Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

MAXILLARY EXPANSION IN GROWING PATIENTS WITH CLEAR ALIGNERS

Madrid, academic year 2025/2026

Identification number: 147

RESUMEN

Introducción: La deficiencia transversal maxilar es un problema frecuente que provoca alteraciones funcionales y estéticas. La expansión rápida maxilar (RME) y lenta (SME) son técnicas establecidas para su corrección. Los alineadores transparentes han sido propuestos como alternativa, mejorando la estética y la comodidad del paciente; **Objectivos:** Investigar la expansión maxilar mediante alineadores transparentes en pacientes en crecimiento, comparando la eficacia de la expansión palatina obtenida con técnicas convencionales frente a los alineadores. Se analizaron las indicaciones clínicas y las consideraciones necesarias para lograr una expansión exitosa con alineadores; **Materiales y métodos:** Se realizó una revisión de la literatura basada en artículos centrados en la expansión maxilar mediante terapia con alineadores transparentes (CAT) y en comparación entre CAT y técnicas tradicionales. Los estudios fueron analizados para comparar los resultados del tratamiento, la cantidad, la naturaleza de la expansión y las limitaciones clínicas; **Resultados:** Los alineadores transparentes fueron eficaces para lograr expansión transversal principalmente mediante mecanismos dentoalveolares, a través de inclinación. La RME produjo una expansión esquelética significativa, especialmente durante el crecimiento, mientras que la SME mostró resultados similares a la CAT. Los alineadores ofrecieron ventajas en estética, comodidad e higiene oral, pero fueron limitados para inducir expansión importante o cambio esquelético. Su éxito depende de la colaboración del paciente y de una planificación optimizada, incluyendo el uso de attachments, staging, sobrecorrección y sobreingeniería; **Conclusion:** Los alineadores transparentes representan una alternativa para deficiencias leves a moderadas, especialmente para expansión dentoalveolar es suficiente. No pueden sustituir a la RME para corrección esquelética significativa.

PALABRAS CLAVE

Odontología, Ortodoncia, Alineadores transparentes, Expansión maxilar, Pacientes en crecimientos.

ABSTRACT

Introduction: Maxillary transverse deficiency is a common problem that can lead to functional and aesthetic issues. Rapid maxillary expansion (RME) and Slow maxillary expansion (SME) are established techniques for their correction. Clear aligners have been proposed as an alternative, improving aesthetics and patient comfort.; **Objectives:** Investigate maxillary expansion with clear aligners in growing patients, comparing the effectiveness of palatal expansion achieved with conventional techniques versus clear aligners in growing patients. Clinical indications and considerations necessary for achieving successful expansion with aligners were also analyzed. **Material and methods:** A literature review was conducted based on articles focusing on maxillary expansion with clear aligner therapy (CAT) and comparison between CAT and traditional techniques. Studies were analyzed to compare treatment outcome, amount and nature of expansion (skeletal or dentoalveolar), and clinical limitations; **Results:** clear aligners were effective in achieving transverse expansion through dentoalveolar mechanism, via buccal tipping. RME produced significant skeletal expansion, particularly in growing patients, while SME worked similarly to CAT. Aligners offered advantages in aesthetics, comfort, and oral hygiene but were limited in their ability to induce important expansion or skeletal changes. Their success also depends on patient compliance and optimized treatment planning, such as attachment, staging, overcorrection, and overingeneering; **Conclusion:** Clear aligners represent a valuable alternative for Mild to moderate transverse deficiencies, especially when dentoalveolar expansion is sufficient. However, they cannot replace RME in cases requiring significant skeletal correction.

KEYWORDS

Dentistry, orthodontics, Clear aligners, Maxillary expansion, Growing patients.

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1. INTRODUCTION

1.1. Background and Context

1.1.1. Maxillary expansion and its relevance

Maxillary constriction is a condition in which the maxilla presents an insufficient transversal width. This means that the upper jaw is too narrow in relation to the transverse dimension of the mandible, forming a transverse discrepancy (1,2). Maxillary expansion is the orthodontic treatment of maxillary constriction; its objective is to correct the malocclusion that makes growing patients suffer from different pathologies, such as respiratory, hygiene, hearing, or space problems (3,4,5). The treatment consists of expanding the compressed arch by increasing its length, giving more space for tooth alignment (6). To perform that treatment, orthodontic appliances need to be used, but many are available, and their selection will depend on different characteristics; the maturity level of the midpalatal suture is one of them (7). Indeed, some traditional palatal expansion appliances produce a skeletal expansion thanks to an unfused palatal suture. The midpalatal suture can close at different time points according to the gender of the patient, their age, or even their facial growth pattern. A study conducted in 2024 concluded that generally, females' sutures mature earlier as much as patients with hypodivergent and normodivergent growth patterns. Usually, the suture is closed in stage C or D at an age ranging between 8 and 20 years old, making those appliances inappropriate for older patients(16, 17). The expansion provided by appliances can also be dentoalveolar, in which case the patient is not necessarily required to be at a certain suture maturation point. When the patient does not present skeletal discrepancies but is affected by a constricted maxilla, the dentoalveolar expansion will be of choice, for example, with slow maxillary expansion appliances like Quad Helix or removable appliances like clear aligners (9).

1.1.2. Usage of Clear aligners for orthodontic treatment

Clear aligners are a more modern, practical, and aesthetically pleasing way to treat malocclusion. They are removable appliances that gained popularity recently, especially thanks to the brand Invisalign, invented in 1997 and commercialized in 1999 in the USA. Those aligners are made of different transparent materials that need to be flexible and resilient, inert, non-toxic, without any odor or taste, able to withstand cleaning, and above all, inalterable in the

buccal environment. One of the materials used for those functions is the Polyurethane foil, with a thickness of approximately 0.75mm (10,11). The thicker the thermoplastic of the aligner, the more forces would be transmitted to the tooth: the thickness is thus selected according to the case and necessity of the occlusion modification. Clear aligners are designed thanks to a CAD/CAM (design and manufacturing realized thanks to a computer) process to achieve a tooth movement between 0.15 and 0.25 for each aligner, which themselves are changed every week or two in most cases (6,10).

