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Review Article

Expanding the Airway: Surgical Jaw Expansion Techniques in Sleep Apnea Management

MR Haranadha Reddy[1], Lavanya Ummadisingh[2], Sarah Fatima[3]*, Lasya Snkp Duggirala[4], Phalguni KN[4], Sultan Mohammed Riyaan Zaid[4], Ghazala Hussain[4], Gunda Amitha[4], Mohammed Abdul Majid[4], Barla Divya[4], Seerla Varsha[4], Kovvuri Ramya Reddy[5], Sri Nanditha Ravula[5], Rathod Prathyusha[5] and Sanjna Jayesh Harakhchand[5]

[1]MDS, Professor, Department of Oral and Maxillofacial Surgery, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India

[2]MDS, Associate Professor, Department of Oral and Maxillofacial Surgery, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India

[3]MDS, Assistant Professor, Department of Oral and Maxillofacial Surgery, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India

[4]BDS, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India

[5]BDS IV YEAR, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India

***Corresponding Author:** Sarah Fatima, MDS, Assistant Professor, Department of Oral and Maxillofacial Surgery, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, India.

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Abstract

Transverse maxillary deficiency is a frequent skeletal deformity associated with occlusal imbalance, dentofacial disharmony, and reduced nasal airway function. In growing patients, rapid maxillary expansion (RME) provides reliable skeletal widening, but its effectiveness declines with age due to progressive interdigitation of the midpalatal suture and increased circummaxillary resistance. In skeletally mature individuals, surgical intervention is often required to achieve predictable correction.

Surgically assisted rapid palatal expansion (SARPE) remains the most established approach for isolated transverse deficiency, employing targeted osteotomies to reduce resistance and permit controlled expansion. Distraction osteogenesis (DO) offers gradual skeletal separation with new bone formation, making it particularly valuable when larger or more controlled movements are needed. Segmental maxillary osteotomy provides an alternative when transverse correction is incorporated into comprehensive orthognathic surgery.

Beyond dental alignment, surgical expansion has been shown to enlarge the nasal cavity and improve airway dimensions. Selected studies report favourable changes in oxygen saturation and reductions in obstructive sleep apnea indices, highlighting the potential role of maxillary expansion in airway management. However, outcomes vary depending on craniofacial anatomy and the level of obstruction, underscoring the importance of careful patient selection.

Successful treatment requires thorough evaluation of skeletal morphology, periodontal support, bone quality, systemic health, and the magnitude of discrepancy. Advances in threedimensional imaging, virtual surgical planning, and customized expansion devices have enhanced diagnostic accuracy and surgical precision. This review outlines current surgical strategies for transverse maxillary expansion, emphasizing indications, protocols, complications, stability, and the emerging role of expansion in sleepdisordered breathing.

Keywords: Transverse Maxillary Deficiency; Surgically Assisted Rapid Palatal Expansion (SARPE); Distraction Osteogenesis (DO); Segmental Maxillary Osteotomy; Orthognathic Surgery; Nasal Airway Resistance, Obstructive Sleep Apnea (OSA); ConeBeam Computed Tomography (CBCT); Virtual Surgical Planning; Skeletal Stability

Introduction

Transverse maxillary deficiency is a common skeletal discrepancy encountered in oral and maxillofacial, craniofacial, and orthodontic practice. Reported prevalence ranges from 8–23% in adolescents and adults [1]. The deformity may manifest as maxillary arch constriction, posterior crossbite, dental crowding, and an altered transverse relationship between the maxilla and mandible [2]. Importantly, the clinical consequences are not restricted to occlusion. Reduction in nasal cavity dimensions and increased nasal airway resistance may accompany maxillary constriction, making transverse correction relevant to both dentofacial function and upper airway physiology.

In growing patients, rapid maxillary expansion (RME) is a well-established method of achieving orthopaedic widening of the maxilla. The relatively favourable skeletal response during growth allows expansion forces to be transmitted across the midpalatal suture and associated maxillary articulations [3]. With skeletal maturation, however, the midpalatal suture becomes increasingly interdigitated, and the circummaxillary articulations provide greater resistance to orthopaedic expansion [4]. Consequently, conventional tooth-borne expansion in adults may produce predominantly dentoalveolar effects, including buccal tipping and alveolar bending, rather than the desired skeletal widening. Excessive dental loading may also increase the risk of periodontal complications and instability.

The fundamental principle of surgical expansion is to reduce the anatomical resistance to transverse displacement while maintaining sufficient skeletal continuity for controlled movement and subsequent healing. Surgically assisted rapid palatal expansion (SARPE) applies this principle by combining a surgically weakened maxillary complex with a mechanical expansion device. Osteotomies are strategically placed to address the principal areas of resistance, allowing the maxillary segments to be progressively separated under controlled activation [5]. The exact osteotomy design varies according to the surgical philosophy, skeletal anatomy, magnitude of expansion, and surgeon preference. Depending on the technique, the lateral maxillary walls, anterior maxilla, midpalatal region, and pterygomaxillary region may be addressed.

