3D assessment of transverse changes associated with hybrid hyrax and MSE (Moon) appliances

by

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With deep and heartful gratitude, I dedicate this thesis and all the work behind it to my beloved mother, whose unconditional support made the impossible possible, all the sacrifices you made, made me the woman who is writing this. To my beautiful son Alex who fuels my determination and left home to follow my dreams without complaining, being your mom is my most important accomplishment; I love you mijo .

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ABSTRACT

Introduction

The aims of this study are to compare the transverse, dental, and skeletal changes in patients treated with a hybrid hyrax expander and Moon appliance expander using Cone-beam computed tomography (CBCT) and 3D image analysis.

Materials and Methods: The sample consists of patients treated at Case Western Reserve University at the Orthodontics Department. This retrospective study was approved by the Case Western Reserve University Institutional Review Board (IRB) (Appendix 1). Our sample consisted in 38 patients with a transverse maxillary deficiency that were divided into two groups; the first group (19, average age 18.5 years old) were treated with the Moon appliance, and the second group (19 patients, average age 18.7) were treated with the Hybrid Hyrax appliance. Cone-beam computed tomography scans were taken at pre-treatment (T1) and post-expansion (T2) to measure transverse dental and skeletal changes in maxillary width (MW), palatal width (PW), midpalate suture opening (PSO), alveolar bone bending (ABB), buccal bone thickness (BBT), Case Western transverse analysis on UR6 and UL6, intermolar distance (IMD)and inter-premolar diastance (IPMD). Data were analyzed using paired t-test and two-sample t-test.

Results: Hybrid Hyrax showed 65% skeletal expansion and 35% of dental expansion, and MSE Moon appliance showed a slightly larger ratio but not statistically significant, with 66% of skeletal expansion and 34% dental expansion. Skeletal and dentoalveolar values in both groups were compared, and no significant differences were observed in any of the variables.

Conclusion: Both appliances, MSE and Hybrid Hyrax deliver acceptable results and are a good option to correct mild to moderate transverse deficiency in nongrowing patients. Buccal tipping was reduced in the MSE group when compared with Hybrid Hyrax but not statistically relevant.
MSE appliance and Hybrid Hyrax deliver a noticeable parallel expansion pattern.
The expansion ratio of the MSE appliance group was 66% skeletal expansion and 34% dental expansion. Hybrid Hyrax showed 65% skeletal expansion and 35% of dental expansion

Keywords: MSE, Hybrid Hyrax, maxillary expansion, mini screw assisted rapid palatal expander.

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LITERATURE REVIEW

Maxillary deficiency, a common problem in orthodontic patients, is often accompanied by unilateral or bilateral posterior crossbite, narrow nasal cavity, and crowding. Maxillary expansion is used to correct maxillary width deficiency or posterior crossbite, expand arch perimeter and even facilitate conservative, non-extraction treatment in appropriate arch forms. It has been reported that 9.4% of the population and nearly 30% of adult orthodontic patients have a maxillary transverse deficiency related to a posterior crossbite. (1) Previous research has indicated that approximately 18% of mixed dentition patients have a maxillary transverse deficiency (MTD).(2, 3)

A variety of appliances and treatment protocols have been utilized to treat constricted maxillary arches. The most prevalent method is rapid maxillary expansion (RME) performed with a tooth-anchored expander (hyrax). (4) Treatment options consist of orthodontic treatment, non-surgical, and surgical treatment. Studies of models and radiographs have been used to compare these two appliances and found that both appliances caused tipping on posterior teeth, and this tipping was variable and many times asymmetric.(5)

Traditional tooth-anchored appliances for maxillary expansion can have a limit skeletal movement, potentially leading to undesirable tooth movement, root

resorption, and an inability to maintain long-term expansion due to the lack of firm anchorage at the sutures.

Codivilla published the first theory of distraction in 1905, but it was not until 1938 that surgical and orthodontic treatment was used for nongrowing patients (6). Expansion of maxillary bone has been done for over a century to correct maxillary transverse deficiency. Angell published about maxillary expansion in Dental Cosmos in 1860. (7) He performed rapid maxillary expansion with the use of a jackscrew appliance on a 14-year-old girl. He observed that by turning the jackscrew daily, he was able to open the maxillary suture sufficiently in 2 weeks. Angell mentioned the correction of maxillary width discrepancies by opening the midpalatal suture. However, his work was not accepted due to the absence of radiographic evidence. Later, in 1961 Haas published his maxillary expander and its effects, and nowadays maxillary expansion is a widely used treatment to correct maxillary transverse deficiencies. Haas et al mentioned in 1970 that the use of RME was ideal during the growth spurt, especially in cases with transverse deficiencies of more than 5mm. For less than that, orthodontic treatment is able to camouflage transverse deficiencies that are less than 5mm. (8)

Rapid Palatal Expander (RPE)

Since Dr. Andrew J Haas introduced his expansion device to the United States in 1956 called Haas Expander(American Orthodontics, USA), many different kinds of expander have been used to treat maxillary transverse deficiency and the most common treatment for growing patients is the rapid palatal expander (RPE) that consists of a combination of orthopedic and dental expansion to correct the maxillary transverse disharmony.

Many types of RPE appliances have been used with different rates of expansion, but the principles are essentially the same and all of them are used to address deficiencies of the maxilla in the transverse dimension such as bilateral or unilateral crossbite and constricted maxilla, and to increase dental arch perimeter in patients with tooth size and arch length discrepancies.

Orthodontists mostly use rapid palatal expansion (RPE) to treat transverse maxillary deficiency in growing patients and to alleviate crowding by increasing the maxillary arch perimeter, but the closure of the palatal suture after puberty can cause undesirable side effects with RPE treatment, such as dental buccal tipping of anchor teeth, loss of pulp vitality, root resorption, bony dehiscence, dental extrusion, anterior open bite alveolar bone bending, causing limited skeletal movement and unstable results. (9)

Many studies demonstrated that rapid maxillary expansion contributes to a vertical dimension increment. And those studies mentioned as well as descent of the maxilla resulting in an anterior open bite.

Midpalate sutures can be opened with maxillary expansion during the period of skeletal growth. Melsen (3) described changes in the tightness of surface junctions in four stages infantile, juvenile, adolescent, and adult. As the patient grows, the more interdigitated the suture is, and it becomes more difficult to reopen.

Since separation of the maxillary palatal sutures becomes difficult after the midpalatal suture closes in late adolescence and there is controversy about the age limit for conservative rapid palatal expansion, depending on the results that we expect to happen.(10)

Upon applying transverse biomechanical forces, initial changes involve the lateral tipping of the posterior maxillary teeth as the periodontal and palatal soft tissues are compressed and stretched.(11)

The traditional RPE anchors to the upper first permanent molars and bicuspids. During rapid palatal expansion treatment heavy, intermittent forces are transmitted through the teeth that are used as anchorage. This causes the opening of the midpalate suture and, consequently, the expansion of the maxillary bone. For disarticulation of the mid palatal suture with a RPE, a force of four to nine kilograms is required. The screw is activated daily and forces are transmitted

across the anchor teeth and across the palatal vault in the case of the Haas design, to palatal bones and the cranial base.(12)The suture will open when the load produced by the screw is more than the resistance of the skeletal structures involved.(13)

The principle of maxillary expansion in terms of biomechanics is to promote a load of force that will separate maxillary sutures. And this force will decrease gradually. However, the decrease in load is not linear. From 30% to 50% of the load will dissipate within fifteen minutes and the last 50% to 70% over a twenty-four-hour period. After this interval, the residual load that persists is classified as an increment in skeletal resistance.

