GRADUATION PROJECT

Dentistry Degree

ORTHODONTICS FOR ADULT PATIENTS: CHALLENGES AND MODERN SOLUTIONS

Madrid, academic year 2024/2025

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ABSTRACT

Introduction: Adult orthodontics presents unique challenges due to their demands and biological limitations. Modern solutions like MARPE, SARPE or corticotomy have emerged to address these challenges. **Objectives:** Primary objective was to evaluate the efficacy of MARPE, SARPE and corticotomy in adult treatment. Secondary objectives included identification of complications, indications, and duration of treatment. **Methodology:** A comprehensive review over the last 10 years was carried out using databases such as PubMed, following 3 search equations determined from the PICO Question. **Results:** MARPE demonstrated significant skeletal expansion in adults. Complications were minimal, including minor bone loss and buccal tilting. SARPE achieved greater expansion and stayed necessary for patients with advanced skeletal maturity or requiring extensive expansion but presented significant side effects such as tooth tilting and alveolar resorption. Corticotomy accelerated orthodontic movement, reducing treatment time, especially in cases of moderate to severe crowding. Complications for corticotomy included minor gingival recession or bone sequestration. Treatment durations varied, with MARPE expansions typically lasting several weeks, SARPE requiring several months including retention, and corticotomy reducing alignment time significantly. **Conclusion:** MARPE, SARPE, and corticotomy are effective modern solutions for adult orthodontics, with specific indications and potential complications. MARPE emerged as an effective solution for significant skeletal expansion of young adults with less ossified sutures, with minimal adverse effects. SARPE remained essential for patients with advanced skeletal maturity or requiring extensive expansion, and corticotomy accelerated orthodontic movement in cases of moderate to severe crowding.

KEYWORDS

Dentistry, orthodontics, adults, modern solutions, efficacy

RESUMEN

Introducción: La ortodoncia en adultos presenta retos únicos debido a sus exigencias y limitaciones biológicas. Para hacer frente a estos retos han surgido soluciones modernas como MARPE, SARPE o la corticotomía. **Objetivos:** El objetivo primario fue evaluar la eficacia de MARPE, SARPE y corticotomía en el tratamiento de adultos. Los objetivos secundarios incluían la identificación de complicaciones, indicaciones y duración del tratamiento. **Metodología:** Se realizó una revisión exhaustiva en los últimos 10 años utilizando bases de datos como PubMed, siguiendo 3 ecuaciones de búsqueda determinadas a partir de la Pregunta PICO. **Resultados:** MARPE demostró una expansión esquelética significativa en adultos. Las complicaciones fueron mínimas, incluida una pérdida ósea menor y inclinación bucal. El SARPE consiguió una mayor expansión y siguió siendo necesaria para pacientes con una madurez esquelética avanzada o que requerían una expansión extensa, pero presentó efectos secundarios significativos como inclinación dental y reabsorción alveolar. La corticotomía aceleró el movimiento ortodóncico, reduciendo el tiempo de tratamiento, especialmente en casos de apiñamiento moderado a severo. Entre las complicaciones de la corticotomía se incluían pequeñas recesiones gingivales o secuestros óseos. La duración de los tratamientos varió: las expansiones MARPE duraron normalmente varias semanas, las SARPE requirieron varios meses, incluida la retención, y la corticotomía redujo significativamente el tiempo de alineamiento. **Conclusiones:** MARPE, SARPE y corticotomía son soluciones modernas eficaces para la ortodoncia en adultos, con indicaciones específicas y complicaciones potenciales. MARPE surgió como solución eficaz para la expansión esquelética significativa de adultos jóvenes con suturas menos osificadas, con efectos adversos mínimos. El SARPE siguió siendo esencial para pacientes con madurez esquelética avanzada o que requerían una expansión extensa, y la corticotomía aceleró el movimiento ortodóncico en casos de apiñamiento de moderado a grave.

PALABRAS CLAVES

Odontologia, ortodoncia, adultos, soluciones modernas, eficacia

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1. INTRODUCTION

1.1 Definition of Orthodontics

Orthodontics is a specialty of dentistry which seeks to correct the alignment of the teeth in the mouth and the unfavorable positioning of the jaws resulting in an improper bite also known as malocclusions. Malocclusions represents one of the most frequent oral pathologies and gives rise to important complications such as periodontal disease or even higher risk of caries for example.

One of the goals of orthodontics is therefore to prevent the appearance of those complications and consequently improve the well-being of the patient from a functioning point of view, but also for aesthetic purposes by means of different therapies.

Orthodontics focuses on the development of the dento-facial complex, diagnosing, preventing, and correcting irregularities to achieve the most perfect possible result in terms of function and aesthetics and therefore enabling a favorable oral health.(1)

1.2. Historical Evolution of Orthodontic Treatment

From its beginnings to nowadays, orthodontics has undergone major evolutions. Previously used just as an approach to align teeth, orthodontics today is using highly sophisticated techniques, customized to the needs of each patient.

1.2.1. Antiquity and the Middle Ages

Even in the era of ancient civilizations, certain techniques were used in the hope of aligning teeth. In those days, dentists regularly performed extractions for example, to reduce crowding and then used ligatures to hold the teeth in place.(2)

Treatment options were quite limited; extractions were an effective solution often used. Unfortunately, this type of solution could have numerous consequences for the patient's dentofacial complex. Side-effects included bone loss, loss of labial structure and possible consequences on upper airway affecting the breathing of the patient. This solution was therefore highly invasive, with numerous possible consequences.(3)

While extraction was once a routine method of creating space for tooth alignment, modern orthodontics favors non-extraction treatment wherever possible.(4)

1.2.2. 18th century

Less invasive techniques began to be studied and promoted. In 1728, Pierre Fauchard, one of the pioneers of dentistry, described techniques using strips and wires to straighten teeth in “Le Chirurgien Dentiste”.(5)

It was also at this time that the importance of studying jaw growth and development gained importance.(2)

1.2.3. 19th century

Orthodontics gains in recognition as a specialty, sketches of the first appliances are developed, such as plates and splints. The use of wire for ligatures and gum elastics, for example, is introduced by Edward Maynard.(2)

In 1899 Edward Angle is also the first to introduce the classification system of malocclusions, divided in three classes.

Class I defined as a normal occlusion where the upper first molar is correctly positioned in relation to the lower first molar meaning the mesio-vestibular cusp of the upper molar matches with the mesio-vestibular groove of the lower molar.

Class II defined as distal occlusion where the upper first molar is advanced relative to the lower molar; class II includes two subdivisions. Class II division 1 with upper incisors strongly advanced or proclined and class II division 2 with upper incisors tilted backwards or retroclined.

And finally, Class III defined as mesial occlusion where the upper first molar is backward in relation to the lower molar, usually associated with prognathism.(1)

1.2.4. 20th century

Edward Angle left his mark on modern orthodontics, not only by classifying malocclusions but also by developing standardized appliances such as the E-arch and bracket. The use of stainless-steel revolutionized appliance manufacture, while the bonding technique for brackets improved the comfort and precision of treatment. Finally, lingual orthodontics saw the light, improving aesthetics during the treatment.(2,6)

1.2.5. 21st century

Today, orthodontics is a recognized specialty, and treatments are becoming increasingly precise and personalized to meet patient expectations. Orthodontics has seen major technological advances, such as the use of self-ligating brackets to speed up treatment and reduce friction. The use of 3D imaging and virtual planning enables high-precision, personalized treatment.(7)

Transparent aligners such as Invisalign are increasingly used for their comfort and discretion, and finally, artificial intelligence is helping to improve diagnosis and treatment planning.(7,8)

1.3. Orthodontic movement

Orthodontic tooth movement is based on biological and biomechanical principles involving bone remodeling under the effect of applied forces.