1.1.3. Importance of treating maxillary constriction in growing patients

Treating transversal discrepancies problems before it is too late is one of the priorities of orthodontists. While the prevalence of maxillary constriction is situated between 13% to 23% during childhood, the percentage increases to 30% in adults. This demonstrates the importance of treating those problems in time since they tend to persist or even increase into adulthood (12,13). Indeed, even if some muscular patterns can compensate for those skeletal or dento-alveolar problems, they must be eliminated soon enough to allow a physiological growth with a normal growth pattern (4). Beyond aesthetic concerns, early treatment of maxillary compressions is essential to address the underlying cause of patients' problems rather than merely their symptoms, such as periodontal problems or exaggerated display of buccal corridors (14). The best moment to perform maxillary expansion is not a fixed time point identical for every patient. Indeed, the chronological age of the patient needs to be differentiated from their dental age. Dental age is an estimation method dependent on the stage of the tooth maturation and age-related changes of the patient's mouth, such as secondary dentine deposition or even dental radiographs (15). A stable orthodontic discrepancy is an important factor in determining the start of the treatment. The best time to start was determined as the moment when all the temporary teeth have been lost, and most permanent teeth are present in the mouth (14). That time point corresponds to growing patients around childhood or early adolescence, prior to 13 to 15 years old, to prevent relapse (16). It is also really important to note that expansion will be more effective in children due to the greater plasticity of craniofacial sutures during growth (5). Ultimately, the start of the treatment is a decision made by the Orthodontist, the parent, and the patient based on all the factors that impact success, such as for example, compliance with the treatment plan (14).

1.2. Clinical Problem

1.2.1. Prevalence and consequences of maxillary constriction in pediatric and adolescent populations

Epidemiological studies revealed that maxillary constriction is a very common problem in pediatric and adolescent patients. A study conducted in 2018 showed that 7.7% of patient with deciduous teeth or mixed dentition presented a dental crossbite in their childhood (17). Moreover, another study found that the prevalence of maxillary constriction in children was between 13% to 23%, making maxillary expansion one of the most common orthodontic treatments (12).

Correcting transversal discrepancies is not only necessary for the aesthetic and confidence of our patient, but it also presents an important therapeutic goal for their health. Indeed, treating dental discrepancies improves the periodontal states of patients, eliminates buccal corridors providing better facial harmony, and contributes to a better airway space for the patient (13). Maxillary compressions were also proven to affect children's hearing in some cases (3), and cause abnormal pressure habits and buccal respiration (1), leading in the long term to a modification of bone growth patterns in growing patients. In severe cases, maxillary constriction could also affect chewing function, disturbing the patient's alimentation, and cause hygiene problems by making access by a toothbrush or dental floss difficult due to significant crowding (1). This could easily lead to dental health complications such as cavities, loss of teeth, or periodontal problems.

1.2.2. Traditionals approaches and their limitations.

Traditional maxillary expansion appliances are usually classified into two distinct categories: Rapid maxillary expansion appliances (RME) and Slow maxillary expansion appliances (SME). Those classifications are determined according to the rate and intensity of the forces applied, ultimately changing the duration of treatment.

SME works thanks to continuous and soft forces applied over a long timeframe. They have been proven to be significantly less painful than RME, especially at the beginning of treatment (18,19). They can achieve a maxillary transversal width increase of 2.5mm after 9 to 11 months of treatment (19). Quad Helix and W arch expander are examples of SME appliances traditionally used to treat maxillary constriction. Quad Helix (QH) is a fixed maxillary expansion appliance

made of stainless steel wire. Unlike RME, QH can not open the midpalatal suture to provoke expansion. This tends to lead to problems such as accentuated buccal bone loss and gingival recession and, in worst cases, fenestration, but also to root resorptions (20). A W arch expander is an orthodontic appliance made of stainless steel wire shaped like a horseshoe, fixed on molar bands and activated before being placed on the patient's teeth (21). As it doesn't necessarily allow separation of the suture, they can only be used for mild to moderate cases of constriction and tend to present the same complications as QH.

RME are orthopedic appliances fixed on teeth or tissue. They function by intermittent and heavy forces that result in the opening of the midpalatal suture in a short time. RME are able to perform an expansion of the maxillary bone of approximately 8 mm during a course of treatment of a few weeks, or 0.5 mm per day on average (22,23). Some examples of RME are Hyrax or Haas appliances, and surgically assisted rapid palatal expansion (SARPE). In order to expand the maxilla, Hyrax and Haas appliances rely on the separation of the midpalatal suture before its fusion, and are thus only useful on young patients. SARPE can be performed on patients with mature sutures, but requires an osteostomy before the application of the appliance (24). Hyrax or Haas appliances are fixed jackscrew appliances that can be supported by tooth (for Hyrax) or adjacent tissues (for Haas). They are typically made out of acrylic with a metallic screw positioned on the palate of the patient, activated every day by a key (25). They allow an expansion of maxillary bone thanks to a transfer of the load on the midpalatal suture in order to initiate bone remodeling and correct the discrepancies (26). It was concluded in a 2024 study that RME appliances were as effective as Clear aligners except for the molar region, where acrylic appliances were more effective (25). However, due to the rapidity of treatment and the fact that only a certain percentage (1/3 in late adolescence) of expansion is due to the orthopedic separation of the suture itself, those appliances can provoke buccal tipping of the anchor teeth, leading to fenestration or bone dehiscence and gingival recession (16).

1.3.Innovation and Rationale

1.3.1. Usage of clear aligners for maxillary expansion

Nowadays, clear aligner therapy is considered a viable option to treat orthodontic patients for pathologies such as maxillary constriction. As patients' demand for less bulky appliances augment, brands such as Invisalign created removable clear aligners with Young patients in early mixed dentition in mind, able to correct narrow maxilla (27). As mentioned before, clear aligners

are only able to perform or bodily movement, making those appliances more adequate for people suffering from mild to moderate constriction. In those cases, maxillary expansion is performed by augmenting the arch perimeter through transverse expansion and incisor proclination (5) (annex 1). Thanks to controlled bodily movement and buccal tipping, clear aligners have been proven to achieve effective expansion, which allows for gaining space and correcting crowding and even dental crossbite. The efficacy of palatal expansion via clear aligners was proven to be more effective at the premolar level and expansion to be more proficient anteriorly than posteriorly (28). The biomechanical movement allowed by those appliances is performed by progressively augmenting the arch width of aligner trays. Buccal forces and buccal root torque are then applied, provoking a lateral movement of the teeth thanks to attachments that are bonded to the teeth, giving precision to the movement (29). Movement is especially efficient in growing patients, where alveolar remodeling and a limited skeletal effect may happen. Globally, it was determined that with mixed dentition patients, an intermolar width gain of 2mm to 3mm could be achieved (27).

1.3.2. Advantages and challenges of clear aligners compared to traditional methods

Using clear aligners instead of traditional appliances to correct maxillary compression presents some advantages, improving clinical workflow as much as patient experience, but it can also present some challenges.

