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Morphological Analysis of Stages of Midpalatal Suture Maturation in Adolescents and Young Adults using Cone Beam Computed Tomography in Saudi Population

Análisis Morfológico de las Etapas de Maduración de la Sutura Palatina Mediana en Adolescentes y Adultos Jóvenes Mediante Tomografía Computarizada de Haz Cónico en una Población Saudí

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SUMMARY: The midpalatine suture is an active site for growth of maxillary bone. Developmental abnormalities of the suture can result in various malformations and malocclusions. The morphological stages of maturation can act as a predictor for maxillary bone expansion especially, after childhood. Hence the aim of the present study was to evaluate the stages of midpalatal suture maturation among adolescents and young adults using cone beam computed tomography (CBCT). A retrospective CBCT analysis was carried out in a Saudi population. 163 cases were evaluated and staged according to a standard classification using CBCT. The results of our study showed a sex showed statistically significant differences in the stages of maturation. The suture was found show evidences of initiation of ossification above 17 years of age. The possibilities to find an open non ossified suture was 11.65 % in 10-13 years, 30.06 % in 14-17 years, 15.33 % in 18-21 years and 6.74 % in 22-25 years. The findings of this study reinforce the usefulness of CBCT to evaluate the stages of midpalatal suture maturation in aiding the decision for the treatment of maxillary bone developmental abnormalities that requires maxillary bone expansion procedures.

KEY WORDS: Midpalatal suture; Hard palate; Palatine bone; Cone beam computed tomography; Cone beam CT; Cranial suture.

INTRODUCTION

The mid palatine suture is a fibrous joint that divides the hard palate into left and right halves. The intervening fibrous tissue in between the suture differentiates from the embryonic mesenchyme. In addition to providing articulation between the bones, they have an important role in mediating the growth of the face due to its osteogenic potential. The osteoprogenitor cells lining these sutures proliferate, differentiates and functions at the osteogenic front or bone margins, thus acting as an epicenter of growth and expansion for maxillary bones (Rice, 2008). Disturbances in the normal growth of maxilla at these suture sites can lead to transverse maxillary constriction leading to crowding of dentition; malocclusion, such as dental or skeletal posterior cross bites; narrowing of pharyngeal airway contributing to obstructive sleep apnea; variation in the posture of the tongue, mouth breathing and esthetics (Jang *et al*., 2016). To resolve the aforementioned problems, dental specialists in orthodontics employ different orthodontic and fixed appliances to achieve palatal expansion (Barbosa *et al*., 2023). Among these techniques, rapid maxillary expansion (RME) is considered to be the gold standard which targets the growth potential of

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midpalatine suture (Willershausen *et al*., 2019). In cases of transverse growth deficiency along with obstructive sleep apnea, apart from RME various medical specialties are involved in the management including oro-surgical procedures such as maxillomandibular expansion, uvulopharyngeplasty etc. are performed by oral and maxillofacial surgeons (Holty & Guilleminault, 2012). Hence the midpalatine suture targeted expansion is critical and the amount of expansion achieved may also depend on the stages of maturation of mid palatine suture. The expansion is recommended to be attained before puberty (Thadani *et al*., 2010) or before the fusion of the mid palatine suture takes place (Jimenez-Valdivia *et al*., 2019).

Various methods of assessments can be utilized for mid palatine suture evaluation. 2-dimensional and 3-dimensional imaging including the use of cone beam computed tomography (CBCT) images can contribute to the diagnostic evaluation of mid palatine sutures. (Jimenez-Valdivia *et al*., 2019). A clear understanding of the variance in the fusion of the midpalatine suture is necessary to categorize patients that can avail RME or other surgical assisted expansion (Angelieri *et al*., 2013). Multiple studies have been performed in the assessment of midpalatine suture using CBCT among different populations (Angelieri *et al*., 2013; Jang *et al*., 2016; Haghanifar *et al*., 2017; Jimenez-Valdivia *et al*., 2019; Katti *et al*., 2022). Although the staging of midpalatine suture has advantages, it needs further research, especially across different populations to determine its validity. Since there are no previous studies reported to evaluate the maturation patterns of midpalatine suture using CBCT in Saudi Arabia, the rationale of this study is to provide information of the midpalatine suture by staging the maturation of these sutures among Saudi population which can aid the dental specialists in determining the management plan for the treatment of transverse maxillary constriction and associated skeletal, soft tissue and dental changes with or without RME. The aim of the study was to assess the stages of maturation of midpalatal suture in adolescents and young adults using cone beam computed tomography in a Saudi Population.

MATERIAL AND METHOD

The study was conducted after the ethical committee approval from the private dental university in Riyadh (ARP/2023/17/972/886). Retrospective observation study design was followed with stratified random sampling method. The CBCT images was obtained from the Radiology Clinic database from the private dental university hospital clinics. Retrospective CBCT data of patients captured using Sirona Galileos (Germany) at 85 kV, 57 mA, and 14s with a voxel size of 0.29mm was retrieved from January 2018–January 2022. The analysis of the CBCT images was done using the digital imaging analysis software, Galileos viewer (Sidexis XG), version 1.6.