When an orthodontic force is exerted on a tooth, it leads to bone resorption on the pressure side and bone apposition on the tension side (figure1) but in adults this

remodeling is slower than in children, due to higher bone density and reduced bone metabolism.

Adding to that tooth movement is influenced by the direction, duration and intensity of the force applied.(9)

So, a balance between force and resistance is required to avoid undesirable side effects such as root resorption.

An anchorage is used to stabilize certain teeth while moving others without altering the overall occlusion. It can be dental, skeletal; with minivis or implants; or extra-oral.

After the treatment a retention phase with retainers is usually essential to prevent recurrence and stabilize the results achieved.

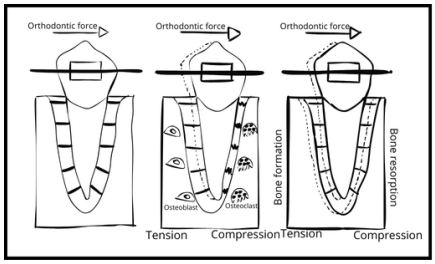

Figure 1: Diagram of the orthodontic movement**.**

1.4. Orthodontic from children to adults

Although the sector of orthodontics is often considered to be mainly focused on children, this is not always the case. Today, orthodontics is becoming a thriving sector in the adult world, for whom comfort is increasingly a priority and physical beauty is becoming more and more important.(10) Orthodontic treatment is also becoming an important solution for some major buccal problems in adults. Breathing problems such as sleep apnea represents a growing issue in adult patients that can nowadays be treated by the means of orthodontics to reduce the obstruction of the respiratory tract and improve sleep parameters.(11)

It also has been mentioned recently that orthodontic treatments could help improve the periodontal condition of some patients.(12)

To achieve these goals, orthodontists use a variety of methods that have evolved over the last few decades. The aim is to become less and less invasive and faster, while giving patients more options and longer-lasting results.

1.4.1. Key advancements

Over the years, several key discoveries have helped make orthodontic treatment for adults possible. For example, Calvin Case, a pioneer in the use of extraoral anchors has extended the field of orthodontic treatment to adults with a technique using external

devices like orthopedic helmets to apply controlled forces to teeth and maxillofacial structures. Or Robert Ricketts, a leader in cephalometric analysis, which is a radiological evaluation method to measure craniofacial structures from a profile radiograph helping in the diagnosis and treatment planning for adults. And many other techniques are still emerging nowadays to improve the treatment of grown-up patients.

Indeed, the use of conventional devices like brackets or aligners for adult patients has become more and more popular, now not only children and teenagers are treated with this type of appliance. Those devices can be effective even in adults but unfortunately, the oral environment of adults is far less adaptive than that of children, and this kind of appliance is sometimes not enough and can have consequences for the oral environment of older patients whose growth has come to an end.(10) Important side effects with an orthodontic treatment are common in some adult patients. Gingivitis, hyperplasia and gingival recession appear to be the most common, which could induce a loosening of the teeth. In fact, even if the treatment of adults with orthodontic advice also used in children is possible some inconvenient and important challenges exist.(13)

1.4.2. Prevalence of Malocclusion in Adults

The prevalence of malocclusions in the adult population is difficult to determine and varies a lot depending on different factors like the age of the population studied that can have an impact, malocclusions can worsen with time or even appear later in life. Also, the origin of the population studied, the sociodemographic and genetic factors will change influencing the frequency. The method of diagnosis can also impact the results and finally there exists different types of malocclusions that will not have the same frequency of appearance in the population. Really precise data are indeed difficult to obtain but for example in Sweden it goes from 17 to 53% which as a matter of fact is a big range which depends on the age of the population.(14) In Brazil another study shows that the prevalence swings around 45%.(15) It seems important to notice that the most common malocclusion types in adults appear to be incisors crowding, lateral gap and increased overbite. However, malocclusions seem to have an important role in adult oral health and that is why the demand for those has increased significantly in the past years.

1.5. Challenges in Adult Orthodontic Treatment

Today, new objectives have emerged in orthodontics: the aim is to use the least invasive treatment to obtain the best possible result, while trying to guarantee a long-term outcome. What's more, when dealing with adult patients, professionals must respect biological limits to avoid causing further harm to the patient. Our aim is to move the teeth into the right position, while respecting the bone and oral tissues. Orthodontists need to

consider certain circumstances not usually considered with children and adolescents. In addition to completed growth, adult patients may have buccal pathologies that complicate treatment.(10) In adult patients it is not only the type of occlusions that matter in fact it is not always possible to reach the ideal situation like we can do in children. The goal here is to reach the best result possible while respecting the limitations of the patient.

1.5.1 Less invasive faster treatment with better outcomes

Orthodontics is constantly evolving, with an unceasing pursuit of more discreet, faster and more comfortable treatments. Even though orthodontic treatment has made great progress, many challenges remain to offer even more effective and less invasive treatments. Researchers and clinicians are working constantly, with the help of new technologies, to develop new solutions and improve patient care.(16)

1.5.2 Biological limits

Adult orthodontics has certain limitations linked to the biology of the individual which influence the duration, efficacy, and predictability of treatment.

1.5.2.1. Bone limit

One of the main limiting factors is the bone limit. Unlike adolescents, adults no longer benefit of an important remodeling of the bone to facilitate dental movements. Therefore, the bone adaptation is slower and the loss of alveolar bone during the treatment can be more pronounced.

The anatomical limits of the movement of the teeth are defined by the cortical plates. If the alveolar bone width is not big enough the movements during the treatment can be limited.

So treating an adult patient means potentially longer treatment times and more difficult tooth movements.(10) Also, the management of treatments requiring maxillary expansion for example can represent a challenge as their maxillary sutures present usually complete ossification.(17)

1.5.2.2. Periodontal disease

Adults are more likely to suffer from periodontal disease, which can compromise tooth retention and limit tooth movement. Patients with bad periodontal statue can present gingival inflammation during the treatment and therefore a more important risk of loose of periodontal attachment, but some studies show that actually if the periodontal statue of the patient is stabilized the orthodontic treatment should not have negative consequences on the periodontal health of the patient.(10,18)

1.6. Modern Solutions Available

Faced with these new expectations, modern diagnostic and treatment methods have emerged.

1.6.1. Digital planification

Firstly, the rise of new technologies enables orthodontists to make a precise diagnosis and prognosis of treatment using digital planning, enabling the professional to visualize treatment progress in relation to the patient's biological limits. This helps to avoid certain undesirable effects.(19,20)

In fact, by combining the use of CBCT and STL files the possible outcomes of the treatments can be visualized.

1.6.1.1 CBCT or Cone Beam Computed Tomography

It is a 3D imaging technique using X-rays to produce detailed images of bone and dental structures. Like that a precise 3D visualization of the maxilla-facial structure is possible.

It is a highly accurate imaging technique that helps dentists and in this case orthodontists to make precise clinical decisions.(21)

1.6.1.2. STL files

In orthodontics, an STL file is a three-dimensional digital representation of a patient's dentition. This file consists of a multitude of small triangles which, when put together, form a precise 3D digital image of the surface of the teeth and dental arch.(19)

1.6.1.3. Protocol

First the data acquisition with CBCT to obtain a detailed 3D image of the patient's dentition. Then dental impressions are digitized to create an STL file of the tooth surface. The CBCT and STL files are imported into specialized software where the two files are aligned to create a complete and accurate 3D image of the dentition.