The effects of maxillary expansion are not limited to open maxillary sutures, RPE causes movement of the maxilla downward and forward during suture opening. (14)

The maxillary bone and palatine bones move apart during RPE, along with the pterygoid processes of the sphenoid bone. Christie et al demonstrated that the nasal cavity increased by one-third the width of the opening of the jackscrew appliance. The widest portion of the skeletal expansion is seen at the anterior nasal spine and reduces gradually posteriorly towards the posterior nasal spine.

In a study published by MacGinnis et al. mentioned that the stress distribution caused by traditional expansion was distributed along the

zygomaticomaxillary buttress, the pterygomaxillary buttress, and the nasomaxillary buttress (15)

The RPE prognosis depends on the patient's age; the best age to do expansion with RPE is between 13 to 15 years. A histological evaluation of the palatal suture published by Melsen in 1979 showed that growth in the transverse direction of the midpalatal suture is done after 15 years old in females and 17 years old in boys.(3)

The maxillary expansion physiologic process that is the alveolar bone bending, and even if the art or repositioning teeth has been practiced for centuries, the actual mechanisms of tooth movement are not fully explained. Oppenheim W in 1911, described bone resorption ahead of the tooth and apposition on the other surface without considering the alveolar bone bending as a part of the process , however a century later , have not only quantitively evaluated the bone deflection at the alveolar margins, but Picton mentioned that it could be as much as 25% of the initial tooth movement.(16)

Alveolar bone bending

Holberg and Rudzki-Janson studied the stress occurring in cranial bones (frontal, sphenoid, occipital, and temporal bones), particularly those near the foramina when the pterygoid process bends. They calculated that the greater the bending, the stronger the stress will be on the cranial base and the higher the risk of bone fractures. Consequently, microfractures can harm the vulnerable structures passing through cranial foramina (round foramen, maxillary nerve, oval foramen, mandibular nerve; superior orbital fissure, accessory meningeal artery, superior ophthalmic vein, inferior ophthalmic vein, oculomotor nerve, trochlear nerve, three branches of the ophthalmic nerve, and abducent nerve). However, bone elasticity is a property of the bone that protects against stress and fractures and decreases when patients stop growing. Therefore, rapid maxillary expansion that is not surgically assisted is a high-risk procedure in adult individuals. This risk is not limited to bony defects and periodontal issues.

Surgical Assisted Rapid Palatal Expansion (SARPE)

Surgical procedures such as segmental Lefort I osteotomies and surgically assisted rapid palatal expansion have successfully treated transverse maxillary deficiencies in skeletally mature patients, but the risks involved in these invasive treatments have caused controversy in the literature.

SARPE is indicated in cases where orthodontic expansion would be insufficient and resistance of sutures is present, transverse maxillary deficiencies of more than 5mm in nongrowing patients are taken in consideration as well, but if the maxillary deficiency is more than 7 mm SARPE is definitely indicated; SARPE is also considered if patient presents posterior crossbite related to a narrow maxilla and wide mandibular arch specially because a surgical procedure to narrowing a wide mandible cause negative effects on condyles. Patients with arch perimeter deficiencies and incisors with ideal vertical and sagittal position are ideal for SARPE. Relapse may result once the fixation is removed.

Advantages of SARPE include better periodontal health, elimination of negative space, improved nasal air flow and improvement of buccal corridors. (17). Also, extraction of teeth for alignment is often unnecessary after treatment. Another advantage of SARPE over segmental LeFort 1 osteotomy is that periodontal defects are limited, and the canines do not need to be distalized, as it is required in segmental LeFort osteotomies. Surgical complications may occur in cases where there is insufficient release of the maxilla or when the expansion

device is not constructed correctly. Inadequate bone release causes excessive pain and pressure during the activation of the appliance. This is due to the load of force against the fused sutures. If this expansion proceeds without the necessary bone release, it can cause tipping of teeth and alveolar bone, along with gingival recession. While complications related to the appliance are not common, they may involve issues like the device becoming loose, the screw locking, or the possibility of the palatal mucosa being injured, causing vascular compromise**.** The risk of periodontal defects, vascular compromise and relapse are also reduced when compared with segmental LeFort surgery.

These complications can be avoided by surgically releasing the bony structures that resist the expansion forces (18) But most patients are not willing to undergo a surgical intervention However, for non-growing patients with severe maxillary transverse deficiency the treatment of election was the segmental LeFort 1 osteotomy.

Even if SARPE offers numerous advantages, segmental LeFort 1 osteotomies may be the treatment of election in certain circumstances. Especially when vertical and sagittal discrepancies are present. It must be taken in consideration that SARPE delivers a more stable result in transverse dimensions than the Segmentalized LeFort 1(19) Surgically assisted rapid maxillary expansion affects primarily the canines and less at the molars. On the other hand, the segmental LeFort 1 osteotomy delivers more expansion in the molar area than at the canines, and this is because the posterior articulation of the maxilla is not

separated with SARPE. LeFort 1 osteotomies requires toot alignment before surgery for correction of arch length and this can lead to extractions need for compensation purposes. The risks of relapse and compromised blood supply are also reduced when compared with the segmentalized LeFort procedure. Orthodontic alignment also is faster and easier after SARPE treatment.

The two techniques (SARPE and single-unit LeFort osteotomy) are less complex compared to a segmented LeFort osteotomy, resulting in a reduced likelihood of bone misalignment and vascular compromise.

Relatively recently, rapid palatal expanders with skeletal anchorage added have been utilized to treat successfully maxillary expansion without the risk of a surgical procedure. The skeletal anchorage is obtained by the implementation of mini implants.

MINI SCREW-ASSISTED RAPID PALATAL EXPANSION

There is a variety of designs of tooth-bone-borne expansion appliances, the miniscrew-assisted rapid palatal expander (MARPE) has been modified to allow more advantages and outcomes to become familiar in clinical practice.(20)

MARPE has increased the rate of success in the separation of the midpalatal suture in non-growing patients to an 84-87% success rate. The main objective of maxillary expansion with MARPE is to maximize the orthopedic effect while minimizing the tipping or extrusion of teeth.

The advantages of MARPE are the expansion of the maxilla without the undesirable effects of the tooth–borne expansion in non-growing patients, and the disadvantages are the difficulty of keeping the are clean and the risk of infection that could lead to the need for early removal of the appliance.

In tooth-borne expanders, the expansion forces are transmitted through the teeth and to the skeletal structures, thus decreasing the amount of force transmitted to the bony structures and resulting in undesirable tooth movement. Bone-anchored maxillary expansion appliances transmit forces directly to the skeletal components, resulting in more skeletal movement.

One form of MARPE that is widely used by orthodontists around the world is a hybrid tooth-bone and bone-borne maxillary skeletal expander (MSE) which uses four mini-screws as a bone anchor, and maxillary posterior teeth as tooth anchorage.

Lin et al 2015, evaluated the immediate effects of rapid maxillary expansion (RME) on the transverse skeletal and dentoalveolar changes with bone-borne (C-expander) and tooth-borne type expanders using cone-beam computed tomography (CBCT) in late adolescents. Their results showed that the C-expander group produced greater skeletal expansion, except in the region of the first premolar which showed slight buccal tipping of the alveolar bone. The Hyrax group had more buccal tipping of the alveolar bone and the tooth axes, except in the region of the second molar. Dental expansion at the apex level was similar in the banded teeth (the first premolar and the first molar. The authors concluded that for patients in late adolescence, bone-borne expanders produced greater orthopedic effects and fewer dentoalveolar side effects compared to the hyrax expanders.