One of the benefits of clear aligner therapy is the improvement in aesthetic and social acceptance compared to some metallic traditional methods. They are indeed considered a really great option for people looking for a comfortable and discreet alternative, as it is almost invisible and can be taken off if necessary (30). They can, for example, be a perfect option for self-conscious teenagers who wish to avoid noticeable appliances. Clear aligners are also an ideal option to improve the oral hygiene of orthodontic patients. Studies concluded that the use of removable clear aligners allowed better control of biofilm accumulation compared to traditional fixed appliances, inducing a reduction of gingival inflammation and periodontal probing depth (31). Another advantage of clear aligners is the lower risk of demineralization and better detection of caries. White spot lesions are a common complication of fixed orthodontic treatment due to the accumulation of plaque at the appliance level: studies revealed a prevalence of about 2 to 97% in orthodontic patients (32). The improved accessibility and visibility are also beneficial to the dentist as they allow better caries detection and closer monitoring of the treatment evolution, allowing early management if necessary. The facilitated

access to the tooth surfaces for patients is thus a great Benefit, allowing better hygiene procedures, reducing the risk of periodontal disease or cavities (33). It can also be added that more modern appliances allow newer technologies to be used in our daily practices, such as AI monitoring. Some devices scanning the mouth of patients at home allow immediate feedback, thanks to Artificial intelligence, to be sent at the same time to the patient and practitioners on oral health and hygiene, and the evolution of treatment. The precision of those scans is granted thanks to the absence of physical obstacles to the scans that occur in fixed appliances (34).

Of course, clear aligners can also present challenges. The main one is that they are not adapted to every patient. Indeed, clear aligners only provide a tipping or bodily dentoalveolar movement of the tooth rather than expanding the bone itself (23,24). This makes treatment of severe maxillary constriction with clear aligners not a suitable option. Since clear aligners are a removable appliance, the treatment success is also based on the compliance of the patient, which can be a big challenge with some patients, especially pediatric ones (35). The cost of treatment is also superior to that of a fixed oral appliance, representing an obstacle to some patients.

1.3.3. Rationale of the subject

Transversal discrepancy problems are one of the most common malocclusions in children and adolescents. The early diagnosis and treatment of those pathologies are crucial to provide a balanced facial growth, occlusion, or even a correct respiratory space. Traditionally, maxillary expansion has been accomplished using fixed appliances such as Rapid maxillary expander (RME), which, even if proven very effective, create discomfort, hygiene problems, and are overall an aesthetic burden for the patient. Nowadays, the opportunity to respond to those problems by proposing treatments with clear aligners is present. That modern alternative, more comfortable and aesthetic, leads to better patient compliance with the treatment. However, aligners produce dentoalveolar expansion rather than purely skeletal, which can remain a debate on their usage versus regular fixed appliances. Most of the studies on that subject are performed on adults, leaving questions about the best choice for growing patients. Thus, our study aims at evaluating the effectiveness of achieving maxillary expansion on growing patient with the use of clear aligners, to understand the biological and mechanical limitations, and analyze the current indications of their use. Our literature review will thus try to link all research on the use of clear aligners on growing patients in the treatment of maxillary expansion together in order to better understand when that treatment is recommended.

2. OBJETIVES

2.1.Main Objective

The main objectives would be to investigate maxillary expansion with clear aligners in growing patients.

2.2.Secondary objectives

To compare the effectiveness of palatal expansion achieved with conventional techniques versus clear aligners in growing patients.

To determine the clinical indications for maxillary expansion using clear aligners in growing patients.

To analyze the key clinical considerations necessary for achieving successful palatal expansion with aligners, including treatment planning strategies and biomechanical principles.

