Cone Beam Computed Tomography evaluation of midpalatal suture maturation according to age and sex: A systematic review

A. M. Gonzálvez Moreno[1], D. Garcovich[1], A Zhou Wu[1], A. Alvarado Lorenzo[2], L. Bernes Martinez[1], R. Aiuto[3-5], M. Dioguardi[4], D. Re[3], L. Paglia[5], M. Adobes Martin[1]

[1]*Department of Dentistry, Universidad Europea de Valencia, Spain*
[2]*Department of Oral Surgery, Universidad de Salamanca, Salamanca, Spain*
[3]*Department of Biomedical, Surgical and Dental Sciences, University of Milan, Italy. Istituto Stomatologico Italiano, Milan, Italy*
[4]*Department of Clinical and Experimental Medicine, University of Foggia, Foggia, Italy*
[5]*Department of Paediatric Dentistry, Istituto Stomatologico Italiano, Milan, Italy*

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e-mail: daniele.garcovich@universidadeuropea.es

Abstract

Aim To systematically review and analyse the available evidence and assess if a correlation exists in children and young adults between the chronological age and the degree of midpalatal suture maturation as assessed according to the method proposed by Angelieri et al. [2013].

Methods A search was performed in Medline/Pubmed, Scopus, and Web of Science during October 2020 for published studies analysing midpalatal suture maturation through cone beam tomography according to the method proposed by Angelieri et al. [2013]. The review was performed according to the PRISMA protocol and the articles were selected according to the established inclusion and exclusion criteria. To assess the quality of reporting, the STROBE checklist was applied.

Results The search retrieved a total of 308 articles. After the screening and eligibility phase, only 7 studies fulfilled the inclusion criteria. Most of the studies highlighted a higher prevalence of stages B and A in subjects below the age of 11; of stage C in the 11–14 years cohort, followed by stage B. In the 14–18 years cohort, the most frequent stage was C, followed by stage D. In all cohorts, females presented stages related to a higher maturation of the midpalatal suture than males. Retrieved data belong to studies of moderate quality, especially due to the methodological limitations.

Conclusions The high variability of the maturational stages in the studied cohorts, highlights the poor correlation between suture maturation and chronological age in both genders, especially in young adults. According to our findings until the age of 14, the high prevalence of stages related to sutural opening does not justify CBCT assessment of the MPS and supports the use of a conventional protocol for maxillary expansion.

KEYWORDS Midpalatal suture maturation; Midpalatal suture maturation classification; Cone beam computed tomography; Chronological age; Maxillary expansion.

Introduction

The Rapid Maxillary Expansion protocol was first described by Angell in 1860. A century later, Haas published a study proving how this clinical procedure was able to open mechanically the midpalatal suture (MPS) [Di Ventura et al., 2019]. A successful opening of the midpalatal suture can be achieved with tooth-borne appliances, only in growing patients where suture fusion has not yet occurred. Along with the increase of MPS maturation, a variable degree of fusion occurs making the procedure less predictable and increasing side effects such as pain, excessive buccal tipping, gingival recession in the posterior segments, ulceration or necrosis of the palatal mucosa [Bell, 1982; Kiliç et al., 2008; Betts, 2016], root resorptions [Langford et al., 1982], fenestration of the buccal cortex, and instability of the expansion [Wertz, 1970; Hass, 1980; Greenbaum et al., 1982; Nota et al., 2019].

To avoid these side effects and accomplish a significant palatal expansion at older ages, procedures such as Surgical Assisted Rapid Maxillary Expansion (SARME) have been proposed [Suri et al., 2008]. In recent years, Lee et al. [2010] demonstrated how it was possible to open up a suture with a high degree fusion through a Miniscrew-Assisted Rapid Palatal Expansion (MARPE) [Lee et al., 2010]. Since the degree of fusion in the MPS increases with age, chronological age has been often used to choose when to perform a conventional or surgically assisted protocol [Angelieri et al., 2016]. The findings of histological studies, however, indicated how the beginning and development of sutural fusion greatly varies according to the age and sex of an individual [Persson et al., 1977]. Some authors highlighted a slight to poor correlation between chronological age and the degree of fusion, especially in young adults [Angelieri et al., 2013]. Thus, there is a lack of consensus on the cut-off age to perform a conventional or surgically assisted expansion [Melsen, 1975; Persson et al., 1977; Angelieri et al., 2013; Di Ventura et al., 2019].