Ding et al 2023, study the stability of the different components of MSE expansion post-orthodontic treatment. They had Fourteen subjects (mean age of 20.4 ± 3.5 years) were treated with the MSE. The pre-expansion (T0), post-expansion (T1), and post-treatment (T2) CBCT records were superimposed and compared. The rotational fulcrum of the zygomaticomaxillary complex was identified, and angular measurements were generated to assess changes in the zygomaticomaxillary complex (skeletal expansion), dentoalveolar bone (alveolar

bone bending), and maxillary first molars (dental tipping). The stability of all three components after orthodontic treatment was also assessed by comparing changes between T0–T1 and T0–T2. The authors concluded the MSE mainly produces skeletal changes with insignificant and negligible dentoalveolar changes immediately after expansion. In the long term, most of the skeletal expansion was maintained.

HYBRID HYRAX

The other kind of expander that is used in this study is the Hybrid Hyrax which was introduced by Lee et al. in 2010. He was one of the first authors to introduce MARPE as an alternative treatment for adult maxillary expansion. They recognized that the demand for nonsurgical maxillary expansion may increase as patients become more aware of the potential drawbacks of orthognathic surgery, such as prolonged recovery times, increased risk of complications, and detrimental periodontal effects and relapse. Considering this, they developed and implemented a miniscrew-assisted rapid palatal expansion (MARPE) technique to treat a 20-year-old patient with a severe transverse maxillary deficiency and mandibular prognathism. They successfully achieved sufficient skeletal maxillary expansion with minimal tipping of the buccal segment prior to orthognathic surgery, which subsequently corrected the anteroposterior discrepancy. The periodontal health and short-term stability of the maxillary expansion were confirmed both

clinically and radiologically. The effective incorporation of orthodontic mini screws for transverse correction holds promise in reducing the need for surgical procedures in patients with complex craniofacial discrepancies, provided that the suture remains patent.

Wilmes et al, which uses just two tads placed on the paramedian anterior palate as bone anchorage and bands fitted on maxillary posterior teeth and he indicated the use of this appliance in growing patients, also the use of the Hybrid hyrax was indicated for protraction of the maxilla with facemask therapy. (21)The literature on regards to hybrid hyrax dental-skeletal effects on non-growing patients is still limited. These last two appliances have been studied separately but not compared with each other.

CBCT Imaging

Over the years, several types of palatal expanders and their effects on skeletal and dental structures have been studied using different diagnostic resources such as casts and radiographs. Still, more recent studies have used 3-dimensional imaging (Cone beam computerized tomography). This last one provides more accurate imaging, assessing all craniofacial structures including maxillary sutures(22) for diagnosis and treatment planning, A CBCT image is considered superior to other 2D images. A superimposition in three dimensions allows the use of way more than the 20 landmarks used in 2D superimpositions.(23)

Thanks to this technology, we can evaluate the advantages and disadvantages of every expansion appliance. The literature on this topic is extensive and controversial. Cone Beam Computed Tomography (CBCT) scans help orthodontists assess both the hard and soft tissue of a patient in three dimensions. Rigorous research has affirmed the accuracy and reliability of CBCT images, making them adequate for diagnostic purposes in orthodontics. Modern orthodontics imaging software allows the operator to perform comprehensive 3D measurements and the development of craniofacial and cephalometric analyses. These measurements, derived from CT images, help the orthodontist to detect and diagnose craniofacial conditions like face asymmetries, functional shifts, and occlusal cants and can serve as a valuable quantitative tool.

MEASUREMENTS ANALYSIS

The imaging protocol started importing the CBCT DICOM file into the patient chart using Dolphin Software (Dolphin Imaging and Management Solutions, Chatsworth, California, USA) followed by the standardized orientation in the three planes of space

The linear and angular measurements that were retrieved for this study to measure transverse dental and skeletal changes were the maxillary width (MW), palatal width(PW), midpalate suture opening(PSO), alveolar bone bending (ABB), buccal bone thickness(BBT), Case Western transverse analysis(CWRUTA), intermolar width (IMW)and inter premolar width(IPMW) The CWRU transverse

analysis have been developed at Case Western Reserve University(Cleveland Ohio), and derived from coronal slices helps to diagnose a transverse dimension deficiency if present.

The CWRU transverse analysis allows to address specific problems related to patients' malocclusions. (24)

Palomo et al. specified the clinical and methods applications of the CWRU transverse analysis. And in those studies, the buccolingual inclination of molars an canines was measured. In our study, only the molar angulations according to CWRU transverse analysis were measured. Figure 1.1

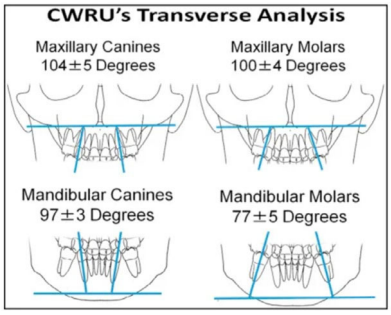


Fig.1.1 CWRU's Transverse Analysis

Villareal G.D, Palomo J. M, Elnagar H. M, ElShebiny T. 3D assessment of transverse changes associated with hybrid hyrax and MSE (Moon) appliance. 2023

Objectives: The aims of this study are to compare the transverse, dental, and skeletal changes in patients treated with a hybrid hyrax expander and Moon appliance expander using Cone-beam computed tomography (CBCT) and 3D image analysis.

Hypothesis: Null Hypothesis: There is no statistically significant difference in dentoalveolar complex, skeletal transverse, and palatal suture opening in patients who have undergone Hybrid Hyrax, or MSE appliance. Alternative Hypothesis: There is a statistically significant difference in dentoalveolar complex and skeletal transverse and palatal suture opening in patients who have undergone Hybrid hyrax, and MSE appliance

MANUSCRIPT FOR PUBLICATION

3D assessment of transverse changes associated with hybrid hyrax and MSE (Moon) appliances.

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ABSTRACT

Introduction

The aims of this study are to compare the transverse, dental, and skeletal changes in patients treated with a hybrid hyrax expander and Moon appliance expander using Cone-beam computed tomography (CBCT) and 3D image analysis.

Materials and Methods

The sample consists of patients treated at Case Western Reserve University at the Orthodontics Department. This retrospective study was approved by the Case Western Reserve University Institutional Review Board (IRB) (Appendix 1). Our sample consisted in 38 patients with a transverse maxillary deficiency that were divided into two groups; the first group (19, average age 18.5 years old) were treated with the Moon appliance, and the second group (19 patients, average age 18.7) were treated with the Hybrid Hyrax appliance. Cone-beam computed tomography scans were taken at pre-treatment (T1) and post-expansion (T2) to measure transverse dental and skeletal changes in maxillary width (MW), palatal width (PW), midpalate suture opening (PSO), alveolar bone bending (ABB), buccal bone thickness (BBT), Case Western transverse analysis on UR6 and UL6, intermolar distance (IMD)and inter-premolar diastance (IPMD). Data were analyzed using paired t-test and two-sample t-test.

Results

Hybrid Hyrax showed 65% skeletal expansion and 35% of dental expansion, and MSE Moon appliance showed a slightly larger ratio but not statistically significant, with 66% of skeletal expansion and 34% dental expansion. Skeletal and dentoalveolar values in both groups were compared, and no significant differences were observed in any of the variables.

Conclusion

Both appliances, MSE and hybrid hyrax deliver acceptable results and are a good option to correct mild to moderate transverse deficiency on nongrowing patients.