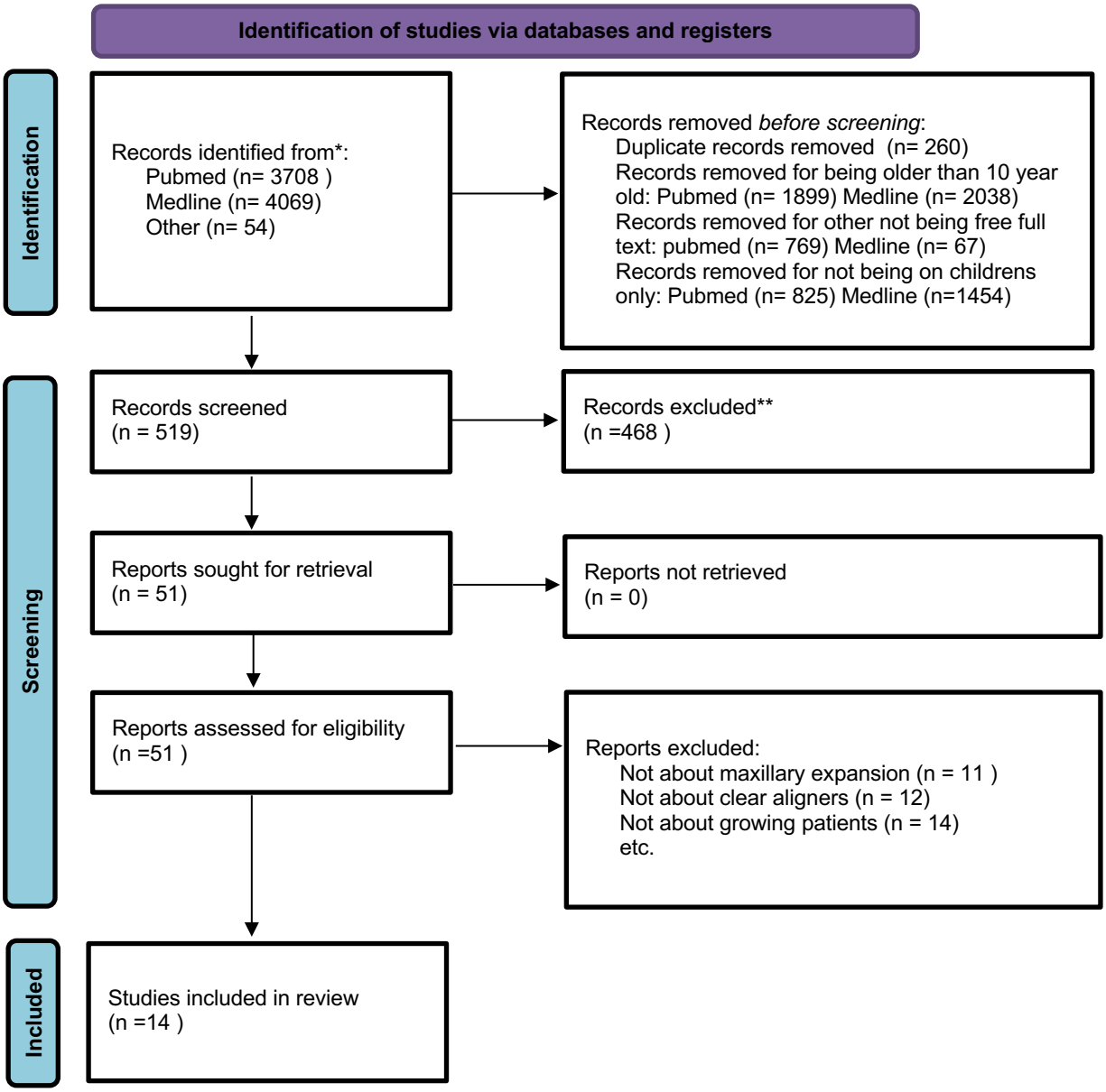
3. MATERIAL AND METHODS

To conduct that literature review, a research of scientific articles was made in the Biblioteca CRAI Dulce Chacón and on databases such as PubMed, Medline, eureka, or Dentistry & Oral Science Source. The research was also conducted using the websites of some clear aligner brands, such as Invisalign or NewSmile, to have direct access to the brand recommendations. The goal was to identify articles about maxillary expansion using clear aligners, exclusively on growing patients. To only get articles of interest, keywords such as maxillary expansion, clear aligners, Invisalign, growing, mixed dentition, pediatric patients, and fixed appliances were used. Excluded parameters have been used to focus the database on research papers that could be helpful for us. Articles that were not based on adult patients or on patients who were not in their growth phase have been excluded. Thus, the keywords “adults” and “grown” were excluded from the research. The advanced research question used in the databases was (“child” OR “adolescent”) AND (“clear aligners” OR “aligner therapy” OR “Invisalign”) OR “orthodontic appliances” AND (“maxillary expansion” OR “Palatal Expansion Technique” OR “transverse expansion”) AND (“orthodontic appliances” OR “traditional orthodontics”).

To be up to date and accurate, only articles that were written less than 10 years ago were selected, meaning published after 2015.

Out of 7831 records identified, 519 were screened, and finally, 14 were selected for this literature review.

The PICO research question (participants, intervention, comparison, and outcomes) that helped find the objective of that study and thus helped to select relevant articles is the following: In pediatric and adolescent patients (participants), is clear aligner therapy (intervention) more adapted than traditional appliances (comparison) in order to perform maxillary expansion (outcome).



4. RESULTS

N= number of participant
GD= gender distribution
F= female
M=male
IFS= Invisilign First System
CAT= clear aligner therapy

	Authors years	Type of study	sample	methods	Objectives	Clinical consideration	Summary	outcomes
1	2021 Levrini L &al (27)	preliminary study	6.9 - 11.2 years old 20N= 12F 8M	Superimposition of maxillary 3D digital models in mixed dentition at T0 and T1 to measure transverse width at multiple level.	Evaluate transverse maxillary changes achieved by Invisalign First.	Digital model superimposition allows precise non invasive assessment of transverse width at multiple levels.	- quantitative framework for transverse dentoalveolar expansion in mixed dentition - dimensional changes of ± 2-4 mm across posterior maxillary regions - early evidence base of aligner interceptive expansion.	mild crowding and small transverse maxillary deficiency: IFS is an alternative to SME.
2	2023 Lu &al (36)	prospective cohort study	6 – 10 years old. 70N (40 RME, 30 invisilign). No GD	Propensy score matching groups of invisalign, RME and natural growth groups. Analyze of digital models at baseline and 6 months.	Compare dental and dentoalveolar expansion produce by Invisilign First and RME to control the growth effect.	Invisalign First provide dentoalveolar expansion but RME remains superior for skeletal transverse deficiency. Treatment choice should depend on skeletal maturity and deficiency severity.	- prove transverse arch development in mixed dentition - reporting transverse dimensional changes (± 2-5 mm) - differentiation between dentoalveolar and skeletal expansion patterns in early treatment.	RME and IFS produce expansion of mixed dentition. Mild to moderate maxillary transverse deficiency: IFS reasonable option, for severe ones RME more effective.
3	2023 Lione Roberta &al (37)	Prospective study	9.4 ± 1.2 years old. 23N= 9F 14M	23 digital 3D models superimposed to measure transversal width at temporary and permanent tooth level.	Evaluate maxillary transverse changes performed by Invisalign first in mixed dentition.	Digital 3D models are reliable for monitoring early transverse development and guiding interceptive orthodontic decisions.	- allow quantitative characterization of early transverse maxillary development with progressive changes going from 2.6mm to 3.7mm across temporary and permanent molars showing an region dependent pattern of expansion.	IFS is effective in growing patient for expansion with better increase at level of upper first deciduous molar. At permanent molar level a rotation around the palatal root allowed more expansion mesially.
4	2023 Galluccio Gabriella &al (38)	prospective study	17 ± 3.2 years old 28N= 18F 15M	Digital models and cephalometrics assesments of adolescents treated with	Evaluate arch development and dental inclination during	Clinical monitoring is essential to control pain, tissue response,	- provide a quantitative framework for transverse expansion accuracy	average accuracy of efficacy of expansion with CAT= 70.88%

				clear aligner assessed to track expansion effect.	aligners treatment.	and patient adaptation.	- predictability of ±70%. - identify differential expression between vestibular and gingival expansion components.	regardless of tooth type.
5	2024 Moravedje TP &al (39)	Comparative study	8.91 6 1.2 years. 80N (40 IFS (15M, 25F) / 40 hyrax (19M, 21F))	Analyze of lateral cephalogram and digital cast before and after treatment with Invisalign first or Hyrax expander and growth match control.	Compare vertical and transversal effect of Invisalign first treatment versus hyrax expanders in mixed dentitions.	Early interceptive orthodontic therapy may optimize growth-related transverse development.	- present distinct development profiles - report maxillary intermolar expansion around 2.5mm for IFS and 4.4mm for hyrax. - contribute to the appliance choice for mild dentoalveolar problems or more pronounced expansion.	IFS is a viable option for correcting mild constriction, with an intermolar width augmentation prediction of ± 2.5 mm.
6	2024 Kim CH &al (6)	retrospective study	8.42 (0.93) 90N, no GD	Pretreatment, prediction by Clincheck and post treatment digital models of 90 patients treated by Invisalign treatment.	Quantify the predictability of maxillary and mandibular expansion using Invisalign system in mixed dentition.	Retrospective data support clinical decision-making for early orthodontic expansion protocols.	- document the transverse palatal development - dimensional efficiency value equal to 64%.	predictability of expansion with IFS depends on arch and tooth type. Predictability and expansion are affected by amount of predicted expansion and tooth attachments.
7	2024 Pamukçu hande &al (25)	Comparative study	Children (no age mentioned) N= 34 IF group 17N= 11F, 6M RE group 17N= 9F 8M	Analyzing of CBCT scans before and after treatment with clear aligners or RME to compare palatal volume and surface.	Evaluate how clear aligners produce changes in palatal morphology compared to RME.	Careful monitoring of oral hygiene and gingival health during expansion therapy is necessary.	- quantify transversal augmentation at multiple levels. - shows dimensional changes between anterior and posterior sectors - mark the non uniform response pattern through the arch.	Acrylic expender and aligners both expanded the intercanine region in growing patients. Lower predictability in 1M than in canines for the IFS group. acrylic is preferred for