To rely on diagnostic procedures able to determine the degree of maturation of the MPS can help in choosing the correct treatment alternative among the ones proposed. Revelo and Fishman in 1994 proposed to appraise MPS through occlusal radiographs, however the method presented a low accuracy due to the superimposition of multiple structures in this 2D diagnostic method [Revelo et al., 1994]. Angelieri et al. [2013] described a method of MPS maturation assessment based on Cone Beam Computed Tomography (CBCT). According to the authors, five maturational stages (A to E) can be described (Fig.

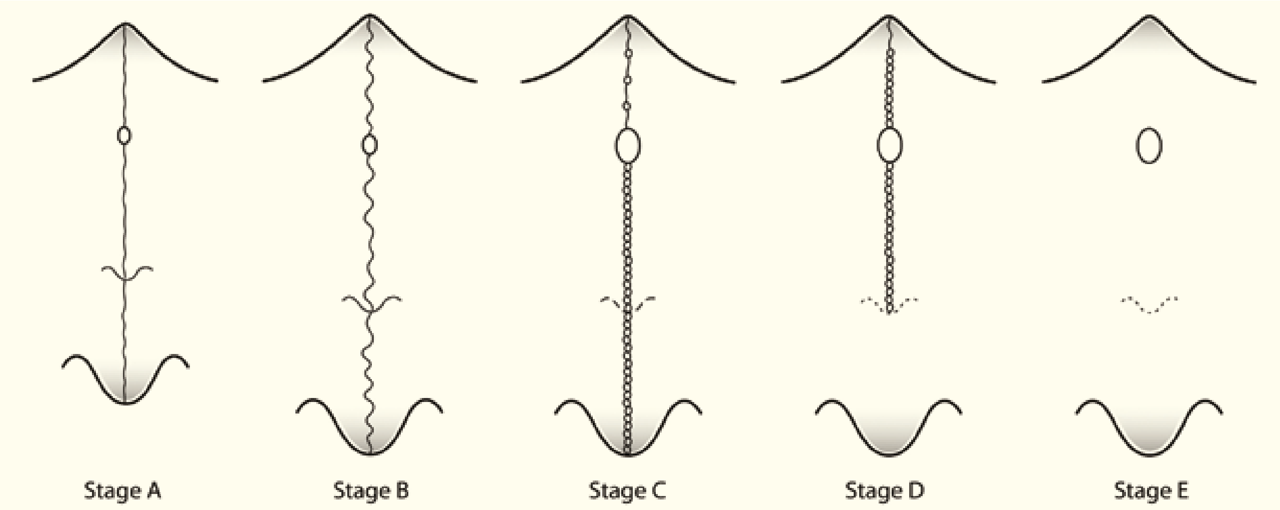

FIG. 1 Diagrammatic representation of the MPS maturation classification identifying key radiologic morphologic characteristics specific to each maturity level. It is a simplification of the sutural morphology and should not be used for diagnosis. From Angelieri et al. (Permission to reproduce granted by Elsevier (©2013).

1) [Angelieri et al., 2013]. Patients with a maturational stage A or B are successfully treated with conventional protocols that can be still applied along stage C but with a lower skeletal effect, while patients in stages D or E are better treated with SARME [Jimenez-Valdivia et al., 2019]. MARPE protocol represents a valuable treatment alternative in stage C allowing a better skeletal result [Oliveira et al., 2021].
This systematic review was performed to assess if a correlation exists in children and young adults (P) between the midpalatal suture maturational stage (I) assessed by CBCT according to the method described by Angelieri et al. [2013] (O) and chronological age.

Methods

This systematic review was performed in accordance with the statement of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [Moher et al., 2009]. The review protocol was registered in Open Science Framework (OSF) (Registration number 10.17605/OSF.IO/PY64D).

Eligibility criteria

The articles were selected according to the following inclusion criteria: human studies; Controlled Clinical Trials (CCTs); Randomized Clinical Trials (RCTs); Observational studies, both retrospective and prospective; articles in English; published or in press; studies assessing the maturational stage according to the method described by Angelieri et al. [2013]; studies reporting results segregated for age and sex. The following exclusion criteria were applied: animal studies; case reports; case series; systematic reviews; studies assessing the maturational stage with methods either than CBCT; studies with a quality score lower than 55% according to the STROBE checklist [Vandenbroucke et al., 2007; Dreyer et al., 2018].

