total or partial blockage of the upper airways and the resultant effect on airflow, leading to oxygen desaturations and sleep disturbance. The prevalence of the condition is increasingly high due to the limited focus placed on it by patients [6]. In most cases, patients suffering from the disorder may be unaware hence it takes a third party, such as a partner or roommate, to detect particularly when it results in snoring. Medical researchers have devised numerous correctional measures for OSA, including pharmacologic, surgical operations, use of oral appliances, treatments involving positive airway pressure, and therapies. The choice of the treatment option to apply relies on many factors, such as the cause OSA, patient's age, and the severity of the condition. Continuous positive airway pressure is generally regarded as the gold-standard treatment due to its high efficacy and success levels hence account for the most OSA treatment [31]. However, other treatment options are gradually gaining prominence particularly among people with tolerability issues toward positive airway pressure treatment options, such as bi-level positive airway pressure (BPAP), continuous positive airway pressure (CPAP), and automatic positive airway pressure (APAP).

Pirelli., *et al*. establishes a connection between malocclusions and maxillofacial deformities to OSA. An examination of OSA patients exposes that a majority suffer from craniofacial malformations involving both the maxilla and mandible and affecting the skeletal structure by limiting the respiratory dynamic space [41]. Infant examination during routine checks may expose these aberrations early enough for timely interventions. These maxillomandibular malformations/discrepancies lead to major malocclusions that may adversely affect airflow and breathing of the individual. The malformations reduce the space for airflow affecting nasal breathing. The effect may lead to OSA depending on the degree of the malformation and severity of its effect on nasal breathing and airflow [9]. In such cases, CPAP may be ineffective without correcting the origin of the problem sitting in the nasal septal deviation hence the need to perform a maxillary expansion as the permanent solution to the problem. There are numerous maxillary expansion options for correcting the malformations and by extension the resultant OSA. They include surgical-aided expansion, slow expansion, and rapid expansion.

Rapid palatal expansion or rapid maxillary expansionin children

Rapid Maxillary Expansion (RME) involves the deliberate expansion of the palate to ensure increased free airflow and breathing through the upper airways. It is a dentofacial procedure that involves the stretching of the mid-palatal suture resulting in the pushing of the maxillary shelves in opposite directions creating more room by expanding the hard palate. The procedure involves the use of an appliance containing an expansion screw fixed on chosen/designated teeth. The central expansion screw contains four arms for attachment to teeth and has a 1.5 millimeter diameter. The procedure involves the use of a heavy force estimated at 1kg applied on the anchor teeth resulting in an expansion of the palatal suture. The expansion results from the trans palatal force surpassing the physiologic level hence gradually opening the mid-palatal suture [41]. The aim of the RME is the increase of the hard palate's transversal diameter to create more room in the maxillomandibular area hence facilitating free airflow. There are numerous specifications for the appliance and the procedure that increases its efficacy. For instance, it ensures that the device is not too big or heavy to trigger issues of intolerability from the patients.

The dentists should fix the expansion screw up the palate to ensure it applies enough pressure/force enough to increase mid-palatal suture, widening the transversal diameter.

The anchor teeth hold the expansion screw into place. These teeth are not definite hence depend on the developmental phase of the patient's teeth. For instance, the dentist selects the permanent premolars and the first molar as anchor teeth in children that are a little older unlike in toddlers [41]. Dentists also always prefer the use of the second molars in patients with deciduous teeth due to the need for stability. The device applies force on the anchor teeth after the turning of the central screw hence separating the palatal suture. In rapid maxillary expansion, day one may include up to six activations within an interlude of ten-minutes each with three performed in the morning and the other three in the evening. A single activation in the morning and evening is recommended from the second day onwards often performed by the caregiver in children. Therefore, there is pressure and gradual expansion of the palatal suture in each activation.

In addition, an intraoral occlusal radiograph can be performed before the beginning of the activations and another three days or more after beginning the RME to help track the changes in the midpalatal suture and ensure safety of the expansion process. The choice of the best diagnostic radiograph to use depends on the intended use or area of focus. The most common types include periapical, cephalometric and panoramic radiographs. Periapical radiograph uses miniature film cards placed in the mouth and provides clear images of the teeth. The timeframe for an RME is not definite as it depends on the narrowness of the patient's maxilla besides other personal needs. Therefore, the period for active expansion may take a minimum ten days to a maximum twenty with a 1mm expansion target daily. There are a further six to twelve months after the end of the expansion phase when the device is kept in place to facilitate permanent adjustment of the craniofacial structure after the RME. A panoramic x-ray provides images of the jaws and the position of the teeth and is wrapped around the mouth. In contrast, the cephalometric x-ray provides images of the craniofacial complex including the facial bone and the cranium. It is best suited in the diagnosis of bite challenges or misalignment of the jaw [54]. The dentists would choose the most befitting intraoral occlusal radiograph to use based on the patient's condition and severity of the problem.

