COMPARISON OF MARPE AND ALT-RAMEC PROTOCOL IN CORRECTING SKELETAL TRANSVERSE DISCREPANCY IN YOUNG ADULTS:

A RANDOMIZED CONTROLLED CLINICAL TRIAL

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by

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LIST OF ABBREVIATIONS

3D	3-dimensional
ALT-RAMEC	Alternate Rapid Maxillary Expansion and Constriction
ANCOVA	Analysis of Covariance
ANS	Anterior Nasal Spine
BAMP	Bone Anchored Maxillary Protraction
BCA	Bootstrap for pairwise Comparison Analysis
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
CV3	Cervical Vertebra 3
FCPC	Force Controlled Polycyclic Expansion
FM	Facemask
ICC	Intra-class Correlation Coefficient
M1	First molar
MARPE	Mini-screw Assisted Rapid Palatal Expansion
MSE	Maxillary Skeletal Expander
NSD	Nasal Septal Deviation
OMIM	Online Mendelian Inheritance in Man
OPG x-ray	Panoramic x-ray
OSAS	Obstructive Sleep Apnea Syndrome
PNS	Posterior Nasal Spine
PPD	Periodontal Probing Depth
RME	Rapid Maxillary Expansion

SARME	Surgical Assisted Rapid Maxillary Expansion
T1	Pre-treatment
T2	Post-treatment

LIST OF APPENDICES

PERBANDINGAN PROTOKOL MARPE DAN ALT-RAMEC DALAM MEMBETULKAN KETIDAKSEIMBANGAN RANGKA TRANVERS DALAM KALANGAN DEWASA MUDA : PERCUBAAN KLINIKAL TERKAWAL RAWAK

ABSTRAK

Kekurangan rangka boleh diekspresikan dalam maksila secara sagittal. Rawatan terbaik bagi kekurangan maksilari secara melintang dalam kalangan kanak-kanak dan remaja masih merupakan pengembangan maksilari yang pantas. (RME) Dalam kalangan orang dewasa, pengembangan pantas palatal dengan bantuan skru mini telah dibuktikan sebagai satu kaedah yang berkesan untuk menangani kesan buruk dentoalveolar. Dalam merawat pesakit dewasa dengan kekurangan maksila anteroposterior (skeletal kelas III), pakar klinikal perlu memilih di antara pendekatan pembedahan invasive atau terapi penyamaran untuk menutup maloklusi kelas III. Bagaimanapun, dalam kalangan pesakit yang lebih muda, pengembangan pantas maksilari secara gentian dan penjerutan (ALT-RAMEC) merupakan rawatan pilihan. Dalam kajian ini, protocol 7 minggu ALT-RAMEC telah telah diubahsuai dan digabungkan dengan MARPE bagi menilai keberkesanan dan kebaikan-kebaikannya berbanding MARPE konvensional dalam kalangan umur dewasa muda. Dua puluh Sembilan pesakit dengan kekurangan maksilari melintang (purata umur 21.3) telah dimasukkan ke dalam dua kumpulan secara rawak. Kumpulan konvensional menerima MARPE dengan kombinasi MARPE dengan protocol ALT-RAMEC yang telah diubahsuai. Segala keberkesanan pengembangan, anjakan jahitan sirkum maksilari, dentoskeletal, pernafasan dan kesna-kesan periodontal klinikal telah dinilai. Analisis

perubahan sebelum dan Selepas intervensi telah dibuat pemeriksaan menggunakan ujian t berpasangan manakala analisis parameter yang membandingkan kedua-dua kumpulan telah diperiksa menggunakan ujian t bebas. Bagi pembolehubah-pembolehubah yang tidak terbahagi secara normal, nilai p telah didapati daripada Bootstrap untuk perbandingan secara berpasangan. Analisis kovarians telah digunakan apabila data garis dasar didapati berbeza secara signifikan di antara kumpulan. Hasil kajian menunjukkan 100% keberkesanan bagi kedua-dua teknik untuk menghasilkan pengembangan dalam kedua-dua kumpulan. Jahitan-jahitan pertengahan palatal, frontasal, dan intermaksilari teranjak dan meningkat kelebarannya secara signifikan ($p \leq 0.001$) selepas rawatan dengan kedua-dua protocol, manakala jahitan zigomatik maksilari memampatkan dan meningkatkan kelebaran secara signifikan dengan MARPE konvensional, dan walaupun dikembangkan dan meningkat lebarnya secara signifikan ($p \leq 0.001$) dengan kumpulan ALT-RAMEC. Kesan-kesan dentoskeletal menunjukkan bahawa MARPE konvensional menghasilkan hujung gigi molar bukal manakala ALT-RAMEC menunjukkan lebih kepada pergerakan badan molar ankor. Tiada kesan-kesan tambahan ALT-RAMEC ke atas isipadu saluran udara daripada kesan MARPE. Kedua-dua protokol meningkat secara signifikan dalam rongga hidung dan isipadu orofarinks dan merendahkan isipadu sinus($p < 0.001$) nasofarinks dan maksilari dengan tiada perbezaan signifikan di antara kumpulan ($p > 0.05$). Keadaan periodontium tidak berkolerasi dengan protocol pengaktifan dalam kajian semasa, tetapi masa rawatan kumpulan ALT-RAMEC yang lebih Panjang membuktikan terdapat impak negatif ke atas persekitaran gingiva berbanding dengan MARPE konvensional. Di sebalik kegagalan gingiva, teknik ALT-RAME terubahsuai merupakan protocol yang memberangsangkan dan mencukup dalam mengembangkan maksila secara melintang tanpa mencungkil gigi penambat dalam kalangan pesakit dewasa muda