								expansion of molar region.
8	2024 Loberto Saveria &al (40)	retrospective study	8.3 ± 1.5 years old 36N= 20F 16M	Digital cast of mixed dentition patients analysed to compare expectation and actual measurement after treatment with Invisalign.	Asses the predictability of Invisalign First maxillary expansion in mixed dentition.	Orthodontic expansion should be individualized based on growth stage and periodontal condition.	- transverse dimensional development - progressive augmentation through treatment phases -stepwise improvement in expansion predictability from early to late treatment stages. - reached 70% at the end of the treatment.	CAT induce expansion, predictability is variable and was <50% during the first series. A refinement phase was required to improve predictability, reaching ±70%.
9	2024 Bruni Alessandro &al (26)	randomized controlled trial	8.12 ± 1.53 years old 39 N= 22F and 19M	Evaluation of digital models and cephalometric of patient randomly treated with RME or clear aligners.	Compare expansion efficiency under controlled randomized conditions.	Interceptive orthodontics can guide physiological maxillary growth.	- volumetrics and dimensional parameters. - augmentation of palatal volume of 240- 530 mm^3 and of transversal width. - contribute to an understanding of 3D maxillary development.	RME present better outcomes than IFS in phase I across all measure. No statistical difference except IFS present greater intermolar width at gingival level indicating buccal tipping.
10	2024 Lin TianW &al (41)	Observational study	8.76 years old average 21N= 10F 11M	Superimposition of intraoral scans using palatal rugae to quantify tooth movement in 3D.	Analyze efficacy and expansion patterns of Invisalign treatment on children.	Early orthodontic treatment may prevent future skeletal discrepancies.	- transverse arch intermolar - planned dimensional changes of 4.1 mm (±1.4 mm). - Actual expansion= 3.0 mm (±1.7 mm).	IFS correct occlusion of mixed dentition patients, widen the circumference of dental arch, and control the torque of incisors.
11	2025 Kurnaz Merve &al (11)	Comparative study	9.5 years old 1N= 1F	Comparison of pre and post treatment digital scans of patient treated with RME or clear aligners.	Compare maxillary transversal changes performed by Clear aligners versus RME.	Biological response should be considered when planning expansion therapy.	- biomechanical response of maxillary expansion thanks to different stress patterns	RPE provoke more stress on palatal region than CAT. Only RPE showed high stress

							produced by appliances. - help identify the mechanisms of dentoalveolar and skeletal pathways.	distribution in the region of the midpalatal suture.
12	2025 Bruni alessandro &al (42)	prospective study	8.72 ± 1.17 years old 40N= 18M, 22F	Longitudinal analyze of mixed dentition digital models to measure transverse movement.	Study real world dentoalveolar expansion achieved with clear aligners on children.	Long-term stability must be considered in expansion protocols.	- tooth specific predictability patterns for expansion - accuracy value of ±68% to 88% depending of the region - higher predictability in anterior regions rather than molar regions.	CAT have a reliable predictability for dentoalveolar expansion for mixed dentition patients. More accuracy anteriorly than posteriorly. Effective for moderate discrepancies.
13	2025 Caruso Silvia &al (5)	Digital Retrospective Analysis	9 ± 2.1 years old 15N= 8F, 7M	evaluation of digital cast to compare planned and achieved expansion using ClinCheck software.	Measure predictability and accuracy of expansion movements in pediatric aligners therapy.	Early treatment improves functional and skeletal balance.	- simultaneous development of both arches at cusp and gingival level - highlight differences between tipping and bodily movement.	Clear aligners are effectives for arch expansion of mixed dentition patients. Good predictability at coronal level. To provoke bodily movement and lower cuspal gingival discrepancies: overengineer buccal root torque.
14	2025 Meuli Simonetta &al (43)	retrospective study	6–10 years 40N= 17M, 23F	Analyze of digital cast after clear aligner treatment and measure of transversal width at different levels.	Quantify transverse dental and alveolar changes.	Oral microbiome monitoring is important during orthodontic therapy.	multidimensional transverse and occlusal expansion with a mean augmentation of 3.3mm for maxillary one.	Effective and predicable dentoalveolar expansion with IFS with better outcomes than the control group.

5. DISCUSSION

5.1 Biomechanics of maxillary expansion with clear aligners on growing patients.

The selected studies explain how maxillary expansion is achieved in growing patients using clear aligners. They address key concepts such as biomechanics of clear aligners, the type of movement they produce, and the role of key elements like attachments.

During orthodontic treatment, tooth movements are allowed thanks to the bone homeostasis, a phenomenon combining bone resorption and formation thanks to compression or tension forces (annex 2)(44). Clear aligners allow an expansion of the maxilla thanks to a movement of tipping of the tooth. That is called dentoalveolar expansion (11). That movement is proven by measures taken at the cusp and gingival height on patients following IFS treatment and traditional RME or SME. When a difference is present with a greater distance at the cusp level, buccal tipping of maxillary teeth is proven. Nevertheless, there exist biomechanical principles applicable to create a correct expansion along with the occlusion. One of them is the rotation around the palatal root of the first permanent molar, permitting a great expansion at the mesial level of the tooth (37). This contributes to one of the most used arch expansion schemes named “molar move first”, as indicated, the molar will first move to create space before aligning the rest of the tooth (41). This gives space for expansion without proclining incisors excessively or extracting the tooth and contributes to better biomechanical properties thanks to the large roots of molars, enabling a great anchorage. Side effects of buccal tipping can also be overthrown by achieving an overcorrection with additional root torque (37). Moreover, even if tipping movements are commonly produced during those treatments, controlled bodily movement can also be achieved. They are indeed created thanks to an overengineering of the buccal root torque of approximately 22-35%, reducing the difference between the gingival and cusps observed points (5). Overengineering is a way of controlling the torque of the tooth while expanding the maxilla, giving the opportunity for the crown to move parallel to its root. The efficiency of the bodily expansion of a first molar was measured at 36.35% by Levrini L & al, meaning that while those movements are hard to obtain, they are realizable (27).

That bodily movement was judged only important in permanent molars by Caruso Silvia, as the deciduous ones are exfoliated (5).

5.2. Treatment strategies influencing the clinical outcome with clear aligners

Some factors, such as tooth attachment designs, expansion protocol, rate of aligner changes, and treatment planification, can influence the results of clear aligner therapy (CAT). Those parameters are essential to guarantee long-term treatment stability.

