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(Review Article)

Maturation of the palatine median suture: A literature review

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Abstract

The maturation of the midpalate suture (MPS) is a progressive process that evolves from a fibrous joint to complete bone fusion, which directly influences orthodontic planning for maxillary transverse expansion. The purpose of this review was to analyze the biological mechanisms, diagnostic methods, and clinical applicability associated with MPS in order to optimize therapeutic choices according to the stage of maturation. Histological characteristics, structural changes, and advances in imaging techniques such as cone beam computed tomography (CBCT) were reviewed, which have allowed classifications such as Angeli Eri's to be established, useful for guiding the selection between conventional orthopedic expansion, micro-screw-assisted (MARPE), or surgically assisted (SARPE). Sutural maturation is highly variable and does not depend exclusively on chronological age, but also on genetic, biomechanical, and functional factors. In addition, an inadequate diagnosis can lead to undesirable side effects such as pain, gingival recession, root resorption, or limitations in treatment stability. In conclusion, correct assessment of the degree of sutural maturation is essential for personalizing the orthodontic approach, minimizing risks, and ensuring the long-term stability of the results obtained.

Keywords: Bone maturation; Palatal suture; Maxillary expansion; Bone age

1. Introduction

The median palatine suture (MPS) plays a fundamental role in the stability and transverse development of the maxilla and is a key factor in the planning of orthodontic and orthopaedic treatments. Its maturation is a dynamic process that progresses from a fibrous junction to complete synostosis, which conditions the maxilla's response to expansion forces and limits the effectiveness of non-surgical treatments in patients with a higher degree of maturation [1].

During childhood and early adolescence, the SMP exhibits a linear pattern with high vascularisation and remodelling capacity; however, with advancing age, progressive mineralisation, interdigitation, and loss of vascularity occur, which provide greater biomechanical resistance and hinder orthopaedic expansion [2].

These morphological changes are not always directly related to chronological age, which highlights the importance of more accurate diagnostic methods. In this context, the advent of cone beam computed tomography (CBCT) has made it possible to evaluate the degree of sutural maturation in greater detail, facilitating objective classifications and therapeutic guidelines for selecting between rapid maxillary expansion (RME), micro-screw-assisted expansion (MSAE) or surgically assisted expansion (SAE). [3]

A thorough understanding of the biology and diagnosis of SMP is essential to minimise iatrogenic risks, optimise therapeutic choices and ensure stable results in orthodontic practice.

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2. Theoretical framework

2.1. General information

The median palatine suture (MPS), also known as the intermaxillary suture, is a synfibrous synarthrodial fibrous joint located in the sagittal midline of the hard palate, joining the palatine processes of the maxillary bones in the anteroposterior direction, from the anterior nasal spine (ANS) to the posterior margin of the horizontal plates of the palatine bone [1].

From a histological perspective, the SMP is initially composed of dense, highly cellular, and vascularised connective tissue, which allows for a certain degree of mobility and orthopaedic adaptation at an early age. As skeletal maturation progresses, this structure undergoes a process of progressive ossification, in which sutural interdigitation increases, vascularisation decreases, and eventually complete obliteration occurs, transforming into continuous bone synostosis [2].

This process is not synchronous with chronological age and presents high interindividual variability influenced by biomechanical, genetic, and functional factors. For example, the loss of functional load associated with edentulism has been shown to induce substantial morphological alterations in the SMP, such as increased obliteration, decreased vascular lumen, and a significant reduction in sutural width, suggesting that functional occlusal stimulation plays a key role in maintaining sutural anatomical integrity [2].

From a clinical-orthodontic point of view, the SMP is a structure of particular interest, as it is the main site of bone resistance during rapid maxillary expansion (RME) procedures and micro-screw-assisted expansion (MARPE) techniques. The degree of sutural maturation is a critical determinant in the selection of the type of maxillary expansion, as a partially open suture may allow orthopaedic separation of the maxillary complex, while a fused suture will require surgically assisted interventions or complementary procedures such as corticotomies [3].

2.2. Physiology of sutural maturation

The maturation of the median palatine suture (MPS) is a dynamic and progressive process that reflects the transition from a fibrous synarthrodial joint (synfibrosis) to a complete bony union (synostosis). This process involves multiple interdependent biological mechanisms, including progressive mineralisation, loss of vascularisation, and structural reorganisation of connective tissue into mature bone tissue [1].

