REVIEW ARTICLE

Maxillary Expansion in Cleft Lip and Palate Patients: A Review

Liyana Ghazali[1], Om Prakash Kharbanda[2,3], Umi Mardhiyyah Mat Ali[1], Mayank Khandelwal[4]

[1] Orthodontic Unit, School of Dental Sciences, Universiti Sains Malaysia, Health Campus, 16150 Kota Bharu, Kelantan, Malaysia
[2] National Academy of Medical Sciences, New Delhi 110029, India
[3] Director, Delhi Cleft Care Centre, New Delhi 110029, India
[4] Department of Orthodontics, Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bengaluru 560054, India

ABSTRACT

Cleft lip and palate (CLP) is a complex craniofacial condition that involve the lip, alveolus, and palate, along with associated structures, and may involve systemic abnormalities. Post-surgery, these children experience a range of issues. Maxilla is small in transverse dimensions, and the severity and location of collapse vary depending on the cleft type and surgical outcomes. Children with cleft deformities require palatal expansion during comprehensive orthodontic treatment. Clinicians and researchers have debated the age, type of appliance, and schedule of expansion. Newer appliances and protocols have emerged with the evolution of material science and manufacturing technology. This narrative review explores the modes of palatal expansion, timing, and techniques utilized in managing CLP patients. Palatal expansion procedures effectively obtain adequate palatal width and maxillary arch alignment as a pre-surgical step to promote better oral functioning. Types, modes, timing, and protocols of maxillary expansion were discussed.
Malaysian Journal of Medicine and Health Sciences (2026) 22(1): 1-12. doi:10.47836/mjmhs.v22.i1.1468

Keywords: Bilateral cleft lip and palate, Craniofacial anomalies, Maxillary expansion, Maxillary transverse deficiency, Unilateral cleft lip and palate

Corresponding Author:
Liyana Ghazali, DClinDent Orthodontics
Email: gliyana@usm.my
Tel : +6097675896

INTRODUCTION

Orofacial cleft is the most frequent congenital deformity affecting the craniofacial region in humans, having an average prevalence of 1.7 in 1000 live births (1). The cleft lip and palate (CLP) can range from simple notching or clefting on the upper lip or palate to a more severe form involving the lip, alveolus, hard and soft palate, and can result in adverse effects on the patient's physical, social, and psychological health. A study conducted in South Africa reported that the highest prevalence of cleft was CLP (45%), followed by cleft palate (CP), 35%, and cleft lip (CL), 20% (2). The aetiology and pathogenesis of CLP are multifactorial, influenced by genetic and environmental interactions, including drug exposure and prenatal nutrition. Patients with severe orofacial cleft typically require complex and long-term treatment to restore appearance, occlusion, and speech (3).

DENTOALVEOLAR DEFECT IN CLP

Maxillary growth in children with operated CLP is often inadequate and restricted, affecting the transverse, sagittal, and vertical dimensions, leading to midface hypoplasia (4). The scarring from surgical interventions, particularly palate repair, can further inhibit maxillary development and lead to a V-shaped dental arch. This scarring can cause inward deflection of the dentoalveolar processes, resulting in anterior and transverse crossbites (3). According to Vettore et al., approximately 60% of children with CLP experience anterior crossbites, and 40% have posterior crossbites (5).

Maxillary teeth may be crowded, rotated, or tipped, especially adjacent to cleft areas. Midline discrepancy is commonly seen due to a history of defects in the premaxilla area. Other dental anomalies found near the cleft area include the presence of supernumerary teeth, hypodontia of lateral incisors, impacted teeth, and structural and morphological defects of the teeth. The timing of tooth bud formation coincides with developmental defects resulting in cleft formation. Maxillary constriction can also be associated with functional difficulties such as narrowing of the pharyngeal airway, increased nasal resistance, alterations in tongue posture, and mouth breathing (6,7).

The pattern of maxillary constriction varies in different cleft types. In unilateral CLP (UCLP), there is more collapse of the smaller segment of the arch, while in bilateral CLP (BCLP), collapse is more evident in the canine premolar region, with significant meso-lingual rotation of the maxillary first molars. The availability of space in the palatal region and the associated dental movements required can influence the choice and design of the appliance (8).

JUSTIFICATION FOR EXPANSION

CLP patients experience restricted growth and midface hypoplasia, resulting in a constricted maxilla and anterior and posterior crossbites along with a collapsed arch. To aid in the correction of these problems, expansion of the upper arch is deemed necessary. The cleft defect compromises the alveolar integrity, resulting in a discontinuity of the alveolus.

A bone grafting procedure involving the placement of cancellous bone to provide continuity to the alveolar ridge is recommended to facilitate the eruption of teeth into the graft and orthodontic movement into the cleft site. Based on the eruption status and age of bone graft and dentition, bone grafting can be categorized as primary, secondary, late, and tertiary. Secondary alveolar bone grafting (SABG) is the most frequent procedure done worldwide in cleft cases before the eruption of the maxillary permanent canine (9). In rehabilitation protocol, orthodontic expansion is frequently required to create surgical access and maximize the amount of bone graft that can be placed in the cleft site (10).

TIMING OF EXPANSION

Current thinking revolves around expanding the maxillary arch in preparation for SABG and placement of autogenous bone graft obtained from the iliac crest to stabilize the premaxilla after expansion and prevent arch collapse. This is normally performed around 9-11 years old, before the eruption of maxillary canines (11). However, researchers have reported that rapid maxillary expansion can be performed after SABG without compromising the bone graft (12). Case reports of two patients having cervical vertebrae maturation (CVM) stage three underwent rapid maxillary expansion and showed successful expansion with the presence of midline diastema and radiolucency at palatal suture area indicating an opening at the midpalate (13).

MODE OF MAXILLARY EXPANSION IN ORTHODONTICS

The maxillary expansion could be skeletal or dentoalveolar. Different types of appliances to achieve expansion can be removable (Coffin spring, Schwarz appliance) or fixed appliances (Quadhelix, NiTi expander, W arch) (Figure 1). Expansion can be categorized as slow or rapid expansion based on the velocity of the expansion. The absence of mid-palatal suture in complete UCLP and BCLP and the presence of soft tissue palatal closure should be attended with caution for expansion. The expansion in the maxilla is more focused on the anterior region due to the cleft present. The examples of randomized controlled trials regarding maxillary expansion in cleft patients are summarized in Table I (14-18).