Introduced in 1988 by Martz, attachment buttons are an auxiliary component that augments the biomechanical capacities of clear aligners and enhances the results of treatment. They are made of composite and composed of 3 parts: an active surface, a passive one, and a base. Attachments are bonded to teeth to facilitate controlled movement, such as rotation or extrusion, and help improve appliance retention and augment predictability (45). They are automatically positioned by the software, generally on buccal and palatal surfaces of posterior teeth, most of the time in the horizontal direction to produce forces and contacts allowing tooth movement (6,37). When a patient inserts their aligners, a contact is made with the active surface of the attachment. This generates a pushing force that is transmitted to the attachment and then the tooth. That force vector allows the tooth to move with controlled movement and force. In the case of expansion, attachment buttons will be cylindrical, positioned on molars, and inclined occlusally. This, associated with additional torque support, will avoid uncontrolled buccal tipping and provide adequate dental movement (45).

Clear aligners also provide a bite block effect thanks to the plastic coverage on occlusal surfaces of molars, increasing the vertical anchorage (37). By managing tooth contacts and excessive forces, it speeds up orthodontics treatment timeline.

Other auxiliary elements can be added to CAT, such as power ridges that are horizontal spaces on aligners, or precision cuts, a plastic notch that accommodates elements like elastics, which provide better control of root movement and tooth torque (38).

Thanks to those strategies, CAT reached a great accuracy and efficiency of around 70%, meaning that most planned expansions were successfully achieved (38).

5.3 Comparison of expansion appliances: Slow maxillary expansion and Rapid maxillary expansion vs Clear aligner therapy

In order to plan a treatment adapted to each patient, a comparison between aligners and traditional techniques needs to be performed. Thus, the efficiency of the clear aligner's maxillary expansion will be compared to RME (rapid maxillary expansion) and SME (slow maxillary expansion) appliances (annex 3) .

RME expansion is mainly a skeletal expansion, associated with an opening of the midpalatal suture, while for clear aligners, it appears to be mainly dento-alveolar without opening the

suture (36,40). The movements performed by RME are described as a combination of bodily movement and buccal tipping at the molar level while clear aligners present mostly coronal tipping (36,37). Nonetheless, bodily movement can be achieved by clear aligners thanks to an overengineering of the palatal root. RME's tipping provokes a molar inclination of around -9.6° while clear aligners provide a slightly smaller inclination of -4.5° to -5.8°(36). This is explained by the fact that RME provokes a bigger expansion faster than CAT, leading to more inclination. As stated, one of the main advantages of RME is the amount of expansion it provides, with around 4.4mm to 5.5mm at the intermolar level. It is thus more effective than clear aligners, which only provide a limited effect of 2mm to 2.8mm enlargement (25,36,39). This suggests that clear aligner treatments are only useful for small expansions of less than 2.5mm (39). When planning orthodontic treatments, predictability is an important factor. It is the capacity to obtain the dental movement exactly as planned. Thanks to direct mechanical activation of the appliance, RME has a high predictability, almost independent of patient compliance, while clear aligners have a more moderate predictability of around 55-72% (6,36,39). Another point of comparison between the appliances is the root control they perform. With RME, it is noticed that root position control is limited during expansion (36). In this perspective, clear aligners tend to perform better thanks to bilateral attachment and buccal root torque. Nonetheless, it is still incomplete (6). Finally, the comfort of the patient is a decisive factor in the choice of an appliance. It is admitted that while RME is often associated with discomfort and hygiene difficulties, clear aligners improve comfort and allow better access for oral hygiene (26,36,43). To conclude, RME is indicated for moderate to severe transverse maxillary deficiency that requires a skeletal correction, and clear aligners are more adapted for mild to moderate transverse deficiency that only requires dental correction (25,26,36,39,40). It is also important to note that clear aligner treatment is only useful for patients with a good compliance level.

On the other hand, SME are clinically more similar to clear aligner therapy. They both provide a dentoalveolar expansion without opening of the palatal suture, with a limited increase of around 2.49-3.58mm (27,42). Similarly to CAT, they are thus more adapted for mild to moderate discrepancies. They are also both mostly based on a buccal tipping movement that makes a molar inclination predictable and limits the radicular control (42). However, root control is slightly improved in CAT thanks to attachment and torque overcorrection. CAT is also surpassing SME for comfort and hygiene parameters, especially for fixed SME, principally for social reasons and cleaning accessibility(42). It is important to indicate that for fixed appliances, SME is mostly independent of patient compliance, while CAT will only show results in willing patients.

It is contemplated that forces generated by clear aligner therapy lead to physiological changes similar to those from SME (27). Thus, while clear aligner therapy (CAT) does not seem to be

appropriate when considerable expansion is required, it is the best option for smaller discrepancies in growing patients. CAT allows control of every tooth at the same time and creates space for permanent teeth by limiting the development of the anterior arch area in order to align the tooth before their full eruption and thus control the unwanted effect that SME provides (42).

5.4 Indication in the treatment of growing patients with clear aligners

Nowadays, young people are more reluctant to go under traditional fixed orthodontic treatment, as much for comfort reasons as social ones (27,46). Treating a patient with clear aligner therapy (CAT) provokes less difficulty in eating, fewer emergencies such as broken appliances, and less missed school days, all leading to a better acceptance of the appliance by the patient (6). Apart from those practical aspects, treating growing patients is beneficial. Indeed, expansion appears to be more predictable in children than in adults, as permanent teeth, especially permanent molars, demonstrate a lower predictability due to their root anatomy and the limited force delivery of aligners (6). Thus, temporal teeth present a better predictability of expansion than permanent ones, with 81,2% for the first temporal molar compared to 69.4% for the permanent one, making temporal and mixed dentition key timepoints for orthodontic treatment (40).

Clear aligners can also be used to replace the first phase of orthodontic treatment, typically performed through an expander or other functional appliance for interceptive goals during growth (27). This provides early improvement of the constriction, allows for maintaining the achieved space during eruption, and, if necessary, a possibility to proceed to the second phase of the treatment plan (37,44). Treating early is then used to acquire the necessary space for the transition between the temporary and permanent dentition. Moreover, growing patients in mixed dentition stages also benefit from features of eruption compensations, that provides necessary space for teeth eruption (37).

Younger patients also represent a special population in orthodontic treatment thanks to their dental particularities. For instance, a patient with a pulpotomy performed with Vitapex on a temporal tooth may present a different root resorption from normal, changing tooth movement features (6). A modified crown shape after a restoration can also affect the tooth movement during treatment, requiring a specific treatment plan to achieve expansion (6).

5.5 Treatment planning and digital workflow considerations

When planning orthodontic treatment and in order to achieve success, the duration and number of aligners used and sofwares are important factors. Most of the time, treatments are planned on software such as ClinCheck thanks to digital casts in ".STL" format, obtained thanks to intraoral scanners such as iTero (36,46). They follow protocols such as "molar move first" to achieve an expansion of around 0.15mm per stage, and at the end of treatment, a cusps to fossa relationship (37,38,40). That space could be achieved by an approach such as digitally planning interproximal spaces around temporal canines (37). Some software can also design aligners to provide compensation for dental eruption thanks to algorithms able to predict the shape and size of erupting teeth, which is particularly useful in the case of growing patients in mixed dentition stages (6).