During childhood and early adolescence, the SMP appears as a linear, hypocellular structure composed of collagen fibres arranged in parallel, with high vascular content and the capacity for remodelling in response to functional or mechanical stimuli. As skeletal maturation progresses, gradual mineralisation of the extracellular matrix occurs, with the appearance of bone trabeculae extending from the maxillary palatine apophyses towards the sutural centre. This phenomenon is accompanied by increasing interdigitation, which reduces the linearity of the suture and reinforces its biomechanical strength [1].

At the same time, there is a progressive reduction in vascular lumen, accompanied by a decrease in cellularity and osteogenic activity, eventually leading to complete obliteration of the sutural space. This final stage of maturation is known as synostosis and represents true bone fusion, which significantly limits the possibility of non-surgical orthopaedic expansion of the maxilla [1].

2.3. Methods for diagnosing the maturation of the midpalatal suture

2.3.1. X-ray

The diagnostic stage is fundamental to the success of biomechanics, and today a growing number of adult patients receive orthodontic treatment. It is important to understand the development of sutures throughout life in order to obtain orthodontic treatment techniques tailored to each age group [4].

A broad, interdigitated, well-vascularised suture was observed in younger specimens, compared with straighter, smaller sutures with fewer vessels and lower bone density in the adult patient group [5].

Various methodologies have been proposed to discern the architecture and degree of fusion of the palatal suture, including histological studies in animals and humans, evaluation of occlusal radiographs, and computed tomography of autopsy material and animal samples [6,7].

Revelo and Fishman have presented the individual assessment of the midpalatal suture on occlusal radiographs, which is a commonly used method for evaluating the palatal expansion zone, ideally during the 1970s [8,9].

However, a few years later it was demonstrated that occlusal radiographs are not reliable for diagnosing fusion of the midpalatal suture due to the overlap of the vomer and external nasal structures in the midpalatal area. These methodologies presented inherent difficulties in assessing the degree of palatal suture fusion [6,8].

2.3.2. Tomography

Since its introduction in dentistry in 1998, cone beam computed tomography (CBCT) has been increasingly used for orthodontic diagnosis, treatment planning, and research. The use of CBCT has been facilitated by the advantages of three-dimensional (3D) imaging over two-dimensional radiography. The development of computer software allows for multiplanar reconstruction without overlapping nearby anatomy and delivers a lower absorbed radiation dose to the patient than medical CT [10].

2.3.3. Classification of midpalatal suture maturation according to Angelieri using cone beam computed tomography (CBCT)

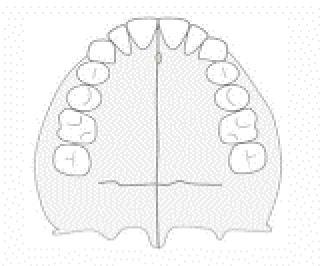
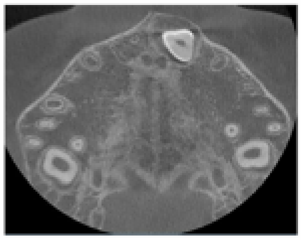
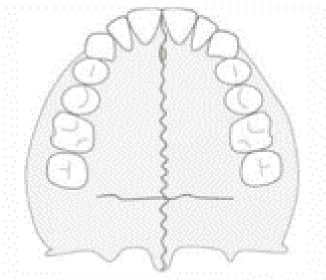
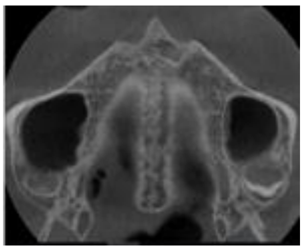
The assessment of midpalatal suture (MPS) maturation has become fundamental in the diagnosis and planning of orthodontic treatments involving maxillary transverse expansion. In this context, Angelieri et al. (2013) developed a five-stage tomographic classification (A–E) based on CBCT, which has been widely adopted in contemporary literature.