The investigators used panoramic reconstruction views from the CBCT data for initial screening to select the samples based on eligibility criteria. The included sample CBCT images was viewed using multiplanar reformatted windows using axial, coronal and sagittal planes for detailed analysis. The analysis was done after the horizontal reference line in the sagittal view of CBCT imaging data coincides with the median region of the thickness of palate antero-posteriorly. If the CBCT image data shows a curved palate in sagittal section, for a meticulous evaluation, two axial slices were used, the axial reference line was well-adjusted to the palatal plane for precise assessment. Finally, the skeletal maturation stage of the mid-palatal suture was visualized and classified using axial sections.

The eligibility criteria of the samples included Saudi population in the age group of 10 to 25 years old of both sexs. High resolution CBCT scans with clear visualization of the midpalatal suture were included. However, samples with previous trauma or surgery in the maxilla and palate, previous orthodontic treatment or use pf appliance, history of systemic disease affecting the bone (thyroid disease, hyperparathyroidism, diabetes mellitus, chronic renal disease and osteoporosis), history of cleft lip/palate or fistula, developmental or anomalies affecting the maxilla, impacted supernumerary teeth in anterior maxilla were excluded. The sample was later segregated into intervals in 4 groups, viz, early adolescence (10-13 years); mid adolescence (14-17 years), late adolescence (18-21 years) and young adulthood (22-25 years), followed by random sampling from these groups thereby using stratified simple random sampling method.

The sample size was ascertained using the formula to calculate one proportion (with a prospect in finding an open mid palatal suture in individuals in their late adolescence or young adulthood in more than 18 years of age) with a confidence level of 95 %, precision level of 5 % and 10 % proportion of this possibility to occur. The minimum required sample required will be 163 CBCTs (Jimenez-Valdivia *et al*., 2019).

Criteria for Staging the Maturation of Midpalatine Suture. The maturation of mid-palatal suture was determined by using the classification system detailed below proposed by Angelieri *et al*. (2013).

- Stage A. Straight, high density mid palatine sutural line, with no or little interdigitation.

-Stage B. Scalloped appearance of the high-density mid palatine sutural line.
- Stage C. Two parallel, scalloped, high density mid palatine sutural lines that is close to each other, separated into a few areas by small low-density spaces.
-Stage D. Fusion completed in the palatal bone, with no evidence of a suture ossification in the anterior maxilla
- Stage E. Fusion completed also anteriorly in the maxilla.

In this study we found alternate representations within the same stage in Stage B and Stage C (Fig. 1).

- Stage B. Pattern A was designated when the suture was straight high- density line in the maxillary region (similar to Stage A) whereas the palatal bone region resembled scalloped like stage B.
-Stage B. Pattern B was same as Angeleri *et al*., 2013 classification- Stage B.
-Stage C. Pattern A was designated when the maxillary part resembled Stage B and the palatal region was similar to stage C.
-Stage C. Pattern B was same as Angeleri *et al* 2013 classification- Stage C.

Statistical Analysis. The data was first entered into a Google sheet then subjected to statistical analysis by using the Statistical Package for the Social Sciences (SPSS), version 28.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics including the mean values and respective standard deviations (SDs) was calculated for all measurements. The chi-square test was used to determine any significant differences between suture maturation and the age and sex of the patient and the possibility to find open midpalatal sutures in different age groups. A binary logistic regression model was performed using the stage of maturation of the midpalatine suture as an outcome variable. The predictor variables were age (in years) and sex. The impact of each factor on the outcome variable was expressed as an Odds Ratio with its 95 % confidence interval (95 % CI). The statistical significance was be set at $p < 0.05$.

Bias Assessment. To avoid investigator bias, Inter-examiner reliability was carried out after an experienced Oral and Maxillofacial radiologist calibrates the investigators using 20 randomly selected CBCT images. Intra-examiner reliability was conducted after the CBCT images are analyzed at two times, with an interval of two weeks. Inter-examiner reliability was tested using a concordance analysis with weighted kappa coefficients [.80–.90 with strong level of agreement] (McHugh, 2012).