SARPE is particularly useful in skeletally mature patients presenting with a significant isolated transverse maxillary deficiency. Its major advantages include direct skeletal correction and the ability to achieve expansion that would be difficult or unpredictable with orthodontic mechanics alone. However, the procedure is not without limitations. Asymmetrical expansion, dental tipping, periodontal complications, pain, infection, device-related problems, and postoperative relapse have all been described. Accurate diagnosis and appropriate osteotomy design are therefore essential for predictable outcomes.

Distraction osteogenesis (DO) represents another surgical strategy for skeletal expansion. Following osteotomy, a latency period allows initial callus formation before controlled distraction is initiated. Progressive activation separates the skeletal segments at a predetermined rate, with new bone forming within the distraction gap [6]. Unlike conventional single-stage repositioning, distraction allows gradual tissue adaptation and may be advantageous when substantial skeletal movement is required. The technique, however, requires a stable distraction device, patient compliance, and careful control of the distraction vector.

Segmental maxillary osteotomy provides a further option for transverse correction, particularly when maxillary expansion is required as part of a larger orthognathic procedure. In this setting, the maxilla is divided into multiple dentoalveolar segments and repositioned to achieve the desired transverse and anteroposterior or vertical correction [7]. Its principal advantage is the ability to address several components of a dentofacial deformity during a single operation. The technique nevertheless requires careful management of the interdental osteotomy sites and preservation of adequate vascular supply to the mobilized segments.

From an airway perspective, the effects of maxillary expansion are of increasing clinical interest. Widening of the maxilla can increase the transverse dimensions of the nasal cavity and may reduce nasal airway resistance. Studies evaluating patients after expansion procedures have reported increases in nasal airway volume, improvement in oxygen saturation, and reductions in selected obstructive sleep apnea indices [8,9]. These findings provide a physiological rationale for considering maxillary expansion in carefully selected patients with sleep-disordered breathing.

The relationship between maxillary expansion and OSA, however, should be interpreted within the broader context of upper airway obstruction. OSA is frequently multifactorial, and obstruction may occur at the nasal, retropalatal, retroglossal, or hypopharyngeal levels. Consequently, correction of transverse maxillary deficiency may improve nasal airflow and contribute to overall airway improvement but may not adequately address multilevel or predominantly pharyngeal obstruction. Patient selection should therefore be based on a comprehensive airway assessment rather than the presence of maxillary constriction alone.

Preoperative evaluation should include clinical examination, assessment of the occlusion and transverse discrepancy, periodontal evaluation, and appropriate radiographic or three-dimensional imaging. The quality and thickness of the supporting alveolar bone, position of the tooth roots, anatomy of the nasal cavity, maxillary buttresses, and relevant adjacent structures should be considered when planning osteotomies. Medical comorbidities and factors that may impair bone healing must also be identified. Significant periodontal compromise, poor bone quality, uncontrolled systemic disease, and inadequate skeletal support may represent contraindications or relative contraindications depending on the individual surgical plan [10].

The development of cone-beam computed tomography (CBCT), three-dimensional virtual surgical planning, computer-assisted design and manufacturing, and patient-specific expansion appliances has further refined the management of transverse maxillary deficiency. These technologies allow more accurate assessment of skeletal anatomy, simulation of expansion, identification of potential anatomical hazards, and fabrication of customized surgical and orthodontic components.

The purpose of this review is to examine the contemporary surgical management of transverse maxillary deficiency, with emphasis on SARPE, distraction osteogenesis, and segmental maxillary osteotomy. The indications, contraindications, surgical approaches, activation protocols, complications, and factors influencing skeletal stability are discussed. Particular attention is given to the emerging role of surgical maxillary expansion in nasal airway improvement and the management of selected patients with obstructive sleep apnea.

Methods and Techniques

Preoperative planning

Successful surgical maxillary expansion begins with a systematic preoperative assessment aimed at defining the skeletal deformity, identifying relevant anatomical limitations, and establishing the functional objectives of treatment. Particular attention should be given to the transverse discrepancy, dental and periodontal status, nasal airway, and the presence of sleep-disordered breathing.

- **Clinical evaluation:** A comprehensive clinical assessment should include evaluation of the maxillary transverse deficiency, occlusal relationships, posterior crossbite, dental compensation, arch form, and periodontal status. Nasal obstruction and other symptoms suggestive of impaired airway function should also be documented [1,2].
- **Imaging:** Cone-beam computed tomography (CBCT) provides three-dimensional assessment of the maxillofacial skeleton and is useful for evaluating the midpalatal suture, maxillary buttresses, nasal cavity, alveolar bone, and adjacent anatomical structures. In patients being considered for airway-related intervention, CBCT may also assist in assessing changes in nasal and upper airway dimensions and in planning the surgical approach [16].

- **Sleep assessment:** In patients with suspected or established obstructive sleep apnea (OSA), baseline polysomnography should be obtained when clinically indicated. The apnea–hypopnea index (AHI), oxygen saturation, and other relevant respiratory parameters provide an objective baseline against which postoperative changes can be assessed [4,19].
- **Digital surgical planning:** Three-dimensional virtual planning can be used to simulate the proposed expansion and determine the location and extent of osteotomies, appliance positioning, and the expected skeletal movement. Digital workflows may also facilitate assessment of anticipated changes in nasal and upper airway dimensions and improve communication between the surgical and orthodontic teams [20].