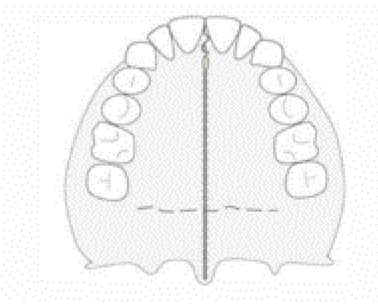
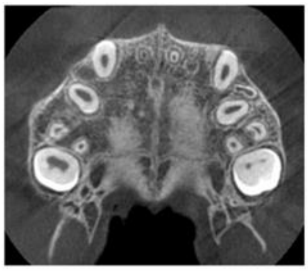
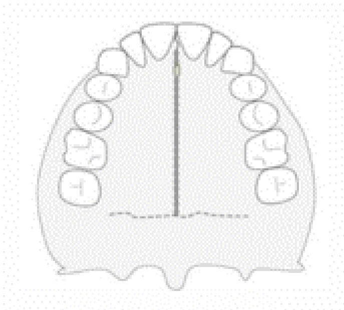
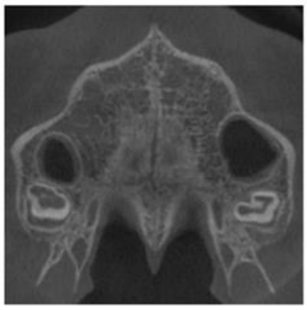
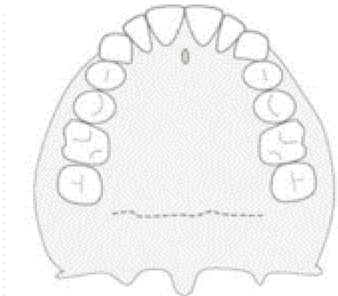
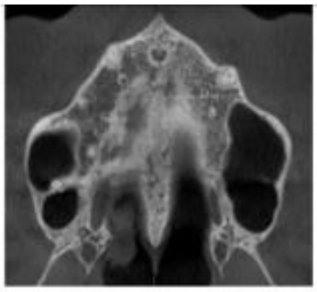
Each stage represents a progressive degree of structural maturation and ossification of the suture

- Stage A: The suture appears as a thin, hypodense line with no evidence of interdigitation.
- Stage B: Incipient interdigitation appears, but the suture line is still clearly identifiable.
- Stage C: Areas of partial fusion and structural discontinuity are observed, with increased bone trabeculation.
- Stage D: Fusion is present in the posterior region; only a trace of the suture is visible in its anterior portion.
- Stage E: Complete ossification along the entire suture; no remaining suture morphology is distinguishable.

This classification has been validated to predict the biomechanical response of the maxilla to disjunction procedures and allows for more precise selection of the therapeutic protocol [11,12].

Table 1 Stages of maturation of the median palatal suture on cone beam computed tomography. Adapted from Angelieri et al., 2013. [1]

Maturación Sage	**Maturation stage diagram (axial view)**	**Axial view in cone beam computed tomography**
Stage A		
Stage B		

Stage C		
Stage D		
Stage E		

From a histological point of view, the distinction between synfibrosis (partially mineralised and still functionally active suture) and synostosis (consolidated bone fusion) is essential for understanding the clinical response of SMP to expansion procedures. However, recent studies have questioned the diagnostic accuracy of cone beam computed tomography (CBCT) as a predictive tool for the actual histological status of the suture [13].

In particular, Georgi et al. (2023), through the combined use of CBCT and microcomputed tomography (μCT) in human specimens aged 14 to 34 years, demonstrated that the morphological stages observed by CBCT do not always correlate with objective histological parameters such as bone volume fraction (BV/TV), suture width, degree of interdigitation, or ossification. Furthermore, they found that the suture can maintain a relatively high volume and low mineralisation even in stages D or E according to Angelieri, questioning the clinical validity of these classifications as the sole criterion for deciding the need for surgical intervention [13].

These findings reinforce the importance of considering sutural maturation as a structural continuum rather than a set of discrete stages, and suggest the need for complementary diagnostic tools such as magnetic resonance imaging or artificial intelligence models that allow for a more accurate and less invasive assessment of sutural physiology [14].

2.3.4. Histological Analysis

Histological evaluation is the gold standard for assessing the maturation of the midpalatal suture. Unfortunately, its implementation in patients undergoing orthodontic treatment would require an invasive biopsy, which limits its use. The few studies that have been conducted use cadaver samples, observing a wide, interdigitated, and well-vascularised suture in younger specimens compared to straighter and smaller sutures with fewer vessels and lower bone density in the older age group [7,15].