There are numerous important factors to consider before expansion as they determine the mode of expansion to use and the efficacy and success of the chosen method. The first consideration before expansion should be on the expansion rate since it helps determine the choice of slow or rapid expansion. Each of the two modes has their advantages and disadvantages hence the dentists choice relies on the patient's situation. Secondly, the sex and age of the patient is also a critical determinant in expansion. According to Kumar., *et al*., the facial skeletal becomes more rigid as one advance in age limiting bony movements particularly those out of touch with the expansion device [27]. The rigidity of the bones as one advance in age also differs among the sexes hence the significance of gender and age before making expansion decisions. Thirdly, the degree of the mandibular and maxillary discrepancy particularly with those with a 4mm or more difference is also critical as it determines the time frame and rate of the expansion. A bigger difference may require a longer period and high target for daily expansion than a negligible or smaller difference [18,52]. Fourth, the extent of the cross bite depending on the number of teeth involved is also an indication of the severity of the malformation hence significant in determining the most effective expansion method and the duration and daily expansion target during RME. Thus, the mode of expansion and the efficacy and success of the chosen method in the treatment of OSA in children consider various critical factors in the quest to achieve expansion.

Scholars also assert the significance of conducting an evaluation of the roots of the deciduous tooth before expansion. The temporary nature of deciduous tooth complicates expansion in children since the anchor tooth has to be strong enough to sustain the continued pressure during the weeks of the RME. A tooth that is not well-anchored may adversely affect the expansion. Kumar., *et al.* also underscore the significance of examining the patient for nasal obstruction before embarking on the expansion. A patient experiencing nasal obstruction should first receive treatment from an otolaryngologist to ensure free nasal airflow before undergoing the orthodontic procedure [14]. The medical history of the patient is equally critical prior to the expansion due to the extensive effect of the expansion on the craniofacial

complex. The craniofacial structure flexibility and the suture patency determine the expansion since they are directly affected by the mechanical changes. The periodontal type relating to the gingiva tissue thickness or thinness is also crucial before expansion since it determines the stability of the gingiva following a recession resulting from inflammatory, traumatic or surgical injuries. Other factors worth noting prior to the expansion include metabolic disorders and mucogingival health, which are also critical determiners of the efficacy and success of the process.

There are numerous indications and contraindications for RME. Kumar., *et al.* explain that people with lateral discrepancies lading to bilateral or unilateral posterior crossbites affecting numerous teeth are potential RME candidates [27]. Anteroposterior discrepancy is one of the major reasons to consider a rapid maxillary expansion. There are numerous causes for posterior bite and maxillary making a patient a candidate for RME. These factors include Treacher Collins, crynosynostosis, cleft lip and palate, palatal inheritance and dimensions, nasal pyriform aperture stenosis, Duchenne muscular dystrophy, marfan syndrome, osteopatia striata and Klippel-Fell syndrome among others. Conversely, there are conditions that eliminate the use of RME as a treatment option in children with sleep apnea. "Patients with convex profiles, anterior open bites, and steep mandibular planes may not be RME potential beneficiaries due to their condition" [27]. RME also presents numerous risks to the patient such as tissue damage, suture's failure to open and a long length of fixation may lead to poor oral hygiene or potential bacterial infections presenting new problems other than what was diagnosed.

Types of RME

In a study comparing 3 types of Rapid Maxillary Expansion devices, Singaraju., *et al.* outlines three of them that are conventionally used in the Surgically Assisted Maxillary Expansion treatments [2,31,46]. They include the use of tooth-borne and tooth-tissue borne expanders. The two types all aim toward widening or expanding the mid-palatal suture by pilling pressure on the opposite sides of the maxilla to cause a lateral shift. However, the design of the two expanders differs despite aiming at achieving the same goal. The main difference between the tooth-tissue borne and the tooth borne appliances is that the former appliance contains an acrylic pad bilaterally covering the palatal mucosa. The Haas appliance is the most common tooth-tissue borne expander in most dental offices today [8]. There is an 11 mm screw holding the acrylic pads in place and which provide anchorage for the two plates. The difference between the two expanders lies in the point of exerting force during RME with the tooth-tissue borne applying force on both the palatal vault and posterior teeth. The tooth-borne expander applies pressure solely on the maxilla due to its teeth support without the palatal mucosa-resting acrylic pad that would otherwise distribute the force to the tissue and the teeth. Comparably, even though the tooth-borne expander lacks this acrylic plate's addition, studies show no significant difference in the efficacy and success of the two expanders in RME. Thus, the dentist performing the procedure can choose either of the two expanders based on the patient or dentist's preference.

In addition, the Haas type expander derived its name from the inventor (Andrew Haas) and has become so widely used that it now is synonymous with the tissue-borne expander. Its palatal acrylic is its unique feature that distinguishes it from the tooth-borne expander enabling distribution of the expansion force. Some dentists underscore its superiority over the tooth-borne expander by asserting the need to reduce dental tipping by applying all the force on the teeth, and instead facilitating more bodily movement through the distribution of the force on the dental and the tissue [28]. In contrast, the tooth-borne expander exerts force on the teeth and not tissue.

