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Methods of Maxillary Expansion in Cleft lip and palate Rehabilitation Cases- A review

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Abstract

Cleft lip and palate (CLP) is considered to be a heterogeneous clinical entity comprising of various congenital deformities of mixed genetic and environmental origin. Though its etiology is considered to be multifactorial, anatomically it occurs due to fusion defects seen in the embryonic buds between the 4-12 weeks of gestation. It manifests in the orofacial region, with involvement of varying complexity of the nose, lip, alveolar region, hard and soft palate regions. Individuals exhibiting this entity show major anterior- posterior, transverse and vertical problems. One of the major concerns are the transverse deficiencies which need to be treated before bone grafting procedures. Expansion of the maxilla needs to be carried out in order to correct various skeletal and dental transverse discrepancies between the maxilla and mandible. A wide number of expansion modalities and methods have been used over the long period of time. This review article records different expansion appliances enlisted in cleft rehabilitation cases.

Keywords: Cleft palate, Orthodontics, expansion, rehabilitation,

Introduction

Cleft lip and palate are one of the most common yet complex facial deformities witnessed. Treatment of this modality requires a multidisciplinary approach considering the complex and prolonged treatment time. [1] The craniofacial orthodontist plays a critical role during the care of individuals with cleft lip and/or palate owing to the excessive knowledge of the anatomy of the nasal, maxillary structures, growth patterns, growth timings, cephalometric diagnosis etc. Their involvement with these patients starts from birth to adulthood. Some of the important treatments provided are infant pre-surgical orthopedics, maxillary arch expansion, orthodontic preparation for the alveolar bone graft (ABG), early phase of orthodontic treatment after ABG, and comprehensive orthodontic treatment associated with or without orthognathic surgery.[2] Orthodontic preparation by maxillary expansion before alveolar bone grafting is a key step in management and success of the treatment.

Epidermiology of Cleft Lip and Palate

According to World Health Organization 2001 (WHO), oral clefts in any form occur in about one in every 700 live births. According to Tanaka et al, cleft lip with or without cleft palate range from 7.94 to 9.92 per 10,000 live births. [3] The occurrence rate of orofacial clefts is known to vary according to population. Higher rates have been reported in Asians and American Indians (one in 500 births), and lower rates have been reported in African-derived populations (one in 2,500 births).[4] Isolated cleft palate is more frequently found in females than in males, at a ratio of 2:1. In contrast, there is a 2:1 male-to-female ratio for cleft lip with or without cleft palate. [5] In India alone, with an estimation of 24.5 million births per year, the birth prevalence of clefts is considered somewhere between 27,000 and 33,000 clefts per year. [6]

Rationale for expansion in cleft patients[7]

In cleft lip and palate cases, physiology of the maxilla is considered exceptional, as there is an absence of median palatine suture between the fragments; hence the behavior of surrounding structures during maxillary expansion differs from that of a classical patient.[1]

The basic requirement for expansion comprises of:

1) Correction of anterior and posterior cross bites,

2) Alignment of the collapsed arches,

3) Maintaining the integrity of the arch form

4) Providing space for impacted teeth in the arch

5) Preparation for ABG (alveolar bone graft),

6) Improving the airway dimensions and facilitates nasal expansion

7) To aid in maxillary protraction, since palatal expansion in cleft patients disarticulates circum-maxillary sutures thus rendering protraction of maxilla easier to correct the antero-posterior deficiencies,

8) help to improve tongue placement,

9) Facilitating speech development and early rehabilitation of facial appearance and dental functions.

Biological Rationale For Expansion In Cleft Cases

Unlike in non- cleft individuals, the skeletal stability in the transverse section is reduced[8] in cleft palate patients because of the special anatomical situation present in the jaw and palate area. This can occasionally lead to a collapse of lateral segments in the medial direction [8-13] if proper retention protocols are not followed.

According to Reitan [14], expansion forces applied to these areas are known to induce only a dental effect. For a skeletal effect, higher orthopedic forces14 greater than 5 N are required. Biomechanical studies with respect to the special anatomical conditions with cleft patients have not yet been published in literature.

Expansion Appliances

There are a wide number of appliances used in Orthodontics for rehabilitation of Cleft affected patients. Appliances can be classified into Sow Maxillary Expanders or Rapid Maxillary Expanders.