Buccal tipping was reduced in the MSE group when compared
with Hybrid Hyrax but not statistically relevant.
MSE appliance and Hybrid Hyrax deliver a noticeable parallel expansion pattern.
The expansion ratio of the MSE appliance group was 66% skeletal expansion and 34% dental expansion. Hybrid Hyrax showed 65% skeletal expansion and 35% of dental expansion

Keywords

MSE, Hybrid Hyrax, maxillary expansion, mini screw assisted rapid palatal expander.

Maxillary transverse deficiency, which is known as well as maxillary arch constriction describes a condition where the maxillary bone is narrower than the ideal dimensions. This can cause a constricted maxillary arch and consequent crowding of posterior or anterior teeth. The etiology of maxillary transverse deficiency is discussed in many articles but includes genetics factors, environmental causes, or a combination of both. The bibliography of this topic is extensive and over the years many research articles have been published.

Addressing the maxillary transverse deficiency is important for functional and esthetical reasons and without proper and early intervention, this condition can lead not just to crowded teeth, but it can cause impacted tooth, crossbites, compromised facial aesthetics and difficulties with adequate occlusion. A transverse deficiency can be accompanied by a functional shift with a posterior crossbite. If is left untreated, this can affect the symmetry of the facial third and temporomandibular function.

In orthodontics, the most common approach to address maxillary transverse deficiency is the rapid palatal expansion (RPE) which is often recommended during the growing phase, mostly in children and teenagers. After the completion of the growth phase, treatment utilizing the rapid palatal expander is discouraged due to the fusion of the maxillary sutures. An alternative less invasive option to avoid undesirable effects once the mid-palatal suture is closed is the Mini screw-assisted rapid palatal expansion, this is a nonsurgical approach that delivers acceptable results but with less of side effects of the RPE in non- growing patients.

The MARPE appliance consists of a palatal expansion screw that is fixed to the palate using temporary mini-screws. This design allows for controlled and precise expansion of the maxillary arch. The screws provide more stability and enable the expansion forces to be directly applied to the bone without relying just on dental anchorage.

The main advantage of MARPE over other traditional tooth borne appliances is that it can achieve greater skeletal expansion and minimize dental side effects. By application of forces directly to the bone, it reduces the risk of unwanted dental movements such tipping or flaring of teeth. This can result in a more stable and long-lasting expansion, as well as improved treatment results

Rapid maxillary expansion is used to correct maxillary arch constriction, but its effects are more than just expanding the maxilla. Its effects are reported and associated with at least 10 bones in the face and head. There are different studies on 2D imaging and 3D imaging indicating a nonparallel, triangular expansion pattern, and anterior expansion that is greater than posterior(25) . And there are extensive bibliographies comparing tooth borne expanders and tooth–bone-borne expanders. However, no studies have been conducted comparing hybrid hyrax appliance and MSE Moon appliance from a 3-dimensional standpoint.

The aim of this study is to compare the transverse, dental, and skeletal changes in patients treated with a hybrid hyrax expander and Moon appliance expander using Cone-beam computed tomography (CBCT) and 3D image analysis.

METHODS

This retrospective study was approved by the Case Western Reserve University Institutional Review Board (IRB) (Appendix A). Before the initiation of treatment, a patient or a legal guardian signed the American Association of Orthodontist Informed Consent (Appendix 2) including a paragraph consenting to the use of records for research purposes (appendix 3). Subjects were retrospectively selected from patients aged 18.4 for Hybrid Hyrax and 18.7 years old for MSE that presenting to the orthodontic clinic for treatment at Case Western Reserve University School of dental medicine at the orthodontics department.

The i-CAT FLX (Imaging Sciences international LLC,PA,USA) was used to obtain CBCT images and data were derived from pre-treatment(T1) and post-treatment(T2) DICOM files. All scans were taken at the oral radiology department at CWRU School of Dental Medicine during routine records appointments using the 2mA setting and the largest field of view (0.38mm Voxel Size).

All images were calibrated according to the following parameters, exposure of 10 mA for 32.5 s, power of 70 kVp, and 76 μm voxel size with volume dimensions of 8cm × 8 cm. All CBCT scans were taken with the Frankfort plane parallel to the floor.

Statistical Analysis

The reliability of the measurements was tested by randomly selecting 5 cases. of each group and repeating the measurements by the same examiner two weeks after the initial measurements.

Intraclass correlation coefficients were calculated to evaluate the reliability.

of the repeated measurements.

All tests were conducted in SPSS, paired t-tests were conducted to evaluate transverse dental and skeletal changes after maxillary expansion performed with MSE and Hybrid Hyrax. Two independent sample t-test were conducted to compare the difference between MSE and Hybrid Hyrax groups. All the statistical tests were two-sided, and P,0.05 was considered statistically significant.

The sample size which was 39 subjects was calculated using G*Power (Faul, Erdfelder, Lang, and Buchner, 2007) and estimated that at least 34 patients would be needed to find a minimum clinically significant difference of 0.5mm in palatal suture opening based on a power of 0.90 and an alpha of 0.05.

The sample consisted in a total 38 patients treated either with Hybrid Hyrax expander or MSE Moon appliance, with a transverse maxillary deficiency that were divided into two groups: 1) the first group (19, average age 18.7 years old) were treated with the MSE Moon appliance, and the second group (19 patients, average age 18.4) were treated with the Hybrid Hyrax appliance. Patients were selected according to the inclusion and exclusion criteria, after reviewing the subjects that met the inclusion criteria, 39 (19 on each of 2 groups) remained.

The inclusion criteria were the following:

- Patients treated in the orthodontics clinic at CWRU either with Hybrid Hyrax expander or MSE Moon appliance.
- Permanent dentition
- Insufficient maxillary arch circumference, with or without crossbite
- Successful opening of mid palatal suture
- Pre-expansion and post-expansion CBCT were available with diagnostic quality.

The exclusion criteria were the following:

- Periodontal disease
- Previous orthodontic treatment
- Congenital malformations.

Cone-beam computed tomography scans were taken at pre-treatment (T1) and post-expansion (T2) to measure the changes in maxillary width (MW), palatal width(PW), midpalate suture opening(PSO), alveolar bone bending (ABB), buccal bone thickness(BBT), case western transverse analysis(CWTA), intermolar width (IMW)and interpremolar width(IPMW). DICOM files were assessed using the dolphin imaging software (version 11.95, Dolphin Imaging and Management Solutions, Chatsworth, CA).

APPLIANCE DESIGN

Figure 1(a and b) shows the MSE (Designed by Dr. Won Moon UCLA school of dentistry)

is a specific appliance manufactured by BioMaterials Korea, Inc , and consists of a central expansion jackscrew with four attached arms that are soldered to the pre-fitted orthodontics bands on the teeth that serve as anchorage, around the maxillary first molars(1M), and to the premolars in addition to the first molar to provide. supplementary anchorage. Four mini-screws were placed in the palate, the anterior two mini-screws are placed bilaterally in between the roots of the first premolars (1 PM) and the second premolars (2 PM).

The posterior mini-screws are inserted in between the roots of the second premolar and the first molar. 6-8 mm palatal to the gingival margin of the teeth, following a perpendicular insertion between the roots into the palatal bone. The central screw has four tubes welded to it that serve as guides for the placement of the mini-screws. The mini-screws are 1.5-1.8 mm in diameter and 10 mm in length. DENTAURUM). The length of the mini screws allows for bicortical insertion, and the diameter allows for a secure fit within the tubes.