The orthodontist can now use the software to simulate different tooth movements and select the most appropriate treatment plan facilitating treatment simulation, device manufacturing and surgical planning.(22)

The association of CBCT and STL file permits to simulate dental movements before and during the treatment and predict the place of the root in the bone, like that the bone is still respected while moving the teeth and there is less risk for the root to get out of the bone limit.(20,22)

This use of new technologies allows a digital planification of the situation and therefore a precise 3D visualization. Orthodontists obtain a complete and accurate view of the patient's dentition including tooth roots and surrounding tissues which enables them to predict tooth movements, assess potential risks and optimize treatment times. Therefore, a patient-specific treatment plan is possible.(20)

1.6.2. New treatment options

New means of treatment have also appeared, enabling adult patients to see a better-quality result while being faster and less intrusive. Those new treatments enable adult patients to have an effective orthodontic treatment while facing less complications.

1.6.2.1. Aligners

Aligners represent a modern solution that more and more patients ask for nowadays. Being a removable transparent device, it represents a less invasive solution for adult patients that can wear them without the aesthetic inconveniences of other devices. Unfortunately, even if aligners represent an important progress in the field of orthodontics, orthodontists can't achieve everything they want with them.(23) In fact, they present some biological limits, they can be useful for the treatment of light to moderate malocclusion but have some limits regarding complex malocclusions. For example, if an expansion or important tooth movements are needed, unlike children whose bone is still malleable, adult patients present complete ossification, therefore conventional technique are less effective.

That is why they can be combined with the use of some auxiliary techniques to become successful.

1.6.2.2. Auxiliary techniques

The surgical assisted rapid palatal expansion (SARPE) and miniscrew assisted rapid palatal expansion (MARPE) are a great example of modern solutions combined with aligners available for adult patients. Those techniques offer new perspectives in adult orthodontics, particularly for correcting narrow palates that can be often the cause of the crowding and malocclusions.(24)

In fact, the size of the bone can make it difficult to move the teeth to the correct position in the bone while respecting the biological limits of the patient, modern treatments are available nowadays to permit the treatment without creating more harm.

Depending on different criteria like patient's age and closing of maxillary suture one option might be more appropriate than the other.

Corticotomy is also a surgical technique used in adult orthodontics to accelerate tooth movement and facilitate treatment of complex cases. It involves making superficial incisions or perforations in the cortical bone surrounding the teeth to be moved enabling the bone to remodulate easier.

• SARPE

The SARPE is a technique that targets to widen the palate to correct certain types of malocclusions, especially related to upper maxilla width problems.

In the case of SARPE the expansion is achieved through surgical intervention and the use of an expander. This technique was first developed by Angell a century ago, the surgeon makes a small incision in the palate to divide the maxilla in two halves, allowing a faster and more effective expansion.

This technique is usually used for a bigger expansion that cannot be achieved with mini screws only.

There are no absolute contraindications for these techniques but a generalized periodontal disease or a smoker patient can increase the risk of the loss of gingival attachment. In the case of the SARPE as it is a surgical act some general contraindications like coagulopathy also exist.

Unfortunately, this technique stays an invasive solution that most adults nowadays prefer to avoid as it can be painful and presents some complications.

The SARPE usually goes this way: anesthesia, incision, buccal osteotomy, palatal incision, palatal osteotomy, midline osteotomy, expansion device placement, wound closure and finally activation protocol of the expander to widen the palate.(24,25)

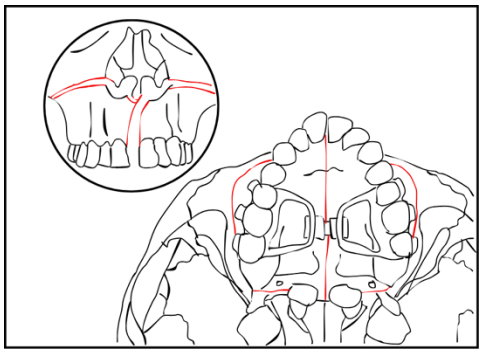

Figure 2: Diagram of the incisions that can be done in SARPE.

• MARPE

The MARPE is defined as a non-surgical technique using mini screws in the palate to expand the maxilla bone. As no surgery is needed it is a less invasive solution than the SARPE which is therefore more and more requested.

Miniscrews are an innovative device for the treatment of adults, used as temporary anchorage devices that can give a stable anchorage in order to move the teeth with precision and enable real bone expansion resulting in improved occlusion and periodontal health.

MARPE is an innovative technique that is beginning to prove its worth. Different types of devices and screws can be used. But its effectiveness has yet to be proven in certain cases. The patient conditions and factors will determine its success.(24,26,27)

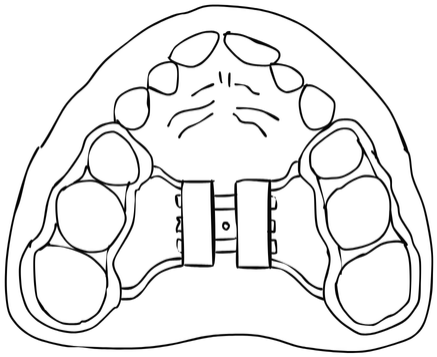

Figure 3: Diagram of an expander.

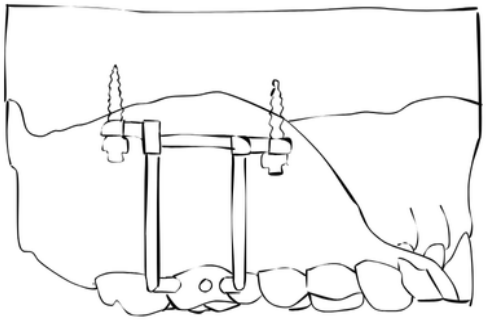

Figure 4: Diagram of an expander from a sagittal view.

- Corticotomy and piezocision

This surgical procedure is based on the RAP (Regional Acceleratory Phenomenon) where the cortical bone (dense outer layer of bone) is partially sectioned to induce a biological response. The realized incisions stimulate osteoclastic and osteoblastic activity responsible for the remodeling of the bone, leading to rapid bone resorption and accelerated regeneration.

In adults, cortical bone is denser and bone remodeling is slower, which slows tooth movement under orthodontic forces. But this technique claims to facilitate complex dental movements and reduce orthodontic forces required, thereby reducing undesirable side effects induced by longer treatment.(28)

The piezocision is also a new technique based on the same principle, but which seems to be less invasive. In fact, where the corticotomy use a gingival flap to expose the bone, followed by deeper incisions in the cortical bone the piezocision uses an ultrasonic device to realize small gingival incisions followed by superficial bone incisions. Therefore, piezocision is a softer, more modern alternative to corticotomy.(29)

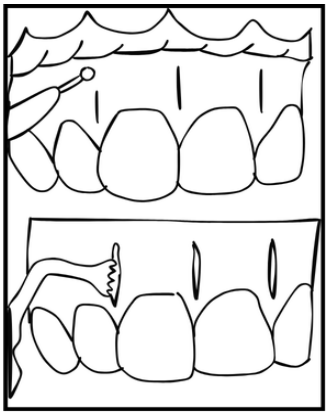

Figure 5: Diagram of a corticotomy (upper) and piezocision procedure (lower).

Those new alternatives of treatment represent an important progress in the field of adult orthodontics as it can make it possible to treat adult patients in better conditions regardless of their biological limits.

1.7. Justification

Orthodontics has been booming among adults for several years now, no longer reserved for children. The reason for this is that more and more people today want to have an aesthetically pleasing smile but also, a better quality of life. And finally, thanks to new technologies, more effective, rapid, and discreet treatments are available to treat adult patients. Despite all this, orthodontists face several challenges when treating adult patients, concerning their expectations and biological limitations. That's why it's important to know and understand the modern solutions available to meet these patients' expectations and respect their biological limits. Those new orthodontic techniques are becoming increasingly essential for treating older patients with malocclusion and skeletal problems without the use of major surgery. These techniques offer many advantages when complex orthodontic movements are required. That is why it seems important to understand better their use, efficacy, and impact.