Table I: Randomized Clinical Trial of expansion appliance in reference to CLP

Author(s)	Target group	Appliance	Protocol used	Findings
Singh et al, 2021 (17)	27 BCLP vs 26 non-cleft patients Mean age 11.1 years	Bonded Hyrax expander (9mm; Leone, Italy)	1x turn each in the morning and evening (0.5mm/day) for 7-14 days until the desired expansion is achieved, followed by keeping the Expander for 3 months and using the trans-palatal arch for 6 months as retainers.	RME effectively improves the hearing and normal functions in BCLP and non- cleft patients RME influences voice quality in non-cleft patients but has no significant effect in BCLP patients.
Figueiredo et al, 2016 (15)	20 UCLP aged 8-15 years.	Modified hyrax vs inverted mini hyrax	2x turns per day till the palatal cusp of the maxillary first molar touches the buccal cusp of the mandibular first molar. The appliance was kept as a passive retainer for 3 months and then replaced with a transpalatal bar with anterior extensions.	Both appliances effectively achieve transverse expansion of the maxilla. They are suitable for cleft cases with posterior transverse discrepancies. They provide more significant expansion in the posterior maxillary region compared to the anterior region
Ayub et al, 2016 (14)	25 complete UCLP and posterior crossbite mean age 10.6 years	Haas- type Expander	1x complete turn every day for 7 days/ till overcorrection of transverse width and contact of the palatal cusp of the upper molar to the buccal cusp of the lower molar. The appliance was retained for 6 months for retention.	Comparable changes in maxillary arch dimensions, palatal volume and dentition changes were noted. A reduction in arch length and palatal depth was reported in the UCLP group.
Ayub et al, 2022 (18)	22 UCLP mean age 9.9 years vs 29 UCLP mean age 10.7 years	Hyrax vs QH	Hyrax type expander: 1x complete turn a day (0.8mm) for 7- 14 days till slight overcorrection is seen. After the active phase, the appliance was maintained for 6 months for retention. QH: Upper molars were expanded to a similar width as lower molars. QH was widened anteriorly by pulling the canine loop apart. QH activation was done by removing the molar band, expanding the appliance, and recementation of the molar band every 6 weeks.	Equivalent dentoalveolar effects were noted in both types of expanders, with greater transverse changes in the RME group.

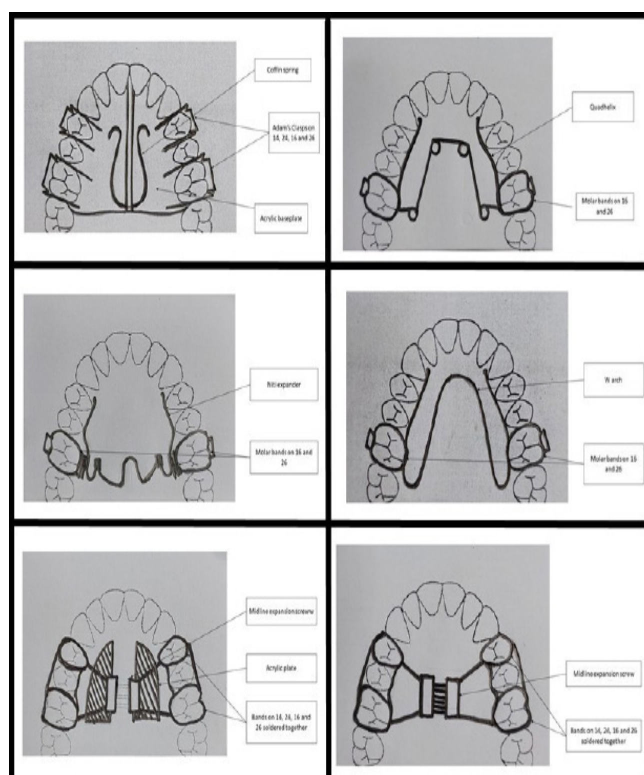

Figure 1: (clockwise): Coffin spring, Quadhelix appliance, W arch expander, Hyrax expander, Haas expander, NiTi expander

SLOW MAXILLARY EXPANSION (SME)

The SME gives low continuous forces applied to teeth over a long period. The main effects seen are on the dentition; however, younger patients might experience some skeletal changes. SME can be removable (Coffin spring, Schwarz appliance) or fixed (Quad helix/ trihelix/ bihelix/ reverse quad helix and NiTi expander).

Coffin spring (Fig. 1)

Coffin spring was first introduced by Sir Walter Coffin in 1875 for slow dentoalveolar expansion. Coffin spring is an omega-shaped wire constructed using 1.25 mm wire, and the ends of the wire are embedded into the acrylic baseplate. This heavy spring can be activated by manually pulling or flattening the two halves of the spring apart or using pliers. Coffin spring delivers heavy force. Thus, well-fitting rigid retention of upper removable appliances is crucial to maintain the results (19).

Schwarz appliance (Fig.1)

Schwarz appliance was introduced by Artur Martin Schwartz in 1956 and is indicated to be used in mixed dentition. The appliance consists of one or two expansion screws incorporated into an acrylic baseplate, and the appliance is retained by Adams clasp on the first molars or premolars and labial bow anteriorly. Kurniaty et al advocated for 0.2mm expansion every week on the anterior and posterior part of the screw in UCLP patient (20).

Quadhelix/ Trihelix/ Bihelix/ Reversed Quad helix (Fig.1)

A quadhelix (QH) is made from either 0.9 - 1.0 mm stainless steel wire or 0.95 mm cobalt chromium wire. The appliance is soldered to bands cemented on the upper first molars and normally incorporates four helices, two at the posterior and two at the anterior regions, to increase the range of action. The appliance has the advantage of being more flexible and can be modified as a trihelix to fit into a collapsed anterior maxilla with a narrow arch. This is particularly useful in cleft patients. The QH is activated by approximately one molar tooth width every 4- 6 week until crossbite is slightly overcorrected. QH is flexible and can be modified to suit patients' needs. It can be designed to contain 3 helices (trihelix) or 2 helices (bihelix) in a very narrow upper arch. Aizenbud et al described a modification in the form of a reverse QH design. The reverse QH is an efficient appliance for differential expansion of the anterior maxillary region before SABG in UCLP patients (21).

NiTi Expander (Fig. 1)

The nickel titanium (NiTi) maxillary expander was first developed as a fixed-removable tandem-loop appliance by Wendell Arndt in 1993. This appliance was designed to deliver a uniform, slow and continuous force for maxillary expansion and arch development, along with rotation and distalisation of the molars. The slow expansion rate of the NiTi expander maintains tissue integrity by promoting tissue regeneration during the repositioning and remodeling of teeth and bone (22). Torres et al reported a case series of using a reprogrammable NiTi expander to treat UCLP patients before SABG. Reprogramming the Niti expander is useful for reducing chairside time and frequent appointments (23).