Information sources

An electronic search was performed during October 2020 on the studies published from 2013 to September 2020 in the following databases: Medline/Pubmed, Scopus and Web of Science.

Search strategy

The search was performed with the advanced PubMed search tool with a combination of the following keywords, MeSH (Medical Subject Heading), non-indexed terms, and the corresponding Boolean operators: (((((((children) OR (young adult*)) OR (postadolescent*)) OR (patient*)) OR (adolescent*)) AND (((((Cone beam computed tomography [MeSH Terms]) OR (CBCT)) OR (cone beam CT)) OR (computed tomography)) OR (tomography))) AND (((((Midpalatal suture maturation) OR (MPSM)) OR (mid-palatal suture maturation)) OR (palate suture)) OR (midpalatal suture))) AND ((chronological age) OR (age)).

Study selection

Two authors (AMG and MAM) simultaneously and independently conducted the search process according to the criteria of the PRISMA Protocol [Moher et al., 2009]. A first screening of the retrieved articles was performed on titles and abstracts, selecting any potentially eligible studies. Later, a second screening was conducted by the same researchers on the full text of the articles applying the established inclusion and exclusion criteria. In case of any disagreement, a third reviewer was consulted (DG).

Data collection process

The data of the selected articles were extracted by one reviewer and exported to an Excel datasheet (Microsoft Office for Mac 2011 package) organised according to the Cochrane Consumers and Communication Review Group's data extraction template. A second author checked the extracted data and disagreements were resolved by consensus. In this phase, the corresponding author of a retrieved article was contacted since all numerical data were not provided in the published paper [Ok et al., 2020].

Data items

The following data were extracted: a) Authors' name; b) year of publication; c) title; d) journal; e) study design; f) prevalence of maturational stages; g) origin of the sample; h) sample size; i) demographic data (age and sex); j) number of examiners; k) included age cohorts.

Quality assessment

Since most of the studies were observational cross-sectional

STROBE Checklist Item		Angelieri et al. 2013	Jang et al 2016	Tonello et al. 2017	Angelieri et al. 2017	Ladewig et al. 2018	Jimenez-Valdivia et al. 2019	Reis et al. 2020
Title and abstract	1 Title and abstract	0.5	0.5	0.5	1	0.5	0.5	0.5
Introduction	2 Background/ rationale	1	1	1	1	1	1	1
	3 Objectives	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Methods	4 Study design	0	0.5	0	0	0	1	0.5
	5 Setting	0.5	1	0.5	0.5	0.5	0.5	1
	6 Participants	0.5	1	1	1	1	1	1
	7 Variables	1	1	1	1	0.5	0.5	1
	8 Data sources/ measurement	1	1	1	0.5	0.5	1	1
	9 Bias	1	1	1	1	1	1	1
	10 Study size	0	1	0	1	1	1	1
	11 Quantitative variables	0.5	0.5	0	0.5	0	0.5	0
	12 Statistical methods	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Results	13 Participants	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	14 Descriptive data	0.5	0.5	0.5	0.5	0.5	0.5	1
	15 Outcome data	1	1	1	1	1	1	1
	16 Main results	0.5	1	1	1	0.5	1	0.5
	17 Other analyses	0	0	0	0	0	0	0
Discussion	18 Key results	1	1	1	1	1	1	1
	19 Limitations	0	1	0	0	0	0	0.5
	20 Interpretation	0.5	1	0.5	0.5	1	0.5	0.5
	21 Generalisability	1	1	1	1	1	1	1
Other information	22 Funding	0	0	0	1	0	1	1
Total		12	16.5	12.5	15	12.5	15.5	16
Total (%)		55%	75%	57%	68%	57%	70%	73%

TABLE 1 Quality assessment scores of the included studies according to the STROBE checklist.