2. OBJECTIVES

The objectives which this study aims to fulfill are:

Main objective: Evaluate the efficacy of the different modern solutions (marpe, sarpe, corticotomy) available to treat adult patients.

Secondary objectives:

-Identify the possible complications, the indications and treatment duration of those techniques.

3. MATERIALS AND METHODS

In order to meet our objectives and carry out this documentary research work a query was carried out in various scientific research databases in spanish, french and english.

The research databases Pubmed, Medline, Web of science and google scholar were used. Using the Crai Dulce Chacón library of Universidad Europea de Madrid access to obtain full access to the various articles.

The following keywords were selected for the research by the mean of a PICO question (annex1): *MARPE, maxillary expander, Miniscrew assisted rapid palatal expander, Microimplant assisted rapid palatal expander, palatal expansion, maxillary expansion, SARPE, surgically assisted rapid palatal expansion, corticotomy, piezocision, adult, efficacy, success and effectiveness.*

Following our objectives, the following criteria were determined:

In order to select the articles a table of inclusion and exclusion criteria was established

Inclusion criteria	**Exclusion criteria**
-Articles of the last 10 years. 2015-2025 -Written in English, Spanish or French including the keywords and relevant information: adult patients treated under MARPE, SARPE or corticotomy. -Studies using different types of expander designs and different protocols were included.	-Articles published before 2015 -Written in another language than the one selected - Articles not available in their entirety -Patients with systemic diseases, craniofacial syndrome and previous maxillofacial surgery treatments were not included in the research. -Patients under 18 years old were excluded unless it was to compare with adults.

Table 1: Inclusion and exclusion criteria.

The different outcomes were integrated: firstly, the efficacy of the treatment and secondly, the duration, side effects and possible complications. Different types of studies were included such as randomized or non-randomized clinical trials, prospective or retrospective studies and observational studies and case reports.

To search for articles relevant to this study, the following search equations were determined with the selected keyword and put into pubmed:

-(((MARPE) OR (miniscrew assisted rapid palatal expander)) OR (micro implant assisted rapid palatal expander)) AND ((((success) OR (efficacy)) OR (maxillary expansion)) OR (palatal expansion)).

-((SARPE) OR (Surgically assisted rapid palatal expansion)) AND (((((success) OR (efficacy)) OR (effectiveness)) OR (maxillary expansion)) OR (palatal expansion))

-(Corticotomy) AND (((efficacy) OR (effectiveness)) OR (success))

Citation research was also done in google scholar to find relevant articles to include in the study. The articles had to follow the previous criteria table.

4.RESULTS

After performing a PubMed search using the three defined equations, in total 201, 535 and 489 articles were found. After applying the inclusion and exclusion criteria 66, 52 and 42 articles were eligible. After reading the titles and abstracts, 28,13 and 21 articles were selected. Finally, after detailed study of the articles a total of 32 articles were retained for the results. And 2 other articles were included, researched by name on google scholar. The results were then divided into two tables: one regarding maxillary expansion (MARPE and SARPE) and another regarding corticotomy.

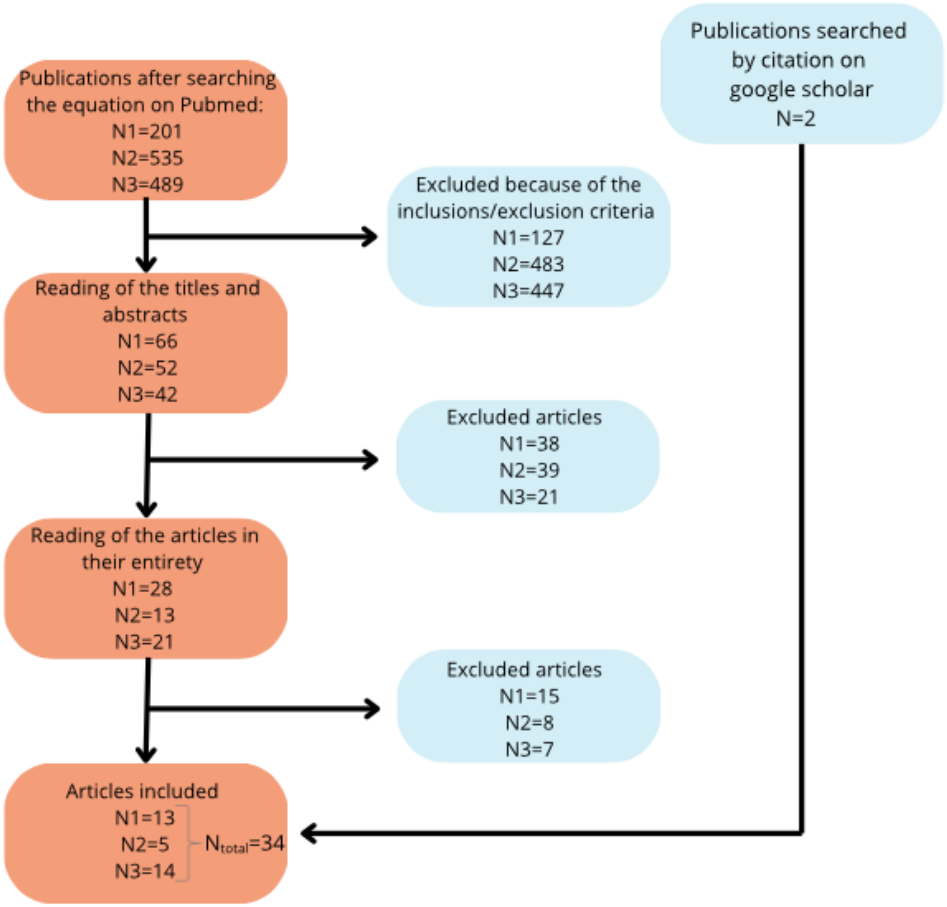

Figure 6: Flow chart.