RAPID MAXILLARY EXPANSION (RME)

RME delivers intermittent and heavy forces to anchor teeth or tissue during a short period in growing patients. The incomplete interdigitation and ossification of the midpalatal suture in growing patients makes RME an effective procedure for expanding the arch by further opening the midpalatal suture and providing stable skeletal expansion (24). The activation takes place for 20- 40 days, and the appliance is left in situ as a retainer for six months (25). RME technique is indicated for a variety of clinical indications, particularly constricted high-arched palate and poor transverse or sagittal maxillary growth.

The expanders for RME can be categorized as tooth-tissue-borne (Haas expander) or tooth-borne appliances (Hyrax expander). The appliance is activated by turning the expansion screw twice daily (2 turns = 0.5 mm) to open the palatal suture, and the remodeling and

ossification process of the suture will happen, creating firm interdigitation and expanding the maxilla in the transverse plane (26). Hyrax design appliance with molar bands on the upper first molars and first premolars with a 9 mm expansion screw is the most common RME design. Mini Hyrax with molar bands on the first molars and an 8mm expansion screw can be an alternative in a severely constricted arch. Silveira et al. reported that both types of expanders (Hyrax and mini-Hyrax) are equivalent in efficiency in obtaining skeletal and dental effects and patient comfort (27).

The orofacial complex is significantly affected by RME. De Meideros Alves et al reported RME caused significant increase of arch widths and arch perimeter. Arch length and palatal depth decreased significantly with RME (28). Fatima et al investigated the effects of RME on hearing improvement in cleft patients. There was no improvement or deterioration in the hearing levels after RME. Thus, the authors concluded that RME may be undertaken in UCLP patients safely in terms of hearing is concerned (29).

Traditional tooth-borne RME appliances are associated with root resorption because of the force transmitted to teeth during activation (30). Upper posterior teeth tip buccally causing dentoalveolar expansion and might result in interference with the occlusion and further reduce the overbite. Hence, the expansion of RME must always aim to maximize skeletal and minimize dental effects of expansion. Other negative effects include posterior tooth extrusion, bone dehiscence, gingival recession, and alveolar bone loss (26).

Tooth tissue-borne expanders

Haas expander (Fig. 1)

Haas expander, introduced by Andrew Haas in 1961, is a tooth tissue-borne expander. It consists of a jackscrew embedded in an acrylic base plate and consists of four arms banded to the first premolars and first molar. It is effective in increasing the transverse dimension of the maxilla by 12-15 mm in 10 days. Haas expander is the preferred expander in patients having sufficient palatal depth due to the anchorage provided by the acrylic base plate (31).

Tooth borne expanders

Hyrax expander (Fig. 1)

The Hygienic Rapid Expander (Hyrax), by William Biederman in 1968, is one of the most widely used expansion devices to expand the mid-palatal suture for correction of maxillary constriction in growing patients. It has the advantage of being less irritating to the palate and facilitates better oral hygiene maintenance due to the absence of acrylic pads. The traditional design of the Hyrax expander incorporates bands on the first premolars and molars teeth with four arms and a non-spring-loaded jack screw for causing expansion, capable of opening by 11-13 mm. Figueiredo et al investigated the effects of Hyrax appliances in UCLP patients. They found that Hyrax is effective in the transverse expansion of the maxilla and produces greater expansion in the posterior maxillary region than in the anterior (15).
The expansion appliances used in cleft patients are summarised in Table II.

c. Alt- RAMEC protocol

In 2005, a new protocol of alternate rapid expansion and constrictions (Alt-RAMEC) in cleft patients was introduced by Liou et al. (32). The concept of the protocol was based on the idea that repetitive and frequent expansion and constriction protocol on an alternate basis will displace and open the circummaxillary sutures allowing effective displacement of the maxilla. The protocol sequence of Alt-RAMEC is alternate expansion and contraction for one week each, four times, followed by a final expansion. Every cycle of expansion or contraction includes opening or closing the screw by 1 mm per day for 7 days. Compared to RME, the repetitive weekly protocol of Alt-RAMEC was found to displace the maxilla twice as effectively and promote maxillary protraction three times as well as a single course of RME (32). Table III discusses the evidence related to Alt-RAMEC protocol used in cleft patients (33-36).

Table III: Alt-RAMEC protocol in cleft patients

Author(s)	Objectives	Appliance used	Protocol used	Findings
Sami et al, 2023 (3 3)	to evaluate the skeletal, dentoalveolar, and soft tissue changes before and after treatment with Alt-RAMEC protocol and protraction headgear	Intervention: Alt-RAMEC protocol followed by facemask therapy Control group: RME and facemask therapy.	Alt-RAMEC: 1st week: open the screw by 1 mm, i.e., 4 turns per day Following week: close it by 1 mm, i.e., 4 turns per day. Repeat for 7 consecutive weeks. It was followed by facemask therapy for 4 to 5 months. Control group: Open the hyrax screw by 1 mm per day, i.e., 4 turns per day, for 1 week. Followed by face mask therapy for 5–6 months. The total treatment time in both groups was 6–7 months.	The Alt-RAMEC protocol and facemask therapy in CLP patients have been shown to have considerable positive outcomes. There was a - remarkable forward movement of point A with a better maxillo-mandibular relationship. - Anterior movement of the maxilla improved. - The mandible showed a slight decrease in SNB angle. - The increase in width of the inter-canine and intermolar regions was more evident in the Alt-RAMEC group.
Khalil et al, 2023 (34)	to assess the effectiveness of the expander with differential opening (EDO) with alternate rapid maxillary expansion and contraction (Alt-RAMEC), and Facemask Protraction in patients with CLP.	All patients treated with the Alt-RAMEC protocol used EDO and a protraction facemask.	Alt-RAMEC protocol: 4x/ day (1mm/day, turn each) for both screws two turns in the morning and two turns in the evening. 1st week: 7 days of expansion 2nd week: 7 days of constriction 3rd week: 7 days of expansion 4th week: 7 days of constriction 5th week: 7 days of expansion 6th week: 7 days of constriction 7th week: 7 days of expansion If the anterior crossbite was still present, the anterior screw would only be activated 4x a day until the anterior crossbite was corrected.	- Significant maxillary expansion and advancement were achieved while using the EDO with Alt-RAMEC and facemask protraction. - There was a slight decrease in buccal bone thickness and height and a significant increase in buccal molar inclination
Meazzini et al, 2018 (35)	to evaluate short- and long-term results of the application of the Liou Alt-RAMEC technique, a late orthopedic maxillary protraction technique, with intraoral anchorage, in patients with cleft.	• Double-hinged maxillary expander. • Lower double lingual arch. • Temporary anchorage devices positioned in the maxillary and mandibular arch. • Heavy intraoral elastics. • Protraction springs.	Alt- RAMEC protocol: 7 cycles with 7 days of expansion and 7 days of constriction, 1 mm per day, alternatively. After 7 weeks of alternate expansion–constriction. In 30% of the patients, there was a need to go up to 9 or 11 cycles, to achieve mildly perceivable maxillary mobility.	The Liou Alt-RAMEC technique allows for a satisfactory maxillary protraction, if performed: - With the right timing, close to growth peak and not in early deciduous dentition. - With the correct double-hinged expander, which allows true mobilization of the maxilla, and not a traditional RPE. Followed by class III springs or elastic traction, applied 24 h/d, and not only nightly traction.
Meazzini, 2020 (36)	to describe the rationale behind a protocol for the treatment of maxillary hypoplasia in cleft lip and palate (CLP) patients where timing is guided by different indications.	Thirty patients were treated early with expansion and facemask. A traditional RPE, bonded (McNamara type) or soldered to bands on deciduous molars was cemented to which a face mask was applied for at least 14 h/day.	Upper arch: double-hinged maxillary expander (DHME) consisted of a jackscrew in the center, and two hinges of rotation posteriorly. Lower arch, a double lingual arch with anterior hooks was soldered on molar and premolar bands. The treatment protocol consisted in 7 cycles with 7 days of expansion and 7 days of constriction, 1 mm/day, alternatively. In 30% of the patients, there was a need to go up to 9 or 11 cycles, to achieve mildly perceivable maxillary mobility.	Early correction of maxillary hypoplasia, even though skeletal relapse is expected, might be indicated in patients with functional problems, such as hearing or breathing disorders, to avoid more complex treatments. For correction of the occlusal aesthetic problem, it is advisable to wait till after the growth peak and apply a modified Alt-RAMEC technique, with a double-hinged expander, This technique significantly reduces, especially in female patients, the need for final orthognathic surgery.