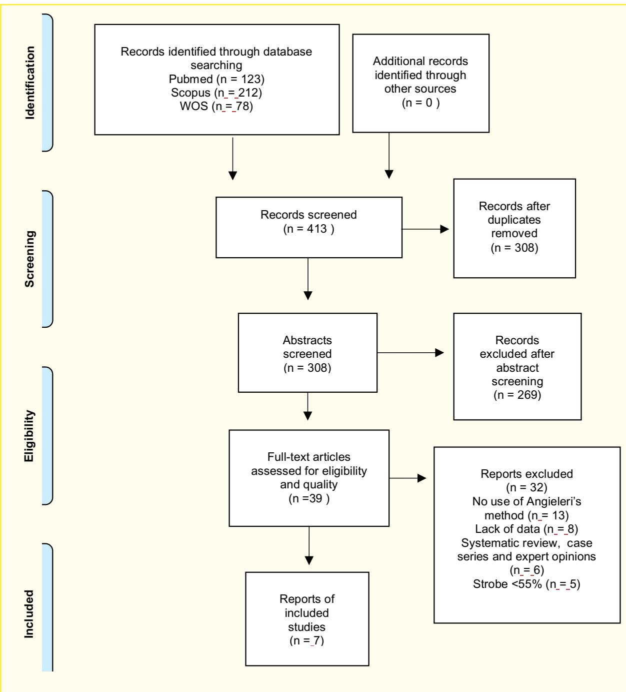

FIG. 2 Flow diagram of the performed search.

studies, the STROBE checklist was applied for quality check as in previously published reviews involving studies with the same design [Vandenbroucke et al., 2007]. Quality assessment was performed by two reviewers and all disagreement was resolved by consensus. The items on the checklist were assessed for each of the included articles as: (1) present; (2) partially present; or (3) not present. The final degree of adherence was expressed in percentage [Dreyer et al., 2018] (Table 1).

Results

The search performed in different databases retrieved a total of 413 articles, after duplicate removal, 308 articles were assessed through their titles and abstracts. After this first screening, the full-text of 39 articles were assessed for eligibility. Out of these 39 articles, 32 were excluded after applying the inclusion and exclusion criteria. The flow chart of the screening process according to the PRISMA statement is displayed in Figure 2. Finally, seven studies were included in the qualitative analyses (15,18,24–28). As the data from the included studies were non numerical, a meta-analysis was not justified. Only a qualitative synthesis was therefore performed. Main characteristics of the included studies are presented in Table 2.
Of the included articles, six were observational retrospective and one prospective [Jang et al., 2016]. All were published

Author (yr.)	Characteristics of the included subjects	Study design	Studied Outcome	Country	Sample size	M/F	Age range yr.	Nº Examiners	Blind tested
Angelieri et al. (2013)	CBCT images acquired for clinical purpose in subjects with no history of previous orthodontic treatment	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Brazil	140	54/86	5.6–58.4	3	yes
Jang et al. (2016)	CBCT images acquired for clinical purpose in subjects with no history of previous orthodontic treatment, patients with no disease or medicine intake affecting bone metabolism	O-L	MPS Maturation Stage according to the Angelieri et al. (2013), Hand and wrist maturation, cervical vertebrae maturation	Korea	99	40/59	6-20	1	yes
Tonello et al. (2017)	CBCT scans obtained from a dental diagnostic imaging center, mainly requested to diagnose retained teeth. Patient without syndromic conditions or previous orthodontic treatment.	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Brazil	84	40/44	11–15	1	n/r
Angelieri et al. (2017)	CBCT images obtained from the archives of a maxillofacial surgeon private practice. Patients without craniofacial syndromes, systemic diseases, or previous orthognathic surgery,	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Brazil	78	14/64	18–66	1	yes
Ladewig et al. (2018)	CBCT scans obtained from two, dental diagnostic imaging centers mainly requested to diagnose retained teeth. Patient without syndromic conditions or previous orthodontic treatment.	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Brazil	112	44/68	16–20	2	n/r
Jimenez-Valdivia et al. (2019)	CBCT scans obtained from a dental diagnostic imaging center. Patients without syndromic conditions or previous orthodontic treatment.	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Peru	200	95/105	10-25	1	n/r
Reis et al. (2020)	CBCT scans selected from the archive of the university Dental Radiology Clinic. Patients without syndromic conditions or previous orthodontic treatment.	O-R	MPS Maturation Stage according to the Angelieri et al. (2013)	Brazil	487	198/289	15-40	1	n/r

O-R: Observational- Retrospective; O-L: Observational- Longitudinal; M: Males; F: Females; yr.:years; n/r: not reported

TABLE 2 Main characteristics of the included studies.