Hyrax expander sometimes called the Biedermann device is the most-used tooth-borne expander by most dentists. The appliance derives its name "Biedermann expander" from William Biedermann who invented it in 1968. It consists of a wire frame with a central screw called the Hyrax. The name Hyrax originates from the acronym "hygienic rapid expander" due to the expanders reputation as being more hygienic than the Haas-type expander because it lacks the palatal acrylic plates which often cause irritation. Consequently, some scholars call it the "hygienic appliance" in light of its hygienic reputation [43]. The manufacturers use stainless steel to make the Hyrax expander

contributing to its hygienic reputation. The advantages include being hygienic, providing greater comfort and being lesions-free due to the absence of the acrylic plates that often cause irritations and abrasions to the palatal mucosa. Some scholars divide tooth-borne appliances into bonded and banded.

The third type of RME is the bone-borne expanders. The type differs markedly from the HAAS-type expanders and the Hyrax expanders based on the point of applying the force during palatal expansion. Unlike the Haas appliances that apply force to the palatal mucosa tissue and the Hyrax that applies force on the teeth, the bone-borne applies force to the maxilla. Palatal distractors and miniscrew-assisted rapid palatal expansion are some of the known examples of bone-borne expanders. The bone-borne expanders have gained popularity particularly over tooth-borne expanders known to cause dental tipping. MARPE uses mini-screws to anchor to the maxilla (particularly the palatal vault area) hence avoid pilling force/pressure on the teeth as it happens in the tooth-borne expanders, eliminating dental tipping [11]. There are two major types of MARPE as well as the distraction osteogenesis maxillary expansion (DOME), which is widely unknown and the more MSE devise in the healthcare.

Rapid maxillary expansion in adults

Miniscrew-assisted rapid palatal expansion (MARPE)

In a study reviewing literatures on the Alternative Rapid Maxillary Expansion and Constriction (Alt-RAMEC) protocol and Maxillary skeletal expansion or MARPE as well as the differences amidst them, Al Kawari established that "MARPE is a valid substitute to surgery in patients with multifaceted craniofacial discrepancies, while securing the stability and safety of the transverse correction" [3]. To keep away from surgery to achieve both dentoalveolar as well as skeletal expansion for transverse corrections, a doctor can do nonsurgical maxillary developments. Notably, skeletal expansion rapidly decreases post-puberty exposing the patient to numerous side effects and complicating many RPE options. Some of the side effects associated with RME after puberty due to the decrease in skeletal expansion includes gingival recession, alveolar bone dehiscence, relapse, posterior teeth tipping/buccal crown tipping, root resorption, and marginal bone loss [21]. These adverse impacts complicate some RPE options particularly those that use the tooth-borne technology due to the increased risk of dental tipping.

Jia., *et al.* sets the age-limit for tooth-borne maxillary expansion at 15 years, claiming that using the RME treatment option on patients above this optimal age is very unpredictable and unstable [21]. The scholar also accord more credence to skeletal age over chronological age as a measure of skeletal maturity. The scholars explain that there is a steady increase in the interdigitation rate in the mid-palatal suture when observed using the skeletal maturity indicator (SMI). The SMI 8 seems to be the limit for maxillary expansion hence patients above this level, such as those in the SMI 9, which are post-pubertal experience challenges due to the rigidity of maxilla to further expansion. Park., *et al.* also concurs with the observation claiming that past histological researches have confirmed the obliteration and closure of mid-palatal suture after the juvenile stage [39,45]. However, unlike Jia., *et al.* who caps the optimal age at fifteen years, Park., *et al*. claims that the limit extends to the third decade of life from where it becomes extremely risky to conduct some types of RME on a patient.

The increased risk of rapid palatal expansion after the post-pubertal growth spurt motivated scholars to seek for alternative correctional measures suitable for adults. There was particularly need to avoid the tooth-borne expanders due to the many side effects associated with them in adults. Thus, bone-borne expanders and appliances, such as MARPE, gained prominence due to limited side effects when used in adults [48-50]. The procedure involves the orthopedic expansion particularly of the basal bone making it ideal for patients who are past the pubertal growing spurt. MARPE is non-surgical and is bone-anchored and not tooth or tissue anchored as noted in the tooth-borne and tooth-tissue borne expanders making it ideal or adult patients [39]. MARPE provides the most effective bone-anchored procedure for lateral osteotomy in the maxillary expansion. Studies have also credit MARPE as being more effective in adults than other

RPE options such as the tooth-borne in children.