Table II: Summary of Expansion Appliances used in Cleft Lip and Palate Patients

Types of appliances	Construction	Mode of action	Advantages	Disadvantages	Cleft protocol
			SLOW MAXILLARY EXPANSION		
Coffin Spring	Omega-shaped 1.25mm wire embedded into acrylic	Activation by manually pulling 2 halves of the spring	• can be used for unilateral/ bilateral crossbite • anteroposterior expansion	• Mainly dental effect • Minimal expansion (3mm) • less flexible	Kaiser et al, 2024 (52) • Modification: Coffin spring was anchored to teeth by posterior acrylic capping using glass ionomer cement. • Activated every 4 weeks
Schwarz appliance	• Expansion screw • Acrylic resin • Adams hooks on upper molars	Activation is achieved by opening the screw.	• Increase dental inclination • Can be used for mandibular expansion/ correction of crowding	• Long treatment period 1 year (Tai et al, 2010) (53)	Kurniaty et al, 2018 (20) • ¼ or 0.2mm expansion every week on the anterior and posterior part of the screw
Quad-helix/ Trihelix/ Bihelix/ reverse quad-helix	• made from 0.036-inch/ 0.965mm SS, soldered to bands on the permanent first molars with extension arms • consisted of four loops or helices, two anterior and two posteriors	QH is pre-activated by stretching the two molar bands/extensions apart before cementation.	• Flexible • Allow modifications • Provide continuous force • Enhance rotation of molars • expansion in the anterior region was greater than that of the posterior in UCLP patients (Li and Lin, 2007) (54)	• require regular monitoring to determine the desired expansion • interfere with the surgical field • inability to precisely predict the expansion • extra appointments • expansion is not self-limiting, which can lead to overexpansion	• Appliance is used to expand the upper arch until posterior crossbite is overcorrected by approximately 2 mm. • QH is kept in place until a heavy rectangular SS wire is used. • The active quad-helix treatment time is 4–7 months.
Niti expander	• Round W Ni–ti wire (NiTi loop) • Connected to 0.036″ stainless steel (SS) wire arms that can be adapted to the dentition • NiTi loop is curved up in the vertical plane to follow the vault of the palate. • NiTi connecting wire between SS arms and Niti loop allows differential expansion • A connecting pad can be inserted in the lingual sheaths of the molar bands (Torres et al, 2019) (23)	• Prefabricated • Maxillary arch width is measured between the central pits of permanent maxillary first molars. • 2mm overexpansion is added to the measurement. • generate forces of 180 to 300 gm. (Poornima et al, 2000) (22)	• does not interfere with the surgical field • differential expansion can be programmed into it • NiTi expansion was precise and self-limiting, eliminating the risk of overexpansion. • no need for additional appointments • easier for patients to accept • removal of the appliance was not necessary before the ABG surgery • enabled a longer period of stabilization of the expansion • can be customized to the desired width and becomes passive once that dimension is achieved (Torres et al, 2019) (23)	• Not suitable in flatter palatal vault, which can cause impingement of the palatal tissue. • requires a wire shaper power supply unit which is not a standard piece of orthodontic equipment. (Torres et al, 2019) (23)	Poornima et al, 2000 (22) • Permanent maxillary first molars are banded after an appropriate Niti expander is selected. • The lingual sheaths are welded and soldered to each band. • The molar bands are cemented with Glass Ionomer luting cement. • Niti expander is cooled with ice and the martensitic form is inserted into the bands as one passive unit. • Reviews are at 6-week intervals till the end of expansion time (3 months).

CONTINUE

Table II: Summary of Expansion Appliances used in Cleft Lip and Palate Patients (CONT.)

Types of appliances	Construction	Mode of action	Advantages	Disadvantages	Cleft protocol
			RAPID MAXILLARY EXPANSION		
Tooth-tissue Borne Appliance Haas Expander	Expansion screw with arm extension. anchored onto the bands of the first permanent molars and premolars (or deciduous molars) and 1.0mm SS frame and to the palatal vault by an acrylic mass to reinforce anchorage.	Expansion is achieved by opening of the expansion screw.	• Comfortable • Can be anchored to deciduous teeth (Mutinelli et al, 2025) (55) • reinforce the anchorage for greater orthopaedic response and better force distribution	• Must have enough initial palatal depth to receive the Haas-type expander • Increase risk of mucosal inflammation • require monitoring to determine whether the desired expansion is reached • interfere with the surgical field.	Ayub et al, 2022 (18) • 1 complete turn a day (2/4 screw activation in the morning and 2/4 screw activation in the evening) for 7 days. • performed until a slight overcorrection is reached. • Appliance is maintained as retention for 6 months. Facanha et al, 2012 (31) • 2/4 turns in the morning and 2/4 turns in the evening for 7 days. Whenever necessary, further activation is performed until overcorrection is reached.
Tooth-tooth Borne Appliance Hyrax Expander	Expansion screw with arm extension, anchored onto the bands of the first permanent molars and premolars (or deciduous molars) and 1.0mm SS frame without palatal acrylic coverage. When the maxillary deciduous second molars were banded, a lingual extension wire was placed in the partially erupted maxillary permanent first molars. (Garib et al, 2016) (45)	Expansion is achieved by opening of the expansion screw.	• more comfortable • more hygienic • prevent soft tissue irritation • can be used in deciduous teeth	• Higher pain level is reported as compared to Haas expander (Ugolini et al, 2020) (56) • require monitoring to determine whether the desired expansion was reached • interfere with the surgical field.	Garib et al, 2016 (45) • Anterior and posterior screws are activated with a complete turn a day (approximately 0.8 mm) until achieving an overcorrection at the molar region. • During the following days, only the anterior screw is activated until achieving a slight overcorrection of 2 mm in the intercanine distance. Facanha et al, 2012 (31) • 2/4 turns in the morning and 2/4 turns in the evening for 7 days. Whenever necessary, further activation is performed until overcorrection is reached.