The duration of those treatment plans can vary and would have an average of 8 to 14 months with aligner changes every 7 days for a total of around 33-37 to 60 aligners, depending on the treatment plan difficulty (27,37,40,43).

Digitally planning orthodontic treatment in CAT allows a previsualisation of the future occlusion by the dentist and the patient before starting the therapy, improving patient understanding of the treatment and its compliance (38).

5.6 Challenges of clear aligner therapy

Clear aligner therapy (CAT) relies almost exclusively on buccal tipping to achieve expansion. When excessive, it can produce some negative secondary effects. Reduction of the alveolar bone crest, recession of the gingival margin, or even bone dehiscence and fenestration are the risks of inadequate treatment planning (27). Palatal expansion on growing patients with CAT represents a challenge due to the fact that maxillary teeth are naturally already more buccally inclined than mandibular ones, especially in temporal dentition (6). In order to avoid those risks, a limit of 2-3mm for each quadrant should be appreciated, staying in the range of the 1-5mm expansion achievable by CAT (38).

Another problem that needs to be faced during CAT is the appliance fit while teeth are erupting and exfoliating. But the personalized manufacturing of those appliances, especially for the Invisalign First System, is designed with younger people in mind to adapt to their malocclusion, such as transverse discrepancies, shorter crowns, and tooth eruptions (37,40).

It should be known that previsualization of the patient's future occlusion, although useful for patient-clinician communication, can also be deceitful for patients since certain types of movement cannot be completely achieved (38).

Patient's treatment compliance is a fundamental part of therapy success. Compliance with CAT corresponds to wearing more than 20h each day the appliance, only taking them off in order to eat (40).

5.7 Limitations of the study and perspective of further research

Despite growing interest in the use of clear aligner therapy (CAT) for maxillary expansion in growing patients, several limitations must be considered when interpreting findings for this review. First, it is important to state that most of the available studies are retrospective or observational with relatively small and heterogeneous sample sizes. This tends to limit the possible generalization of study results. Moreover, many articles focus primarily on dentoalveolar changes through digital models, while three-dimensional skeletal effects are less evaluated, thanks to imaging techniques such as CBCT. This would allow a better understanding of alveolar bone and root movement, but also analyse long term perspective of CAT stability. Another important limitation is the lack of direct comparative studies between clear aligners and other expansion protocols, particularly slow maxillary expansion (SME), which makes it difficult to grant definitive conclusions regarding their relative effectiveness. In addition, variation in treatment protocols used, including aligner staging, attachment designs, and use of auxiliary elements, may influence treatment outcomes and reduce comparability between studies. In order to conduct future research, a focus should be placed on well-designed prospective clinical trials with larger sample sizes and a standardized treatment plan. Studies incorporating three-dimensional imaging with CBCT could provide a better understanding of the skeletal versus dentoalveolar effects of expansion with clear aligners in growing patients. Furthermore, long-term follow-up studies are necessary to evaluate the stability of the provided expansion and to determine the best clinical indications for aligner-based therapy compared to traditional orthodontic and orthopedic approaches.

6. CONCLUSIONS

Clear aligner therapy (CAT) in growing children represents both a clinical opportunity and a challenge. They present undeniable advantages such as being aesthetically pleasing, better accepted among adolescent and preadolescent populations, providing a more comfortable alternative to traditional expansion appliances, and a satisfactory level of oral hygiene access. In patients with mild to moderate dentoalveolar expansion needs, clear aligner therapy represents an efficient and well-accepted treatment option. However, from a biomechanical point of view, clear aligners predominantly produce dentoalveolar movement to obtain maxillary expansion. The literature showed consistent results stating that expansion happened thanks to a buccal crown tipping rather than bodily movement or skeletal expansion.

While it was concluded that the results of slow maxillary expansion (SME) were comparable for mild to moderate transverse discrepancies to CAT, traditional rapid maxillary expansion (RME), such as hyrax stay a more adapted solution in patients requiring significant skeletal correction. It is especially the case in the growing population with open midpalatal sutures. It was determined that while clear aligners were a great alternative to SME, they currently cannot replace conventional orthopedic correction with RME for true maxillary skeletal compression cases. In conclusion, maxillary expansion with clear aligners in growing patients represents a promising adjunctive modality rather than a universal substitute for traditional techniques.

Regarding clinical indications, clear aligners appear particularly suitable for growing patients presenting mild to moderate transverse discrepancies with predominantly dentoalveolar components and high aesthetic demands. Growing patients with temporal or mixed dentitions represent a special population that needs to be studied in order to provide them with treatment plans and appliances adapted to their needs. Growth represents a key moment for maxillary expansion, especially thanks to the high bone plasticity of patients, leading to a higher predictability of clear aligner therapy maxillary expansion.

The effectiveness of expansion with clear aligners is highly dependent of a precise digital planning and biomechanical control. Usage of adequate attachments, bite block effects, careful Clincheck planning are critical factor influencing treatment predictability. Without strict protocol control and patient compliance, the risk of uncontrolled tipping and reduced efficiency increases significantly. Consequently, case selection remains fundamental. It offers significant advantages in selected cases but requires careful diagnosis, appropriate indication, and rigorous

biomechanical planning. As digital orthodontics continues to evolve. Improving material properties, attachment design, and treatment planning algorithms may enhance the skeletal effects and predictability of expansion with aligners. Future high-quality clinical studies are needed to clarify their orthopedic potential and long-term stability.

7. SUSTAINABILITY

A sustainable approach to maxillary expansion with clear aligner therapy require to address environmental, economic, and social factors to allow a long-term perspective of those types of treatments.

7.1. Environmental sustainability

On the environmental level, the advantage of clear aligners is their production form. Digital Workflow, thanks to digital planning and intraoral scanners, allows a reduction of waste produced for impression and conception of the appliances. Moreover, that customized expansion may reduce the need for additional appliances, lowering overall product consumption. Nonetheless, it is important to address the fact that clear aligners are made of plastic materials and need to be changed regularly, generating plastic waste and raising concerns about recycling and material revalorization. To reduce that impact, recent developments have been made about orthodontic recycling programs and research on biodegradable aligner materials.

7.2. Economic sustainability

Clear aligners help reduce appointment frequency thanks to digital monitoring, lowering indirect costs and optimizing clinical time for the practitioner. Thus, even though the initial investment for digital technologies can be high, maxillary expansion with clear aligners remains an economic option for its long-term efficiency and reproducibility.

7.3. Social sustainability

Clear aligners are a less invasive and more acceptable option, improving patients' comfort, oral hygiene, and aesthetics. This contributes to better treatment adherence and overall well-being of patients, improving their satisfaction but also the patient-clinician relationship. This approach aligns with the Sustainable Development Goals (SDGs), particularly SDG3: good health and well-being, SDG9: industry innovation and infrastructure, and SDG12: responsible consumption and production.