Article	Date & authors	Type of Study	Number of Patients	Device Model & Mini Screws	Activation Protocol	Treatment Duration	Expansion Gained	Complications	Main Conclusions
1 *(30)*	2022, Kapetanović et al.	Prospective Clinical Cohort Study	34 patients (Mean age 27.0 ± 9.4 years) (8M, 26F)	3D-printed cobalt-chromium D-MED 4 mini-screws (Ø 2.0 mm; 11–13 mm L), bicortical anchorage	0.25 mm/day, weekly monitoring Retention: 3 months	Expansion: 31.7 ± 8 days (21–56 days) Follow-up: 12 months	Total expansion: Molar +6.56 mm, P1 +4.19 mm Nasal cavity +2.07 mm 60.4% skeletal expansion at Molar	Buccal tipping (Molar: 3.88°; P1: 2.29°), minor crown height increase, buccal bone loss (-0.31 mm) 2 failures (device breakage, molar translation)	D-MED provides high skeletal expansion with minimal side effects. MARPE is a viable non-surgical option for late adolescents/adults. Small parodontal impact
2 (31)	2017, Brunetto et al.	Case Report	1 adult patient 22,5y	Maxillary Skeletal Expander and 4 Mini-screws (Ø 1.8 mm; 11 mm L) bicortical anchorage	Initial: 3 activations Daily: 2 activations until desired expansion	Expansion: 22 days Retention: 3 months	Palatal suture opening: 8.8 mm Skeletal expansion: Nasal floor: +8.2 mm, Maxilla:+6.3 mm	Mild molar inclination, slight hyperplasia, minor buccal bone loss	MARPE is a viable alternative to SARPE for non-growing patients with significant skeletal expansion and improved breathing
3 (32)	2021, Winsauer et al.	Consecutive Study	33 patients (18-58 years, mean 29.1)	MICRO-4 Expander, 4 Dual Top Jetscrew	12-week latency, 2 activations/day for 1 week, force-controlled polycyclic activation	Average 81.2 ± 31 days, Retention ≈9 months	Anterior: +5.4 mm, Posterior: +2.5 mm	18.5% complications, 5 patients required surgery (SARPE), inflammation, mini screw deformation	MARPE effective in 84.4% of adults, V-shaped expansion, complications increase with age.
4 *(33)*	2022, Salmoria et al.	Comparative Study	20 patients mean: 24.9 ± 1.8 years 10 Stage D 10 Stage E	Expander PecLab 4 miniscrews (customized)	1/4 turn/12 hours until diastema, then 1 per day	6 months (including retention)	Intermolar width increase: Stage D: +6.6 mm Stage E: +7.1 mm Interpremolar width increase: Stage D: +4.6 mm Stage E: +4.6 mm	6 treatment failures (30%) mostly in stage E, mild inflammation, buccal tipping, bone loss in some cases	MARPE expands maxilla in adults with advanced ossification, better outcomes in Stage D
5 *(34)*	2023, Marín et al.	Prospective study	19: 3 excluded the suture didn't open (24.92 ± 7.60years, 17-40)	Expander Peclab and 4 titanium miniscrews (Ø 1,8 mm, L 7 mm)	In morning: ¼ turn At night: ¼ turn	1.64 months (average), retention : 4 months	Maxillary gain: +3.06 mm, intermolar: +6.37 mm	Molar bone loss, molar inclination increases with expansion	MARPE expansion effective but reduced with age, clinical follow-up required
6 (35)	2021, Oliveira et al.	Retrospective CBCT study	28 patients (22.7years, 15-37)	Peclab expander 4 miniscrews (Ø 1.8 mm, 7 mm anterior 5 mm posterior L)	Right after implant placement: 2/4 turns Daily: 2/4 turns	2-3 weeks expansion, 4 months follow-up	Maxillary expansion posterior: 2.5 mm, anterior: 3.4 mm 71.4% success rate	Failure in patients >30 years, no influence of gender/bi-corticality	MARPE success decreases with advanced age, major influence of suture maturation

					Retention : 4 months				
7 *(36)*	2017, Park et al.	Retrospective CBCT study	14 patients (20,1years ± 2,4)	Modified Hyrax, 4 miniscrews (Ø 1,8 mm, L 7 mm)	1 turn/day (0,2 mm)	mean: 27 days expansion, 38 days in total	IMW(intermolar width) : +5,4 mm, IPMW(Interpremolar width) : +5,5 mm, basal maxillary : +2,0 mm	Buccal tipping (1,1° - 2,9°), buccal bone loss (0,6 - 1,1 mm)	Non-surgical alternative to SARPE with pyramidal pattern

8 *(37)*	2024, Kim et al.	Case Report	1 patient (F), 52 years old	MARPE 4 miniscrews (9 mm L, Ø 2 mm)	1 turn/day (0.2 mm) during 4 weeks, total 42 turns	~14 months in total With other treatments 31 months	IMW: 6.3 mm, Maxillomandibular width: 4 mm	Mild gingival recession, slight crown height increase	MARPE expanded the maxilla in a periodontally compromised patient, maintaining stability without further periodontal damage
9 *(38)*	2016, Choi et al.	Retrospective cohort study	20 patients (10 men, 10 women), 18–28 years old	Hyrax expander, 4 miniscrews (Ø 1.8 mm, 7 mm L)	0.2 mm per two days Slow expansion	Average of 21.6 months total (including post-expansion retention)	Maxillary width: 2.11 mm, IMW: 8.32 mm (retained: 4.43 mm), IPMW: 6.09 mm (retained: 4.16 mm)	9/69 patients failed midpalatal suture opening, 5% miniscrew dislodgment, 13% mobility	MARPE is an effective expansion method, but success rates vary due to differences in suture maturation. Success rate of 86.96%
10 *(39)*	2017, Cantarella et al.	Retrospective study	15 patients (6M, 9F); Mean age: 17.2 years (13.9–26.2)	Maxillary Skeletal Expander(MSE) 4 miniscrews (Ø 1.8mm, 11/13mm L)	2 turns/day (0.25mm/turn) till diastema, after 1 turn/day; Retention for 3+ months	12–36 days of active expansion	MSE activation: 6.8 ± 1.9 mm (4.1–10.5 mm); ANS: 4.8 mm, PNS: 4.3 mm; Pterygopalatine suture split (53% cases)	Slight asymmetry in suture opening; Variability in pterygopalatine disarticulation	MSE achieved parallel midpalatal expansion and separated the pterygopalatine suture in young adults (first time in non-surgical cases); Bicortical anchorage reduced dental tipping.
11 *(40)*	2025, Chen et al.	Prospective longitudinal cohort study	31 patients (6M, 25F); Average age: 26.2 ± 8.2 (16+)	4 bicortical self-tapping miniscrews	1 turn/day (0.25 mm) until desired expansion; Screw fixated as a retainer	Active: 32.1 ± 7.9 days; Retention: 12.2 ± 1.3 months	IPMW: 4.2 ± 1.3 mm; IMW: 6.6 ± 1.7 mm (net gain at 1 year: 2.8 mm)	IMW relapse: 3.8 ± 2.1 mm (60.2%); Skeletal relapse: 0.6 ± 1.2 mm (11.6%)	MARPE provided stable skeletal expansion but some dental relapse; Age, sex did not significantly affect stability

12 *(41)*	2022, Tanaka & ota-Junior.	Case report	1 female (23 yrs, 10 months)	PecLab Expander; 4 miniscrews (Ø 1.8mm, anterior: 5mm L, posterior: 7mm L)	2/4 turn initially, then 2 turns/day for 1 week, reduced to 1 turn/day due to discomfort	Active expansion: ~10 days; Total treatment: 28 months	Maxillary IMW: +9 mm, Mandibular IMW: +8 mm; Maxillary intercanine: +3 mm	Pain, nasal discomfort, headaches, mild buccal tipping of left maxillary molar	MARPE avoided SARPE in an adult; Achieved functional occlusion and stable results at 1-year follow-up.
13*(42)*	2024, Javier et al.	Retrospective CBCT study	30 adult patients (18-34y) (mean: 23.9 ± 4.88 years)	Power MARPE Type 1 Palalign Round Head Type miniscrews, (Ø 1.8mm, 10–16 mm L)	Initial activation: 4 turns/day until interincisal diastema appears Then reduced to 2 turns/day until 1.5 mm overcorrection per side	~1.5 months	Mean increase in maxillary width: 2.61 ± 1.93 mm	No significant complications reported but potential risks include microimplant deformation, fracture, or asymmetric expansion	Younger patients had higher success rates, lower bone density in middle/posterior regions of the nasal spine gave better expansion results. Sex and initial maxillary width did not significantly impact treatment success.
14 *(43)*	2021, Oliveira et al.	Comparative CBCT Study	32 patients MARPE: 17 (22,9y), SARPE 15 (30,4y)	MARPE: Expander with Peclab screws SARPE : hyrax + Partial Le Fort I osteotomy	MARPE: 2/4 turn/day (0,4 mm) SARPE: 1/4 turn (0,2 mm) 2x/day	MARPE: 2 to 3 weeks active expansion SARPE: post-operative follow-up activation until full expansion	MARPE : IMW : +5,25 mm, nasal : +2,92 mm SARPE : IMW : +7,91 mm	MARPE: controlled expansion, slight bone loss SARPE: greater tooth inclination (7°), more alveolar resorption, surgical risks	MARPE offers more parallel expansion; SARPE results in greater molar widening but more tooth tilt and bone loss. Older patients may require SARPE.
15*(44)*	2022, Han et al.	Case report	1 female 35yrs with open bite, and severe transverse deficiency Class III malocclusion	conventional hyrax expander with a 9-mm expansion screw	SARPE to address the transverse deficiency. Presurgical Orthodontic Treatment Orthognathic Surgery LeFort I osteotomy for maxillary impaction and BSSRO for mandibular rotation Hyrax expander activated twice a	Total : 40 months Presurgical orthodontic treatment: 20 months Expander kept in situ for 6 months for retention	Maxillary expansion: 4 mm IMW: +10.4 mm Intercanine width: + 2.6 mm Maxillary skeletal base width: + 6.3 mm	No resorption of root or bone	The patient achieved satisfactory occlusion and a significantly improved facial profile, with stable results at a 1-year follow-up. The treatment was successful in treating the patient's complex orthodontic and orthognathic issues, resulting in a harmonious facial profile and stable occlusion