Figure1a shows an MSE appliance in place before activation

Figure1b shows an MSE appliance after full activation

The Thomas 2 tads eyelet RPE (Hyrax, Dentaurum, Ispringen, Germany) (Figure 2a,2b), it consists of a central expansion jackscrew, two anterior eyelets positioned at the level between upper first and second premolars oriented perpendicular to the occlusal plane that serves as a guide for mini implants placement, the mini implants are 1.5-1.8 mm in diameter and 10 mm of length, (Dentaurum, Ispringen ,Germany).

Two extension arms are welded to the orthodontics bands placed on upper first molars, the orthodontics bands have .22 tubes welded to them, and two arms, extended to 1 PM and 2 PM and an occlusal rest on the second premolar.

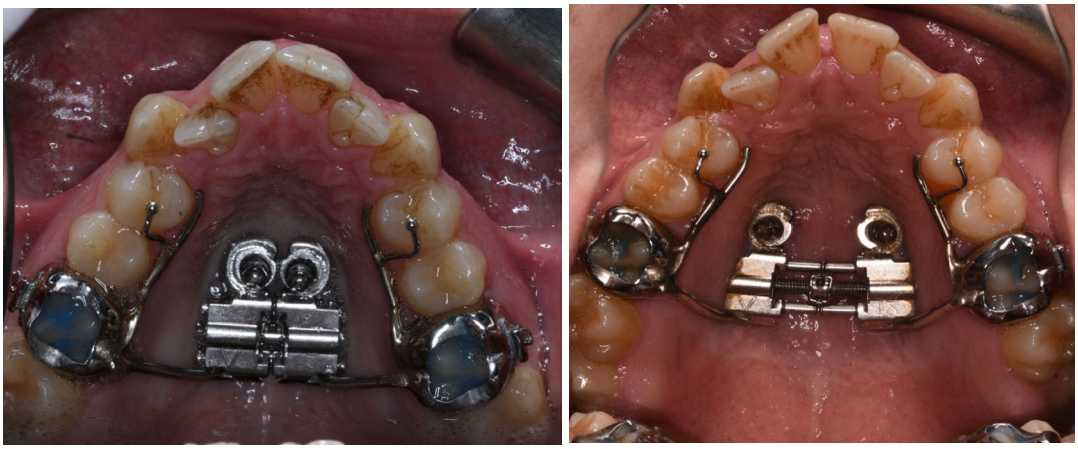


Figure 2a shows a HH appliance in place before activation.

Figure 2b shows a HH appliance after full activation

TREATMENT PROTOCOL

The protocol for the installation of the Hybrid Hyrax was: local anesthesia, cement of the Hybrid hyrax with light-curing glass ionomer the first step is the insertion of the two mini-screws in the anterior palate using the anterior Thomas eyelets as a guide (hybrid hyrax) using a contra-angle implant driver with a maximum insertion torque. 8-11 mm mini-implants (DENTAURUM, Ispringen,Germany) are inserted perpendicular to the palate at the same level as of first premolars , and placed parallel to the palatal suture.

The jackscrew was positioned at the anterior palate at the same level of the third rugae.Rapid maxillary expansion was performed by activation of the expansion screw four times a day which means a daily expansion 0.8 mm. On the MSE the treatment protocol is the same but with the insertion of four miniscrews. A transversal overcorrection is expected for relapse compensation. Turns are performed until diastema is present or correction or posterior crossbite is achieved. The post-activation retention time was of four to six months .CBCT scans were taken before expansion (T1) and after expansion (T2)

Although the same expander was used for all subjects in this study, there were some treatment-related variations: The number of teeth used as anchor teeth, the expander was banded either to the 1PM and 1M or to the 1M only; the number of bicortical engaged mini–implants. The appliance activation protocol varied with the severity of the transverse deficiency. 2 – 3mm of overexpansion was expected to be seen to stop with activations and this was determined by the faculty at the clinic.

**Sari et al, described that “expansion was considered adequate when the occlusal aspect of the lingual cusp of the maxillary first molars contacted the occlusal aspect of the facial cusp of the mandibular first molars” . The 2-3 mm of overexpansion is indicated to compensate for relapse(26)

MEASUREMENTS ANALYSIS

All CBCT Images were oriented in three planes of space to standardize the image analysis and to set an identical reference plane for the CBCT scans taken on T1(pre-expansion) and T2 (post-expansion) the reorientation protocol was adopted from the method by Ngan et al.(27) all CBCT volumes were oriented on the three planes of space; coronal, sagittal, and axial.

The orientation of the sagittal view was parallel to the software's horizontal line that runs transverse to the middle of the palatal plane (ANS-PNS).The orientation of the axial view was parallel to the software's horizontal line that connects both lingual cusps of the upper 1 PM. The coronal view was parallel to the software's horizontal indicator line that connects the intersection of the right and left lateral contour of the maxillary alveolar process and the lower contour of the zygomatic process of the maxilla.

LINEAR AND ANGULAR MEASUREMENTS

Following the alignment of the CBCT images by standardization of orientation, we proceed to take linear and angular measurements. The analysis of the DICOM images was done with Dolphin Imaging Software (version 11.8 Premium), using the measuring tool feature. The CBCT measurements were categorized into two different groups; the one pertained to skeletal changes and the second group included the dentoalveolar changes.

Skeletal Changes Measurements

Alveolar Bone bending: is an angular measurement defined as the angle intersecting between the palatal alveolar bone of the upper right and left first molar and the software's horizontal blue line that runs transversally through the middle of the palate, on a cross sectional coronal slice,(fig.3) This is an angular measurement that describes the degree difference between the palatal alveolar bone angles measured on first molars, from a coronal cross-sectional slice through the midportion of the teeth

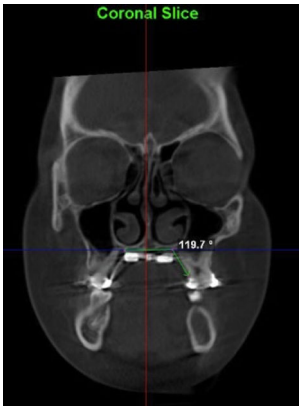


Fig.3 Alveolar Bone Bending

Buccal Bone thickness (BBT) : (fig.4) is a linear measurement and is defined as the distance from the most buccal surface of 1PM and the 1M (anchor teeth) and the most external aspect of the maxillary buccal cortical bone and it was measured at the mesiobuccally root of right and left first molars, on an axial cross-sectional slice through the furcation of 1M.

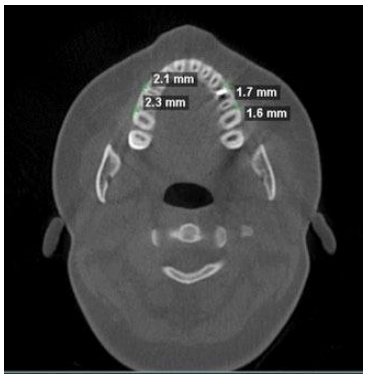


Figure 4. Buccal bone thickness

Palatal suture opening (PSO): This measurement describes the width of the palatal suture separation through the mid palatal suture at the level of canines, first bicuspids, second bicuspids .To avoid mistakes due to the presence of artifacts for example on the images of subjects with the expander in place , landmarks were placed on canines, first bicuspids, second bicuspids and first molar levels.The suture width opening was measured between the right and left external edges of the suture measured on an axial cross-sectional slice. (fig.5)