Surgical Expansion

SLOW VS RAPID MAXILLARY EXPANSION IN CLEFT LIP AND PALATE

Skeletal Effects

SME and RME were found to have equivalent expansion efficiency in the posterior region in cleft patients and SME showed higher anterior differential expansion QH appliance (1). A randomized controlled clinical trial (RCT) compared the skeletal effects of SME and RME in BCLP patients by CBCT and reported more controlled anterior expansion was seen in cases treated with QH, which is favourable due to the collapse of the maxillary arch (37). The findings are slightly contradicting with Rutili et al who reported that RME induced greater posterior skeletal expansion than SME and anterior skeletal expansion was comparable between both modalities (38). Considering that anterior expansion is more controlled and predictable with SME, many clinicians prefer to use SME.

Dentoalveolar effects

Expansion modalities have been associated with unfavorable dentoalveolar effects such as molar tipping and root dehiscence. On comparing the effects of slow and rapid expansion in 50 BCLP patients, it was found that both expansion modalities were equivalent in increasing the arch width, arch perimeter, and intermolar width. Whereas for buccal tipping, deciduous canines were found to have significant differences (28) while molars were found to have similar findings without periodontal changes (37). There contradicting evidences regarding adverse effects related to maxillary expansion in cleft patients. Schultz reported that it was a common occurrence to see new fistulae development after maxillary expansion (39). Shankar et al, however, disagreed and affirmed that these small, pre-existing fistulae are made more visible through the expansion procedure (40). There is a lack of conclusive evidence on the adverse effects of SME and RME in cleft patients (1).

EXPANSION PROTOCOL IN CLEFT LIP AND PALATE

Expansion protocol has relatively remained similar throughout the years. Expansion protocol of SME using QH appliance differs slightly in activation timings between studies. Several expansion protocols are discussed in Table I.

For RME, activation of the jack screw was found consistent among the studies with a protocol of two turns per day until parallel expansion was achieved. All RME appliances were maintained for 3-6 months for retention.

SME OR RME?

Cleft patients are found to have minimal to no intermaxillary suture, thus giving the least resistance to expansion forces. Higher forces of RME are transferred to the teeth and greater skeletal effects and transverse development of the maxilla are seen. The appliance design and force vectors of the jack screw give almost parallel expansion and are recommended in BCLP cases having collapsed anterior arch which requires greater stabilization.

SME by the QH appliance is more flexible with the force vectors and effects seen. It can be modified to a trihelix, bihelix or reversed in cases of severely constricted arch and can be manipulated to meet the treatment goals and better regional control of the expansion matching the patient's needs. No consensus exists on the choice of appliance for expansion, and the timing of expansion in CLP cases.

Relationship of Expansion with alveolar bone grafting

In cleft patients, the lack of integrity of the alveolus may restrict the orthodontic treatment, which can be restored with an alveolar bone grafting (ABG) procedure. They are categorized based on timing as primary, secondary, and tertiary. Primary ABG is performed during infancy or early childhood. SABG which is the most performed procedure is done between the ages of 9 to 12 years old and has demonstrated minimal midfacial growth disturbances (41). Lastly, late ABG is the procedure performed after all permanent teeth have erupted and has been associated with high relapse. ABG procedure is crucial to correct the bony defect, facilitate maxillary canine and lateral incisor eruption, permit orthodontic correction and stabilize the upper arch. It also helps to close the fistula improving the contour of the alar base. Maxillary expansion can be either performed prior to or after ABG. Based on conventional protocol, maxillary expansion is performed before ABG to aid the alignment of arch segments and provide the surgeon with a more favourable environment for alveolar bone reconstruction (42). Maxillary expansion also corrects the transverse discrepancy of maxillary without compromising the integrity of the graft (43). Cavassan et al reported that maxillary expansion can be performed after the ABG especially when the ideal timing for maxillary expansion is missed or when there is a relapse after ABG (44) without compromising the integrity of the grafted alveolar cleft (45). However, no comparison was reported between maxillary expansion before and after ABG.

Expansion in adult cleft cases

Maxillary expansion can be done in adults with CLP. A case report described the lack of treatment experienced by an adult CLP patient who was never examined by dental professionals. Severely constricted maxillary base width was seen, and a QH was given for 6 months to expand the maxilla, followed by a denture-type appliance with expansion to further expand the maxilla. Lefort 1 osteotomy was performed to bring down the right segment of maxilla and correct occlusal plane (46).

Expansion in UCLP vs BCLP cases

Evaluation of SME (QH) and RME (Hyrax) for occlusal

effects in UCLP patients was evaluated in growing patients. Cases requiring surgical advancement of the maxilla later do not require much posterior expansion and either RME or SME can be provided. Cases requiring more posterior expansion should be treated by RME and those requiring more anterior expansion should be treated by SME (18).

In BCLP patients, SME and RME helped expand the maxilla with no discernible difference between the two modalities. Faster expansion can be achieved using RME thus, some studies advocated the use of RME (28, 37). However, in patients with the absence of midpalatal sutures, the dentoskeletal effects of SME and RME will have a different outcome and should be done with caution.

STABILITY OF EXPANSION IN CLP

All the expansion appliances either RME or SME should be left at least 3- 6 months after active expansion is completed (47). This stabilization period is particularly important to complete the bone remodelling procedure and ossification thus, avoiding the collapse of the maxilla in CLP patients. Factors affecting the outcomes and stability include scar contraction, muscle strain, and rotation of bone segments (13).

Relapse after expansion

Relapse is commonly seen in orthodontic treatment. Relapse in cleft patients is highly associated with scarring secondary to extensive surgical procedures. Relapse occurred especially in the upper canine and premolar region although most treatment results (inter-molar, basal bone width and alveolar arch width were maintained 15 months – 4 years after retention (48). New techniques of expansion, particularly Alt-RAMEC and adjunct procedures have been used to increase the stability of treatment.