COMPARISON OF MARPE AND ALT-RAMEC PROTOCOL IN CORRECTING SKELETAL TRANSVERSE DISCREPANCY IN YOUNG ADULTS:

A RANDOMIZED CONTROLLED CLINICAL TRIAL

ABSTRACT

The skeletal deficiency could be expressed in the maxilla sagittally, vertically, and transversally. The most effective treatment for transverse maxillary deficiency in growing children and adolescents is still rapid maxillary expansion (RME). In adults, mini-screw-assisted rapid palatal expansion (MARPE) proved to be the efficient method for overcoming all dentoalveolar drawbacks. In treating adult patients with anteroposterior deficient maxilla (skeletal class III), the clinician had to decide between an invasive surgical approach to resolve the skeletal imbalance or a camouflage therapy to mask the class III malocclusion. However, in younger patients, alternate rapid maxillary expansion and constriction (ALT-RAMEC) is the treatment of choice. In this study, the 7-week ALT-RAMEC protocol was modified and combined with MARPE to evaluate its efficiency and advantages over conventional MARPE in young adult ages. Twenty-nine patients with transverse maxillary deficiency (mean age of 21.3) were randomly assigned to two groups. The conventional group received MARPE with its conventional rate of expansion, while the ALT-RAMEC group was treated with a combination of MARPE with ALT-RAMEC modified protocol. The efficiency of expansion, circummaxillary sutural displacement, dentoskeletal, respiratory, and clinical periodontal effects were all assessed. Analysis of the change before and after intervention was examined using paired t-tests while analysis of the parameters comparing the two groups was examined using an independent t-test. For variables that were not normally distributed, the p-value was obtained from Bootstrap for pairwise comparison (BCA). The analysis of covariance (ANCOVA) was used when the baseline data was significantly different between groups. The results showed 100% efficiency of both techniques to produce expansion in both groups. Mid-palatal, frontonasal, and intermaxillary sutures displaced and increased significantly ($p \leq 0.001$) in width after treatment with both protocols, while the zygomaticomaxillary sutures compressed and showed a significant decrease in width with conventional MARPE, though, expanded and increased significantly in width with the ALT-RAMEC group ($p < 0.001$). The dentoskeletal effects revealed that conventional MARPE produced a buccal molar tipping while ALT-RAMEC showed a more bodily movement of the anchor molars. There were no additional effects of ALT-RAMEC on airway volume than MARPE did. Both protocols significantly increased the nasal cavity and oropharynx volumes and significantly decreased the nasopharynx and maxillary sinus volumes ($p < 0.001$) with a non-significant difference between groups ($p > 0.05$). The periodontium conditions were not correlated to the activation protocols in the current study, but the longer treatment time in the ALT-RAMEC group proved to have a more negative impact on the surrounding gingiva than conventional MARPE did. The modified ALT-RAMEC technique is a promising protocol sufficient to expand the maxilla transversely without tipping the anchored teeth in young adult patients.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The most effective treatment for transverse maxillary deficit in growing children and adolescents is rapid maxillary expansion (RME). The two halves of the maxilla cannot be separated with traditional tooth-borne RME appliances due to increased skeletal maturity, significant inter-digitation of the suture, and lateral bone resistance. In light of all the dentoalveolar side effects of tooth-born RME, several authors have looked at the use of orthodontic alternatives as bone anchoring devices to optimize the application of expansion pressures to circum-maxillary sutures and prevent the otherwise necessary surgical osteotomies. This procedure guaranteed basal bone development and averted any potential dentoalveolar problems (Carlson, 2016).

The maxillary skeletal expander (MSE), is a device created by Lee *et al*., (2010), and was utilized to treat a patient with a transverse discrepancy who was 20 years old without orthognathic surgery. Mini-screws are still a relatively new addition to orthodontics as bone anchoring devices. The use of mini-screws in maxillary expansion in adolescents was rationalized, however, by the variable nature of skeletal development and the degree of undesirable dental alterations that accompany the use of traditional appliances.

Clinicians treating adult patients with skeletal class III had to decide between an intrusive surgical approach to resolve the skeletal imbalance or a camouflage therapy to mask the class III malocclusion. However, in younger patients, the circum-maxillary sutures are patent, and when used in conjunction with facemask (FM) treatment, traditional maxillary expansion pressures can accomplish a forward movement of the maxilla. Liou first presented the alternative rapid maxillary expansion and constriction (ALT-RAMEC) procedure in 2005 (Liou and Tsai, 2005). For 7-9 consecutive weeks, with the opening and closure of the RME screw, it permits sutural mobilization and luxation. The reasoning behind it is similar to that of a straightforward tooth extraction, in which the tooth is repeatedly rocked buccally and lingually until it becomes loose or "disarticulates" out of the alveolar socket. (Büyükçavuş, 2019). According to studies, utilizing the Alt-RAMEC procedure before FM treatment might improve the maxilla's forward movement compared to using the traditional techniques. (Liou and Tsai, 2005; Kaya *et al*., 2011). However, the effects of this treatment method in adults remain controversial.