MARPE includes the expansion of the maxilla using non-surgical means making it the gold-treatment for skeletal maxillary transverse deficiency. Transverse deficiency leads to many problems such as teeth crowding, excessive vertical alveolar growth, nasal obstruction and hindered facial development making it one of the major risk factors for obstructive sleep apnea (OSA) [58]. MARPE stands out as the best treatment option for adults since majority of the conventional rapid palatal expansion options suit children more than adults due to the fusion of the mid-palatal suture during puberty. According to Park., *et al.* MARPE increases the oral and nasal cavity through the expansion of the maxillary bone [39]. The increase of the maxillary bone creates more room for airflow particularly in the upper airway by providing more room for the forward and upward sitting of the tongue. The process includes the fixing of a custom-made maxillary expander on the mid-palatal suture using mini-screws hence the name mini-screw assisted RPE. Cunha., *et al.* assert that MARPE includes the use of four miniscrews strategically placed on the palatal vault depending on the nature and severity of the patent's transverse deficiency syndrome [12]. According to the authors, orthodontic miniscrews measure 1.8 mm in diameter and are 7mm and 8mm in length for posterior and anterior regions respectively. Thus, MARPE expansion employs maxilla expansion using non-surgical means for skeletal maxillary transverse deficiency cases.

The activation protocol during MARPE treatment is not definite or static but instead is dependent on the context of specific patient such as the severity of the crossbite. For instance, the activation protocol can be a 0.2 mm per day which is equivalent of a quarter turn for a period of at least 40 days besides the retention period that could also last an estimated three months [12]. Often, there is balancing of the four miniscrews. Two miniscrews are placed between the second and the first molar attached to the palate alveolar bone, while the remaining two placed between the first molars and the lower second premolars in the buccal alveolar bone. Balancing of the miniscrews should be such that two are on the left and two on the right side with the distance between increasing with every activation or quarter turn signifying maxillary expansion. A qualified dentist would take an estimated 20 - 30 minutes to perform the procedure under local anesthesia [49]. There is minimal pain post-procedure manageable by over-the-counter painkillers taken for a maximum two days. After the installation, the patient assumes the responsibility of the daily activation of the expander by adjusting the crew for a period lasting 4 - 6 weeks. Researchers confirm that the splitting of the suture is bound to create a gap between the front teeth. The gap should not worry the patients as it is evidence of the splitting of the palatal suture and of maxillary expansion hence should not be a point of concern with the treatment [3,49]. Orthodontic treatment often helps close the gap having achieved the desired maxillary expansion to enhance a stable bite even though the expander remains fixed for a couple months until the formation of a new bone at the suture.

MARPE holds numerous advantages over the conventional RPE techniques. First, it caters for a wider patient demographic than the other conventional RPE types. MARPE carters for patients of all ages and gender because it uses the bone-borne methods which is effective against the decrease in skeletal expansion and the increase in the interdigitation rate in the mid-palatal suture [57]. The decrease in skeletal growth and expansion exposes patients to several dangers in case of tooth-borne or tooth-tissue borne techniques in RPE. It also applies to children particularly those with deciduous teeth that may present anchoring challenge to the dentists in cases of tooth-borne expanders. Thus, MARPE has no age limit and applies in the palatal expansion for people of all ages including children, adolescents and adults [13,48]. Secondly, MARPE prevents dental tipping because it uses the palatal bone as the anchor unit unlike the tooth-borne expanders that use the teeth as the anchor units. Teeth are susceptible to tipping if used as anchor for expanders for a long time. Dental tipping arises from the direct force applied on the anchor teeth leading to an alteration of the axis of the tooth. However, MARPE applies the force directly to the mid-palatal suture hence leaves the teeth safe. Thirdly, studies show that MARPE is more effective in palatal expansion achieving greater success than the other conventional RPE techniques. It guarantees the greatest non-surgical expansion.

Comparatively, the mid-palatal suture has bone margins containing with substantial connective tissues stacked between their ana-

tomical structures to represent the "fusion of maxillary palatal procedures, palatal processes of the jaws, as well as the palatal bones' horizontal osseous laminae" [22]. Unfortunately, changing the structure can affect the neighboring areas. According to Suzuki., *et al.* in a study that exploring MARPE in pure orthopedic movement, "the midpalatal suture has got three segments that should be considered by all clinical analyses, whether therapeutic or experimental: *the anterior segment* (before the incisive foramen, or intermaxillary segment), *the middle segment* (from the incisive foramen to the suture transversal to the palatal bone) and *the posterior segment* (after the suture transversal to the palatal bone)" [48]. Often, patients at their last/final pubertal growth stage and those with maxillary limitations should go for RPE (Rapid Palatal Expansion), which is a non-surgical treatment solution. When it is integrated with rapid palatal expanders, the procedure can enhance skeletal effects in patients. Considering the availability of various designs of expansion appliances, MARPE can be modified to earn several operational merits and results in the overall clinical practice.

"Since the narrow maxilla hinders facial development, causes nasal obstruction, and leads to crowded teeth due to the limited space, MARPE is quite effective in young individuals with fused suture. The process incorporates efforts to expand the maxillary bone and create more room for free airflow during inhalation as well as exhalation by increasing the volume of the oral and nasal cavity" [6]. In the MARPE process, a custom-designed maxillary expander with mini-screws is to fasten the mid-palatal suture. In this regard, the use of expanders for a period ranging 4 - 6 months during which the new bone forms enables the splitting of the suture to create a gap between the front teeth. "The dentists can help close the gap and guarantee a stable bite through orthodontic treatment" [37]. Therefore, MARPE remains an effective non-surgical treatment option for OSA particularly for youths due to its simple maxillary bone expansion.