Meazzini et al retrospectively compared a sample of treated (n=29) and non-treated (n=12) class III UCLP patients and suggested a positive effect of treatment on maxillary position. Patients receiving treatment have lesser chances of requiring orthognathic surgery in the future (36).

A case report of a 32-year-old female with UCLP, transverse collapse of the maxilla, and significant palatal scarring after undergoing several orthodontic and surgical procedures was reported. The clinicians re-expanded and realigned her maxilla along with triamcinolone injections to soften scarred palatal tissue. The expansion was retained using full-time use of a removable cobalt-chrome frame and no further relapse was seen in 4 years follow-up (49).

Case studies related to the expansion

A case report examining the effects of RME performed after secondary bone grafting found that RME can effectively open the midpalatal suture and provide better expansion stability in adolescents with unilateral cleft lip and palate (UCLP). The study observed a triangular expansion pattern and a significant increase in both maxillary and dental arch width following RME (13).

Another case study of a 12-year-old girl presenting with UCLP with hypoplastic and flattened alar cartilage, short columella, and the anterior and posterior crossbite. She was treated with a quad-helix to achieve the expansion on the upper arch before the late ABG to restore the integrity of the maxilla (50).

A case report of a 9-year-old boy with a history of UCLP and skeletal class III malocclusion and the anterior and posterior crossbite was treated with a quad-helix for expansion. Quad-helix was retained for 12 months followed by SABG. The quad-helix was replaced by the transpalatal arch during fixed orthodontic treatment to maintain the transverse correction of the maxilla (51).

Limitation

Current literature review summarizes the evidences on maxillary expansion in cleft patients. However, significant variability in epidemiological and scientific data hinders the ability to draw conclusive evidence. Many evidences are based on case reports and lack of high quality studies such as randomized controlled trial were included in this review.

CONCLUSION

Palatal expansion in CLP patients is indicated to aid alignment in a collapsed arch, correct posterior crossbite, to create surgical access, and maximize the amount of bone graft that can be placed in the cleft site during the alveolar bone grafting procedure.

1. The timing/age of maxillary expansion is essentially influenced by the type of deformity and its influence on functional occlusion. Unilateral cross-bites causing functional shifts should be attended to whenever they are first reported.
2. In general, the consensus age for maxillary expansion is linked to the pre-bone graft expansion (9-11 years old before the eruption of maxillary canine).
3. Slow maxillary expansion, particularly quad helix, is preferable in unilateral cleft lip and palate cases.
4. Rapid maxillary expansion is preferable in bilateral cleft lip and palate.
5. Alternate rapid expansion and constriction (Alt-RAMEC) protocol is relatively more effective for protracting the maxilla.
6. There is a need to conduct studies to generate robust data on age severity type of appliance and protocol of expansion in reference to cleft type, severity of defect at birth vis a viz defect at the time of starting the therapy. The study should evaluate effects in three dimensions and not just transverse expansion.

REFERENCES

1. Luyten J, De Roo NM, Christiaens J, Van Overberghe L, Temmerman L, De Pauw GAM. Rapid maxillary expansion vs slow maxillary expansion in patients with cleft lip and/or palate: a systematic review and meta-analysis. Angle Orthod. 2023 Jan 1;93(1):95-103. doi: 10.2319/030122-188.1.
2. Hlongwa P., Levin J., Rispel L.C. Epidemiology and clinical profile of individuals with cleft lip and palate utilising specialised academic treatment centres in South Africa. PLoS ONE. 2019;14:e0215931. doi: 10.1371/journal.pone.0215931
3. Kharbanda OP, Agrawal K, Khazanchi R, Sharma SC, Sagar S, Singhal M, Mathur NN, Handa KK, Kabra M, Gupta N, Wadhwan N. Clinical profile and treatment status of subjects with cleft lip and palate anomaly in India: Preliminary report of a three-center study. Journal of Cleft Lip Palate and Craniofacial Anomalies. 2014 Jan 1;1(1):26-33. doi.org/10.4103/2348-2125.126550
4. Kharbanda OP. Orthodontics: Diagnosis and Management of Malocclusion and Dentofacial Deformities. 3rd India: Elsevier. 2019
5. Vettore MV, Sousa Campos AE. Malocclusion characteristics of patients with cleft lip and/or palate. The European Journal of Orthodontics. 2011 Jun 1;33(3):311-7. doi.org/10.1093/ejo/cjq078
6. Aloufi F, Preston CB, Zawawi KH. Changes in the upper and lower pharyngeal airway spaces associated with rapid maxillary expansion. ISRN Dent. 2012;2012:290964. doi: 10.5402/2012/290964.
7. Vidya VS, Sumathi FA. Rapid maxillary expansion as a standard treatment for obstructive sleep apnea syndrome: a systematic review. J Dental Med Sci. 2015; 14:51–5. doi.org/10.9790/0853-14225155
8. Kharbanda OP. Cleft Orthodontics: A Holistic and Interdisplinary Approach. 1st Edition. Delhi, Thieme. 2021
9. Fahradyan A, Wolfswinkel EM, Clarke N, Park S, Tsuha M, Urata MM, Hammoudeh JA, Yamashita DD. Impact of the distance of maxillary advancement on horizontal relapse after orthognathic surgery. The Cleft Palate-Craniofacial Journal. 2018 Apr;55(4):546-53. doi.org/10.1177/1055665617739731
10. Freitas JA, Garib DG, Oliveira M, Lauris RD, Almeida AL, Neves LT, Trindade-Suedam IK, Yaedь RY, Soares S, Pinto JH. Rehabilitative treatment of cleft lip and palate: experience of the Hospital for Rehabilitation of Craniofacial Anomalies-USP (HRAC-USP)-Part 2: Pediatric Dentistry and Orthodontics. Journal of Applied Oral Science. 2012; 20:268-81. doi.org/10.1590/S1678-77572012000200024
11. Brudnicki, A., Petrova, T., Dubovska, I., Kuijpers-Jagtman, A. M., Ren, Y., & Fudalej, P. S. (2023). Alveolar Bone Grafting in Unilateral Cleft Lip and Palate: Impact of Timing on Palatal Shape. Journal of Clinical Medicine, 12(24), 7519. doi.org/10.3390/jcm12247519
12. Precious DS. A new reliable method for alveolar bone grafting at about 6 years of age. Journal of oral and maxillofacial surgery. 2009 Oct 1;67(10):2045-53. doi.org/10.1016/j.joms.2009.04.102
13. Yang CJ, Pan XG, Qian YF, and Wang GM. Impact of rapid maxillary expansion in unilateral cleft lip and palate patients after secondary alveolar bone grafting: review and case report. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012; 114(1):e25-e30 doi.org/10.1016/j.tripleo.2011.08.030
14. Ayub PV, Janson G, Gribel BF, Lara TS, Garib DG. Analysis of the maxillary dental arch after rapid maxillary expansion in patients with unilateral complete cleft lip and palate. American Journal of Orthodontics and Dentofacial Orthopedics. 2016 May 1;149(5):705-15. doi.org/10.1016/j.ajodo.2015.11.022
15. Figueiredo DS, Cardinal L, Bartolomeo FU, Palomo JM, Horta MC, Andrade Jr I, Oliveira DD. Effects of rapid maxillary expansion in cleft patients resulting from the use of two different expanders. Dental Press Journal of Orthodontics. 2016 Sep 22;21(06):82-90. doi.org/10.1590/2177-6709.2016-001.aop
16. Pugliese F, Palomo JM, Calil LR, Alves AD, Lauris JRP, Garib D. Dental arch size and shape after maxillary expansion in bilateral complete cleft palate: a comparison of three expander designs. Angle Orthod. 2020; 90 (2): 233– 238. doi.org/10.2319/020219-74.1
17. Singh H, Maurya RK, Sharma P, Kapoor P, Mittal T, Atri M. Effects of maxillary expansion on hearing and voice function in non-cleft lip palate and cleft lip palate patients with transverse maxillary deficiency: a multicentric randomized controlled trial. Brazilian Journal of Otorhinolaryngology. 2021 Jul 5;87(3):315-25. doi.org/10.1016/j.bjorl.2019.09.010
18. Ayub PV, Garib DG, Ebrahim H, Polido J, Blasca W, Yen S. Intercenter comparison of slow and rapid maxillary expansion in unilateral complete cleft lip and palate. Dental Press Journal of Orthodontics. 2022 Jul 4;27(03):e2220233. doi.org/10.1016/j.ajodo.2015.11.022
19. Cobourne MT, DiBiase AT. Handbook of Orthodontics E-Book: Handbook of Orthodontics E-Book. Elsevier Health Sciences; 2015 Aug 17.
20. Kurniaty K, Pertiwi AS. Schwarz three-way expansion screw pada perawatan ortodontik cleft lip palate. Indonesian Journal of Paediatric Dentistry. 2019 Sep 6;1(2):160-5.
21. Aizenbud D, Ciceu C, Rachmiel A, Hazan-Molina H. Reverse Quad Helix Appliance: Differential Anterior Maxillary Expansion of the Cleft Area Before Bone Grafting. Journal of Craniofacial