					day, creating 0.5 mm of maxillary expansion daily				
16*(45)*	2015, Siqueira et al.	Retrospective study	18 patients (6 men, 12 women) mean age of 23.3 years (18-35)	13-mm Hyrax expansion screw	SARME: conservative surgical technique LeFort I osteotomy to approach the midpalatal suture without involving the pterygopalatine suture Screw activated twice daily (1/4 turn each time) until desired overcorrection Appliance remained for 3 months as retainer, followed by acrylic plate for 3 months before fixed orthodontic	Assesment at 3 and 6 months	Increase in transverse widths: First molars: 9.26 mm Second molars: 5.4 mm First premolars: 9.8 mm Second premolars: 9.49 mm Canines: 5.87 mm	Risk of alveolar bone dehiscence Potential for relapse of the open bite and transverse discrepancy over time Dental tipping	The study concluded that SARME is an effective and stable procedure with minimal periodontal risks, though close monitoring of keratinized mucosa and tooth brushing is recommended
17*(46)*	2018, Gürler et al.	Retrospective study	14 patients (6 males and 8 females) mean age 21.3 years (18-30)	Tooth-borne Hyrax appliance	LeFort I osteotomy without down fracture Midpalatal and pterygomaxillary sutures separated, anterior nasal wall osteotomized Hyrax appliance for expansion activated 8turns (2 mm) at surgery end and then deactivated by 4 turns After 1 week activated 2times/day until desired expansion	Assesment pre surgery and at 6 months	Nasal floor width at first premolars and first molars significantly increased. Palatal bone width at first premolars and first molars significantly increased	No nasal septum deviation	This study evaluates the skeletal changes in the nasal and palatal regions following SARPE using Cone Beam Computed Tomography and posteroanterior cephalograms. The findings indicate that SARME effectively increases nasal and palatal transverse dimensions, potentially improving nasal airflow

18*(47)*	2020, Rachmiel et al.	Retrospective study	32 patients (17 males and 15 females) between 19 and 54 years	Tooth-borne Hyrax device	Bilateral transverse L-shaped maxillary osteotomy, Palatal expansion with Hyrax device activated 2times/day (0,5mm), starting on the first postoperative day	Assesment pre surgery, after surgery and at 12 months	transverse maxillary expansion: 6.2 mm at canine 6.4 mm at first molar 1 year postoperative: 5.8 mm and 6.2 mm	Gingival Recession (2) Alveolar Bone Exposure (1) Light relapse No damage to root	The study presents a unique L-shaped osteotomy technique to achieve stable results in treating transverse maxillary discrepancies The procedure was effective with a stable maxillary expansion
19*(48)*	2019, Behnia et al.	Case report	One patient, 21 year old male with skeletal Class III malocclusion, an open bite, and a vertical growth pattern	Tooth-borne Hyrax device Facemask connected to the Hyrax device with elastics for maxillary protraction	SARPE Orthodontic treatment used for alignment and leveling before and after SARPE, Hyrax activated 2times/day for 12 days Facemask was used for 3 months	Total treatment duration: 16 months	Expansion between the maxillary central incisors: +6mm Post-treatment cephalometric analysis showed improvements in skeletal relationships and dental alignment	Patient Compliance Long treatment No gingival recession here	The treatment aimed to correct maxillary transverse deficiency and improve facial aesthetics, resulting in significant improvements after initial attempts at nonsurgical rapid palatal expansion were unsuccessful due to flaring of posterior teeth and gingival recession.

Table 2: Collected Results of the articles about the MARPE and the SARPE.

Article Date & Authors	Type of Study	Number of Patients, Age	Initial Pathology	Protocols of Treatment	Treatment Duration	Results of the Treatment	Possible Complications	Main Conclusions
20 *(49)* 2018, Alfawal et al.	Randomized controlled trial	36 patients (12 males, 24 females; age range: 15 to 27 years)	Class II division I malocclusion requiring extraction of the first upper premolars, canine retraction	Patients underwent piezocision or LAFC(laser-assisted flapless corticotomy) on one randomly selected side, the other side serving as the control Canine retraction done immediately after the surgical intervention using NiTi closed-coil springs	4 months following the onset of canine retraction	Rate of canine retraction higher in the experimental sides compared to the control during the first two months. No significant differences between the experimental and control sides regarding anchorage loss or canine rotation Between piezocision and LAFC in terms of retraction rate, anchorage loss, or canine rotation no significant differences	No harms or significant complications were reported during the study for either piezocision or LAFC	Both methods significantly increased the rate of canine retraction and reduced the retraction time without compromising anchorage or causing significant canine rotation but no significant differences observed between the two techniques
21 *(50)* 2021, Kumar et al.	Prospective study	32 patients in the study group (16 males, 16 females) 26 patients in the control group (13 males, 13 females) Age range: Not specified	maxillary-mandibular protrusion requiring orthodontic retraction of the anterior teeth	Study group underwent corticotomy-assisted en masse retraction, involving selective alveolar decortication and the placement of demineralized freeze-dried allograft mixed with saline The control group underwent conventional en masse retraction without corticotomy	study evaluated the rate of retraction over monthly intervals for 4 months	Corticotomy-assisted retraction showed a higher rate of space closure compared to conventional retraction	No significant complications	Corticotomy-assisted retraction significantly decreased the total length of orthodontic treatment, effectively creating a stable anchorage segment without the need for additional anchorage devices
22 *(51)* 2016, Jahanbakhshi et al.	Clinical trial study	15 adult female patients; mean age: 25 y.o	Patients with need for extraction of maxillary first premolars and maximum canine retraction	Split-mouth: buccal corticotomy performed around the maxillary first premolar on one side of maxilla, the other side was reserved as the control side retraction with simple vertical loop, activated every two weeks Fixed orthodontic appliances with 0.018 × 0.022 slot brackets,	The average time to complete retraction of approximately 4 months	Rate of canine retraction was higher on the corticotomy side (1.8 mm/month) compared to control side (1.1 mm/month). Accelerating tooth movement was most pronounced in the first two months post-surgery	One had bone sequestration, resolved without major issues.No significant differences in root resorption or bone support ratios between the groups	Corticotomy increased the rate of canine retraction compared to conventional methods, particularly in the early stages post-surgery. The buccal corticotomy is a useful adjunct technique for accelerating orthodontic tooth movement