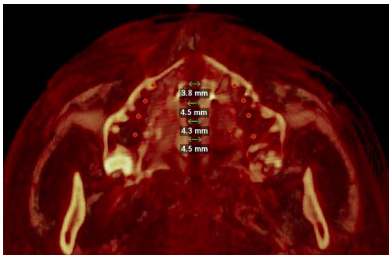


Fig.5 Palatal suture opening measurements

Maxillary Width (MW): This is the measure taken between the lowest point of lateral right and left concavities of the external border of the maxilla, on a coronal axial slice, at the same level as the first molars where the full palatal root and crown are completely visible. (fig.6)



Figure 6.Maxilary width

Palatal width: Measured as the line connecting the junction of the hard palate and the lingual alveolar bone on a coronal axial slice through the furcation of the maxillary right first molar.(fig.7)

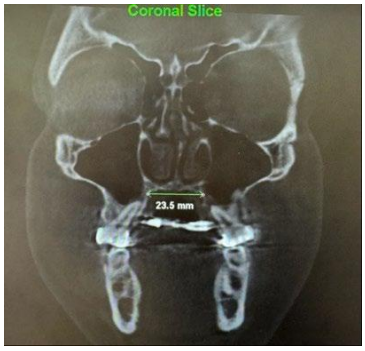


Fig.7 Palatal Width

Dentoalveolar changes measurements

CWRU transverse analysis: (fig.8) The buccolingual inclination of each maxillary first molar is measured through the angle outlined between the palatal long axis of the tooth and that is the line joining the mesial-palatal cusp tip with the palatal root apex and a tangent to the inferior border of the nasal cavity. This measurement was taken just on the upper molars. The CWRU transverse analysis includes lower molars as well.

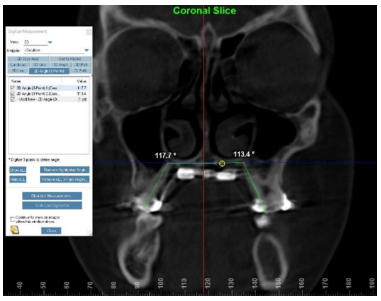


Fig. 8 Case Western Reserve University Transverse analysis

Intermolar distance: (fig.9) The distance between the palatal cusp tip of the right and left first molars measured in a coronal cross-sectional slice through the center of the first molar.

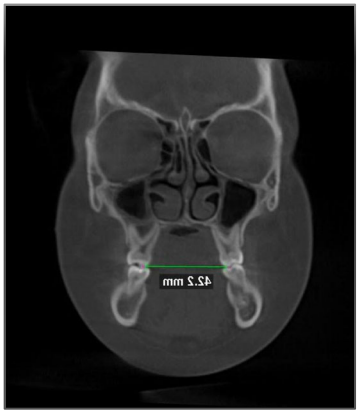


Fig. 9 Intermolar distance

Interpremolar distance: (fig.10) Distance between the palatal cusp tip of the right and left first premolars measured in a coronal cross-sectional slice through the center of the first premolar.



Fig. 10 Interpremolar distance

Results

To calculate the skeletal and dental expansion ratio, the palatal width was divided by the intermolar distance. Hybrid Hyrax showed 65% of skeletal expansion and 35% of dental expansion, MSE Moon appliance showed a slightly larger ratio but not statistically significant with 66% of skeletal expansion and 34% of dental expansion. The difference between the two groups of between T1 and T2 were considered significantly relevant when $P<0.05$.

Skeletal and dentoalveolar values in both groups were compared between each other and no significant differences were observed in any of the variables. Table (1,2,3,4).

However in the paired test when comparing T2 From T1 significant changes were found.

Table 1 . Measurements for dental movements at the Hybrid Hyrax group

Variables	Pre-Expansion		Post-Expansion		Change (T2-T1)		P Value
	Mean	SD	Mean	SD	Mean	SD	
IMD	36.79	3.14	44.19	3.37	7.40	3.43	<.001
IPMD	26.88	3.17	33.30	5.54	6.41	4.26	<.001
CWTA UR6	102.73	5.31	106.81	5.02	4.07	3.58	<.001
CWTA UL6	102.36	6.65	105.43	5.55	3.06	6.34	.025

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: IMD, interpremolar distance; IPMD,inter-premolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UL6, Case Western Transverse Analysis upper left , first molar

Table 2. Measurements for skeletal movements at the Hybrid Hyrax group

Variables	Pre-Expansion		Post-Expansion		Change (T2-T1)		P Value
	Mean	SD	Mean	SD	Mean	SD	
BBT UR1PM	1.31	0.42	1.48	0.73	0.16	0.80	.187
BBT UL1PM	1.28	0.36	1.49	1.05	0.21	1.10	.209
BBT UR1M	1.55	0.31	1.16	0.42	-0.38	0.54	.003
BBT UL1M	1.49	0.44	1.32	0.42	-0.17	0.64	.126
MW	59.27	4.05	61.35	4.20	2.07	2.70	.002
PW	25.17	3.18	28.48	3.23	3.31	2.57	<.001
ABB Left	110.01	6.22	112.59	5.19	2.58	4.36	.009
ABB Right	108.55	5.08	110.95	6.42	2.40	5.30	.032
PSO C	0	0	3.03	1.91	3.03	1.91	<.001
PSO 1st PM	0	0	3.05	1.64	3.05	1.64	<.001
PSO 2nd PM	0	0	2.96	1.81	2.96	1.81	<.001
PSO 1st M	0	0	3.03	1.75	3.03	1.7	<.001

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right; PSO C, palatal suture opening (canine), PSO 1st PM, palatal suture opening first premolar; PSO 2nd PM, palatal suture opening ; PSO 1st M, palatal suture opening first molar

Table 3. Measurements for dental movements at MSE group

	Pre-expansion T1		Post-expansion T2		Change (T2-T1)		P
	Mean	SD	Mean	SD	Mean	SD	
IMD	38.64	3.61	43.92	4.98	5.27	2.84	<.001
IPMD	28.11	2.84	32.88	3.73	4.77	2.48	<.001
CWTA UR6	102.82	7.66	106.27	4.65	3.45	6.98	.023
CWTA UL6	102.11	4.89	104.73	6.27	2.62	5.55	.027

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: IMD, interpremolar distance; IPMD,inter-premolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UL6, Case Western Transverse Analysis upper left , first molar

Table 4. Measurements for skeletal movements at MSE group

Variables	Pre-Expansion		Post-Expansion		Change (T2-T1)		P Value
	Mean	SD	Mean	SD	Mean	SD	
BBT UR1PM	1.24	0.35	1.53	0.58	0.28	0.54	.016
BBT UL1PM	1.20	0.43	1.33	0.44	0.13	0.53	.150
BBT UR1M	1.64	0.55	1.52	0.66	-0.12	0.70	.224
BBT UL1M	1.63	.089	1.43	.58	-0.19	0.92	.186
MW	60.65	4.32	63.83	5.41	3.17	2.70	<.001
PW	24.56	2.46	28.86	2.44	4.29	2.92	<.001
ABB Left	109.68	5.35	113.65	5.97	3.97	3.44	<.001
ABB Right	111.50	6.52	114.31	6.97	2.81	4.43	.006
PSO C	0	0	3.78	1.51	3.78	1.51	<.001
PSO 1st PM	0	0	3.50	1.67	3.50	1.67	<.001
PSO 2nd PM	0	0	3.43	1.73	3.43	1.73	<.001
PSO 1st M	0	0	3.45	1.81	3.45	1.81	<.001

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right; PSO C, palatal suture opening (canine), PSO 1st PM, palatal suture opening first premolar; PSO 2nd PM, palatal suture opening ; PSO 1st M, palatal suture opening first molar

Table 5. Comparison of difference (T2-T1) measurements between Hybrid Hyrax and MSE

	Hybrid Hyrax		MSE		P value
	Mean	SD	Mean	SD	
IMD	7.40	3.43	5.27	2.84	.42
IPMD	6.41	4.26	4.77	2.48	.39
CWTA UR6	4.07	3.58	3.45	6.98	.36
CWTA UL6	3.06	6.34	2.62	5.55	.35
BBT UR1PM	0.16	0.80	0.28	0.54	.40
BBT UL1PM	-0.21	1.10	0.13	0.53	.26
BBT UR1M	-0.38	0.54	-0.12	0.70	.25
BBT UL1M	-0.17	0.64	-0.19	0.92	.46
MW	2.07	2.70	3.17	2.70	.06
PW	3.31	2.57	4.29	2.92	.34
ABB Left	2.58	4.36	3.97	3.44	.28
ABB Right	2.40	5.30	2.81	4.43	.06

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: IMD, interpremolar distance; IPMD,inter-premolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UR6, Case Western Transverse Analysis ,BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right.