A multidisciplinary approach involving the oral and maxillofacial surgeon, orthodontist, and, where appropriate, sleep medicine or otorhinolaryngology specialists is particularly valuable in patients in whom airway improvement is an important treatment objective. The final surgical plan should be based on the severity and anatomical pattern of the transverse deficiency, skeletal maturity, periodontal condition, airway findings, and the overall treatment objectives.

Surgically assisted rapid palatal expansion (SARPE)

Principle

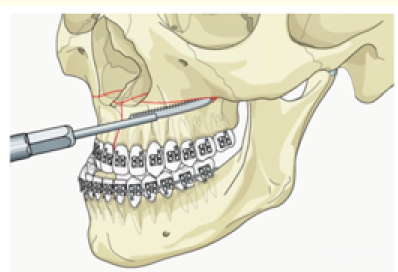
Surgically assisted rapid palatal expansion (SARPE) is an established technique for correction of transverse maxillary deficiency in skeletally mature patients. The procedure is based on controlled surgical release of the principal areas of skeletal resistance, followed by gradual activation of a maxillary expansion device. The objective is to facilitate predominantly skeletal widening while minimizing undesirable dentoalveolar effects [6,7].

Surgical technique

The procedure is generally performed under general anesthesia. The osteotomy design is individualized according to the patient's skeletal anatomy, degree of transverse deficiency, age, and planned magnitude of expansion. The principal areas of surgical release may include the lateral maxillary walls, midpalatal suture, nasal septum, and, when indicated, the pterygomaxillary junction [12].

- **Lateral maxillary wall osteotomies:** Bilateral horizontal osteotomies are performed along the lateral maxillary walls, generally extending from the piriform aperture toward the posterior maxilla. These cuts reduce lateral skeletal resistance to transverse expansion.
- **Midpalatal osteotomy:** A midline osteotomy is used to release the intermaxillary suture, particularly in the anterior maxilla. The osteotomy may be performed through an interdental approach between the maxillary central incisors and continued posteriorly along the midpalatal region, depending on the surgical technique [12].
- **Nasal septal release:** Separation of the nasal septum from the maxillary crest may be performed to reduce resistance and minimize the risk of asymmetric expansion or septal displacement.
- **Pterygomaxillary disjunction:** Release of the pterygomaxillary junction may be incorporated according to the surgical philosophy, posterior expansion requirements, skeletal maturity, and degree of posterior resistance. The necessity of routine pterygomaxillary disjunction remains technique-dependent.

Following adequate skeletal release, a tooth-borne or bone-borne expansion appliance is activated to achieve controlled transverse distraction [13]. The appliance should be stable and appropriately positioned to ensure that the expansion forces are directed toward the intended skeletal segments.



Cuts made in surgically assisted rapid palatal expansion

Figure 1

Phase	Typical protocol	Surgical objective
Latency	Approximately 5–7 days	Initial soft-tissue healing and early callus formation
Distraction/Expansion	Approximately 0.25–0.5 mm/day	Progressive transverse separation of the maxillary segments
Consolidation	Approximately 3–6 months	Maturation and mineralization of the newly formed bone

Table 1

Activation and distraction protocol

Activation is generally initiated after a short postoperative latency period, although the exact protocol varies according to the appliance, surgical technique, patient age, and surgeon preference. A commonly used activation rate is approximately 0.25–0.5 mm per day until the planned transverse correction is achieved [14].

The activation period should be guided by the clinical response rather than a predetermined amount alone. Expansion is generally continued until the desired transverse skeletal and occlusal relationship is obtained. Clinical assessment should include the amount and symmetry of expansion, occlusal changes, appliance stability, periodontal status, and the presence of any complications.

Advantages

SARPE provides effective skeletal expansion in skeletally mature patients by overcoming the resistance associated with midpalatal suture interdigitation and circummaxillary articulations [15]. When appropriately planned, the procedure allows predictable transverse correction and can increase nasal cavity volume, improving airflow in selected patients [15,18]. Expansion may also contribute to enhanced airway function, particularly when nasal constriction is a significant component of the patient's limitation [15]. Favourable long-term skeletal and occlusal stability has been reported when expansion is followed by adequate consolidation and orthodontic retention [16].

At the same time, SARPE is an invasive procedure that requires careful patient selection and postoperative management. Orthodontic treatment and retention are generally necessary to establish and maintain the final occlusal relationship [22]. Tooth-borne appliances may produce dental tipping or dentoalveolar compensation if skeletal resistance is not adequately released [23]. Reported complications include bleeding, infection, postoperative pain, asymmetric expansion, periodontal compromise, dental root or alveolar injury, appliance-related problems, and relapse [17]. Inadequate surgical release or inappropriate activation can result in unfavourable expansion patterns or excessive dental movement. For these reasons, diagnosis, osteotomy design, and activation protocols must be tailored to the patient's anatomy and treatment objectives.