Corticopuncture therapy facilitated MARPE

Due to its 'bone-borne' technique that allow for fixing of the microimplants into the bones, MARPE has become a preferred expansion method in managing maxillary transverse deficiency and treatment for OSA. MARPE has had higher success rate than the other conventional palatal expansion techniques. In a study exploring the application of corticopuncture (CP) facilitated MARPE, Suzuki., *et al.* [50] assert that the success of maxillary expansion diminishes with age, resulting in less successful procedures in adults compared to children. The authors concluded that "the combination of MARPE and corticopuncture method is a critical non-surgical treatment option to correct maxillary transverse deficiency in an adult patient. CP is able to weaken suture interdigitation, thus facilitating the split" [49]. In another study investigating the age and sex factor in the success and effectiveness of MARPE, Jeon., *et al*. assert that the decrease in success rate of conventional palatal expansion procedures in adults results from the maturation of the circummaxillary and midpalatal sutures [20]. The interdigitation of craniofacial sutures and ossification occurs as people grow older, making it difficult for the mid-palatal sutures to expand. The challenge renders most of the palatal expansion techniques highly ineffective in mature as exemplified in numerous studies. Thus, MARPE is preferred in managing maxillary transverse deficiency and treatment for OSA. It has had higher success rate than the other conventional palatal expansion techniques due to its bone-borne technique that allowed for fixing of the microimplants into the bone instead of the tissue or teeth as used in the tissue-borne and tooth-borne techniques [13]. For instance, the tooth-borne technique transmits force on the teeth, which may lead to adverse dental impacts, such as bending of the alveolar bone and dental inclination. Therefore, the corticopuncture therapy facilitated MARPE is considered in the modern treatments to address OSA in severe cases in adults.

There are numerous other side effects of conventional rapid palatal expansion (RPE) techniques that have limited their use with adult patients in the recent past. Some of these limitations include tissue swelling, gingival retraction, relapse and root resorption [51]. Surgically-Assisted Rapid Palatal Expansion (SARPE), which is the separation of the basal bone from the structure of the skull became one of the treatment options that eliminate the limitations of the conventional RPE techniques. SARPE is very intrusive as it involves an extensive surgical procedure, which makes it highly risky. Thus, MARPE, which is less-intrusive even though it guarantees a lower success rate, is a better choice for palatal expansion in adults. However, the challenge of ossification and interdigitation of the craniofacial sutures

also affects MARPE even though to a less degree than the conventional RPE devices. The situation presents the need for corticopuncture therapy in conjunction with MARPE to improve its success rate.

MARPE technique with the use of mid palatal suture corticopuncture

Corticopuncture (CP), also called micro-perforation, has been a clinical practice intended to shorten the period for orthodontic treatment. The coupling of the therapy with MARPE was to help overcome the resistance from the mid-face region made up of the zygomatic buttresses, piriform aperture pillars, pterygoid junctions, and the midpalatal sutures [36]. These structures and surfaces harden due to interdigitation, making it difficult for palatal expansion hence the need for an alternative way to aid the split and guarantee expansion. The therapy includes numerous steps that culminate in increased likelihood for expansion using the MARPE appliance. Before the procedure, a dentist should determine the palatal suture maturation, bone density and anatomy, and other anatomical structures that would be affected by the corticopuncture. The dentist can achieve this using a cone-beam computed tomography (CBCT). Nojima., *et al*. asserts CBCT superiority over bidemnsional dental radiographs due to the accuracy of images, visualization of multiplanar sections in sagittal, coranal and axial features, and the lack of anatomical structures superimposition [37].

In the first step, the patient should be under local anesthesia. Bud., *et al.* recommends the use of Lidocaine topical gel before administering a solution of articaine hydrochloride 4% and epinephrine 1:100000 injection [8]. The use of the greater palatine nerve block anesthesia is recommended, as it helps alleviate any pain associated with the procedure that involves perforations. Secondly, the dentists executes the perforations along the midpalatal suture with the help of a 1.8 mm diameter bur executed using a pilot drill. Dentists can pre-drill the perforations/cortico-punctures with the help of a 1.8 mm and 4mm bur using a contra-angle screw driver in place of a pilot drill at approximately 1000 rpm. The CBCT guides the number and depth of the perforations based on individual results/contexts. For instance, there could be 10 to 15 perforations of a depth of 2 to 5mm based on the cortical plate's thickness [27]. The interval of the perforations would also range with a 2mm range being the standard measurement. Thus, the decisions on the CP procedure rest with the individual dentists upon evaluation of the patient's situation.