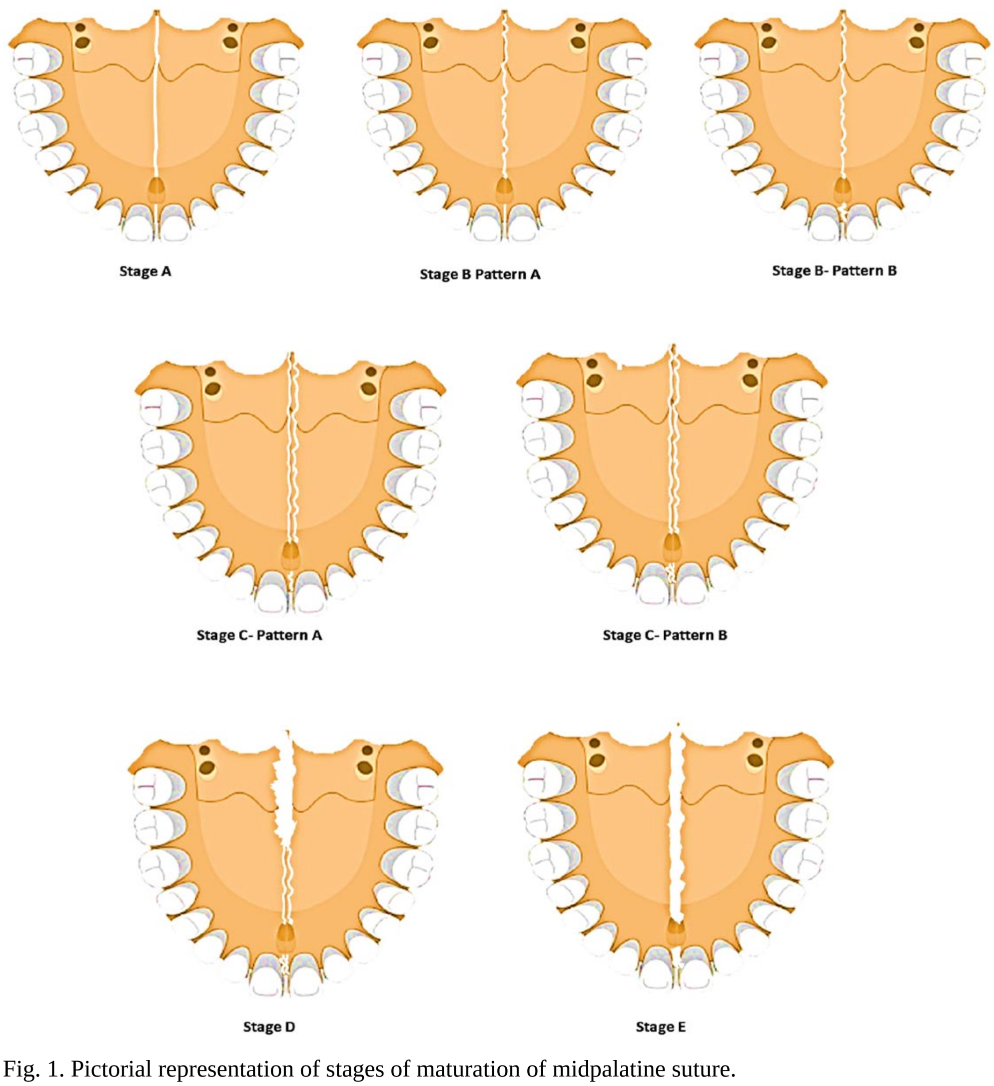

Fig. 1. Pictorial representation of stages of maturation of midpalatine suture.

RESULTS

In this study apart from the stages A,B,C,D,E referred by Angeleri *et al*., (2013), Stage B and Stage C had variations and the authors subclassified them as Stage B, Pattern A and Stage B pattern B- as well as Stage C Pattern A Stage C Pattern B (Fig. 2).

The study evaluated CBCT scans from 19 early adolescent, 49 mid adolescent, 39 late adolescent and 56 young adults with a cumulative sample of 163 as seen in Table I. In this study, the male sex was 45.39 % and the female sex was 54.61 % out of 163 samples. Young adults comprised 34.36 %, mid adolescence age group were 30 %, late adolescence was 23.93 % and early adolescence was 11.65 % in the sample.

The stages of the midpalatal suture maturation were assessed using the CBCT scans as detailed in Table II. Wide range of variability was confirmed in the distribution of the midpalatal suture maturation stages regarding the stages of adolescence. Stage A and Stage B Pattern A were only noted in early adolescence, except for one male in late adolescence, which Stage B Pattern A was verified. Stage B Pattern B was present mainly during mild adolescence (16 out of 22 samples) and 4 of 22 samples in early adolescence.

However, two females with Stage B Pattern B were one in the late adolescence group and another in the young adult group. Stage C Pattern A was observed mainly in mild adolescence, with 8 of 36 samples in early adolescence, and 6 out 36 samples in late adolescence. None was seen in young adults age group for Stage C Pattern A. Stage C Pattern B was seen variably between mid-adolescence, which included 11 out of 38 samples. 17 (out of 38) samples were in late adolescence and 10 samples out of 38 were young adults. Stage D was seen in late adolescence, 12 of 31 samples and in young adults, 19 of 31 samples. Stage E was mainly observed in young adults with 26 samples out of 28 and only 2 samples (out of 28) in late adolescence.

Table I. Total number of the selected samples.