2.4. Clinical applicability according to stage of maturation

The clinical usefulness of this classification lies in its ability to guide the choice of maxillary expansion type

Table 2 Physiological stages of maturation of the midpalatal suture and their correspondence with Angelieri's stages [1]

Functional phase	Stage (Angelieri)	Histological characteristics	Functional status	Clinical implications
Early symphysis	A – B	Dense connective tissue, organised collagen matrix, active vascularisation, no interdigitation.	Active and deformable suture.	High response to orthopaedic expansion (conventional ERM or unassisted MARPE).
Advanced symphysis/ transition	C	Appearance of bone trabeculae, irregular interdigitation, progressive reduction in vascularisation.	Partially active suture.	Preferred indication for MARPE. Possible localised bone resistance.
Partial synostosis	D	Posterior bone fusion, consolidated trabecular pattern, loss of central continuity of the suture.	Increased mechanical strength.	MARPE with surgical assistance or hybrid protocols.
Complete synostosis	E	Total bone fusion, complete obliteration of the sutural lumen, absence of connective space.	Inactive suture, not orthopaedically separable.	Contraindication for orthopaedic expansion. Indication for SARPE or midpalatal osteotomy.

2.5. Complications of a misdiagnosis

The stage of development of the SMP is essential for identifying the timing of the least invasive treatment, if possible, given that the amount of skeletal or dentoalveolar effect of ERM correlates directly with the stage of maturation [16].

Treatment of transverse deficiencies is recommended relatively early, before maximum skeletal growth velocity is reached. Failure to adequately identify key clinical signs and perform an individual assessment to identify the ideal expansion treatment option for a patient may result in iatrogenic side effects and comorbidities [6].

Common side effects of poorly planned and unsuccessful conventional ERM therapy include

- Acute pain.
- Gingival recession.
- Dehiscence formation.
- Root resorption.
- Limited skeletal movement.
- Ulcerations and necrosis of the palatal mucosa.
- Buccal dentoalveolar inclination.
- Poor long-term expansion stability.
- Patient or parental cooperation in activating the appliance.
- Open bite.
- Microtrauma to the temporomandibular joint.
- Asymmetrical mandibular position in growing patients.
- Joint disorders and muscle function alterations [6].

2.6. Treatment

The treatment plan consists of devising the strategy that a specialist would use, based on their best judgement, to obtain the greatest benefit at the lowest cost and risk. The expansion technique traditionally used is based on a combination of orthopaedic and dental expansion to correct skeletal disharmony. Many types of appliances with different expansion rates have been developed, but the principles are essentially the same: exerting a transverse force on the maxilla, causing separation of the PMJ, which increases cellular activity and bone remodelling [17].

Stimulating growth and development at an early age or during peak growth favours correction, unlike in adult patients with no residual growth.

As mentioned above, there are variables to consider for correction, such as age, sex, force applied, duration of treatment, frequency of activation and cost. The right decision will be determined by tomographic evaluation of the SMP. During primary and mixed dentition and the early years of permanent dentition, ERM is a simple procedure with high success rates that has become a routine procedure in orthodontic treatment for patients with SMP [17].

These results can be achieved with removable expansion devices (active plates, functional appliances with palatal springs) or fixed Haas or Hyrax appliances. It should be noted that both types apply their force at the dental level, taking advantage of the favourable growth stimulus.

In patients in late adolescence or early adulthood, a non-surgical approach is suggested, and as an alternative, optimisation of the expansion potential using MARPE mini-implants (Miniscrew Assisted Rapid Palatal Expander). This system applies forces to mini screws placed near the SMP and uses an expansion device to separate them. It does not apply forces to the teeth or periodontium and is also affordable [17].

It is mentioned that the amount of orthodontic movement and its side effects are proportional to the age and skeletal maturation of the patient. Therefore, adolescents have more side effects and less orthopaedic expansion than children.

On the other hand, in patients who show sutural fusion, alternatives such as SARPE are considered, which consists of a partial maxillary osteotomy (LeFort I associated with surgical rupture of the SMP) with the support of expanders (Hyrax, anchored at the dental level). Despite its benefits, it increases the biological and financial costs of treatment, requires hospitalisation and general anaesthesia, which could deter patients from surgical-orthodontic treatment [17].

3. Conclusion

The median palatal suture is a key element in orthodontic planning, as its degree of maturation determines the viability of orthopedic techniques or the need for surgical procedures. The use of CBCT and specific classifications has improved clinical prediction, although diagnostic limitations persist, justifying the search for complementary methods. An individualized assessment of each patient allows the most appropriate expansion strategy to be chosen, reducing iatrogenic risks and promoting stable results, which reinforces the importance of integrating biological knowledge, advanced diagnosis and clinical judgement in orthodontic practice.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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