Distraction osteogenesis (DO)

Principle

Distraction osteogenesis (DO) is a biologically based technique in which controlled mechanical separation of surgically divided bone segments stimulates new bone formation within the distraction gap, accompanied by progressive adaptation of the surrounding soft tissues [12,13]. In maxillary transverse expansion, the technique allows gradual skeletal widening rather than immediate mechanical separation. This gradual process may be advantageous in patients with severe skeletal deficiencies or complex craniofacial deformities in whom conventional expansion techniques are inadequate.

Surgical technique

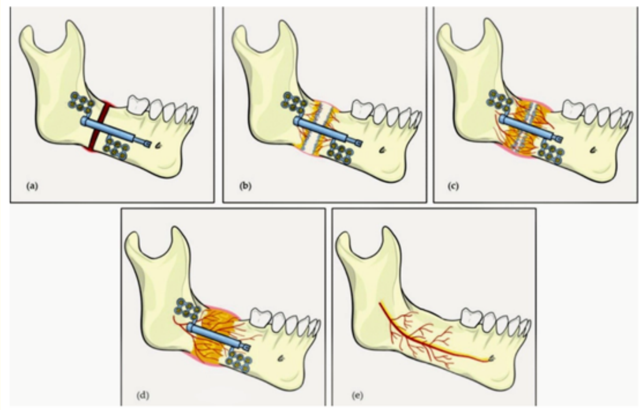
The procedure begins with a maxillary corticotomy or osteotomy designed to create a mobile skeletal segment while preserving the vascularity of the surrounding soft tissues [14]. A rigid, bone-anchored distraction device is then positioned and secured to the maxillary segments. Accurate placement of the distractor is essential to maintain the desired vector of expansion and minimize asymmetric movement.

Following osteotomy, a latency period is allowed before activation. A period of approximately 5–7 days is commonly used to permit initial hematoma organization and early callus formation [15]. Distraction is subsequently initiated at a controlled rate. One commonly described protocol involves activation of approximately 0.25 mm twice daily, although the rate and rhythm should be individualized according to the distraction device, skeletal anatomy, magnitude of the deficiency, and biological response [16].

Once the desired transverse correction has been achieved, the distractor is maintained during the consolidation period to allow maturation and mineralization of the regenerate. Reported consolidation periods vary, with approximately 8–12 weeks commonly used in clinical protocols [17]. The device should not be removed prematurely, as inadequate consolidation may increase the risk of instability and relapse.

Biological phases of distraction

The biological response to distraction osteogenesis can be divided into several overlapping phases.



Distraction Osteogenesis: Controlled Skeletal Expansion Through Gradual Mechanical Traction

Figure 2

Phase	Approximate timeline	Principal biological process
Osteotomy/Corticotomy	Day 0	Surgical separation of the bone while preserving the surrounding vascular and soft-tissue envelope
Latency	Approximately 5–7 days	Hematoma organization, inflammatory response, and development of early fibrovascular callus
Active Distraction	During activation	Controlled mechanical tension promotes cellular proliferation, vascular ingrowth, and progressive new bone formation within the distraction gap
Consolidation	Approximately 6–12 weeks or longer	Progressive mineralization and maturation of the regenerate with increasing mechanical strength
Remodeling	Months to years	Conversion and remodeling of the newly formed bone in response to functional loading

Table 2

The biological response is governed by the tension-stress principle described in distraction osteogenesis. Controlled mechanical strain promotes cellular proliferation, angiogenesis, and tissue regeneration within the distraction zone and facilitates adaptation of the surrounding soft tissues.

Activation protocol

Distraction rates in craniofacial distraction osteogenesis are commonly expressed in millimeters per day and divided into multiple activations. A general distraction rate of approximately 0.5–1.0 mm/day has been described, with some protocols using smaller increments distributed throughout the day [18]. In transverse maxillary distraction, the specific rate should be determined according to the device and surgical protocol rather than applying a single standardized rate to all patients.

A typical sequence consists of:

- **Latency:** Approximately 5–7 days following osteotomy [15].
- **Active distraction**: Gradual activation according to the prescribed device-specific protocol [16].
- **Consolidation:** Maintenance of the distractor until adequate mineralization and mechanical stability of the regenerate are achieved [17].

- **Device removal:** Performed only after satisfactory clinical and radiographic evidence of consolidation.

Applications in maxillary expansion

DO may be considered in patients with severe transverse maxillary deficiency, particularly when conventional orthodontic expansion or SARPE is unlikely to provide adequate skeletal correction. It may also have a role in patients with complex craniofacial deformities, including selected cleft and syndromic conditions, where controlled skeletal expansion is required [20].

In appropriately selected patients, distraction can also be incorporated into a broader maxillofacial reconstruction or orthognathic treatment plan. For example, maxillary advancement and transverse expansion may be addressed within a combined surgical strategy when the underlying deformity involves multiple skeletal dimensions [21].