Sex	Early Adolescence N (%)	Mid Adolescence N (%)	Late Adolescence N (%)	Young Adults N (%)	Total N (%)
Males	8(4.9 %)	24(14.72 %)	22(13.5 %)	20(12.27 %)	74 (45.39 %)
Female	11(6.75 %)	25(15.34 %)	17(10.43 %)	36(22.09 %)	89 (54.61 %)
Total	19(11.65 %)	49(30.06 %)	39(23.93 %)	56(34.36 %)	163(100 %)

n (%)=number (percentage)

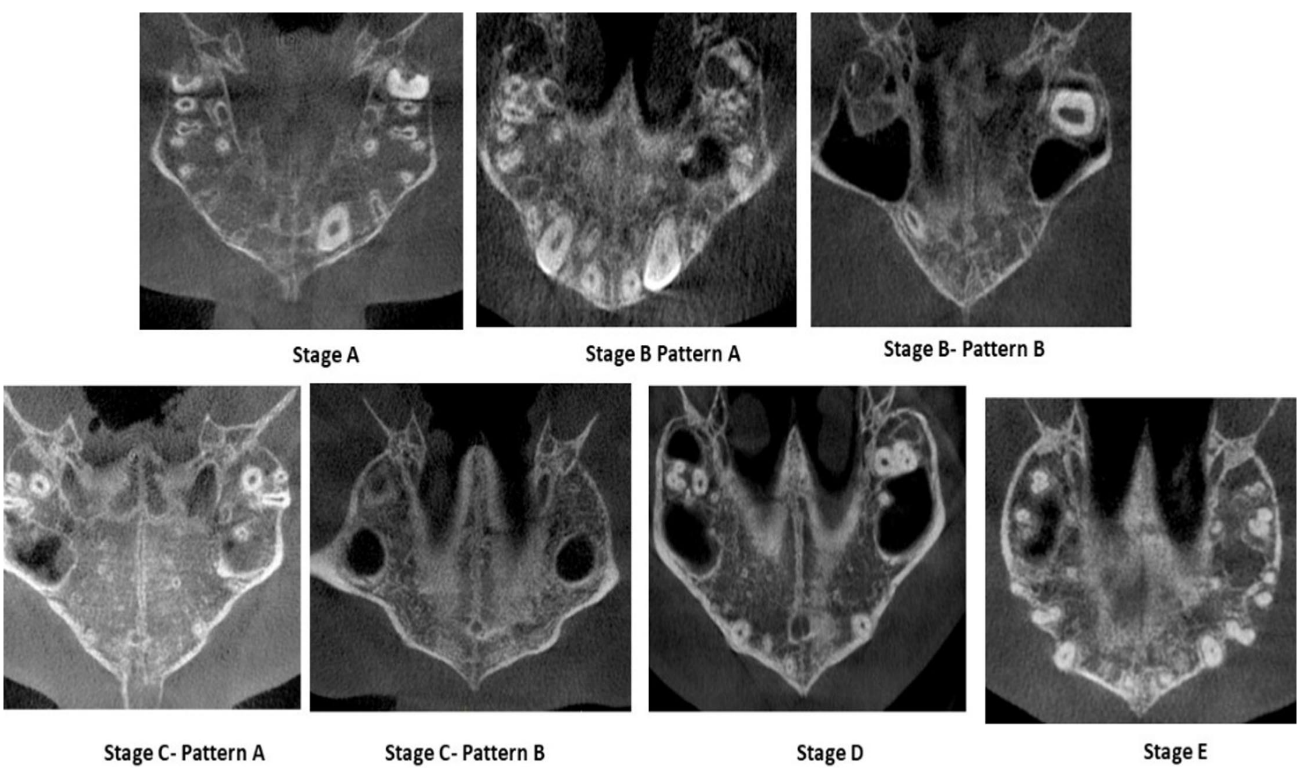

Fig. 2. Various stages of midpalatine suture maturation assessed using cone beam computed tomographic scans.

Table II. Demographics of the sample for sex and age.

Stages	Early Adolescence		Mid Adolescence		Late Adolescence		Young Adults		Total
	Male	Female	Male	Female	Male	Female	Male	Female	
Stage A	1	2	0	0	0	0	0	0	3
Stage B – Pattern A	3	1	0	0	1	0	0	0	5
Stage B – Pattern B	3	1	6	10	0	1	0	1	22
Stage C – Pattern A	1	7	12	10	5	1	0	0	36
Stage C – Pattern B	0	0	6	5	9	8	8	2	38
Stage D	0	0	0	0	7	5	5	14	31
Stage E	0	0	0	0	0	2	7	19	28
Total	8 (4.9 %)	11 (6.75 %)	24 (14.72 %)	25 (15.34 %)	22 (13.5 %)	17 (10.43 %)	20 (12.27 %)	36 (22.09 %)	163 (100 %)

The most prevalent stage found in the study sample was stage C Pattern B (23 %), followed by Stage C Pattern A (22 %), Stage D (19 %), Stage E (17 %), Stage B Pattern A (3 %) and the least prevalent was Stage A (2 %). The distribution of various stages of maturation of the mid palatine suture among age and sex were done.