The perforations are deepest in the mid-palatal sutures where they could go as deep as 5 mm [8]. There should be caution in executing the perforations particularly in the anterior parts of the palate to steer clear of the nasopalatine canal. There are two ways of conducting the corticopuncture facilitated microimplant-assisted rapid palatal expansion; before and after input of the MARPE appliance. Conducting the perforations before the MARPE appliance allows adequate room for more perforations up to 15 whereas inputting the appliance first limits the surface area and space for drilling in more corticopunctures. Suzuki., *et al.* claims that the installation of the MARPE expander's limits the number of corticopunctures since the dentists is unable to drill beneath the jackscrew [22,37,50]. Thus, the scholars recommend that mid-palatal suture perforation precede MARPE to allow adequate room for drilling enough corticopunctures. Regardless of performing perforation pre or post-installation of the MARPE expander, there is need for analgesic medication to aid with pain relief and a daily use of a mouth-rinse containing chlorhexidine for seven days after the all procedure.

In the CP-MARPE process, the length of the mini-implants is not static as it depends on numerous factors. First, a dentist use the dental cast produces after transferring the impression. The dental cast consists of the sites for miniscrews insertion and the mid-palatal suture line to ensure accuracy of the expander during fixing. The dental cast helps determine the length of the mini-implants since it guarantees the inclusion of the expander thickness to the bone thickness in select anatomical regions. CBCT generated Digital Imaging facilitate the calculation of the bone height. The bone thickness is also a consideration in determining the length of the mini-screws. Therefore, mini-screw insertion sites and the mid-palatal suture lines should be accurately determined to ensure accuracy of the expander during fixing.

Nojima., *et al*. provides the formula for calculating the miniscrew length (MI) as "o + m + a + d + (1 or 2)" in which (o) refers to the bone

thickness, (m) to the soft tissue thickness, (a) to the thickness of the fixation ring, and (d) to the distance from the palatal surface to the ring [37]. The cementing of the skeletal expander precedes the placement of the mini-implants. The perforations enhance expansion making it easy for the patient to activate MARPE expander easily. Patients can conduct the activation protocol by initiating a minimum four turns and maximum 6 turns every day equivalent to 0.53-0.80 mm respectively. The activation should continue until a diastema appears between the central incisors signifying success in splitting the mid-palatal suture [23]. Bud., *et al.* also advises that the patient reduces the turn to 2 per day after this split to enhance cross-bite overcorrection [8]. The expander remains in place but inactive for a further 4 to 6 month period to enhance the stability of the expansion. Thus, the cortico-puncture therapy allows for faster split of mid-palatal sutures enhancing expansion than the single use of MARPE due to the maturation and interdigitation of the craniofacial features and the palatal sutures in adult.

Suzuki., *et al.* highlighted the advantages and disadvantages of MARPE as a palatal expansion mechanism [50]. The scholars outlined the long length of time and the force to achieve split of the palatal suture as the greatest limitation of the procedure. They claim that it takes twice the force and longer activation for MARPE to achieve the same palatal expansion as other techniques such as SARPE. Thus, there is the introduction of accompanying surgical techniques to facilitate bone remodeling and enhance MARPE in record time and with less activation. Researchers first proposed corticotomy to facilitate the regional acceleratory phenomenon (RAP), which significantly reduces bone density and volume and accelerates bone remodeling. The combination considerably improves the time and force required for MARPE.

However, corticotomy-assisted MARPE expansion presents adverse side effects that limit its use. For instance, scholars mention adverse effects such as inserted gingiva loss, subcutaneous hematomas, mild bone loss and post-operative discomfort and swelling. There numerous other MARPE accompanying techniques such as micro-osteoperforation that shares similar functioning as corticopuncture speeds up tooth movement by increasing the expression of chemokines and cytokines tasked with osteoclast differentiation in bone remodeling [8]. However, scholars credit corticopuncture as being the best accompaniment to MARPE because it is less invasive amidst numerous other disadvantages.

Overall, corticopuncture assisted method proves very effective in facilitating palatal expansion in adults by encouraging the mid-palatal split and weakening the suture interdigitation. Scholars hail the procedure is highly effective and less intrusive since it does not involve complex surgical procedures as prevalent in SARPE. Scholars also assert that despite the high success rate in maxillary advancement and mid-palatal opening, it also leads to a considerable molar inclination confirming that there still is tooth movement despite anchoring the expander at the molar-level. Numerous studies on the procedure reveal that the mean split at the posterior nasal spine (PNS) is estimated 3.12 mm whereas the one at the anterior nasal spine is relatively 3.76 mm [45]. The difference in the split between PNS and ANS is evidence of the parallel nature of the midpalatal suture in the anteroposterior side. Despite this fault, the procedure is primarily gold-standards in maxillary expansion in adults, just as CPAP is the first line treatment option for OSA.

When corticopuncture is incorporated effectively in the use of microimplants associated with maxillary expanders, most post-interventional complications including "tooth-borne forces that cause limited skeletal movement and undesirable tooth movement, root resorption, and weak haven/anchorage to retain sutural long term expansion" are minimized [17]. The corticopunctures and microimplants can assume a critical function in holding maxillary expanders. It is notable that transverse jaw deficiency, which is common in some adults, can require occlusal plane modification to prevent periodontal structure damage, retraction of the gingival, tongue position change, facial plane asymmetry, and sleep apnea. Given the associated possible co-morbidities, corticopunctures facilitated MARPE is often necessary in clinical practice.