Distraction osteogenesis offers several biological and mechanical advantages in the management of transverse maxillary deficiency. Unlike acute skeletal repositioning, the technique allows gradual expansion of the maxillary segments, promoting controlled widening and reducing soft-tissue stress. The distraction gap undergoes progressive new bone formation, providing biological skeletal continuity after consolidation [19]. This gradual process also permits concurrent adaptation of the mucosa, periosteum, vasculature, and surrounding soft tissues [20]. For patients requiring substantial skeletal movement, DO can achieve magnitudes of expansion that are difficult to obtain predictably with conventional techniques.

Despite these benefits, DO is associated with clinical considerations

The success of maxillary distraction osteogenesis depends on appropriate osteotomy design, preservation of vascularity, accurate distractor positioning, and adherence to a controlled activation protocol. The distraction vector should be planned three-dimensionally because even small deviations in vector orientation may result in asymmetric expansion or unintended skeletal movement.

Unlike conventional acute maxillary expansion, DO provides a gradual biomechanical stimulus that allows simultaneous skeletal and soft-tissue adaptation. This characteristic makes it a useful option in selected patients with severe transverse deficiencies and complex craniofacial anatomy. However, because of the longer treatment course and greater dependence on patient compliance, DO should be reserved for cases in which its biological and mechanical advantages justify the additional treatment burden [19,22,23].

Segmental osteotomies

Segmental osteotomies are performed as part of orthognathic surgery, allowing transverse expansion by mobilizing maxillary segments.

Principles

- The maxilla is segmented into two or more parts during Le Fort I osteotomy.
- Expansion is achieved intraoperatively by repositioning segments laterally [24].
- Fixation is achieved with plates and screws, followed by orthodontic finishing [25].

Applications

- Used when transverse deficiency coexists with sagittal or vertical discrepancies.
- Allows simultaneous correction of multiple planes of deformity [26].

Segmental osteotomy provides immediate transverse expansion intraoperatively and can be combined with other orthognathic corrections when multiple planes of deformity require simultaneous management [27]. This approach is particularly useful when transverse deficiency coexists with sagittal or vertical discrepancies, allowing comprehensive correction in a single procedure.

However, the technique carries certain limitations. Relapse rates are generally higher compared with distraction osteogenesis, and periodontal compromise may occur if interdental osteotomies are not carefully planned and executed [28]. Preservation of vascular supply to mobilized segments and maintenance of adequate safety margins around root apices are critical to minimize complications and ensure long-term stability.

Common surgical techniques

Segmental Osteotomy involves surgical sectioning of isolated dentoalveolar blocks within the maxilla or mandible to correct localized transverse, vertical, or sagittal malocclusions without mobilizing the entire jaw.

Procedure	Anatomic Site	Primary Indication	Key Osteotomy Design
Anterior Maxillary (Wassmund/ Cupar)	Canine-to-canine anterior maxilla	Bimaxillary protrusion, severe vertical maxillary excess	Horizontal subapical cut superior to apices; vertical interdental cuts post-premolar extraction.
Anterior Mandibular (Kole)	Canine-to-canine anterior mandible	Anterior open bite, deep bite, severe dentoalveolar protrusion	Horizontal cut inferior to root apices (above IAN); vertical inter-dental cuts.
Posterior Segmental (Schucha-rdt)	Premolar / molar block (Maxilla or Mandible)	Posterior vertical maxillary excess, localized crossbite, supraerupted molars	Subapical horizontal osteotomy with palatal/lingual osteotomy to mobilize single or multi-tooth blocks.
Multi-piece Le Fort I	Total maxilla divided into 2–4 segments	Transverse expansion, severe arch perimeter discrepancy	Standard Le Fort I combined with midpalatal and/or parasagittal palatal cuts.

Table 3

Critical surgical considerations

- **Vascular Pedicle Maintenance:** Mobilized dentoalveolar segments rely entirely on attached soft tissue pedicles (palatal mucosa for maxilla, labial/lingual mucosa for mandible) to prevent avascular necrosis of bone and pulp death.
- **Root Apex Safety Margin:** Horizontal subapical cuts require a minimum safety margin of 3 to 5 mm apical to the root tips to preserve tooth vitality and periodontal ligament structures.
- **Fixation:** Rigid internal fixation (miniplates and monocortical screws) combined with a pre-prepared surgical splint ensures precise alignment and occlusal stability during primary osseous healing.

Postoperative protocol

Postoperative management is an integral component of successful surgical expansion. The objectives are to maintain the achieved skeletal correction, monitor healing, identify complications at an early stage, and coordinate subsequent orthodontic treatment.

Retention and orthodontic management

Following skeletal expansion, an appropriate retention protocol is required to allow maturation of the newly expanded skeletal and dentoalveolar structures. Depending on the technique, the expansion appliance may be maintained during the consolidation period and subsequently replaced or supplemented by orthodontic retention [30].

The orthodontic phase is directed toward refinement of the occlusion, correction of residual dental compensation, and maintenance of the transverse relationship. Long-term retention is particularly important in patients with significant preoperative skeletal constriction.