The possibilities of open sutures (not ossified) as evident from Stages A to E was 11.65 % in early adolescence (10-13 years), 30.06 % in mid adolescence (14-17 years), 15.33 % in late adolescence (18-21 years) and 6.74 % in young adulthood (22-25 years (Table II). The suture showed initiation of ossification above 17 years of age.

The study found the stages of maturation of midpalatine suture in young adults among male and female were statistically significant (p= 0.013). The other age groups across sexs and maturation stages did not show any significant associations (Table III).

Table III. Distribution of maturation stages among the age groups and sex.

Age group		Stage A N (%)	Stage B – Pattern A N (%)	Stage B – Pattern B N (%)	Stage C – Pattern A N (%)	Stage C – Pattern B N (%)	Stage D N (%)	Stage E N (%)	P Value
Early Adolescence	M	1 (13 %)	3 (38 %)	3 (38 %)	1 (13 %)	0	0	0	0.089
	F	2 (18 %)	1 (9 %)	1 (9 %)	7 (64 %)	0	0	0	
	M+F	3 (16 %)	4 (21 %)	4 (21 %)	8 (42 %)	0	0	0	
Mid Adolescence	M	0	0	6 (25 %)	12 (50 %)	6 (25 %)	0	0	0.535
	F	0	0	10 (40 %)	10 (40 %)	5 (20 %)	0	0	
	M+F	0	0	16 (33 %)	22 (45 %)	11 (22 %)	0	0	
Late Adolescence	M	0	1 (5 %)	0	5 (23 %)	9 (41 %)	7 (32 %)	0	0.258
	F	0	0	1 (6 %)	1 (6 %)	8 (47 %)	5 (29 %)	2 (12 %)	
	M+F	0	1 (3 %)	1 (3 %)	6 (15 %)	17 (44 %)	12 (31 %)	2 (5 %)	
Young Adults	M	0	0	0	0	8 (40 %)	5 (25 %)	7 (35 %)	0.013
	F	0	0	1 (3 %)	0	2 (6 %)	14 (39 %)	19 (53 %)	
	M+F	0	0	1 (2 %)	0	10 (18 %)	19 (34 %)	26 (46 %)	

DISCUSSION

Embryology of formation of the palate and midpalatal suture.

The palate develops during the 9th to 12th week of intrauterine life from the frontonasal process (median nasal process and lateral nasal process) and the maxillary process. The roof of the oral cavity is formed of palate and it separates the oral cavity from the nasal cavity. The palate incorporates primary palate and secondary palate. The primary palate is formed from the median nasal process during embryonic development around 8th week of intrauterine life and seen in the region between the incisive foramen and anterior maxillary alveolar ridge, forming a triangular shaped region known as pre-maxilla (Greene & Pratt, 1976; Gilbert, 2000; Proffit *et al*., 2018). The premaxillary ossification centers appears in the premaxilla. Following this, the interpremaxillary part of the midpalatine suture forms around 45 to 47 days of intraembryonic life. During this time, secondary palate is rudimentary (Latham, 1971).

Secondary palate includes the region behind the primary palate and extends to include hard and soft palate. The formation of secondary palate occurs when the cranial neural crest cells from the forebrain and hindbrain initiates the development of the palate mesenchyme and occurs during 9th to 12th week of intrauterine life. The palatal shelves originate as small extensions at the medial aspect of the maxillary process. Subsequently they grow downwards on either side the tongue around the seventh week of gestation. They further grow by rotating the shelves from a vertical to a horizontal position but following a different pattern in different region of the anteroposterior length of the palatal shelves. The anterior part of the palatal shelve is elevated via rotation of the left and right sides, while the posterior part elevation occurs by the remodeling and apparent shift of the palatine mesenchyme of the vertical shelves, resultant of which is a medially directed elevation (Greene & Pratt, 1976; Gilbert, 2000; Proffit *et al*., 2018).

The first indication of midpalatine suture formation at the region of secondary palate occurs around 10.5 weeks of embryonic life. The intermaxillary suture is the first of all the cranial sutures to develop. The cell remnants of epithelium at the oral aspect of the sutural sites impacted the development of the suture by delaying the process (Latham, 1971).