1.2 Conventional Tooth-anchored RME in Adults

Sutures in the craniofacial region, including the mid-palatal suture, gradually become calcified and interdigitate during growth (Garrett *et al*., 2006). The degree of uncontrolled orthodontic movement with conventional RME (tipping of anchor teeth) was inversely correlated with patient age and skeletal maturity (Garib *et al*., 2007). The therapy becomes considerably more challenging for young adults. Although retrospective case studies have shown that tooth-borne expansion is effective in this age range (Hadelman *et al*., 2000; Stuart and Wiltshire, 2003; Brunetto *et al*., 2017). However, no well-planned clinical trials have determined its success rate, claim the authors. As a result, this treatment in adult ages may be categorized as unexpected, dangerous, and having a greater rate of adverse effects, such as a decrease in the height and thickness of the alveolar bone, bone dehiscence, and gingival recession (Brunetto *et al*., 2017). Many RME appliances, including tooth-borne Hyrax, tooth-tissue-borne Haas, or bonded RME appliances, have been used extensively for a long time in adolescents ages with constricted maxillary arches (Asanza *et al*., 1997; Akkaya, 1999; Davidovitch *et al*., 2005; Garib *et al*., 2006; Christie *et al*., 2010).

The traditional RME appliances widen the maxillary arch primarily by separating the mid-palatal suture and the maxillary halves. RME unavoidably produced an orthodontic effect of buccal movement or tilting of the anchored teeth in addition to this desired orthopedic effect (Wertz, 1970). This alveolar bending, tipping, and extrusion of the posterior teeth enhance bite opening and allow the mandible to rotate posteriorly, also increasing the probability of relapse due to the resistance from surrounding structures (Wertz, 1970). In addition to having iatrogenic effects on the periodontal tissues, tooth-borne (banded) expanders, which concentrate pressures at the dentoalveolar region, can occasionally lead to root resorption, buccal dehiscence, and gingival recession at the buccal surfaces of the supporting anchored teeth (Wertz, 1970; Odenrick, 1991).

According to Haas (1965), adding acrylic palatal covering to support the appliance led to more bodily movement and less dental tipping. Studies have shown that although bonded RME appliances and tooth-tissue-borne (Haas) appliances both reduce some of the undesired effects of tooth-borne devices, they nevertheless have limited effects on the maxillary basal bone and have significant dental tipping and high relapse potential (Yilmaz *et al*., 2015). Therefore, for tooth-anchored palatal expansion in adults, several research evaluations have produced varying findings. Some separated them into three categories: tooth bending or tipping, alveolar expansion, and skeletal expansion (Garrett *et al*., 2008; Mosleh *et al*., 2015). Others consider them to range from failure to a 4 mm horizontal gain (Haas, 1970; Wertz, 1970; Capelozza Filho, 1996).

Failure has been attributed to skeletal maturity. The transverse measuring outcomes variations depend on the after-treatment time during the collection of data, and after proper retention periods; when relapse of horizontal measures is recognized, and the maxilla, later on, restores its original position after its rotation downward (Suzuki *et al*., 2016). Despite its failure, researchers still consider RME as a potential alternative to surgical procedures after evaluation of surgical risks, periodontal status, and molar tipping which become regular outcomes after surgical-assisted rapid maxillary expansion (SARME) (Turker *et al*., 2022).

1.3 The Evolution of MARPE Appliances

Despite all of the dentoalveolar adverse effects of RME, authors investigated the use of orthodontic alternatives as bone anchorage devices to optimize the application of expansion forces to circum-maxillary sutures, thereby avoiding the otherwise necessary surgical osteotomies (Carlson *et al*.,2016). This procedure was to ensure the growth of the underlying basal bone and to prevent all of the aforementioned problems. Wehrbein et al., (1996) first introduced the use of mini-screws in palatal areas. While Mommaerts (1999) was the first to employ mini-screws in maxillary expansion, his trans-palatal distractor was regarded as the first bone-borne surgically assisted RME (SARME).

After the mid-palatal suture and the lateral walls of the maxillary sinuses were osteotomized, the newly designed distractor was used to expand the maxilla's two halves. In the past, all traditional SARME devices were tooth-borne. Due to the potential risks associated with dental fixation which includes buccal root resorption, cortical fenestration, skeletal relapse during and after the expansion phase, and anchoring loss, a bone-borne rapid maxillary expander made of titanium with interchangeable expansion modules and a callous distraction policy was proposed (Mommaerts, 1999).

Despite the inter-canine distance significantly increased, the anterior and posterior dental arch widths widened, and although the values were found to be largely constant (Matteini and Mommaerts, 2001; Gerlach and Zahl, 2003), it is still an invasive procedure with significant costs, a risk of infection, and root damage (Yilmaz *et al*., 2015). Recently, an alternate technique for exerting stresses on the maxilla without invasive surgical procedures has been proposed: implant-supported or assisted expansion devices (Tausche *et al*., 2007; Garib, 2008; Lee *et al*., 2010; Lagravére *et al*., 2010). They are known as MSEs or maxillary skeletal expanders. They exert stresses on the micro-screws, either alone (implant-supported expansion) or with bone-teeth anchoring (mini-screw assisted rapid palatal expansion [MARPE] or Hybrid anchorage expansion) (Figure 1.1).