Airway reassessment

In patients undergoing surgical expansion as part of an airway-focused treatment plan, postoperative assessment should include objective evaluation of respiratory function. Repeat polysomnography may be performed when clinically indicated to determine changes in apnea–hypopnea index (AHI), oxygen saturation, and other sleep-related respiratory parameters [31].

Long-Term Follow-up

Clinical follow-up should assess occlusal stability, transverse skeletal correction, periodontal health, nasal airway symptoms, and evidence of relapse. Serial clinical and radiographic evaluation may be particularly useful in patients undergoing extensive skeletal expansion or distraction osteogenesis [32,33].

Clinical outcomes

Airway volume and nasal resistance

One of the principal functional effects associated with maxillary expansion is an increase in the transverse dimensions of the nasal cavity. Surgical expansion has been associated with increased nasal airway volume and, in selected patients, reduced nasal airway resistance [11,16,18].

Three-dimensional CBCT and cephalometric investigations have demonstrated changes in nasal cavity and upper airway dimensions following SARPE and distraction procedures [20,39]. These changes are particularly relevant in patients in whom maxillary constriction and nasal obstruction coexist.

Segmental maxillary osteotomies performed as part of comprehensive orthognathic surgery may also influence airway dimensions, although the magnitude and direction of airway change depend on the type and extent of skeletal movement [23,25].

Sleep apnea indices

The potential effect of maxillary expansion on obstructive sleep apnea has attracted increasing clinical interest. Several studies have reported reductions in AHI following maxillary expansion procedures, together with improvements in oxygenation and other sleep-related parameters [14,19,31].

Maxillomandibular advancement (MMA), which may be performed in conjunction with transverse correction in selected patients, has demonstrated high success rates in appropriately selected patients, with reported rates exceeding 85% using commonly applied surgical success criteria [4,7,33]. However, the airway effect of transverse expansion should not be equated with the broader airway remodeling achieved by MMA.

Improvements in oxygen saturation and subjective sleep quality have also been reported following appropriate surgical treatment [17,41]. Nevertheless, the magnitude of improvement varies between patients and depends on the anatomical level of obstruction, baseline disease severity, body habitus, and the presence of multilevel airway collapse.

Long-term stability

Skeletal stability is an important consideration following surgical expansion. Distraction osteogenesis may provide favorable skeletal stability because gradual bone formation occurs during the distraction and consolidation phases, with concurrent adaptation of the surrounding soft tissues [12,13,19].

SARPE can also provide stable transverse correction when adequate skeletal expansion is achieved and appropriate retention and orthodontic management are maintained [22,30]. Long-term stability following orthognathic procedures depends on the magnitude and direction of skeletal movement, fixation, soft-tissue forces, postoperative retention, and the underlying deformity [27,33,46].

Functional and aesthetic outcomes

Correction of transverse maxillary deficiency can improve posterior occlusion, arch coordination, and facial proportions in appropriately selected patients [2,8,9]. When expansion is integrated into comprehensive orthognathic treatment, improvements may extend to facial symmetry and overall dentofacial harmony.

Patient-reported outcomes have also demonstrated improvements in functional status and quality of life following appropriate surgical treatment. In patients with OSA, improvements in sleep-related symptoms and daytime function may accompany objective respiratory changes [14,32,50].

Indications and contraindications

Indications

The principal indications for surgical maxillary expansion include:

- Significant transverse maxillary deficiency in skeletally mature patients in whom conventional orthodontic expansion is unlikely to produce adequate skeletal correction [4,6,12].
- Posterior crossbite and dental crowding associated with a constricted maxillary arch [2,9].
- Maxillary constriction associated with reduced nasal airway dimensions or nasal airway compromise [11,16,18].
- Selected patients with obstructive sleep apnea in whom craniofacial anatomy contributes to airway obstruction and in whom skeletal intervention is otherwise indicated [7,14,31].

- Complex dentofacial deformities requiring simultaneous transverse, sagittal, and/or vertical correction [23,25,27].

The indication for surgery should be based on the underlying skeletal deformity rather than the presence of OSA alone. In patients presenting primarily with sleep-disordered breathing, a comprehensive airway evaluation is essential before attributing the disorder to transverse maxillary deficiency.

Contraindications and Relative Contraindications

Potential contraindications or factors requiring careful consideration include:

- Significant periodontal disease or inadequate dentoalveolar support [10,22].
- Poor bone quality or conditions that may impair skeletal healing and expansion stability.
- Uncontrolled systemic disease or medical conditions that substantially increase operative risk [28,33].
- Inability or unwillingness to comply with postoperative orthodontic or distraction protocols [21,22].
- Minimal transverse skeletal deficiency in which the expected functional benefit does not justify surgical morbidity [19,30].
- Medical or anatomical factors that make elective orthognathic surgery inappropriate [26,28].

These factors should be considered in conjunction with the patient's age, skeletal anatomy, airway findings, periodontal condition, and overall treatment objectives.

Complications and limitations

Although surgical maxillary expansion is generally predictable when appropriately planned, complications may occur at both the surgical and postoperative stages.