By the week 12 of intrauterine life, the primary palate (premaxilla) and the secondary palate fuses in the anterior aspect and nasal septum in the antero-dorsal aspect to form a complete palate. The fusion of the premaxilla and the secondary palate occurs in the shape of Y in horizontal view, from cephalic to caudal direction to form the definite palate. Meanwhile the mesoderm of the definite palate undergoes intramembranous ossification from the anterior to the posterior aspect except the future soft palate and uvula region. The palatine part of the midpalatine suture forms at the line of fusion between the palatal shelves at 12 weeks of intrauterine life. It extended from the incisive foramen to the transverse palatomaxillary suture in the posterior maxilla. The intermaxillary suture at this period, will be narrower than the interpremaxillary suture and about half of the width of the latter. It remains wide and unossified at birth and continues to remodel until the suture in completely ossified which occurs in late adulthood (Latham, 1971; Greene & Pratt, 1976; Gilbert, 2000; Proffit *et al*., 2018).

Stages of midpalatine suture maturation

1. Stage of initial fusion. It is noteworthy that during the stages of fusion of the palatal shelves, epithelial adhesion and epithelial autolysis play a major role. The palatal epithelium was found to be 2-3 layers thick with a squamous epithelium on the surface and cuboidal epithelium beneath it, before and during epithelial adhesion and midline epithelial seam formation. The basal lamina of the EM edges remains undisrupted separating both the epithelial and mesenchymal cells. The squamous surface epithelium has cytoplastic extensions that flattened and disappeared on contact with the opposite shelves. Once the contact is achieved, a tight adhesion developed with the presence of a carbohydrate rich coating on the developing epithelium of these shelves, separated by 10-20 nanometer filled with glycoproteins. This adhesion continues until a permanent desmosomal adhesion would be achieved. Thus, an epithelial seam is formed in the midpalatal region of impending secondary palate, which soon transformed from a seam of four to five layer to a strip of cells 1-2 layer in thickness (Greene & Pratt, 1976; Ten Cate & Takei, 2019; Du *et al*., 2021).

2. Stage of epithelial breakdown. Once midline adhesion of the epithelium takes place, autolysis is initiated along the medial edges of the epithelial layer, rendering epithelium derived from both sides of the palatal shelves indistinguishable. The midline seam expands into the nasal direction as well as to the oral direction from the shelves into a triangular area, which subsequently undergoes autolytic breakdown (Greene & Pratt, 1976; Ten Cate & Takei, 2019).

3. Stage of connective tissue growth. The midline seam eventually disintegrates and the mesenchyme of the palatal shelves merge into one structure. The epithelial cells were found at this time to be irregular in outline and separated by large extracellular spaces still connected by desmosomes, which allowed intermixing of the undifferentiated mesenchymal cells from both sides of the palatal shelves (Greene & Pratt, 1976; Ten Cate & Takei, 2019).

4. Stage of initial ossification. At this site of midpalatal region where the palatal shelves approximate, osteogenic progenitors at the osteogenic region of the palatal shelves, and the mesenchymal cells contributes to the development of midpalatine suture (MPS) (Greene & Pratt, 1976; Ten Cate & Takei, 2019; Du *et al*., 2021). The medial edges of the bone display more bone deposition and it continued as sutural growth in accordance with the facial growth

5. Stage of sutural growth and remodeling. The midpalatine suture remains as a fibrous joint between the palatal shelves, being unfused during the embryonic and postnatal development of the cranium. Sutural bone deposition continues and the palatal remodeling takes place. The suture also serves as an active site for new bone formation during cranial expansion. (Latham, 1971; Greene & Pratt, 1976; Proffit & Fields, 2013; Ten Cate & Takei, 2019).

6. Stage of continued remodeling and ossification. The osteoprogenitor cells at the osteogenic front of the opposing palatal shelves generates new bone formation and apposition. The suture mesenchyme retains undifferentiated mesenchymal stem cells that are responsible for the growth, turnover and injury repair at these sites. Several signaling pathways contribute to the regulation of this process (Greene & Pratt, 1976; Proffit & Fields, 2013; Ten Cate & Takei, 2019). During this stage the sutural growth slows down and subsequently stops. Number of osteoblasts are reduced and is sparse. Due to the active remodeling, there is an increase in height of the suture noticed at this stage.(Latham, 1971).

7. Stage of fusion. Further development of the palate involves remodeling along with coordinated tissue movements that results in linking of the initially ossified structures until a final fusion of the palatine shelves over (Proffit & Fields, 2013; Du *et al*., 2021).

Growth potential of the midpalatine suture

After the fusion of the secondary palate, the suture region supposedly undergoes intramembranous ossification. However, the specific feeding pattern of infant suckling generates pressure in this region of the palate. This has been associated to the development of a provisional structure similar to a cartilaginous growing plate in the suture that otherwise ossifies primarily through intramembranous ossification (Du *et al*., 2021).

This explains the fact that this suture can be used for widening of the palate using appliances after childhood years. The mid palatine suture is partly a tension restraining joint and its fairly flat, deep opposing sidesbecomes adapted to counter the intermittent pressures exerted on the medial edges of the bone. After the stage of sutural growth, synostosis of the midpalatine suture does not occur. Masticatory movements involve constant movement of the bones in addition to the tension exerted by the growing cranium at these suture sites are possible reasons for delayed synostosis at this suture. (Latham, 1971). The tissue mechanical forces exert its influence to control the patency of the suture and its morphology (Du *et al*., 2021).