Surgery. 2012 September 23(5):p e440-e443. doi: 10.1097/SCS.0b013e318264681a
22. Poornima KY, Kharbanda OP. Nitinol expansion in cleft palate patients. J Indian Orthodont Soc. 2000; 33:27. doi.org/10.5005/jp-journals-10021-1041
23. Torres A, AlYazeedy I, Yen S. A Programmable Expander for Patients With Cleft Lip and Palate. The Cleft Palate-Craniofacial Journal 2019. 56(6) 837-844. doi. 10.1177/1055665618815398 journals.sagepub.com/home/cpc
24. McNamara JA, Lione R, Franchi L, Angelieri F, Cevidanes LH, Darendeliler MA, Cozza P. The role of rapid maxillary expansion in the promotion of oral and general health. Progress in orthodontics. 2015 Dec; 16:1-7. doi.org/10.1186/s40510-015-0105-x
25. Lione R, Ballanti F, Franchi L, Baccetti T, Cozza P. Treatment and posttreatment skeletal effects of rapid maxillary expansion studied with low-dose computed tomography in growing subjects. American journal of orthodontics and dentofacial orthopedics. 2008 Sep 1;134(3):389-92. doi.org/10.1016/j.ajodo.2008.05.011
26. Inchingolo AD, Ferrara I, Viapiano F, Netti A, Campanelli M, Buongiorno S, Latini G, Carpentiere V, Ciocia AM, Ceci S, Patano A. Rapid Maxillary Expansion on the Adolescent Patient: Systematic Review and Case Report. Children. 2022 Jul 14;9(7):1046. doi.org/10.3390/children9071046
27. Silveira GS, Abreu LG, Palomo JM, da Matta Cid Pinto LS, de Sousa AA, Gribel BF, et al. Mini Hyrax vs Hyrax expanders in the rapid palatal expansion in adolescents with posterior crossbite: a randomized controlled clinical trial. Prog Orthod. 2021 Sep 1;22(1):30. doi: 10.1186/s40510-021-00365-5.
28. de Medeiros Alves AC, Garib DG, Janson G, de Almeida AM, Calil LR. Analysis of the dentoalveolar effects of slow and rapid maxillary expansion in complete bilateral cleft lip and palate patients: a randomized clinical trial. Clinical oral investigations. 2016 Sep; 20:1837-47. doi.org/10.1007/s00784-015-1675-1
29. Fatima K, Chaudhari PK, Duggal R, Kharbanda OP, Thakar A. Effects of RME on Hearing in UCLP Patients: A Pilot Study. Cleft Palate Craniofac J. 2023 Nov;60(11):1442-1449. doi: 10.1177/10556656221104945.
30. Lotfi V, Ghoneima A, Lagravere M, Kula K, Stewart K. Three-dimensional evaluation of airway volume changes in two expansion activation protocols. International orthodontics. 2018 Mar 1;16(1):144-57. doi.org/10.1016/j.ortho.2018.01.001
31. Fазanha AJ, Lara TS, Garib DG, Silva Filho OG. Transverse effect of Haas and Hyrax appliances on the upper dental arch in patients with unilateral complete cleft lip and palate: a comparative study. Dental press journal of orthodontics. 2014;19(02):39-45. doi.org/10.1590/2176-9451.19.2.039-045.oar
32. Liou EJ, Tsai WC. A new protocol for maxillary protraction in cleft patients: repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. The Cleft palate-craniofacial journal. 2005 Mar;42(2):121-7. doi.org/10.1597/03-107.1
33. Sami, QUA, Ali B, Farooqui, WA. Effects of Alt-RAMEC protocol with facemask therapy in cleft lip palate patients in a sample of Pakistani population. BMC Oral Health 2023. 23(1), 401. doi.org/10.1186/s12903-023-03093-w
34. Khalil SS, Salama AE, Mohammad MM, & Awad MM. Evaluation of The Treatment Outcome of Cleft Palate Patients Treated with Differential Opening Expander with Alt-RAMEC Protocol and Facemask:(a cohort clinical study). Eur. Chem. Bull. 2023, 12 (6), 2008 – 2020. doi.org/10.21203/rs.3.rs-2466908/v135.
35. Meazzini MC, Zappia LB, Tortora C, Autelitano L, Tintinelli R. Short-and long-term effects of late maxillary advancement with the Liou-Alt-RAMEC protocol in unilateral cleft lip and palate. The Cleft Palate-Craniofacial Journal. 2019 Feb;56(2):159-67. doi.org/10.1177/1055665618772395
36. Meazzini MC. Treatment of maxillary hypoplasia in cleft lip and palate patients: Keeping the total burden of care as low as possible. Journal of Cleft Lip Palate and Craniofacial Anomalies, Jun 2020 7(1):p 1-7. doi: 10.4103/jclpca.jclpca_25_19
37. de Almeida AM, Ozawa TO, Alves AC, Janson G, Lauris JR, Ioshida MS, Garib DG. Slow versus rapid maxillary expansion in bilateral cleft lip and palate: a CBCT randomized clinical trial. Clinical oral investigations. 2017 Jun; 21:1789-99. doi.org/10.1007/s00784-016-1943-8
38. Rutili V, Nieri M, Franceschi D, Pierleoni F, Giuntini V, Franchi L. Comparison of rapid versus slow maxillary expansion on patient-reported outcome measures in growing patients: a systematic review and meta-analysis. Progress in Orthodontics. 2022 Dec 12;23(1):47. doi.org/10.1186/s40510-022-00440-5
39. Schultz RC. Management and timing of cleft palate fistula repair. Plast Reconstr Surg. 1986 Dec;78(6):739-47. doi: 10.1097/00006534-198678060-00004.
40. Shankar VA, Snyder-Warwick A, Skolnick GB, Woo AS, Patel KB. Incidence of palatal fistula at time of secondary alveolar cleft reconstruction. The Cleft Palate-Craniofacial Journal. 2018 Aug;55(7):999-1005. doi.org/10.1597/16-179
41. McCrary H, Skirko JR. Bone grafting of alveolar clefts. Oral and Maxillofacial Surgery Clinics. 2021 May 1;33(2):231-8. doi.org/10.1016/j.coms.2021.01.007
42. Barillas AP, Michelogiannakis D, Rossouw PE, Javed F. Maxillary expansion in grafted alveolar arches in patients with cleft lip and palate: A literature review. Surgery in Practice and Science. 2021 Jun 1; 5:100034. doi.org/10.1016/j.