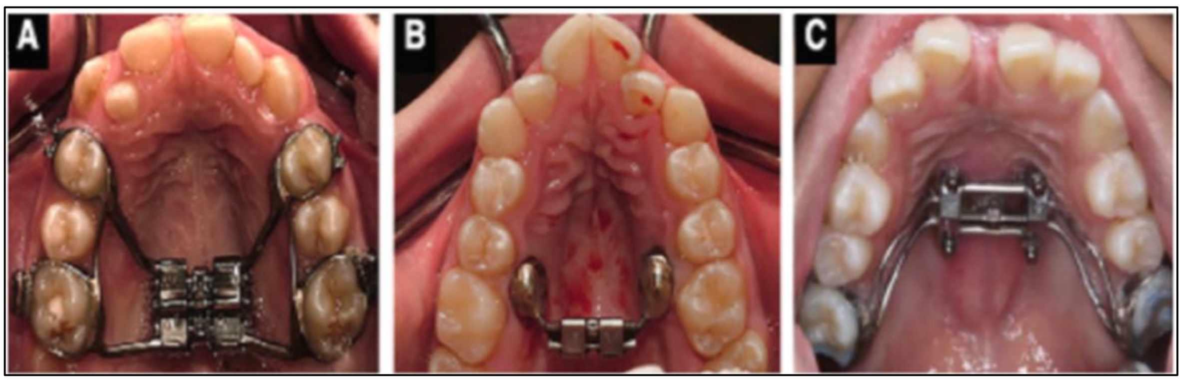

Figure 1.1: Designs of RME (adapted from Oh-Heeso et al., 2019)
A) Conventional RME B) bone-borne MSE C) MARPE

1.4 Stress Distribution with MARPE in Adults

Heavy stress was observed using traditional RME methods within the region of the base of the pterygoid plates of the sphenoid bone in adult individuals where the maxilla is fused to the pterygoid plates (Baldawa and Bhad, 2011), and palatal expansion would be a challenge to obtain. The pterygoid processes are not separate bones like other maxillary bones; rather, they are a component of the sphenoid, which is a single cranial bone. Therefore, even if surgical intervention (Surgically Assisted Rapid Maxillary Expansion) (SARME) is recommended, the fused pterygoid processes tend to bend outward while the osteotomized maxillae and palatine bones would split apart upon application of expansion pressures (Baldawa and Bhad, 2011).

Instead of alveolar remodeling or tipping, maxillary growth in young children and adolescents is accompanied by sutural modifications in distal areas (Baldawa and Bhad, 2011). Because the sutures are no longer patent and the mid-facial skeleton's developed buttresses are now resisting the expansion pressures, these advantageous alterations cannot be achieved following skeletal maturation (Festila *et al*., 2018). Even though adults can achieve expansion with conventional appliances with more anterior expansion than posterior, displacements are more obvious in the structures along the anterior and midline, whereas the posterior and lateral structures exhibit modest displacement but considerable stress especially in the buccal cortical area of anchored teeth (Baldawa and Bhad, 2011).

Hortono *et al*., (2018) when evaluating the stress distribution with MSE which was bone-born, stress was highly concentrated within the mini-screws area, as the mini-screws served as an absolute anchorage on the expansion in their study. Mini screws were used in the transmission of direct expansion force to the maxillary bone, causing skeletal displacement (Mosleh *et al*., 2015). In their investigation, the image of the occlusal aspect revealed a quite parallel inter-maxillary (palatal) suture opening that seemed to open in a straight pattern from anterior to posterior. This was consistent with a study by Lin *et al*., (2015), which found that MSE induced the sutures to open in a more parallel pattern than conventional RME did.

The greatest stress value was also concentrated around the mini-screws in Seong's study (Seong *et al*., 2018) with MARPE, although the stress value was much lower than that with mini-screw-supported expansion (bone-born). The mid-palatal suture had a uniform distribution of stress, which reduced near the anchor teeth's buccal plate. They indicated that the presence of mini-screws may have brought the resulting vector of the expansion force closer to the basal bone's centre of resistance (Koo *et al*., 2017). Consequently, and according to Seong's study (Seong *et al*., 2018), MARPE secured a proper expansion of the anchored teeth to the buccal side with less tipping buccally compared to bone-born expansion.

1.5 Mechanism of MARPE in Adult Ages

The theoretical explanation of MSE in adults is based on previous findings that the true bony displacement of the mid-palatal suture in radiographs does not correlate with chronological age (Persson and Thilander, 1977), and almost identical histological results are shown in patients aged from 10 to 30 years (Knoup *et al*., 2004). In their study (Lin *et al*.,2015), Lin reported that in late adolescents (mean age of 22 years), bone-borne RME provides more skeletal effects and fewer dental side effects than conventional RME. Although significantly smaller than that seen with the bone-borne group, skeletal transverse expansion was nonetheless accomplished with the tooth-borne RME group.

Although ossification seemed complete on radiographs, a histological investigation (Boryor *et al*., 2013) found ossification in only the anterior third of the suture in humans above 70–years old. In their study (Boryor *et al*.,2013), the intermaxillary suture was shown to be opened with a relatively small transverse force. In the 73-year-old woman's specimen, the fused sutures opened with a mild force (80 to 90 N). This force is comparable to that exerted in younger ages with non-fused sutures during RME. In those samples, the posterior areas still included connective tissue. Studies like these supported the theory that the mid-palatal suture may be the sole maxillofacial suture that isn’t found to fully ossify due to the continuing mechanical stresses applied to it (Brunetto *et al*., 2017). This finding was supported by Choi, who conducted a similar study on a young adult age group (Choi *et al*., 2016) and discovered that nine patients out of the 69 participants in the study failed to achieve RME using MARPE. As a result, in 86.9% of the instances, suture split and diastema appeared. Additionally, only three of the 19 patients who had MARPE treatment in Park's study (Park *et al*., 2017) exhibited failure in opening the mid-palatal suture and were excluded, yielding a more than 80% success rate.