				anchorage stabilized with a miniscrew				
23 *(52)* 2019, Al Imam et al.	Randomized controlled clinical trial	40 patients (11 males and 31 females) mean age of 19.15 ± 3.4 years	Patients with Class II division I requiring extraction of upper first premolars and retraction of upper anterior teeth	Patients treated with fixed appliances Experimental group with piezocision surgery with vertical interproximal micro-incisions and cortical alveolar incisions. Incisor retraction performed with NiTi closed coil springs, with force levels checked every two weeks	Retraction time significantly shorter in the experimental group (8.80 ± 0.89 weeks) compared to control group (11.95 ± 0.68 weeks), 27% reduction in treatment time	Rate of incisor retraction higher in the experimental group (0.74 ± 0.09 mm/week) compared to the control group (0.35 ± 0.04 mm/week). Experimental group showed a greater extent of incisor retraction (6.48 ± 0.51 mm) compared to the control group (4.21 ± 0.38 mm). The experimental group showed less molar anchorage loss and more translational movement of incisors	One patient in experimental group had acute post-surgical inflammation, leading to a 2mm recession of the interdental papilla and delayed retraction No other significant complications reported	Piezocision significantly increased the rate of incisor retraction and reduced the retraction time, while also preserving anchorage and enhancing root torque control
24 *(53)* 2016, Charavet et al.	Randomized controlled trial	24 adult patients: (9 males and 15 females) mean age of 30 ± 8 years	Mild to moderate maxillary and mandibular anterior crowding	Patients randomly allocated to control group with conventional orthodontics or a test group that received piezocision surgery with vertical micro-incisions, followed by placement of orthodontic appliances. Archwires changed every two weeks until full bracket engagement achieved	Overall treatment time shorter in the test group (278 ± 80.2 days) compared to the control group (393 ± 55.7 days), A 43% reduction in treatment duration.	Treatment effectively reduced crowding and improved occlusion in both groups. Periodontal parameters, including recession depth, pocket depth, plaque index, and papilla bleeding index, remained stable and comparable between groups. Radiographic analysis showed no increase in dehiscence, fenestration, or root resorption	Minor scars were observed in 50% of patients who underwent piezocision, primarily as point-shaped scars. No significant periodontal or radiographic complications were observed	Piezocision significantly reduced treatment time and intervals between archwire changes, particularly during the alignment phase, without compromising periodontal health. But minor scars were observed in 50% of the patients who underwent piezocision.
25 *(54)* 2015, Suryavanshi et al.	Split-mouth prospective clinical trial	10 patients (18-35 years)	Large overjet requiring maxillary first premolar extractions	The modified corticotomy procedure performed unilaterally on the maxillary arch, involving vertical bur holes and chisel cuts through cortical bone Equal orthodontic forces applied bilaterally for canine retraction immediately after the surgical procedure	The mean velocity of tooth movement in the modified corticotomy group (1.02 mm/month) compared to the conventional	The modified corticotomy technique resulted in a significant increase in the rate of canine movement No adverse effects such as root resorption, periodontal damage, or loss of tooth vitality were observed on the experimental side after 6 months	No significant complications	Modified corticotomy technique significantly increased the rate of tooth movement without adverse effects on the periodontium or tooth vitality

					group (0.81 mm/month)			
26 *(55)* 2022, Sharmin Sultana et al.	Two-arm parallel group randomized controlled trial	16 patients (mean age 20.98 ± 2.65 years)	Severe anterior maxillary crowding requiring bilateral first premolar extractions	Both groups received fixed orthodontic appliances The piezocision group underwent flapless piezocision corticotomy on the labial mucogingiva between the roots of the anterior teeth The control group received conventional orthodontic treatment	The mean overall alignment time in the piezocision group (123.33 ± 18.23 days) compared to the control group (154.86 ± 22.09 days)	The piezocision group showed a significant reduction in overall alignment time by approximately 20% compared to the control group No significant changes in gingival recession, pocket depth, or tooth vitality in either group Patients in the piezocision group reported mild pain and high satisfaction with the procedure	No significant complications or adverse effects reported piezocision procedure was safe for periodontal tissues and did not compromise tooth vitality Mild pain	Piezocision significantly reduced the overall alignment time by approximately 20% compared to conventional treatment with no adverse effects on periodontal health or tooth vitality
27 *(56)* 2019, Gibreal et al.	Parallel-group randomized controlled trial	36 patients (mean age 20.32 ± 1.96 years)	Severely crowded lower anterior teeth	Experimental group underwent piezocision-based flapless corticotomy, with five guided micro-incisions and localized piezoelectric corticotomies between the six anterior teeth Control group received traditional orthodontic treatment Both groups followed the same archwire sequence for alignment	The mean overall alignment time in the experimental group (53.5 ± 12.5 days) compared to the control group (131.4 ± 38.5 days)	The experimental group showed a significant reduction in overall alignment time by approximately 59% compared to the control group. No significant differences in periodontal parameters were observed between the two groups	No complications reported	Piezocision reduced the overall alignment time by 59% compared to conventional orthodontic treatment, with no reported complications
28 *(57)* 2020, Sirri et al.	Randomized Controlled Clinical Trial	60 patients (19 males, 41 females) mean age of 21.40 ± 1.63 years	Mild and moderate crowding in the lower dental arch	Two groups: the corticision group and the control group Corticision group underwent three radiographically guided incisions on the labial surfaces of the alveolar bone between lower anterior teeth using reinforced scalpels and mallets	Mean leveling and alignment duration in the corticision group of 116.46 ± 15.97 days and the control group of 159.69 ± 13.76 days	27% reduction in treatment time for corticision group No significant differences in periodontal parameters between the two groups	No significant complications were observed in any of the patients in both groups	Corticision significantly reduced the treatment time for leveling and alignment without negatively affecting periodontal health

				Both groups received fixed orthodontic appliances				
29 *(58)* 2017, Uribe et al.	Single-center, two-arm parallel group randomized controlled trial	29 patients (16 experimental , 13 control) mean age of 29-30 years	Mandibular anterior crowding with irregularity index greater than 5 mm	Experimental group had piezotome-corticision with vertical incisions and cortical alveolar incisions followed by orthodontic treatment with self-ligating brackets Control group received conventional orthodontic treatment with self-ligating brackets	Mean time to complete alignment was 102.1 ± 34.7 days for the experimental group and 112 ± 46.2 days for the control group	No significant difference found in the rate of alignment between the two groups	No complications observed in any of the patients in both groups	No significant difference in the time required to correct mandibular crowding between the two methods
30 *(59)* 2020, Raj et al.	Split-mouth Randomized Controlled Trial	20 patients (6 males, 14 females) mean age of 23.18 ± 1.41 years	Treatment for Class II malocclusion,extraction of the first premolar and retraction of the canine	Conventional orthodontics performed on one side (control), while Piezocision-assisted orthodontics on the contralateral side with vertical incisions and cortical alveolar incisions using a piezoelectric device(experimental). Followed by canine retraction with a nickel-titanium closed-coil spring	study period of 7 months, with evaluations at debute, 1 month, 3 months, and 6 months postoperativ ely	Experimental side showed an increase in the rate of canine retraction and an increase in alveolar bone level in the mesial and buccal side Gradual increase in relative attachment level (RAL) and probing depth (PD) from baseline to 6 months in both groups, with no significant difference between the experimental and control side Root resorption comparable between the two sides	No significant complications reported, but there was a gradual increase in RAL and PD in both groups over the study period	Piezocision significantly increased the rate of canine retraction and improved alveolar bone levels without compromising periodontal health
31 *(60)* 2019, Charavet et al.	Randomized controlled trial	24 adult patients (9 males and 15 females) mean age of 27.9 ± 7.6 years	Mild to moderate maxillary and mandibular anterior crowding	Patients were all treated with a customized appliance and randomly assigned to either a test group treated with piezocision or a control group without any additional treatment	The overall treatment time in the test group (278 ± 80.2 days) compared to the control group (393 ± 55.7 days).	Treatment time was significantly shorter in the test group Periodontal and radiographic parameters stayed stable in both the groups	Minor scars were observed in 66% of patients with piezocision No significant periodontal or radiographic complications were observed	Piezocision seems to be an effective method to accelerate orthodontic treatment in cases of mild overcrowding The effect was observed during the alignment phase and a greater efficiency was found in the maxilla The technique may be contraindicated in patients with a high smile line since the risk of scarring exists
32 *(61)* 2021, Greco et al.	Case report	One 22-year-old female	Severe skeletal and dental open	Clear aligners were used for molar intrusion and anterior extrusion	16.3 months	Significant reduction in the SN/Go-Gn angle by 4°	Minimal relapse (0.2 mm) in the intrusion of the	Treat severe open bite combining selective MOPS in the posterior and lateral