In individuals older than 18, all authors reported a predominance of Stages D and E. Only in one sample a low prevalence of Stage B could be highlighted (4.3%) [Jimenez-Valdivia et al., 2019].

MPS maturation stage in females

The maturational stage distribution according to the age in females group is reported in Table 4. According to the findings of the included studies in the cohort up to 11 years, there is higher variability of maturational stages: the prevalence of Stages A and B is high according to what reported by Angelieri et al. [2013], but other authors highlighted a high prevalence of Stage C (47.4%) and a low prevalence of Stage D (5.3%) indicating the onset of sutural closure in this age cohort [Jang et al., 2016].

In individuals up to 14 years, all authors except one [Angelieri et al., 2013], demonstrated a higher prevalence of individuals presenting Stage C. The stages related to a degree of MPS closure (D and E) rise in this cohort, ranging from 13.3% of the Brazilian sample presented by Tonello et al. [2017] to 47.6% of the Korean sample of Jang et al. [2016] [Tonello et al., 2017].

In female patients up to 18 years, the data presented by all authors except one [Ladewig et al., 2018] demonstrated a majority of Stages D and E, with Stage E being the most frequent one. Only according to Ladewig et al. [2018] stage C is the most prevalent stage, but also in this sample Stages D and E sum up 48.8%.

In patients older than 18, the prevalence of Stage E rise in all included studies, reaching 100% in one of them [Jang et al., 2016]. But according to the majority of the authors, the stages characterised by a lower maturation are still present and have a variable prevalence ranging from 4.3% (Stage B) in a Peruvian sample with patients aged 21 to 25 years [Jimenez-Valdivia et al., 2019], to the 28.9% (Stage B and C) reported by Reis et al. [2020]. According to Ladewig et al. [2018], Stages B and C accounted for 40% in the female group between 19 and 20 years old.

Discussion

According to the data provided by the included studies, the degree of MPS maturation presents a high variability and seems scarcely related to chronological age, being this finding in agreement with what previously reported by other authors

Angelieri et al. 2013	Age groups N	5–11 yr. 24	11–14 yr. 24	14–18 yr. 19	>18 yr. 19	
	MPS Stages (%)	**B** 75% >A 25%	**B** 66.7% > C 29.2% > A 4.2%	**C** 53.8% > B=D 23.1%	**E** 69.2% > D 23.1% > C 7.7%	
Jang et al., 2016	Age groups N	6–11 yr. 17	11–14 yr. 13	14–18 yr. 5	18–20 yr. 5	
	Male%	**A** 64.7% > B 23.5% > C 11.8%	**C** 46.2 % > B 30.8% > A 15.4% > D 7.7%	**E=D** 40% > C 20%	**D** 60% > E 40%	
Tonello et al., 2017	Age groups N		11–13 yr. 22	14–15 yr. 18		
	MPS Stages (%)		**C** 54.5% > B 40.9% > D 4.5%	**E** 33.3% > C 27.8% > D 22.2% > B 16.7%		
Angelieri et al., 2017	Age groups N				18–30 yr.	
	MPS Stages (%)				**E** 50% > D 33.3% >C 16.7%	
Ladewig et al. 2018	Age groups N			16–18 yr. 29	19–20 yr. 15	
	MPS Stages (%)			**C** 58.6% > D 20.7% > B 10.3%> E 6.9% > A 3.4%	**C** 40% > D 33.3% > E 26.7%	
Jimenez–Valdivia et al., 2019	Age groups N		10–15 yr. 17	16–20 yr. 31	21–25 yr. 47	
	MPS Stages (%)		**B** 41.2% > C 35.3% > D 11.8% > A=E 5.9%	**D** 41.9% >E 35.5% > C 22.6%	**E** 48.9% > D 25.5% > C 21.3% > B 4.3%	
Reis et al., 2020	Age groups N			15–20 yr 34.	21–25 yr 74.	26–30 yr.
	MPS Stages (%)			**C** 52.3%> D=E 23.5%	**C** 41.9% > E 35.1% > D 23%	**E** 47.5% > C 32.5% > D 20%

TABLE 3 Outcome distribution according to age in the male group (Most prevalent stage in boldface). N: number of patients in the age cohort; yr.: years.