Few MARPE cases fail for unknown reasons, but according to Brunetto (Brunetto *et al*., 2017), variations in the calcification patterns of the mid-palatal suture and craniofacial morphology (higher resistance) may be contributing factors. Choi (Choi *et al*., 2016) agreed with Lee's suggestions (Lee *et al*., 2010), that adult expansion failure may be brought on by variances in suture obliteration and resistance from craniofacial tissues. They thus believed that the pterygopalatine junction resistance and the impact of the zygomatic buttress were the reasons behind the failure of their nine cases. Although, in the majority of the cases, skeletal expansion was successfully achieved. However, they believed that the primary factor contributing to the subsequent relapse was craniofacial structural resistance (Choi *et al*., 2016).

In their systematic review, Liu *et al*., (2015) examined articles whose ages ranged from 5 to 20. In two studies (Davidovitch *et al*., 2005; Baydas, 2006), the sample was older than 18 years, but the mid-palate suture was still separated. In a study by Korbmacher *et al*., (2007), human-palate specimens from individuals aged 14 to 71 were divided into three age groups (less than 25, from 25 to 30, and greater than 30 years) using CT. Only the difference in bone density across age groups was found to be significant. The bone density was much lower in the youngest and oldest age groups, with the middle-aged group having the highest bone density. The mid-palatal suture's mean obliteration index and degree of interdigitation did not correlate with chronological age in the results of this investigation. Liu in his study concluded that sutural bone density appeared to be the factor restricting conservative RME (Liu *et al*., 2015).

Despite these results, several studies have recommended the use of CBCT to evaluate each individual’s ossification of the mid-palatal suture before therapy (Angelieri *et al*., 2013; Ladewig *et al*., 2018). Another study's findings revealed that age differs considerably within the phases of development of the mid-palatal suture and was strongly correlated to the opening ratio of the mid-palatal suture (Shin *et al*., 2019). In another trial, the investigators found a significant correlation between age and both unsuccessful expansion and complications (Winsauer *et al*., 2021). This finding was attributed to the mid-palatal and circum-maxillary sutures' increased inter-digitation in late adolescence, which becomes more rigid with advancing age, mostly around 30 (Oliveira and colleagues, 2021).

Despite the difference in opinions about the reasons for the failure of MSE in some literature, the various devices supported by mini-screws still prove to be efficient in the treatment of maxillary deficiency in adult patients (Cardozo, and Carruittero, 2022). Not only the transverse and anteroposterior skeletal deficiency but also some facial deformities might improve with the procedure such as cases with nasal septal deviations (NSD) (Lee *et al*., 2022). The NSD was reduced with varying positive nasofacial alterations after MSE in late adolescent ages. Such a trial proved that MSE can be a promising procedure to improve or camouflage facial deformities as well as treat deficient maxillae in such adult age (Lee *et al*., 2022).

1.6 ALT-RAMEC with Transverse and Anteroposterior Maxillary Deficiency

Class III malocclusion is characterized by complicated dento-alveolar compensations and the imbalance between the development of the maxilla and mandible in the three dimensions (Sanborn, 1955). Maxillary expansion is a beneficial component of the treatment because individuals with a Class III skeletal pattern frequently have a constricted maxilla in the transverse and anteroposterior dimensions. With ALT-

RAMEC protocol, the circum-maxillary sutures may become looser and the maxilla may shift farther forward as a result of growth. Therefore, in such a growing age, maxillary expansion and protraction therapy in early permanent dentition are usually conducted (Zang *et al*., 2015). When Class III malocclusions are interpretatively treated with a tooth-borne appliance, there are frequently problems with uncontrolled dental changes, such as buccal tipping and extrusion of the maxillary molars and decreased arch length due to the maxillary molars' mesial shifting, which causes crowding in the anterior teeth (Zang *et al*., 2015).

Maxillary anteroposterior deficiency till recent times, is still considered a challenging malocclusion in adults, especially when complicated with transverse deficiency, and requires MARPE therapy. As ALT-RAMEC technique was only efficient in the treatment of class III growing ages (Alkawawi, 2021), as far as we know, no previous study combined MARPE with ALT-RAMEC technique to treat the transverse and anteroposterior deficiency in young adult ages.

1.7 Problem Statement

1.7.1 Knowledge Gap in Literature

There are many studies (Hass,1965; Wertz, 1970; Odenrick *et al*., 1991; Akkaya *et al*., 1999; Davidovitch *et al*., 2005; Cantarella *et al*., 2018; Lee *et al*., 2021; Habibnia, 2022) that explored the effects of MARPE on dentoalveolar, skeletal, and airway changes in adult patients, but they all used almost the same rate of expansion to treat only transverse maxillary deficiency. ALT-RAMEC protocol was also widely used with conventional

Hyrax RME (Zang *et al*., 2015; Festila *et al*., 2018**)** and a few case reports and pilot studies introduced it with MARPE to treat class III maxillary deficiency. However, it was all done on growing ages (age $\leq$ 13). To our knowledge, no published clinical trials have combined MARPE with ALT-RAMEC protocol to evaluate its efficiency and advantages over conventional MARPE in young adult ages.