The tissue mechanical forces are best explained by the expansion of brain within the restricted volume of the skull, which slowly creates pressure that can deform the cells including the extracellular matrix in the developing skull. This pressure is also experienced in the region of the sutures as a very slow tensile strain. The tensile forces may modify suture fusion by enabling the suture lining cells respond to increase in tension and reorienting these cells along the course of the force. It also alters the proliferation and differentiation capabilities of these cells to expand the bones. Thus, the mesenchymal cells at the sutures when subjected to tension undergoes enhanced proliferation. An increase in expression of Insulin like growth factor 1, its receptors and fibroblast growth factor receptors along the cells in the midsagittal region in addition to the increased release of fibroblast growth factor 2 protein from the suture specifies that tension may regulate proliferation at suture via various signaling pathways (Du *et al*., 2021).

Another significant role of the tensile forces is the induction of thromboxane 2 (TBX2) expression in midsagittal cells and Bone Morphogenic Protein 4 (BMP 4) expression in the mesenchymal cells concurrently. TBX2 acts by inhibiting the expression of Connexin 43 (gap junction protein). Connexin 43 has propensity to promote osteogenic differentiation. Thus, TBX2 helps in retaining the suture patency through the undifferentiated mesenchymal cells. On the other hand, BMP4 expression in the mesenchymal cells results in their differentiation to osteo blasts cells that causes lengthening of osteogenic bone fronts (Du *et al*., 2021).

The stretching of sutures, muscle loading may result in an immediate influx of intracellular calcium (Ca2+) leading to osteoblast differentiation modulating the patterns of interdigitation and morphology of sutures. Cyclic forces also trigger expression of important proteins at the suture for mineralization of bone during suture development such as matrix metallo proteases (MMP) MMP-1 and MMP-2. They also play a role in regulating osteogenesis (Du *et al*., 2021).

Age as a predictor of suture maturation

The initiation of midpalatine suture is first seen as early as 10.5 weeks of intrauterine life and the suture completely forms around the 12th week of intrauterine life. The suture remains wide and unossified at birth and sutural growth continues till a halt in the growth occurs between 1-2 years after birth. After this, it undergoes phases of active remodeling to delayed remodeling until the suture in completely ossified (Latham, 1971; Greene & Pratt, 1976; Gilbert, 2000; Proffit *et al*., 2018).

The palatine development via the midpalatal suture remodeling continues to around 15 years of age. The fusion of the midpalatine region occurs from the palatal end towards the premaxillary region. The fusion is noted in the late adolescence or early adulthood (Proffit & Fields, 2013; Du *et al*., 2021). The sutural width as well as volume of the suture decreases after 20 years. This was accompanied by commencement of closure of the suture in the palate. The rate of ossification remains low during this phase. However, the ossification rate will be on the rise after 20 years (Georgi *et al*., 2024).

The complete closure of the midpalatine suture might not occur even at an elder age. This was based on the fact that ossifications occur in the anterior aspect of the suture whereas in the posterior regions of the midpalatine suture, there is a persistence of the sutural connective tissue due to the previously explained factors for the growth potential at the suture (N'Guyen *et al*., 2008; Narula *et al*., 2019). This explains the lower stages of suture maturation even though the subject is skeletally mature (Narula *et al*., 2019). Thus, the timing of the different stages of suture maturation can vary among individuals and may be influenced by factors such as age, sex, and genetics.

Role of CBCT in midpalatine suture staging of maturation

Various studies assessed the midpalatine suture staging using cone beam CT (Angelieri *et al*., 2013; Jang *et al*., 2016; Haghanifar *et al*., 2017; Jimenez-Valdivia *et al*., 2019; Narula *et al*., 2019; Katti *et al*., 2022; Georgi *et al*., 2024). In the present study, sex showed a statistically significant difference in the stages of maturation, which was consistent with the previous study (Jimenez-Valdivia *et al*., 2019).

Stage A, Stage B (Pattern A & Pattern B), Stage C Pattern A have a high prevalence during early adolescence which indicates the possibility of a higher skeletal effect during RME and its prognosis. It was noted that Stage B Pattern B and Stage C (Pattern A & B) was prevalent during the mid-adolescence age group indicating promising results for RME during the treatment period in this age group. The early stages before ossification were noted between 10-15 years consistent with the previous studies (Angelieri *et al*., 2013; Jang *et al*., 2016; Haghanifar *et al*., 2017). During the stages A and B patterns, rapid maxillary expansion can show promising results. Whereas in cases of Stage C patterns less skeletal response may be expected using conventional RME due to the bony interdigitations appearing as double scalloped radiopaque lines in the CBCT scans (Angelieri *et al*., 2013).