The table 5 showed there was a statistically significant increase in the IMD between T1 and T2 by a mean of 7.40mm on the subjects treated with hybrid hyrax and a mean of 5.27mm on the ones treated with MSE .The IPMD shows a significant change in the patients treated with hybrid hyrax with a mean of 6.41mm and a mean of 4.77mm on the subjects treated with MSE. The CWTA at the upper right first molar and upper left first molar increased significantly from T1 to T2 by a mean of 4.07 degrees and 3.06 degrees respectively on the subjects treated with hybrid hyrax and a mean of 3.45 degrees and 2.62 degrees on the subjects with MSE appliance. This demonstrates that more buccal tipping occurs on the subjects treated with hybrid hyrax on the upper first molars. However, both appliances deliver acceptable results when compared with each other.

Table 6. Comparison of the dental measurements between Hybrid Hyrax and MSE before expansion

Variables	Pre-Expansion Hybrid Hyrax		Pre-Expansion MSE		P Value
	Mean	SD	Mean	SD	
IMD	36.79	3.14	38.64	3.61	0.10
IPMD	26.88	3.17	28.11	2.84	0.22
CWTA UR6	102.73	5.31	102.82	7.66	0.97
CWTA UL6	102.36	6.65	102.11	4.89	0.89

Statistical significance was determined to be present at *Pvalue < 0.05. Abreviation: IMD inter premolar distance; IPMD interpremolar distance; CWTA UR6 - Case Western transverse analysis upper right first molar; CWTA UL6- Case Western transverse Analysis upper left first molar; molar Abbreviation: IMD, inter premolar distance; IPMD,inter-premolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UL6, Case Western Transverse Analysis .upper left first molar

Table 7. Comparison of the skeletal measurements between Hybrid Hyrax and MSE before expansion

Variables	Pre-Expansion Hybrid hyrax		Pre-Expansion MSE		P Value
	Mean	SD	Mean	SD	
BBT UR1PM	1.31	0.42	1.24	0.35	0.59
BBT UL1PM	1.28	0.36	1.20	0.43	0.52
BBT UR1M	1.55	0.31	1.64	0.55	0.51
BBT UL1M	1.49	0.44	1.63	.089	0.55
MW	59.27	4.05	60.65	4.32	0.31
PW	25.17	3.18	24.56	2.46	0.51
ABB Left	110.01	6.22	109.68	5.35	0.86
ABB Right	108.55	5.08	111.50	6.52	0.12
PSO C	0	0	0	0	0.19
PSO 1st PM	0	0	0	0	0.41
PSO 2nd PM	0	0	0	0	0.38
PSO 1st M	0	0	0	0	0.46

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right; PSO C, palatal suture opening (canine), PSO 1st PM, palatal suture opening first premolar; PSO 2nd PM, palatal suture opening ; PSO 1st M, palatal

The buccal bone thickness was measured at the level of UR1PM, UL1PM, UR1M, and UL1M, on the hybrid hyrax group and just the BBT UR1M changes were significantly relevant with a mean of -0.38mm. In the MSE group, the changes between T1 and T2 for the BBT are significantly relevant at the level of the UR1PM with a mean of 0.28mm.

The Maxillary width was measured at the level of the first molars and on the HH group the results were statistically relevant from T1 to T2 with a mean of 2.07 mm and 3.17mm on the MSE group. The palatal width from T1 to T2 shows a mean of 3.31 mm in the HH group and 4.29 mm in the MSE group. The alveolar bone bending was measured in both groups on the upper left first molar and the upper right first molar. Both showed statistically relevant results, the ABB on the left has a mean of 3.97 degrees , on

the right side 2.81 degrees on the MSE group and a mean of 2.58 degrees on the left and 2.40 degrees on the HH group.

Table 8. Comparison of the changes between Hybrid Hyrax and MSE

Variables	Changes Hybrid Hyrax		Changes MSE	
	Mean	SD	Mean	SD
IMD	7.40	3.43	5.27	2.84
IPMD	6.41	4.26	4.77	2.48
CWTA UR6	4.07	3.58	3.45	6.98
CWTA UL6	3.06	6.34	2.62	5.55

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: IMD, interpremolar distance; IPMD, interpremolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UL6, Case Western Transverse Analysis .upper left first molar

Table 9. Comparison of the dental changes between Hybrid Hyrax and MSE

Variables	Changes Hybrid hyrax		Changes MSE	
	Mean	SD	Mean	SD
BBT UR1PM	0.16	0.80	0.28	0.54
BBT UL1PM	0.21	1.10	0.13	0.53
BBT UR1M	-0.38	0.54	-0.12	0.70
BBT UL1M	-0.17	0.64	-0.19	0.92
MW	2.07	2.70	3.17	2.70
PW	3.31	2.57	4.29	2.92
ABB Left	2.58	4.36	3.97	3.44
ABB Right	2.40	5.30	2.81	4.43
PSO C	3.03	1.91	3.78	1.51
PSO 1st PM	3.05	1.64	3.50	1.67
PSO 2nd PM	2.96	1.81	3.43	1.73
PSO 1st M	3.03	1.7	3.45	1.81

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right; PSO C, palatal suture opening (canine), PSO 1st PM, palatal suture opening first premolar; PSO 2nd PM, palatal suture opening ; PSO 1st M, palatal suture opening first molar

Table 10. Comparison of the dental measurements between Hybrid Hyrax and MSE post-expansion

Variables	Post-Expansion Hybrid Hyrax		Post-Expansion MSE		P value
	Mean	SD	Mean	SD	
IMD	44.19	3.37	43.92	4.98	0.84
IPMD	33.30	5.54	32.88	3.73	0.79
CWTA UR6	106.81	5.02	106.27	4.65	0.37
CWTA UL6	105.43	5.55	104.73	6.27	0.71

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: IMD, interpremolar distance; IPMD, interpremolar distance; CWTA UR6, Case Western Transverse Analysis upper right first molar; CWTA UL6, Case Western Transverse Analysis .upper left first molar

Table 11. Comparison of the skeletal changes between Hybrid Hyrax and MSE post-expansion

Variables	Post-Expansion Hybrid hyrax		Post-Expansion MSE		P value
	Mean	SD	Mean	SD	
BBT UR1PM	1.48	0.73	1.53	0.58	0.80
BBT UL1PM	1.49	1.05	1.33	0.44	0.54
BBT UR1M	1.16	0.42	1.52	0.66	0.57
BBT UL1M	1.32	0.42	1.43	.58	0.49
MW	61.35	4.20	63.83	5.41	0.12
PW	28.48	3.23	28.86	2.44	0.68
ABB Left	112.59	5.19	113.65	5.97	0.56
ABB Right	110.95	6.42	114.31	6.97	0.13
PSO C	3.03	1.91	3.78	1.51	0.19
PSO 1st PM	3.05	1.64	3.50	1.67	0.41
PSO 2nd PM	2.96	1.81	3.43	1.73	0.38
PSO 1st M	3.03	1.75	3.45	1.81	0.46