Slow Maxillary Expanders

Majority of slow expansion appliances consist of a fixed palatal arch wire that is banded to the anchor teeth. It is believed that slow maxillary expansion provides more physiologic adjustments to sutural separation thus producing greater stability resulting in less relapse potential. [15,16] Rates of expansion occurs generally at approximately 0.5 to 1.0 mm per week, thus producing forces from several ounces to as high as 2 pounds.

Types of Slow Maxillary Expanders

1. W- arch (Figure 1)

Ricketts and his colleagues initially popularized the use of W- appliance on cleft palate patients.[17] Preferred in deciduous and mixed dentition where mild to moderate expansion is required. The W-arch is a fixed expansion appliance. It is constructed of 36 mil steel wire soldered

to molar bands. The appliance is activated by opening the apices of W-arch and is adjusted to provide more anterior than posterior expansion, or *vice versa*. The appliance delivers proper force levels when opened 3-4 mm wider than the passive width. [18] Expansion should continue at the rate of 2 mm per month. Over- correction is desired to avoid relapse post expansion. (Figure1)

2. Coffin Spring (Figure 2)

Sir Walter Coffin introduced the Coffin spring in 1875. It is a removable appliance capable of slow dento alveolar expansion.[18] The appliance consists of adam's clasp in the first premolars and first molars of both sides with an omega shaped wire placed in the mid-palatal region. The appliance is made up of 1.2 mm stainless steel wire and the components of the appliance are embedded into an acrylic base plate.[19] The free ends of the omega wire are embedded in acrylic covering the slopes of the palate. The spring is activated by pulling two asides apart manually.[18] Some amount of skeletal changes can also be brought about in mixed dentition period if proper retention protocol is maintained.[19]

3. Quad Helix (Figure 3)

Quad helix proved to be successful in the early treatment of children afflicted with cleft palate whose lateral maxillary segments had collapsed behind the protruding premaxillary processes. In these patients, due to the unilateral or bilateral deficiencies in their bony palate, the narrowness of the palates were reported. Attempts of surgical closure of palatal defects or contraction of scar tissue sometimes ends ups aggravating the existing palatal constriction.

In cleft palate patients, the quad helix appliance is responsible for the expansion of the lateral maxillary shelves and the derotation of the maxillary molar teeth.[20] According to a study carried out by Frank et al the use of quad helix appliances in younger patients produced a midpalatal separation of .92 ram. He also reported that the average inter molar expansion was 5.88 mm and the majority of the change was orthodontic in nature. Frank et al suggested that with the quad helix appliance there was a 6:1 ratio between the orthodontic and the orthopedic expansion. [21] According to Bench et al, in the treatment of narrow restricted maxillary arches, the quad helix appliances tip the maxillary molar teeth and their alveolar sockets bucally, and that this tipping results in a warping of the alveolar ridges.[22-23]

The desirable force level of 400 gm can be delivered by activating the appliance by 8 mm, which equates to approximately one molar width. A degree of overcorrection is desirable as relapse is inevitable. A three-month retention period, with the quadhelix in place is recommended once expansion has been achieved.

Various Modifications of Quad Helix Appliance: (Figure 4-5)

In order to achieve a more effective and promising result, complex malocclusions must be treated by combining treatment concepts and techniques.[24] A wide variety of modifications are available at present for the quad helix appliance to benefit other corrections required in the existing malocclusion. More of such modifications and techniques need to be clinically documented and incooperated in the treatment of cleft palate patients, for better research and success purpose. Satyaprasad et al [25] reported an eight month year old child with digit sucking habit who had the tendency to place the middle fingers into the oral cavity and index finger on the nose while sucking. Considering the age, the child was treated with surgery and Naso- alveolar Moulding successfully. Aizenbud et al and Rachmiel et al [26] created the first design of the reverse quad helix (RQH) utilizing a 0.036-in stainless-steel wire with 4 helical loops incorporated into an inverse W Y arch design. According to Emodi et al [27] the use of RQH

ameliorates the manipulation of the nasal mucosa via a direct view due to the resultant wide separation of the alveolar segments in the cleft area. Furthermore, the gap improved access for the bone grafting procedure by raising the full thickness palatal flaps, enabling the proper stitching and sealing of the nasal mucosal layer, facilitating the adequate packing of the harvested autogenic cancellous bone graft and finalizing the suturing of the oral mucosa layer. Hence use of RQH was known to improve surgical access for bone grafting manipulations, offered enhanced access for nasal layer closure and provided a stable maxillary transversal correction, resulting in improved occlusion of the permanent dentition. To avoid removing and re-cementing of the appliance for every extra amout of activation, Wilson and Wilson[28] came up with an inserting/removing system called the 3D® Fixed/Removable® System (Wilson®), where the Quad-Helix was inserted on lingual sheath tubes for horizontal insertion.