[Persson et al., 1977; Angelieri et al., 2013]. The Angelieri´s classification tries to define the degree of midpalatal suture consolidation on CBCT images (determining stages from A to E) in an attempt to guide the clinician in choosing the best clinical procedure to accomplish a successful maxillary expansion.

Stages A to C indicate an open MPS more suitable for a conventional RME approach, while Stages D and E are possibly related to suture closure and a surgical approach could be preferred. According to the author, the assessment of MPS maturation can avoid the side effects derived from rapid maxillary expansion failure and limit surgically assisted rapid maxillary expansion to late adolescents and young adults with complete closure of the MPS, thus avoiding unnecessary treatment.

CBCT imaging can enable the clinician to three-dimensionally visualise the maxillary anatomy and evaluate the MPS maturation without the overlap of the surrounding structures such as the vomer or the nose on the MPS region, as happens on two-dimension occlusal radiographs [Wehrbein et al., 2001]. However, this radiological assessment is not a risk-free procedure, especially when children are involved, and there is a growing concern of radiation dose in orthodontic CBCT [Maspero et al., 2019; Stratis et al., 2019; Adobes Martin et al., 2020]. To correctly visualise the MPS, a field of view (FOV) of 13 by 16 cm should be used [Isfeld et al., 2019; Oliveira et al., 2021]. This FOV size is considered large and it is related to a high radiation dose and a primary beam involving radiosensitive tissues such as the brain, salivary glands, and the red bone marrow. Many authors highlighted how the stochastic risk of developing cancer is higher in children and decreases with increasing age at exposure [Marcu et al., 2018]. The existing guidelines about the use of CBCT in orthodontics have emphasized the need of a stronger justification when prescribing CBCT examinations. Children or young adults should undergo a CBCT examination only when the benefits of the diagnosis or treatment plan outweigh the potential risks of radiation exposure [Scarfe, 2013].

According to the data of the included studies, a CBCT assessment of MPS seems unnecessary in patients younger than 14 years, especially in males. In this age cohort, only one study reported 5.9% of Stage E [Jimenez-Valdivia et al., 2019] in male patients, thus indicating that it is highly unlikely to find an MPS fusion at this age. In females, decision making can be more difficult since many authors reported around 20% of Stage E in this age cohort. Other authors such as Ok et al. [2020] did not report any stage E in 157 patients up to 16 years of both sexes. From a clinical standpoint, a conventional expansion protocol can be the best choice in this age group. In patients from 14 to 18 years, the decision making could be backed up by an MPS appraisal since the prevalence of stages D and E is rising especially in the female group.

It should be considered that in a recent paper about factors related to the success of MARPE by Oliveira et al. [2021], all failures were related to Stage E, but successful openings were also reported in this maturational Stage and no failure

Angelieri et al., 2013	Age groups N	5-11 yr. 24	11-14 yr. 24	14-18 yr. 19	>18 yr.19	
	MPS Stages (%)	**B** 79.2% > A 12.5% > C 8.3%	**B** 50% >C 25% > E 20.8% >D 4.2%	**E** 42.1% > C 26.3% > B=D 15.8%	**E** 42.1% > D 36.8% > C 15.8% > B 5.3%	
Jang et al. 2016	Age groups N	6-11 yr. 19	11-14 yr. 21	14-18 yr.18	18-20 yr.1	
	MPS Stages (%)	**C** 47.4% > A 31.6% > B 15.8% >D 5.3%	**C** 47.4% >D 28.6% > E 19% > B 4.8%	**E** 61.1% > D 33.3% > C 5.6%	E 100%	
Tonello et al. 2017	Age groups N		11-13 yr. 30	14-15 yr. 14		
	MPS Stages (%)		**C** 53.3% > B 30% > D 10% >A=E 3.3%	**C** 64.3% > D 21.4%> E 14.3%		
Angelieri et al. 2017	Age groups N				18-30 yr.30	
	MPS Stages (%)				**E** 60% > D 30% > C 6.7% > B 3.3%	
Ladewig et al. 2018	Age groups N		16-18 yr. 43	19-20 yr. 25		
	MPS Stages (%)		**C** 41.9%> E 30.2% > D 18.6% > B 9.3%	**C** 36% > E 32% > D 28% > B 4%		
Jimenez-Valdivia et al. 2019	Age groups N		10-15 yr. 31	16-20 yr. 21	21-25 yr. 53	
	MPS Stages (%)		**C** 45.2% > D 22.6% >B 19.4% > E 9.7%> A 3.2%	**E** 42.9% > D 38.1% > C 14.3% > B 4.8%	**E** 603% > D 30.2% > C 9.4%	
Reis et al. 2020	Age groups N			15-20 yr.59	21-25 yr.134	26-30 yr.45
	MPS Stages (%)			**E** 44.1% > C 42.4% > D 15.3%	**E** 56.7% > C 29.9% > D 12.7% > B 0.7%	**E** 55.6% > C 26.7% > D 15.6% > B 2.2%