sipas.2021.100034

43. da Silva Filho OG, Boiani E, de Oliveira Cavassan A, Santamaria Jr M. Rapid maxillary expansion after secondary alveolar bone grafting in patients with alveolar cleft. The Cleft palate-craniofacial journal. 2009 May;46(3):331-8. doi.org/10.1597/07-205.1
44. de Oliveira Cavassan A, de Albuquerque MD, Capelozza Filho L. Rapid maxillary expansion after secondary alveolar bone graft in a patient with bilateral cleft lip and palate. The Cleft palate-craniofacial journal. 2004 May;41(3):332-9. doi.org/10.1597/02-099.1
45. Garib D, Lauris RDCMC, Calil LR, Alves ACDM, Janson G, De Almeida AM & Lauris JRP. Dentoskeletal outcomes of a rapid maxillary expander with differential opening in patients with bilateral cleft lip and palate: A prospective clinical trial. American Journal of Orthodontics and Dentofacial Orthopedics. 2016. 150(4), 564-574. doi.org/10.1016/j.ajodo.2016.05.006
46. Okada W, Fukui T, Saito T, Ohkubo C, Hamada Y, Nakamura Y. Interdisciplinary treatment of an adult with complete bilateral cleft lip and palate. American Journal of Orthodontics and Dentofacial Orthopedics. 2012 Apr 1;141(4): S149-58. doi.org/10.1016/j.ajodo.2011.07.025
47. Thomas Rakosi and Thomas M Graber. Orthodontic and dentofacial orthopedic treatment. Germany. Thieme. 2010
48. Weiran Li; Jiuxiang Lin. Dental Arch Width Stability after Quadhelix and Edgewise Treatment in Complete Unilateral Cleft Lip and Palate. Angle Orthod (2007) 77 (6): 1067–1072. doi.org/10.2319/070506-272.1
49. Figueroa AA, Murphy J, Tragos C. Intra-lesional injection of triamcinolone to palatoplasty scar to aid reversal of transverse maxillary relapse after orthognathic surgery. Journal of Craniofacial Surgery. 2022 Jun 1;33(4):e416-8. doi.org/10.1097/SCS.0000000000008347
50. Noriega ES, Muciz NE, Cortez GP, Luna FR, Castro TA. Treatment of bilateral cleft lip and palate with maxillary collapse sequelae. Case report. Revista Mexicana de Ortodoncia. 2015 May 5;3(2):112-9.
51. Souza RM, Oliveira HT, Farret MM. Orthodontic treatment of unilateral cleft lip and palate associated with maxillary canine/premolar transposition: case report. Dental press journal of orthodontics. 2020 Aug 19;25(03):54-64. doi.org/10.1590/2177-6709.25.3.054-064.oar
52. Kaiser J, Kamble R, Atole S. Comprehensive Cleft Care in a Nine-Year-Old With Unilateral Cleft Lip and Palate Using Coffin Spring Expansion and Surgical Intervention. Cureus. 2024 July. 16(7): e64939. doi.10.7759/cureus.64939
53. Tai K, Hotokezaka H, Park JH, Tai H, Miyajima K, Choi M, Lisa M. Kai, Mishima K. Preliminary cone-beam computed tomography study evaluating dental and skeletal changes after treatment with a mandibular Schwarz appliance. American Journal of Orthodontics and Dentofacial Orthopedics. 2010. 262.e1-262.e11, doi.org/10.1016/j.ajodo.2010.02.023.
54. Weiran Li, Jiuxiang Lin. Dental Arch Width Stability after Quadhelix and Edgewise Treatment in Complete Unilateral Cleft Lip and Palate. Angle Orthod (2007) 77 (6): 1067–1072. doi.org/10.2319/070506-272.1
55. Mutinelli, S., Antonini, S., & Cozzani, M. (2024, May). Rapid maxillary expansion in early mixed dentition with a Haas expander: a critical review. In Seminars in Orthodontics. WB Saunders. doi.org/10.1053/j.sodo.2024.04.013
56. Ugolini A, Cossellu G, Farronato M, Silvestrini-Biavati A, Lanteri V. A multicenter, prospective, randomized trial of pain and discomfort during maxillary expansion: Leaf expander versus hyrax expander. Int J Paediatr Dent. 2020 Jul;30(4):421-428. doi: 10.1111/ipd.12612.