4. Niti Expander (Figure 6)

Arndt et al [29]developed a tandem-loop nickel titanium (NiTi), temperature-activated palatal expander with the ability to produce light, continuous pressure on the midpalatal suture while simultaneously uprighting, rotating and distalizing the maxillary first molars. Cleft patients are deeply benefitted with the use of this appliance as, due to the presence of an alveolar and palatal cleft, low level of force by the Niti palatal expander is actually desirable for maxillary expansion so as not to tear the repaired soft palate. [30]

Rapid Maxillary Expanders

Due to the narrow and constricted anatomical structure of the maxilla, the effects of Rapid maxillary expanders differ in cleft patients. It is known to increase the maxillary dental arch, corrects the existing crossbite, aligns the maxillary segments, increases the alveolar cleft width in order to create room for bone graft placement during surgery. [31] An increase in maxillary arch width upto 10 mm can be achieved. The rate of expansion is about 0.2-0.5 mm per day.

Types of Rapid Maxillary Expanders

1. Hyrax Expander (Figure 7)

William Biederman introduced the expander in 1968. It is a tooth borne appliance. The appliance makes use of a special screw called HYRAX (Hygenic Rapid Expander). The Hyrax Expander is essentially a nonspring loaded jackscrew with an all wire frame.[32] The screw has a heavy gauge wire extension that are adapted to follow the palatal contours and soldered to bands on premolar and molar, thus causing no palatal mucosa irritation. Sutural separation of 11-13 mm can be achieved. Every activation of the screw produces approximately 0.2 mm of lateral expansion. [33] Vega et al [34] devised a distractor using a hyrax expansion screw which was anchored onto the dentition and bone for treatment of cleft patients. He utilized distraction osteogenesis and alveolar bone transport type, with the use of the modified Hyrax device (VEGAX). The use of a hyrax expansion screw in place of bone distractors reduced the costs involved in the use of distractors.

2. Alt-RAMEC Protocol with Rapid Expander (Figure 8)

In 2005, Liou et al[35] introduced the Alt-RAMEC protocol. It enables sutural mobilization with the opening and closing of the RME screw for 7-9 consecutive weeks without unnecessary expansion. In the Alt-RAMEC protocol, the maxilla is expanded by 7 mm on week 1 through an expansion device(most commonly used Hyrax appliance) that expands 1 mm/day, and then the screw is closed at a rate of 1 mm/s on week 2. In the remaining weeks, the screw of the expansion device is turned on for

1 week and closed for 1 week. The Alt-RAMEC protocol is completed at the end of the 9-week cycle. Following completion of this protocol, protraction force is applied to move the maxillae forward.

Liou and Tsai et al [36] carried a study on unilateral cleft lip palate patients, to investigate whether there was a difference between maxillary protraction after the Alt-RAMEC protocol and Rapid Maxillary Expansion. At the end of the study, more protraction was obtained in the Alt-RAMEC group. Isci et al [37] reported that the amount of movement of A point (4.13 mm) in the Alt-RAMEC group was twice as much in the RME group. On the contrary, Viera et al.[38] and Do-delatour et al. [39] reported more forward movement in the maxilla in the RME-treated group than most other studies. Several studies on individuals with Class III malocclusion treated with maxillary protraction do not show long term results. The long-term studies performed on individuals with cleft lip and palate are both retrospective and relatively limited.[40]

3. Hass Expander (Figure 9)

It is a rigid appliance. It utilizes a jackscrew designed for maximum dental anchorage to produce required expansion in 10 to 14 days.[41]

4. Differential opening Expanders (Figure 10)

Many cleft afflicted patients have maxillary constriction with greater transversal deficiency in the intercanine width compared to the intermolar width.[42] In these cases, conventional Rapid Maxillary expanders would end up over expanding the molar region to correct the intercanine width since the screws have a parallel opening. This undesirable effect could cause an increased risk of bone dehiscences and gingival recessions and a significant decrease of the buccal alveolar bone plate thickness. [43-44] Moreover, previous studies on the long-term stability of conventional Rapid Maxillary Expanders showed increased relapse of the intercanine distance in comparison to the interpremolar and intermolar distances. [45-46] This showed the need for differential expansion (EDO- Expansion Differential Opening) with greater expansion at the intercanine region than at the intermolar region. A number of differential expanders have been developed over the years.