TABLE 4 Outcome distribution according to age in the female group (Most prevalent stage in boldface). N: number of patients in the age cohort; yr.: years.

was reported in subjects younger than 19 regardless the MPS maturation Stage. The findings from Oliveira et al. [2021] suggested that other factors than the maturation Stage could play a major role in treatment outcomes such as age or appliance related factors (cortical or bi-cortical anchorage of the mini-screws, the level of force employed). From a clinical standpoint, it seems reasonable to prefer a MARPE approach for individuals in this age cohort to avoid the side effects of conventional expansion failure and maximize the skeletal effect.
In patients older than 18, the high prevalence of Stage E suggests the need of cautious decision making, patients presenting Stage C or B were still detected in this age group, in which a MARPE protocol could be beneficial. Patients in Stage E are probably more suitable for a SARPE approach [Angelieri et al., 2017]. A recent report about MARPE protocol from Shin et al. (2019) including 31 individuals between 18 and 36 years reported a failure rate of 50% in individuals older than 30, while it was 20% in the ones below this age, being all cases except one in Stage E or D [Shin et al., 2019]. The authors support that MPS appraisal, palatal length, and age are strong predictors of MARPE outcome [Shin et al., 2019].
According to our best knowledge, this is the first attempt to systematically review the studies published on MPS maturation according to the Angelieri et al. classification. The review offers a broad insight on MPS maturation segregated by sex and age, but a few limitations should be underlined. The studies included in the present review were all observational, with a STROBE score medium-low except for three of them [Jang et al., 2016; Jimenez-Valdivia et al., 2019; Reis et al., 2020]. The low scores are mainly linked to methodological limitations such as the lack of randomization, missing information about sample size calculation, non blind study design, and uneven distribution between sexes. The age cohorts were not consistent among the different studies and they often overlap, not allowing large data grouping. The samples from different populations presented great differences and it cannot be assumed that ethnicity-specific data should apply to different populations.
According to some authors, the method presents a substantial reliability and reproducibility as assessed through the intraexaminer and interexaminer reliability calculation [Angelieri et al., 2013; Ladewig et al., 2018; Shin et al., 2019], while other authors underlined the low reproducibility of the method [Isfeld et al., 2019; Vieira Barbosa et al., 2019]. Isfeld et al. [2021] described the method as non intuitive and requiring major training for operator calibration. The assessment is dramatically influenced by image quality, sharpness, and clarity, and according to their results, the method has an excellent intraexaminer reliability but a slight to poor interexaminer one [Isfeld et al., 2019]. Barbosa et al. [2019] defined the method as potentially reliable and reproductible, but not enough to date to be applied daily in a clinical setting [Vieira Barbosa et al., 2019]. Future studies about MPS maturation assessment should employ at least two examiners and a strict training protocol to maximise the examiner calibration. Excellent data reliability could allow big data grouping and analyses.

Conclusions

According to the data gathered from the included studies, the degree of MPS maturation presents a great variability in the different age groups. Females present a more advanced maturation than males in the same age cohort. Until the age of 14 years, the high prevalence of stages related to sutural opening does not justify CBCT assessment of the MPS and supports the use of a conventional protocol for maxillary expansion. In patients 14 to 18 years old, the higher prevalence of stages indicating sutural consolidation suggests that decision making could be backed up by an MPS appraisal. In adult patients, the MPS appraisal, among other factors, could play a major role in guiding the choice of a correct clinical protocol.

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