Intraoperative complications

- **Hemorrhage:** Bleeding may arise from injury to branches of the maxillary arterial system, including the descending palatine vessels, or from the nasal mucosa during osteotomy and mobilization [40]. Careful surgical exposure, controlled osteotomy technique, and appropriate hemostatic measures are essential.
- **Injury to adjacent structures:** Inaccurate or uncontrolled osteotomy may result in injury to the nasal septum, lateral nasal wall, maxillary buttresses, or other adjacent structures [41].
- **Pterygoid plate injury:** Uncontrolled manipulation during posterior maxillary release may result in undesirable fracture patterns involving the pterygoid plates and may contribute to postoperative pain or instability [42].

Postoperative complications

- **Infection:** Infection may occur at the surgical site or around an expansion device, particularly in the presence of inadequate oral hygiene or wound contamination [43].
- **Relapse:** Loss of part of the achieved expansion may occur following inadequate retention, insufficient consolidation, or persistent soft-tissue and dentoalveolar forces [44].
- **Asymmetric expansion:** Unequal activation, incomplete skeletal release, or asymmetric resistance may result in unilateral or nonuniform expansion [45].
- **Periodontal complications and root injury:** These complications are particularly relevant when tooth-borne appliances are used or when interdental osteotomies are performed close to the dental roots [46].
- **Pain and discomfort:** Pain, pressure, and mucosal discomfort are common during the active expansion phase and are generally managed with appropriate analgesia and postoperative care [47].

Long-term limitations

Although surgical expansion generally provides greater skeletal correction than nonsurgical orthodontic expansion in adults, some degree of relapse may occur. Reported relapse rates vary according to the surgical technique, magnitude of expansion, retention protocol, and duration of follow-up, with rates of approximately 10–20% reported in some series [48].

Soft-tissue adaptation may also influence long-term skeletal and aesthetic outcomes [49]. In addition, the requirement for an operating-room setting, specialized appliances, multidisciplinary coordination, and prolonged orthodontic management contributes to the overall complexity and cost of treatment [50].

Discussion

Surgical management of transverse maxillary deficiency has evolved substantially with improvements in osteotomy techniques, expansion devices, imaging, and digital planning. In skeletally mature patients, SARPE, distraction osteogenesis, and segmental maxillary osteotomy provide different surgical strategies for overcoming the limitations of conventional orthodontic expansion [4,6,12].

SARPE remains an established option for patients with significant isolated transverse maxillary deficiency. By surgically reducing areas of skeletal resistance and applying controlled expansion forces, the procedure permits transverse skeletal correction in adults. Distraction osteogenesis provides a biologically driven alternative in which gradual mechanical separation is accompanied by new bone formation and soft-tissue adaptation [12,13,19]. Segmental osteotomy, in contrast, is particularly valuable when transverse deficiency forms part of a broader dentofacial deformity requiring simultaneous orthognathic correction [23,25,27].

The potential airway effects of surgical maxillary expansion have expanded the clinical relevance of these procedures. Increased nasal cavity dimensions and reductions in nasal airway resistance have been reported following expansion [16,18,39]. Improvements in AHI and oxygen saturation have also been described in selected patients [14,19,31]. However, these findings should be interpreted cautiously. Maxillary expansion primarily affects the nasal and maxillary components of the upper airway and should not be regarded as equivalent to a comprehensive treatment for OSA.

In patients with OSA, the decision to undertake surgical expansion should therefore follow a detailed assessment of craniofacial morphology and the anatomical sites contributing to airway obstruction. Where obstruction is multilevel or predominantly retropalatal or hypopharyngeal, additional procedures may be required. Maxillomandibular advancement remains an important skeletal treatment option for appropriately selected patients and may be combined with transverse correction when indicated [7,33,46].

Long-term stability remains another important consideration. The gradual skeletal and soft-tissue adaptation associated with distraction osteogenesis may provide favorable stability [12,13,19], while SARPE can also produce durable correction when adequate expansion, consolidation, and orthodontic retention are achieved [22,30]. Nevertheless, relapse remains possible and should be discussed during treatment planning.

Technological advances are increasingly influencing surgical decision-making. CBCT-based three-dimensional assessment, virtual surgical planning, and CAD/CAM fabrication permit detailed evaluation of the maxillary anatomy and more precise planning of osteotomies and expansion devices [20,39]. These technologies may improve surgical accuracy and facilitate individualized treatment, although their ability to predict functional airway outcomes remains an area of ongoing investigation.

Overall, surgical jaw expansion should be viewed as a component of individualized multidisciplinary treatment rather than as a single-purpose procedure. Its principal indication remains correction of a clinically significant skeletal transverse deficiency, while airway improvement represents an important potential functional benefit in appropriately selected patients.

Future Directions

Digital surgical planning

Three-dimensional CBCT imaging and virtual surgical planning are increasingly being incorporated into the management of transverse maxillary deficiency. Digital workflows permit detailed assessment of skeletal anatomy, simulation of osteotomy design, optimization of appliance positioning, and evaluation of anticipated skeletal movements [20,39]. These technologies may reduce intraoperative variability and improve surgical precision.