In 1996, Schellino et al [47] designed a spider screw named “Ragno” that produced differential expansion by allowing “fan opening.” In 1999, Levrini and Filippi [48] used the Ragno screw and esuccessfully treadet a six-year-old male with bilateral cleft lip and palate. This fan-type expander concentrated changes in the anterior region of the dental arch with negligible changes in the molar region. [49-50]

In 2014, Garib et al [51] called the expander with differential opening (EDO). The EDO consisted of 2 parallel-opening screws, 1 anteriorly positioned in the palate and the other posteriorly positioned. Different amounts of activation in the anterior and posterior expansion screws determined a trapezoid-shaped opening of the appliance diverging towards the anterior. The appliance allowed the clinician to control the amount of expansion in the intercanine and intermolar regions with the help of two separate screws. The advantage of the EDO over a fan-shaped expander was that the EDO with its two screws enabled individualised expansion at the intercanine and intermolar region whereas the fan-shaped expander with a single screw anteriorly and a hinge positioned posteriorly was not that effective in the production of differential expansion. In cleft patients, the EDO was successful in producing an ideal archform when compared to the other expanders. [52]

5. Mini Implant Assisted Rapid Palatal Expansion (MARPE) (Figure 11)

Literature available on MARPE on cleft patients is very scarce. Due to lack of maxillary bone, one cannot expect

adequate skeletal anchorage required for the mini implants. Hence the results obtained are predominantly dentoalveolar in nature. The irregular morphology of the patient with cleft lip and palate caused by palate bone deficiencies and the presence of thicker palatal mucosa requires a unique assessment for each patient. More studies are needed to detect soft and bone tissue irregularities, finding sites with sufficient support for the required orthopedic effect.

6. Surgical Assisted Rapid Palatal Expansion (SARPE)

In order to reconstruct the maxillary arch form and correct the intermaxillary transverse discrepancy, various surgical procedures are required for non-growing patients with cleft palate.[53] Distraction osteotomy or SARPE have been used for maxillary anterior advancement or lateral expansion in patients with Cleft lip/palate. [53-55] SARPE is often carried out in adjunct with many other orthognathic surgical procedures. The surgical component of SARPE normally consists of a subtotal LeFort I osteotomy. Some authors recommend additional palatal osteotomies, while others recommend the releasing of the lateral resistance, such as the zygomatico-maxillary buttress and the maxillary articulations, is sufficient. Additional lateral osteotomies are performed on both sides with separation of the pterygoid plates. Mommaerts et al [56] demonstrated that during SARPE, pterygo-maxillary disjunction is desired for the posterior expansion, whereas anterior expansion can be carried out without releasing pterygo-maxillary articulation. Literature available on the stability of this surgical expansion technique is however scarce.

Recent Advances In Expansion For Cleft Cases

1. Mobile Intra Oral Arch (MIA) (Figure 12)

MIA (Mobile Intraoral Arch) is a palatal and lingual appliance. Combining the efficiency of the Quad Helix appliance with the advantage of easy removal and reinsertion, allows greater flexibility and control during treatment. Conventional Quad Helix lingual arches are soldered to molar bands and require frequent recementation or rebanding. The MIA system makes the application less time consuming, offering the advantage of inserting and removing the lingual arches into sheaths pre-welded on bands. The appliance is known for its “fan like expansion” in cleft cases. More case studies are required.[57]

2. Role of Lithium in Mid palatal Expansion

Lithium is considered as an activator of β-catenin signaling. β-catenin is known to mediate bone acquisition in response to any type of mechanical loading in the bone. Tang et all carried out a study on rats to test this hypothesis. His study suggested that β-catenin was successful in regulating proliferation of osteoprogenitors and maturation of osteoblasts during midpalatal suture expansion osteogenesis, and that lithium enhances bone regeneration by elevating β-catenin expression. Human trials on the potential use of lithium are however awaited. [58]

Conclusion

Expansion of the maxilla and the maxillary dentition may be accomplished in numerous ways. Though a wide number of expansion appliances are available for treatment of cleft cases, extensive studies would be fruitful to increase the scope of new modified appliances in Cleft Orthodontics. Both slow and rapid expansion have shown fruitful results in cleft cases.