1.7.2 Justification of the study

The available literature lacks solutions for those who seek and pursue alternative treatments to orthognathic surgery. The current study is searching for an alternative treatment to invasive surgical procedures in adult skeletal deficient patients that will provide solutions for the dental community to overcome the high surgical risks, costs, and malpractice lawsuits.

1.7.3 Research questions

1) Would a combination of MARPE / ALT-RAMEC techniques be effective in the treatment of posterior crossbite in young adult patients with transverse maxillary deficiency?

2) Is the MARPE / ALT-RAMEC technique able to produce sufficient sutural displacement which facilitates further maxillary protraction?

3) How much the differences in the dentoskeletal, and respiratory effects between using MARPE with its conventional use, and MARPE combined with the ALT-RAMEC technique?

1.8 Objectives

1.8.1 General Objective

To investigate if a MARPE and ALT-RAMEC method combination may successfully expand the maxilla in young adult patients with transverse maxillary insufficiency.

1.8.2 Specific Objectives

1.8.2 (a) Primary objectives:

1- To compare the percentage of successful cases in patients receiving MARPE/ALT-RAMEC treatment to those receiving MARPE (Conventional) treatment.

2- To compare the circum-maxillary sutural displacement in patients who are treated with the MARPE/ ALT-RAMEC technique and MARPE**.**

A successful outcome of the treatment is defined as:

a) Achieving skeletal expansion to relieve the posterior crossbite, which will be visible clinically by mid-palatal suture splitting (central diastema) and subsequent molar overcorrection, when the palatal cusp of either maxillary first molar comes into contact with the corresponding buccal cusp tips of the mandibular first molar (Choi *et al*., 2016) with or without;

b) Producing more circum-maxillary sutural displacement when comparing MARPE with ALT-RAMEC than MARPE with its traditional usage, as determined from CBCT images.

1.8.2 (b) Secondary objectives:

1- To evaluate the dentoskeletal changes (the amount of dental tipping) that occurred after applying the two different expansion techniques.

2- To evaluate the respiratory changes resulting from the application of the two techniques.

3- To compare clinically, the changes that occur in the periodontium (Periodontal probing depths) between pre-treatment and post-expansion periods.

1.9 Hypothesis and Novelty of the Study

Transverse skeletal expansion was achieved using the MARPE approach without unfavourable dentoalveolar compensations or negative effects. Additionally, the nasal cavity and zygomatic bone widened as a result of it. According to previously published studies, ALT-RAMEC is superior to conventional RME at causing sutural displacement and subluxation to enable maxillary protraction in growing individuals with transverse and anteroposterior maxillary deficiency. The current study hypothesizes that combining MARPE with the ALT-RAMEC technique will result in transverse skeletal expansion as well as sutural subluxation and displacement in young adults ages, which may be a sign of hope in the treatment of transverse deficient maxilla with anteroposterior deficiency in young adults without resorting to surgery. It also hypothesizes that MARPE/ALT-RAMEC will result in decreased dental tipping, increased sutural widening and increased airway volume than the use of MARPE with its conventional expansion rate.

The ALT-RAMEC protocol is modified in the current study to benefit from its principle as a force that provides sutural subluxation as well as widening the palate in skeletal transverse deficiency cases.