Late adolescence period indicates the prevalence of Stage C (Pattern A & Pattern B) to be higher than Stage D, a good indication of RME possibilities. The possibility to find a unossified (open) midplatal suture was 15.33 % in late adolescence and 6.74 % in young adults in this study. Similar finding was noted in post-adolescents and young adults in a previous study by Jimenez-Valdivia *et al*. (2019).

CBCT findings in the present study showed that a complete fusion of the palate was likely to occur young adulthood. Young adults had the highest prevalence of Stage D and Stage E and found above 17 years of age. For stages D and E where ossification has taken place, surgically assisted RME would be a likely choice (Angelieri *et al*., 2013). However, there are still Stage C Pattern B maturation stage noted in young adults, an indicator that RME is still probable.

The rate of suture closure increases with the aging (Thadani *et al*. 2010; Angelieri *et al*., 2013; Jang *et al*., 2016; Haghanifar *et al*., 2017; Jimenez-Valdivia *et al*., 2019; Narula *et al*., 2019; Katti *et al*., 2022; Georgi *et al*., 2024). However, it is not a reliable factor to predict the stage of maturation (Thadani *et al*. 2010; Angelieri *et al*., 2013; Jang *et al*., 2016; Haghanifar *et al*., 2017; Jimenez-Valdivia *et al*., 2019; Narula *et al*., 2019; Katti *et al*., 2022; Georgi *et al*., 2024). Thandani *et al*. (2010), evaluated rate of ossification of the midpalatine suture using computerized tomographic scans. In this study, it was found that at the age of skeletal maturation there was a gradual rise (22.56 %) in the ossification, while ossification increased to around 40.78 % at the age of 25 years. In this study an interesting fact was that less than 50 % of ossification was noted in young adults were there is transverse maxillary deficiency (Thadani *et al*. 2010). Hence it is very critical to estimate the stages of maturation in these patients prior to any treatment decisions.

Limitations of the study include the resolution of the images taken in low doses. Medium to high resolution CBCT scans can contribute to much detailed analysis. Another limitation was the smaller number of samples in the early adolescence group. Future studies should consider evaluation of data for different patterns of staging in Stage A, Stage D and Stage E that can provide valuable data for the treatment for palatal expansion

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CONCLUSION

CBCT showed statistically significant differences in the stages of maturation in both sexs. The most common stage of maturation of MPS for maxillary expansion in adolescents and young adults was Stage C – Pattern B (23 %).The possibilities of growth at the sutures were 11.65 % in early adolescence, 30.06 % in mid adolescence, 15.33 % in late adolescence and 6.74 % in young adulthood. Thus, CBCT can be recommended to provide important information on midpalatine suture staging to determine the status of open suture maturity, critical for diagnostic planning and decision making for the selection of appropriate method to induce rapid maxillary expansion.

SOMAN, C.; WAHASS, T. S. H.; ALJOHANY, R. S. A.; ALDULIJAN, A. A. A.; SALMA, R. G.; ALDAHASH, F. & ELAGRA, M. E. I. Análisis morfológico de las etapas de maduración de la sutura palatina media en adolescentes y adultos jóvenes mediante tomografía computarizada de haz cónico en una población saudí. *Int. J. Morphol., 43(2)*:574-582, 2025.

RESUMEN: La sutura palatina mediana es un sitio activo para el crecimiento del hueso maxilar. Las anomalías del desarrollo de la sutura pueden dar lugar a diversas malformaciones y maloclusiones. Las etapas morfológicas de maduración pueden actuar como un predictor de la expansión del hueso maxilar, especialmente después de la infancia. Por lo tanto, el objetivo del presente estudio fue evaluar las etapas de maduración de la sutura palatina mediana entre adolescentes y adultos jóvenes mediante tomografía computarizada de haz cónico (CBCT). Se realizó un análisis retrospectivo de CBCT en una población saudí. Se evaluaron 163 casos y se estadificaron según una clasificación estándar utilizando CBCT. Los resultados de nuestro estudio mostraron que el sexo mostró diferencias estadísticamente significativas en las etapas de maduración. Se encontró que la sutura mostraba evidencias de inicio de osificación por encima de los 17 años de edad. Las posibilidades de encontrar una sutura abierta no osificada fueron del 11,65 % en el grupo de 10 a 13 años, del 30,06 % en el grupo de 14 a 17 años, del 15,33 % en el grupo de 18 a 21 años y del 6,74 % en el grupo de 22 a 25 años. Los hallazgos de este estudio refuerzan la utilidad de CBCT para evaluar las etapas de maduración de la sutura medianopalatina, y ayudar a la decisión sobre el tratamiento de anomalías del desarrollo del hueso maxilar que requieren procedimientos de expansión del este hueso.

PALABRAS CLAVE: Sutura medianopalatina; Paladar duro; Hueso palatino; Tomografía computarizada de haz cónico; TC de haz cónico; Sutura craneal.

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