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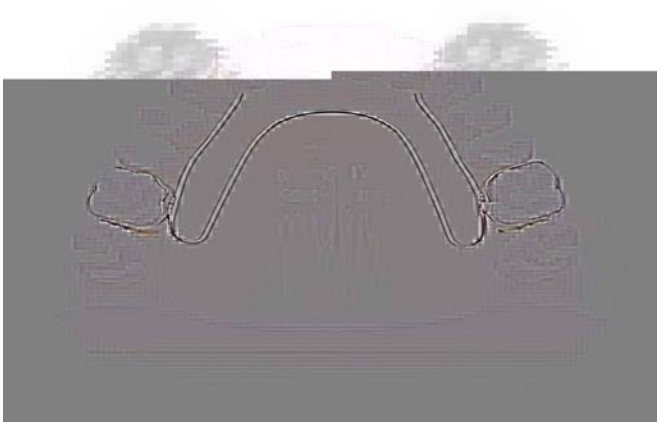
Legend Figures

Figure1: W- Arch Appliance (adopted)

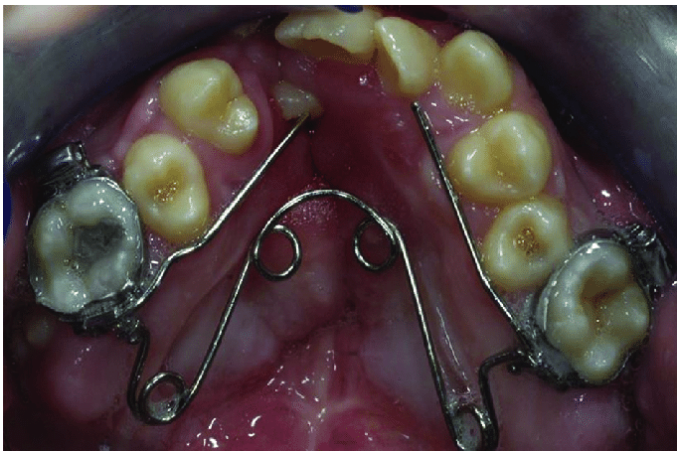


https://odlortho.com/w-arch-1-2/

Figure 2: Coffin Spring (adopted)

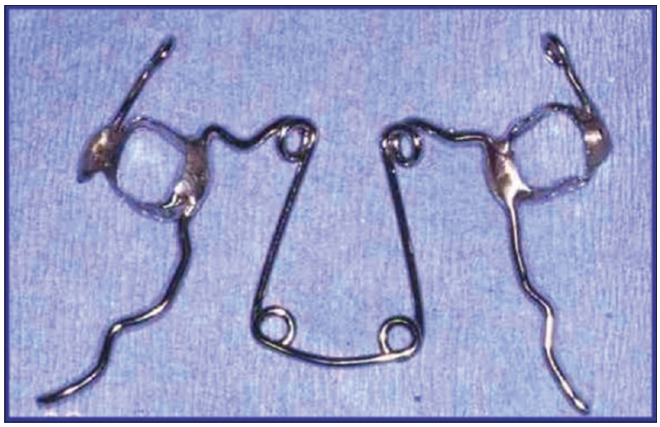
http://www.guident.net/articles/orthodontics/SLOW-PALATAL-EXPANSION--A-NOVEL-METHOD-OF-ARCH-EXPANSION.html

Figure 3: Quad Helix (adopted)



https://www.researchgate.net/figure/Quad-helix-appliance-in-mouth-Uzel-et-al-Maxillary-Expansion-J-Oral-Maxillofac-Surg_fig1_326663121

Figure 4: Reverse Quad Helix (adopted)



https://www.amsjournal.com/article.asp?issn=2231-0746;year=2015;volume=5;issue=1;spage=32;epage=36;aulast=Emodi

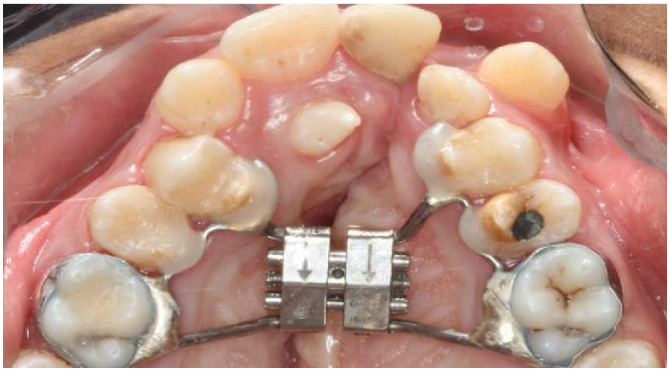
Figure 5: 3D Quad Helix appliance (adopted)

https://www.rmortho.com/products/3d-quad-helix-appliances/

Figure 6: Niti Palatal expander (adopted)