1.10 Conceptual Framework

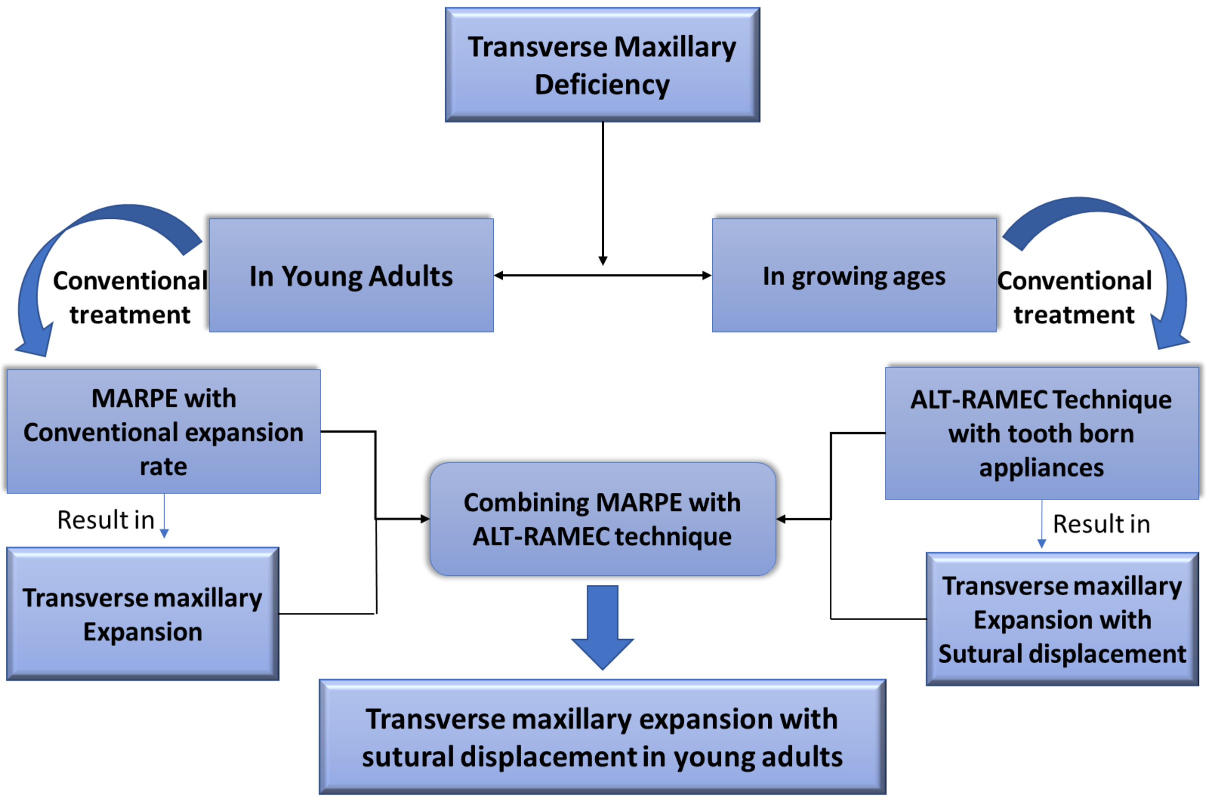

Figure 1.2: Conceptual framework

CHAPTER 2

LITERATURE REVIEW

2.1 Skeletal Malocclusion

All ethnic communities have highly frequent birth abnormalities involving the head and face, which can manifest either singly or as a part of a syndrome. Depending on factors including genetic heritage, geographic location, socioeconomic status, and environmental factors, different ethnic groups have different rates of craniofacial anomalies. Due to the anatomical complexity of the craniofacial area, variations in genetic and environmental factors may have a substantial influence on development and may induce congenital birth defects. Cleft lip and palate, one of the most common birth defects, affects 1 in 500 live births in the Asian population. (De Lima *et al*., 2009).

Another common birth abnormality is skeletal malocclusion, which results from the mandibular and/or maxillary development being distorted. Primary and permanent teeth's position, alignment, and health are all severely impacted by skeletal malocclusion. Micrognathia, which is characterized by a small mandible or maxilla, is the most common cause of skeletal malocclusion, occurring in 1/1,500 live births (Vettraino *et al*., 2003). Other skeletal anomalies, cleft palates, and tongue deformities (glossoptosis) are frequently seen alongside it. According to the Online Mendelian Inheritance in Man (OMIM) database, micrognathia can be present alone or as a component of 468 syndromic illnesses. According to reports, all individuals with micrognathia also have retrognathia, which is an aberrant posterior location of the mandible or maxilla concerning the facial anatomy due to abnormal growth patterns (Proffit *et al*., 2006).

Clefting of the soft palate was the most frequent defect (73% of micrognathia cases), reported by more than 90% of fetuses with isolated micrognathia by 3D ultrasonography (Vettraino *et al*., 2003). This is because the mandible is too small, which prevents the secondary palatal shelves from developing properly since the tongue sticks to the roof of the mouth. In these cases, the typical U or V-shaped clefting of the soft and hard palates indicates a full obstruction of secondary palatal development. According to other research, isolated micrognathia is a sign of serious disorders among individuals (Paladini, 2010). Approximately one-third of infants with micrognathia are also diagnosed with moderate to severe developmental delay (Vettraino *et al*., 2003).

The lack of defined etiological variables prevents genetic test arrangement of several hereditary disorders characterized by micrognathia, including the Pierre Robin sequence, isolated micrognathia, agnathia-autocephaly complex, Catel-Manzke syndrome, and cerebrocostomandibular syndrome. Skeletal malocclusion's genetic and environmental origins are still unidentified. According to Angle's classification, skeletal malocclusions fall into classes II and III according to how close the upper and lower first molars are to each other. As opposed to class III malocclusion, which places the upper first molar's mesiobuccal cusp distally (posteriorly) to the lower first molar's buccal groove (Ghiz *et al*., 2005; Bollhalder *et al*., 2013), class II malocclusion places the upper first molar's mesiobuccal cusp mesially (anterior) to the lower first molar's buccal groove.

The construction of geometric cranial planes and the measurement of various jaw lengths and angles are both possible using a cephalometric radiograph of the face (The most popular technique for determining the anterior/posterior connection of the maxilla and mandible is to relate their positions to the anterior cranial base. The location of the anterior cranial base can be seen by the line connecting the midpoint of the sella turcica (S) and the junction of the frontal and nasal bones (N). The maxillary concavity with the greatest depth (point A) is represented by the SNA angle. The mandible is represented similarly by the S-N-B angle. The "normal" values for SNA, SNB, and other cephalometric variables have been the topic of several research. Unexpectedly, the SNA and SNB norms across all of these studies throughout the years are widely known and remarkably consistent (Oberoi *et al*., 2005; Buschang *et al*., 2013).

Additionally, orthodontists and oral and maxillofacial surgeons routinely utilize them, thus there is no need for specialized radiographic examinations to collect this information. Instead, it may be found in regular orthodontic and surgical records. So, as a measure of retrognathism and prognathism (an aberrant posterior or anterior location of the mandible or maxilla), the use of SNA and SNB was suggested. There are certain limitations to this approach, too, and these must be addressed. Since A and B points are not on the basal bone, tooth movement affects them. In cross-sectional, pre-treatment studies, this shouldn't be an issue. Another limitation is that SNA and SNB do not take the growth direction into account. Mandibular growth can rotate either clockwise or anti-clockwise, which is not an issue in the maxilla because it tends to grow downward and forward from the cranial base. The mandible grows backwards and downwards as a result of the clockwise rotation, which worsens retrognathia in terms of overall facial appearance. Contrarily, anti-clockwise rotation has the reverse effect (downward and forward), which worsens prognathia while improving retrognathia. It is significant to note that age, gender, and ethnic groupings all have different geometric values for normal occlusion (Hamdan, 2001). At younger ages, there is no apparent variation in the mandibular and maxillary lengths in males and females (Ghiz *et al*., 2005). However, as individuals age, the discrepancies become more obvious at the age of 12 years or older.