Tongue retaining devices (TRD)

Even though CPAP is the typical treatment method for OSA, the use of oral appliances is also popular particularly for patients with tolerability issues with the CPAP machine. The Mandibular advancement device (MAD) is the most common oral appliance used as an alternative to CPAP. However, there are numerous other oral appliances such as the tongue retaining device (TRD). The TRD is a monobloc oral device that maintains or keeps the tongue in an interior position. In a study exploring the treatment of OSA using tongue stabilizing devises, Yanagihara., *et al.* claims that TRD is majorly used among patients suffering from mild to moderate OSA since CPAP is remains the preferred treatment option for severe OSA [59]. TRD is mainly applied in cases where contraindication of MAD is prevalent and the nasal continuous positive airway pressure (nCPAP) has failed [32]. The failure of the two treatment options may be due to profound periodontal disease, compromised dentition temporary mandibular joint disorders. TRD help maintain the tongue in a protruding position through suction. The device covers the entire lower and upper dental arches hence the need for customization to ensure it perfectly fits individual users. The TRD comes as a pre-made silicone device with the anterior bulb kept maintained in place by the tongue suction but missing the dental coverage. Thus, the preformation of the silicone appliance eliminates the need for fabrication, as it considerably reduces the bulk.

TRD has numerous advantages that make it suitable as an oral appliance for the treatment of OSA. Firstly, it is the only appliance that can be used in cases of edentulism where a patient is missing one or more teeth making them partially or wholly toothless [2,40]. This provision makes TRD very critical for this category of patients who suffer from edentulism since the rest of the palatal expansion appliances require tooth for anchoring. For instance, the tooth-borne, tooth-tissue borne, and bone-borne techniques for palatal expansion uses the teeth in one way or another either as anchor as is the case in tooth-borne or as support for the palatal pads/plates in tooth-tissue borne where the palatal vault acts as the main anchor. Secondly, the preformation of the device also reduces bulk and makes it easy to fit. Thirdly, TRD emerges as the best alternative to people who have tolerability issues and as the best alternative to positive airway pressure and MAD [53]. Mandibular advancement devices despite being more popular in use also presents many tolerability issues that render it inefficient for some patients making TRD a welcome alternative. Finally, it presents minimal challenges in the temporomandibular unlike other palatal expansion and oral appliances.

However, TRD also presents numerous challenges. For instance, the treatment is associated with discomfort, soreness and irritation of the tongue, excessive saliva leading to a dry mouth, and discomfort of the gums, lips and teeth [59]. Even though the tongue remains free in TRD, tongue discomfort accounts for the most number of discontinuation of the treatment among patients with tolerability challenges. The suction of the tongue into the bulb and the negative pressure cause discomfort and pain to the tongue, depending on the protrusion distance. It is for this reason that device allows for alteration of the mandibular protrusion to create room for adjustment in such cases. The placement or insertion of the tongue in the compartment results in excessive saliva making the mouth dry, which is particularly common after a few days of using the device. Finally, the device also causes discomfort of the lips, gums and teeth since it involves the insertion of a foreign material (appliance) into the mouth to create space. Thus, TRD is similar to MAD's that also exudes such challenges.

Maxillomandibular Advancement and Hypoglossal Nerve Stimulation

Maxillomandibular advancement surgery (MMA) targets OSA patients whose phenotypes indicate craniofacial vulnerability, such as returned mandibles. General physicians often refer such patients to dentist and orthodontist who use various techniques, such as mandibular advancement device (MAD), Osseo-pharyngeal reconstruction (OPR), and maxillomandibular advancement (MMA) to correct the malocclusion and discrepancies. Even though all these treatment options are lauded as alternatives to CPAP, MMA is most effective as it provides a permanent solution through Osseo-pharyngeal reconstruction. The procedure involves repositioning the lower and upper jaw to create space and relieve upper airway obstruction. The fixed pharyngeal airway muscles are suspended in the anterior position

while concurrently improving the pharyngeal soft tissue tension. The procedure aims to enlarge the pharyngeal airway by advancing the mandible and maxilla, causing the attached tissues such as the lateral and anterior pharyngeal tissues and the hyoid bone also to move forward, creating enough space for airflow. The advantage of MMA is that it provides a permanent solution to OSA by reconstructing the craniofacial features such as the mandible and the maxilla. It offers the best alternative treatment to patients intolerant to CPAP and the prolonged use of other oral appliances to realize palatal expansion. The procedure's disadvantage is its age limit. It is best for adults and people whose craniofacial growth is complete due to the unpredictability of residual growth and fear of iatrogenic growth inhibition post-surgery. Thus, children may not undergo surgery since their craniofacial growth is incomplete. The procedure is also invasive, hence presenting challenges associated with surgical procedures, such as post-surgical pain. Finally, the Hypoglossal Nerve Stimulation (HGNS) procedure stimulates specific muscles involved in tongue movement to enable control of the tongue's retraction and protrusion, hence controlling OSA.