Statistical significance was determined to be present at *Pvalue < 0.05. Abbreviation: BBT UR1PM ,buccal bone thickness upper right first premolar, BBT UL1PM, buccal bone thickness upper left first premolar ; BBT UR1M , buccal bone thickness upper right first molar ;BBT UL1M, buccal bone thickness upper left first molar; MW,maxillary width ; PW, palatal width; ABB left ,alveolar bone bending left ; ABB right , alveolar bone bending right; PSO C, palatal suture opening (canine), PSO 1st PM, palatal suture opening first premolar; PSO 2nd PM, palatal suture opening ; PSO 1st M, palatal suture opening first molar

For both groups, the palatal suture opening measurement was defined as zero before expansion, and after expansion we found significant changes for the variables PSO C,

In the Hybrid Hyrax group, the mean of the palatal suture opening at the level on canines , 1PM , 2PM and 1M was 3.03mm, 3.05mm,2.96mm, 3.03mm respectively and on the MSE group the PSO mean was 3.78mm on canines level , 3.50mm at the first premolars level , 3.43 at the second premolars level and 3.45mm at the first molars . All the results on both groups for the palatal suture opening were statistically significantly relevant from T1 to T2 and demonstrated a parallel expansion pattern along the palatal suture in both groups . However the value of palatal suture opening was higher in the MSE group than in the Hybrid Hyrax group .(table 11)

No significant difference was found on the dental or skeletal transverse changes from T1 to T2 between the two groups. However when we see the numbers closely, we found that the mean values for IMD,IPMD,CWTA UR6, and CWTA UL6 are higher in the HH group than in the MSE group .And the mean values for BBT UR1PM,BBT UL1PM,BBT UL1 MW,PW ,ABB left and right are higher for the MSE group. With the exemption of the buccal bone thickness at the UR1M that showed a decrease on the MSE group only (Table 5)

Discussion

CBCT scans were used to evaluate the dentoalveolar and skeletal changes that happen after expansion, and then a comparison was made between the groups that used Hybrid Hyrax expander and the group that used MSE expander.

The results of this study show that both appliances MSE and Hybrid Hyrax are successful in correcting bilateral or unilateral maxillary transverse deficiencies and this finding agrees with previous research results.
(Cantarella et al., 2020; Colak et al., 2020; Sarraj et al., 2021)

Different studies have compared two kinds of expanders and Bazzani et al. found significant transverse changes in two groups, the group with bone-borne expander and the second group using tooth–bone–borne with more skeletal changes than dental . In this same study the amount of expansion at the palatine foramen level was divided by the amount of dental expansion between the first molar cusps, and the bone-bone expander delivered a 77% of skeletal expansion and 23 % of dental expansion.

In our study to calculate the skeletal and dental expansion ratio, the palatal width was divided by the intermolar distance. Hybrid Hyrax showed 65% of skeletal expansion and 35% of dental expansion, and MSE Moon appliance showed a slightly larger ratio but not statistically significant with 66% of skeletal expansion and 34% of dental expansion.

The bone-bone expander delivered a higher amount of skeletal expansion according to Bazzani et al study, and dental transverse changes were relative to the midpalate suture opening cause by the bone-bone appliance since is not anchored to any tooth like it is a tooth bone borne expander.

In a Bazanni et al. study 30 patients with transverse maxillary discrepancy were treated with two different types of appliances: Group BB and Group TBB expanders.

CBCT scans were acquired before (T1) and after completion of maxillary expansion (T2); transverse, anteroposterior and vertical linear and angular three-dimensional dentoskeletal changes were assessed after cranial base superimposition.
The results of our research project agree with the findings of Bazanni et al. study and both of our groups present a greater skeletal expansion than dental. And since both groups of our study are tooth–bone–borne expanders, both of them present a parallel pattern of suture opening.

At the literature review we can find that many studies have been conducted evaluating the differences between tooth bone and tooth bone borne expanders in one of this studies sixty patients during post growth spur stage were divided randomly in MARPE and Hyrax groups and the success rate of palatal suture opening was 100% on MARPE group and 86.7% for Hyrax group , so the MARPE group delivered more reliable and predictable results when skeletal transverse expansion was expected . (Jia et al., 2021)

In our study skeletal and dentoalveolar values in both groups were compared and no significant differences were observed in any of the variables: table (1,2,3,4), And both delivered acceptable quality of skeletal expansion and our results agree with Jia et al. study results. In this study we found as well that the MARPE group presented a more parallel pattern of palatal suture opening when compared with the hyrax group that presented a fan shaped pattern that produced changes in the inclination of anchored teeth.

Table (2,4,9) shows the parallel pattern of the midpalatal suture opening.

The transverse dental and skeletal changes caused by Hybrid Hyrax and MSE (Moon) appliances were not compared according to our literature review.

Moon et al reported a decrease in alveolar bone that was greater in the anchorage 1M (1.15mm and 1.51mm on the right and left side, respectively) this difference could be caused by the measurement method; however, in Table 11, we found a symmetric decrease in buccal bone thickness on the right and left of the MSE group.

Garib et al study compared the effects of a Hybrid Hyrax and conventional hyrax in growing patients , and the found significant greater increases in maxillary width and buccal alveolar crest width for the HH, and no differences for dental arch width or shape differences.

The hybrid hyrax evaluation coincide with our study results

Conclusions

Buccal tipping was reduced in the MSE group when compared with Hybrid Hyrax but not statistically relevant. MSE appliance and Hybrid Hyrax deliver a noticeable parallel expansion pattern. The expansion ratio of the MSE appliance group was 66% skeletal expansion and 34% dental expansion. Hybrid Hyrax showed 65% skeletal expansion and 35% dental expansion.

No significant difference was found on the dental or skeletal transverse changes. from T1 to T2 between the two groups. The mean values for skeletal changes were higher for the MSE group. With the exemption of the buccal bone thickness at the UR1M that showed a decrease on the MSE group only. Further studies on long-term effects of both appliances are desired.

Strengths

This study provided several benefits to previous knowledge surrounding Hybrid Hyrax, and MSE expander since there are no prior studies comparing both appliances.

Study Limitations

Some limitations of this study should be considered: Patient-related variations like age, gender, bone anatomy, treatment-related variations, resolution of the CBCT scan due to artifacts like amalgams and metal crowns, or the expander by itself, made difficult to identify structures, and the accuracy on the standardization of orientation.

Future studies could be conducted to evaluate the long-term effects of both appliances, and a prospective study could be considered to create a difference in T1 (pre-expansion) measurements.

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APPENDIX A



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ck-in" to confirm the status of the study.

The UH IRB operates under HHS Federalwide Assurance (FWA) number 00003937 and IRB registration numbers 00000684, 00001691 and 00008600. The CWRU IRB operates under DHHS FWA00004428 and IRB registration number 00000683.

***Approval by the IRB does NOT mean that you have permission to start your study. Prior to starting your study, you may be required to obtain (1) a coverage analysis for studies that involve patient care, regardless of source of funding, and/or (2) a contract with the Sponsor of your study or an agreement with any third-party collaborator that may receive UH or CWRU patient information in any format. Please ensure that all required approvals are obtained before initiation of research activity. ***