Because jaw phenotypes are heritable, it was advisable to involve the parents in the craniofacial examination and analysis to reduce the degree of error in the treatment of skeletal malocclusion. To identify genetic risk factors for skeletal malocclusion, there is a critical need for greater study in this area. The accuracy of prognosis for treatments will be improved by more studies in this area. As previously noted, oral and facial tissues have been affected by skeletal malocclusion. A few studies have shown that skeletal malocclusion can have an impact on a patient's overall health by contributing to airway obstructions, sleep apnea, digestive disorders, immunological deficiencies, and impaired developmental growth (Paladini, 2010; Bollhalder *et al*., 2013; Masood *et al*., 2013).

Skeletal malocclusion has been linked to negative effects on intellectual health, social abilities, and economic and psychological status, in addition to these physiological issues (Martins-Junior *et al*., 2012; Masood *et al*., 2013). Particularly in younger and more educated individuals, psychological discomfort is more frequently linked to malocclusion (Masood *et al*., 2013). The degree of skeletal malocclusion is inversely related to social and emotional functioning, as well as speech and mastication efficiency, in terms of quality of life (Masood *et al*., 2013). When compared to instances with normal occlusion, skeletal malocclusion patients had a considerably higher prevalence of bruxism, dental trauma, and dental caries (Bendgude *et al*., 2012; Ghafournia, and Hajenourozali, 2012; Baskaradoss *et al*., 2013) The relationship between skeletal malocclusion and late-onset diseases is still unclear.

2.1.1 The Genetic Etiology of Skeletal Malocclusion

Malocclusion is a kind of developmental malformation that can range in severity from mild to severe skeletal or dental abnormalities, including systemic syndromic defects. It could only affect the maxillofacial bones or the whole craniomaxillofacial area. It is crucial to examine how these skeletal malocclusions develop and are categorized since this study is focused on treating the skeletal relation of the craniomaxillofacial skeleton to attain normalcy of health, function, and facial aesthetics. Skeletal malocclusion refers to human craniofacial morphologic traits that show either an excess or a deficiency of volume and proportion. Problems with the temporomandibular joints and dental occlusion result in an irregular connection between the jaws, which disturbs the balance of the face. The conceptual focus of several investigations was on the overall effects of aberrant growth and development of the various skeletal components of the craniofacial anatomy as they relate to function and physical appearance. (Greenberg and Schmelzeisen, 2019).

Problems associated with growth and development, however, may be defined in terms of the interactions between human genetics and the reaction of the genome to environmental conditions that affect its phenotypic manifestation. Skeletal malocclusions are caused by genetic and functional causes, which also explain the problems with vertical, sagittal, and transverse interrelationships. The blueprint for the molecular components that make up cells as well as the collective development of cells as tissues with specific roles are both specified by the human genome. Human craniofacial development is based on genetic expression, which also serves as the mechanism through which this process may go wrong (Enlow and Hans, 1996). Neural crest cells are crucial to the formation of the craniofacial structure. The neurovascular bundles and the head mesenchyme, from which the craniofacial skeleton will develop, move into the mesodermal cell layer. Fundamentally, the amount and quality of vascular network distribution and neural crest cell migration during development may have a direct favourable or unfavourable influence on the facial skeleton (Moss, 1971; Monroy and Moscona, 1979). Genetic factors indicate tissue differentiation at this early period of human growth and development. The development of the skeleton is most directly influenced by these genetic variables. The genetic characteristics of the main functional cranial components interact physiologically with the functional environment to create developmental alterations and balance of the skeletal units, which is related to the differentiation of tissues into functional units (Moss, 1950). The skeletal malocclusions seen in clinical practice can be better understood as a consequence of this kind of genetic and environmental study. Patients might gain a more comprehensive picture of their condition from their doctors. This offers several advantages throughout the phases of diagnosis, planning, treatment, and recovery. Considering the etiologic factors of the problem may help a patient and/or parent have a more accurate picture of the condition and, hopefully, more reasonable expectations when evaluating therapy outcomes.

2.1.2 Classification of Skeletal Malocclusion

According to Angle's classification, all malocclusions may be broadly divided into Classes I, II, or III. However, the three dimensions of craniofacial anatomy defined as the vertical, sagittal, and transverse planes of space, must be taken into account when skeletal malocclusion is discussed. These characteristics form the basis for the evaluation of skeletal malocclusions and help dental practitioners realize that these three dimensions are interconnected from a genetic and functional standpoint. A clinical anomaly will come from an isolated distortion in one of these dimensions, which will affect the other dimensions (Arnett and Bergman, 1993).

2.1.2(a) Sagittal Skeletal Discrepancies

A skeletal open bite or a skeletal deep bite, with retrognathic or prognathic jaw connections, will be associated with sagittal problems. Asymmetry, an open bite, a deep bite, retrognathia, or prognathism can all be symptoms of transverse skeletal problems. Skeletal anatomy's proportions are closely connected as well. A transverse problem may be implied by a significant mandibular retrognathia due to the interactions between the skeletal measurements. The larger aspect of the maxillary arch may occlude with the mandibular arch's narrower portion (Figure 2.1). The broader portion of the mandibular