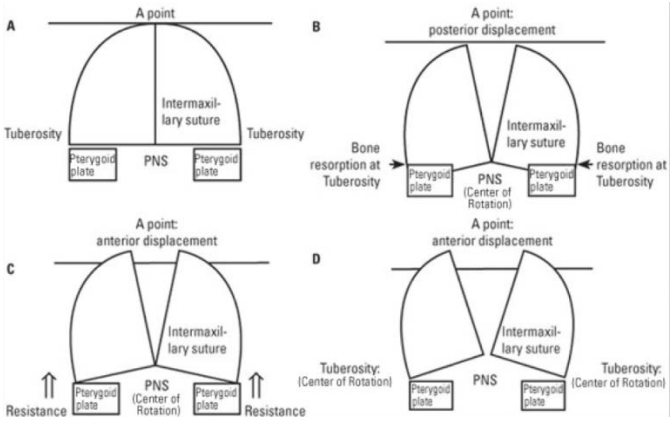
https://www.researchgate.net/figure/IPC-Rapid-Palatal-Expander_fig2_318073309

Figure 7: Hyrax Expander (adopted)



https://www.semanticscholar.org/paper/Effects-of-rapid-maxillary-expansion-in-cleft-from-Figueiredo-Cardinal/e75728d873728643113c595bd9478d8a098d96f3/figure/0

Figure 8: Alt-RAMEC Protocol with Rapid Expander (adopted)

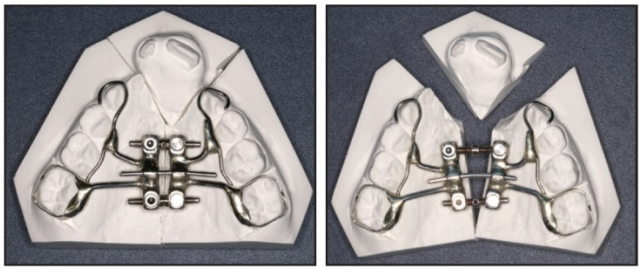


https://www.jsas.co.in/html-article/14499

Figure 9: Haas Expander (adopted)

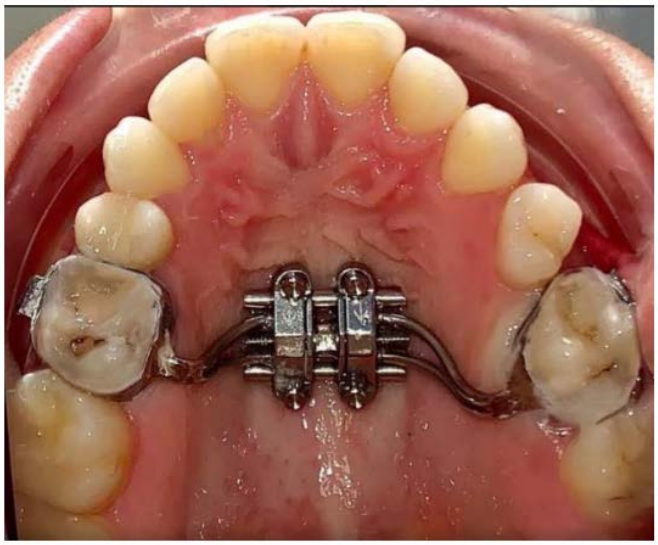
https://www.specialtyappliances.com/appliance-categories.php?type=5

Figure 10: Differential opening Expanders



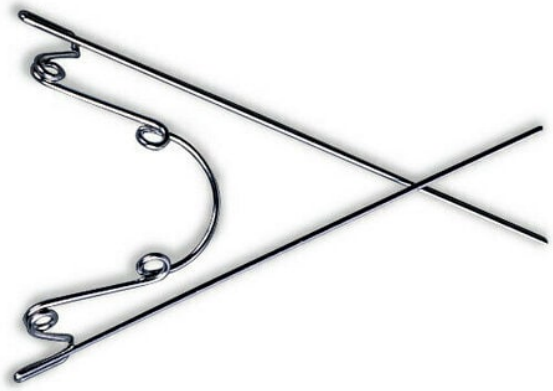
https://www.jco-online.com/archive/2014/07/430/

Figure 11: Mini Implant Assisted Rapid Palatal Expansion (MARPE)



https://www.mdpi.com/2079-7737/10/3/187/htm

Figure 12: Mobile Intra Oral Arch (MIA)



https://www.3m.com/3M/en_US/p/d/b5005128013/