Hyoid suspension/hyoid sling procedure

The hyoid suspension procedures involve making a small skin incision (approximately 1.5 to 3 inches) in a neck skin crease to conceal the incision. There are four sutures placed around the hyoid bone and on the top region of the thyroid cartilage or attached to bone screws fixed behind the mandible. The procedure enhances the forward pulling of the mandible, stabilizing the airway hence addressing OSA.

Tongue reduction procedures

This is a less-invasive tongue reduction procedure, effective and bearable to patients. The patient lies in the supine position for the procedure with nasal intubation, or orotracheal intubation is necessary but not mandatory in ensuring access to the midline section of the tongue base.

Combination of CPAP and appliances

Many treatment options for OSA, with CPAP being the preferred option, are used as the gold-standard treatment. According to Vanderveken, the use of oral appliances in the rapid maxillary expansion is the second most popular treatment option for patients after CPAP [55]. However, each of these treatment options has drawbacks affecting their efficacy and use among various patients. For instance, multiple limitations of CPAP, as a treatment option for OSA, exist, such as low patient acceptance, suboptimal compliance and low tolerance level affecting its efficacy. The efficacy level of oral appliances is considerably inferiorto CPAP. Thus, the single use of CPAP or other non-CPAP treatment modalities results in incomplete OSA elimination with the mean disease alleviation (MDA) index indicating clinical efficacy fluctuating between 40 to 59 percent [55]. Combination therapy drastically increases the MDA index from the range of 40-59% to an index of 70%. The author feels that the combination treatment for OSA is underestimated, under investigated, and undervalued as the surest way to eliminate the disorder in the populace. CPAP and the use of appliances complement each other during combined use eliminating the limitations associated with each. For instance, CPAP's main drawback is intolerance hence a patient can use the Hyrax appliance for maxillary expansion but still CPAP during the expansion period, and discontinue CPAP once they've achieved maximum maxillary expansion.

Surgically assisted rapid palatal expansion (SARPE) and its comparison to microimplant assisted rapid palatal expansion (MARPE)

In a study investigating MARPE vs SARPE for maxillary transverse discrepancy treatment, De Oliveira., *et al.* describe SARPE as an orthodontic procedure used in the maxillary arch expansion [15]. Emerson Angell was the first researcher to describe orthodontic expan-

sion. Kole became the first to use corticotocomy as a treatment option for adults with maxillary constriction. Brown and later Steinhauser described the SARPE technique as a treatment option for OSA, bilateral posterior cross-bite, transverse maxillary hypoplasia, and fused intermaxillary suture through the split of the right and left segments of the maxilla besides the placement of the graft. The procedure involves the placement of the rapid maxillary expander device in the maxilla to facilitate the expansion of the maxillary arch [15]. The procedure involves two surgeries, the first involving the Le Fort fracture of the skull and the midpalatal osteotomy to sever the intermaxillary suture. Some of the limitations of SARPE include its low patient compliance, post-maxillary expansion aesthetic limitation, and high rate of follow-up surgery. It is also very invasive since it is a surgical procedure. De Oliveira., *et al.* compared the efficacy of MARPE and SARPE. MARPE resulted in better transversal skeletal changes, particularly in the anterior and posterior maxillary base and the midface [38] SARPE recorded better transverse displacement of the Alveolarthan MARPE in the study. SARPE also recorded better results over MARPE in interpremolar and intermolar distance. However, there was no significant difference between the two methods in the alveolar expansion.

Conclusion

The frequency of OSA makes it a critical public health concern, considering its high morbidity rates, societal impacts, and economic burden. Due to pharyngeal collapse common in OSA patients, symptoms of the disease include hypoventilation, cyclic apneas, and repetitive hypopneas. Even though CPAP remains the "gold standard" treatment option for OSA, the use of oral appliances, as is the case in MARPE and MAD, have gained widespread use since the dentists can adjust/design them to match individual need of every patient. The oral appliances also act as an alternative treatment option for people who have tolerability issues with CPAP, reducing its efficacy. Some of the popular oral appliances include the mandibular appliance device (MAD) and MARPE. The two devices function to ensure the upper airway stays open during sleep to facilitate breathing. However, other treatment options include "positional therapy, pharmacologic treatment, nEPAP, hypoglossal nerve stimulation, and weight loss." The MARPE process encompasses expansion of the maxilla using non-surgical means to treat skeletal maxillary transverse deficiency leading to numerous problems such as teeth crowding, excessive vertical alveolar growth, nasal obstruction, nasopharyngeal airways collapse and hindered facial development. MARPE stands out as the best treatment option for adults since majority of the conventional rapid palatal expansion options suit children more than adults due to the fusion of the mid-palatal suture during puberty. These alternative treatment options are primarily performed by physicians since they fall out of the dental domain. The American Academy of Dental Sleep Medicine underscores the need for collaboration between dentists and physicians in the treatment of OSA.

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