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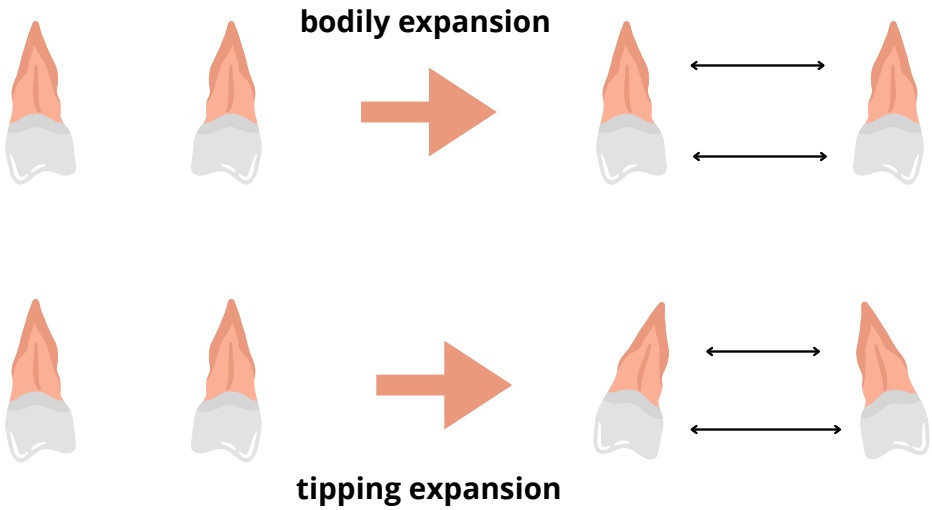
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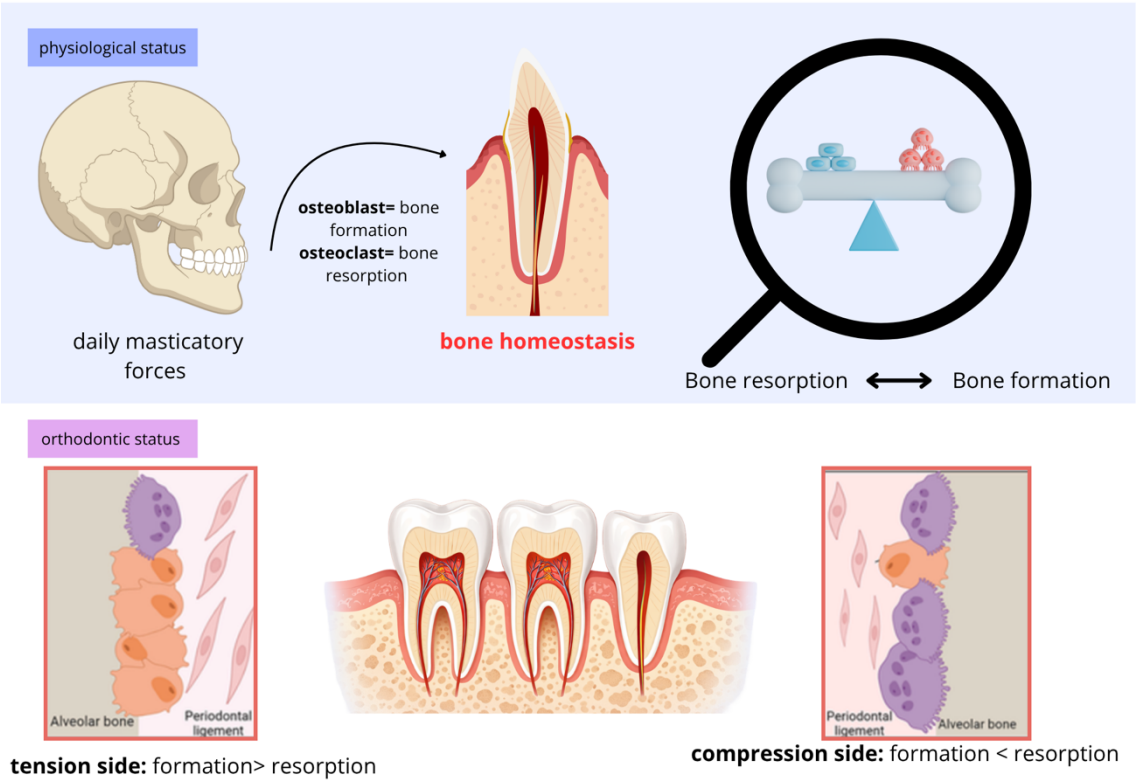
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9. ANNEXES



Annex 1: illustration of bodily expansion versus tipping expansion*



Annex 2: illustration of the bone homeostasis phenomenon *

Annex 3: table of comparison of RME, clear aligner therapy, and SME *

Criteria	RME (rapid maxillary expansion)	Clear aligner therapy	SME (Slow maxillary expansion)
Type of expansion	mainly skeletal, associated with an opening of the midpalatal suture (36).	mainly dento-alveolar without midpalatal opening (36).	Essentially dentoalveolar expansion (42)
Quantity of expansion obtained	Greater maxillary expansion (4.4mm to 5.5mm) at intermolar level (36) (39).	More limited expansion (2mm to 2.8mm) at intermolar level (36) (39).	More limited expansion at intermolar level 2.49–3.58 mm(27)
Predictability of expansion	Thanks to direct mechanical activation of the appliance, RME have a high predictability, almost independent of patient compliance (36).	Clear aligners have a more moderate predictability of around 55-72% (6) (39).	Generally high due to continuous low force application and controlled dentoalveolar response (42).
Type of movement	Combination of bodily movement and buccal tipping at the molar level (36).	Coronal tipping, bodily movement is achievable with overengineering (37).	Mostly coronal buccal tipping (42).
Radicular control	Control of the root position is limited during expansion (36).	Root position is improved thanks to bilateral attachment and buccal root torque. Nonetheless it is still incomplete (6).	Limited, with expected tipping in molars region (42).
Molar inclination effect	Buccal tipping of around -9.6° (36).	Buccal tipping of -4.5° to -5.8° (36).	Mostly buccal tipping (42).

Confort/ hygiene	Often associated with discomfort and hygiene difficulties (36).	Improved comfort and better access for oral hygiene (36).	If fixed can be associated with discomfort abd hygiene difficulties (36).
Indication	Moderate to severe transverse maxillary deficiency that require a skeletal correction (36).	Mild to moderate transverse deficiency that only require dental correction. The patient must show a good compliance level (36) (39).	mild to moderate transverse deficiency in growing patients. Results are Independent of patient compliance if the appliance is fixed (42).

* The figures presented were created by the author of this TFG