Customized expansion devices

CAD/CAM technology has enabled the development of patient-specific expansion appliances and bone-anchored distractors designed according to individual skeletal anatomy [41]. Customized devices may improve force distribution, skeletal control, and appliance stability while minimizing unwanted dental movement [52].

Minimally invasive surgical approaches

Endoscopic visualization and piezoelectric osteotomy techniques may allow more controlled skeletal release while potentially reducing soft-tissue trauma and improving postoperative recovery [53]. Their role in routine surgical expansion remains an area of ongoing evaluation.

Airway-focused planning

Three-dimensional airway modeling and computational fluid dynamics (CFD) offer the possibility of evaluating not only airway volume but also changes in airflow patterns and resistance following skeletal expansion [16,18]. Future integration of these technologies with virtual surgical planning may allow treatment to be tailored toward both skeletal correction and airway objectives.

Regenerative strategies

Advances in regenerative medicine, including investigation of growth factors and stem-cell-based approaches, may improve bone regeneration and potentially shorten the consolidation period following distraction osteogenesis [54]. These approaches remain investigational and require further clinical validation.

Integration with orthognathic and sleep surgery

The future management of patients with combined dentofacial and airway abnormalities is likely to involve increasingly integrated treatment pathways. Transverse expansion may be combined with maxillomandibular advancement or other airway procedures when indicated [7,33,46]. Close collaboration among oral and maxillofacial surgeons, orthodontists, sleep physicians, and otorhinolaryngologists will remain essential for comprehensive patient selection and treatment planning [55].

Long-term outcome research

Although short- and medium-term improvements in skeletal dimensions, occlusion, and selected airway parameters have been reported, further prospective studies with standardized outcome measures and long-term follow-up are required [27,33]. Future research should incorporate objective sleep parameters, airway imaging, skeletal stability, periodontal outcomes, and patient-reported quality-of-life measures.

Conclusion

Surgical jaw expansion provides a reliable means of correcting transverse maxillary deficiency in skeletally mature patients when conventional orthodontic expansion is inadequate. SARPE, distraction osteogenesis, and segmental maxillary osteotomy offer distinct surgical approaches, and the choice of technique should be determined by the severity and pattern of skeletal deficiency, associated dentofacial deformities, and the overall treatment objectives.

Beyond occlusal correction, expansion may increase nasal cavity dimensions and improve nasal airway function, with selected patients demonstrating favourable changes in sleep-related respiratory parameters. However, the role of surgical expansion in obstructive sleep apnea should be considered as part of a comprehensive airway assessment, recognizing that OSA is often multifactorial and may require treatment at multiple anatomical levels.

Predictable outcomes depend on accurate diagnosis, meticulous preoperative planning, appropriate osteotomy design, preservation of vascularity, stable skeletal fixation or distraction, and adequate postoperative retention. Periodontal health, systemic status, bone quality, and patient compliance must be carefully evaluated before surgery.

The continued development of three-dimensional imaging, virtual surgical planning, patient-specific expansion devices, minimally invasive osteotomy techniques, and regenerative strategies is likely to further improve the precision and predictability of surgical maxillary expansion. As the relationship between craniofacial morphology and upper airway function becomes better understood, surgical jaw expansion will continue to play an important role at the interface of orthodontics, maxillofacial surgery, and sleep medicine.

Author Contributions

Dr. M. R. Haranadha Reddy, MDS, Professor, contributed to the conceptualization of the study, provided overall supervision, and critically revised the manuscript. Dr. Lavanya Ummadisingh, MDS, Associate Professor, was involved in methodology design, literature review, and manuscript editing. Dr. Sarah Fatima, MDS, Senior Lecturer, undertook the primary drafting of the manuscript, synthesized surgical techniques, and coordinated author contributions. Dr. Lasya SNKP Duggirala, BDS, carried out the literature search, data compilation, and drafted the section on indications and contraindications. Dr. Phalguni K N, BDS, assisted in manuscript preparation, formatting, and references, while Dr. Sultan Mohammed Riyaan Zaid, BDS, contributed to the clinical outcomes section and aided in data interpretation. Dr. Ghazala Hussain, BDS, supported the review of airway management literature and assisted in proofreading. Dr. Gunda Amitha, BDS, helped structure the surgical methods section and prepared figures. Dr. Mohammed Abdul Majid, BDS, contributed to the postoperative protocol and clinical outcomes subsections. Dr. Barla Divya, BDS, assisted in data organization and manuscript formatting. Dr. Seerla Varsha, BDS, contributed to the literature review and drafting of the introduction. Dr. Kovvuri Ramya Reddy, BDS (IV Year), assisted with references and manuscript editing. Dr. Sri Nanditha Ravula, BDS (III Year), contributed to the literature search and data tabulation. Dr. Rathod Prathyusha, BDS (III Year), assisted in proofreading and formatting, while Dr. Sanjna Jayesh Harakhchand, BDS (III Year), contributed to the compilation of clinical case examples and assisted in editing.

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