			bite, maxillary constriction, and moderate lower crowding	Selective micro-osteo perforations were performed in the molar areas to facilitate intrusion Additional aligner stages were used to refine alignment		indicating counterclockwise rotation of the mandible Achieved a solid Class I bilateral occlusion with normal overjet and overbite Stable results at follow-ups	right maxillary lateral incisor at the 1-year follow-up No signs of apical resorption or root resorption	sectors and clear aligners could predictably control molar vertical position avoiding the use of auxiliary and eliminating the risk of root resorption
33 *(62)* 2023, Mousa et al.	Randomized controlled trial	46 patients (13 males and 33 females) mean age of 20.26 ± 2.17 years in the traditional traction group and 20.39 ± 2.27 years in the corticotomy-assisted traction group	Patients with unilateral palatally or mid-alveolar impacted maxillary canines	Both groups underwent surgical exposure of the impacted canines using closed flap approaches The study group additionally underwent corticotomy procedures during the surgical exposure and a second flapless corticotomy two months post-operatively using piezosurgery Orthodontic traction was applied followed by alignment and leveling with fixed orthodontic appliances	Mean duration of active traction was 9.68 ± 3.24 months in the study group and 6.13 ± 1.81 months in the control group The total treatment duration was 19.98 ± 3.55 months in the study group and 14.23 ± 1.95 months in the control group	The velocity of traction movement was significantly greater in the study group (1.15 ± 0.35 mm/month) compared to control group (0.70 ± 0.33 mm/month) The duration of the active traction and the overall orthodontic treatment were significantly shorter by 36% and 29%, respectively The bone support ratios of the aligned canines and adjacent teeth did not differ significantly between the two groups The amount of root resorption of the adjacent lateral incisors was similar in both groups	One patient in the study group experienced bone sequestration which resolved without major issues. No significant differences in root resorption or bone support ratios	The traction movement velocity of the palatally impacted canines can be increased using minimally-invasive corticotomy-assisted orthodontic treatment. The side effects of the acceleration procedure were minimal and almost similar to those of the traditional technique.
34 *(63)* 2021, Fernandes et al.	Randomized controlled clinical trial	47 patients (19 males and 28 females) mean age of 20.7 years (15 to 38 years)	Canine retraction required	Extraction of maxillary first premolars followed by canine retraction Three groups formed: G1 (AC vs. Control), G2 (PZ vs. Control), and G3 (AC vs. PZ). AC involved full-thickness mucoperiosteal flaps and corticotomies around the canine.	Treatment duration up to 6 months, with measurements every 2 weeks	No significant differences in canine distal movement between AC and control in G1 PZ showed lower cumulative measurements than control from the 2nd to the 24th week in G2 In G3, PZ showed lower measurements than AC from the 16th to the 24th week	One patient experienced bone sequestration associated with PZ, which resolved without major issues. No serious harms were observed during the study	AC and PZ were not effective to accelerate maxillary canine retraction and did not induce a distinct pattern of bone remodeling markers. The findings suggest that these procedures may not be beneficial for accelerating this specific type of orthodontic movement.

				PZ involved vertical incisions with piezoelectric tips without suturing				

Table 3: Collected results of the articles about corticotomy and piezocision.

5. DISCUSSION

This review of different articles on modern solutions for treating adult patients highlighted several challenges and potential solutions with regard to MARPE, SARPE and corticotomy.

5.1. Effectiveness of Treatments

In the first table we can see that MARPE was defined as a non-surgical solution and therefore an effective alternative to SARPE for achieving significant skeletal expansion in adults with minimal adverse effects. As seen in Kapetanović's research in 2022(30) with an expansion of 6.56mm at the level of the first molar on average in 34 patients or Brunetto's case in 2017(31) reporting an 8.8mm expansion of the palatal suture in a 22-year-old adult. These data coincide with this systematic review from 2021(64), which shows that MARPE can achieve significant transverse maxillary expansion in adults past the age generally recommended for performing this method. With a success rate of 92.5%.

Moreover, as Salmoria's study in 2022 shows(33), the success of MARPE is even greater in patients with less advanced skeletal maturity.

Research by Oliveira in 2021(35) and Javier in 2024(42) shows that the effectiveness of this technique is influenced by skeletal maturity and ossification of the palatal suture. The results are generally better in young adults.

Numerous studies show that age and skeletal maturity are crucial factors in the success of orthodontic treatment.(65)

But in reality, this is not always systematic, and some cases are successful despite the patient's advanced age, as seen in this case report by Kim in 2024(37) who treated a 52-year-old patient with MARPE, and the patient had no additional periodontal damage despite his compromised periodontal statue.

SARPE, on the other hand, appears to remain indispensable despite the advances made by MARPE. Indeed, its efficacy in patients with very advanced skeletal maturity or requiring very extensive expansion is significant. In Han's 2022 case report(44), a 35-year-old woman received a 10.4mm molar expansion with SARPE.

Clearly, a debate exists between the less invasive approach of MARPE and the efficacy of SARPE for more complex cases. Indeed, in the comparative study by De Oliveira in 2021, an expansion of 7.91 mm for SARPE versus 5.25 mm for MARPE was found at molar level(43).

Studies on corticotomy and peizocision have proved their effectiveness in contributing to bone remodelling and therefore to orthodontic movement, accelerating this movement. These techniques are effective for canine retraction and reducing treatment time.

Jahanbakhshi's 2016 study(51) shows a retraction rate of 1.8mm per month for corticotomy versus 1.1mm for control, while Al Imam's 2019(52) study also shows a faster retraction rate with piezocision. On the other hand, Fernandes' 2021(63) study found that these techniques were not effective in accelerating movement. In addition, this 2017 review(66) demonstrated that piezocision is a safe and effective method for accelerating orthodontic movement in adults in the short term, but that clinical studies are needed to see the long-term effects.

Some of the studies in this review have also pointed to the effectiveness of new technologies such as CBCT for diagnosis and personalized treatment planning in orthodontics. CBCT enables 3D visualization of oral structures to improve clinical decision-making. In Javier's 2024 study(42), it is mentioned that assessment of bone density with CBCT prior to treatment is important to the efficacy of treatment with MARPE.

5.2. Complications

Complications vary depending on the treatment.

MARPE generally presents few complications such as slight buccal tilt or minor bone loss as seen in studies by Kapetanović in 2022(30) and Salmoria in 2022(33). Kapetanovic found an oral bone loss of 0.31mm in average. Moreover, as seen in the De Oliveira study in 2021(35) failure rates seem to increase with age after 30 years old. Javier's 2024 study(42) also points to the possibility of asymmetric expansion. On the other hand, Kim's case study(37) shows that a patient with compromised periodontal health is unlikely to suffer greater damage.

SARPE, on the other hand, presents the possibility of tooth titling as seen in De Oliveira's research in 2021(43), with an average dental tilt of 7 degrees, or the possibility of alveolar resorption. On the other hand, Siqueira's study(45) mentions that there are normally no periodontal risks with SARPE, but that close monitoring is necessary.

Corticotomy and piezocision appear to be safe in general, but still present certain possible side effects such as gingival recession or bone sequestration. The study by Al Imam(52) showed a gingival recession of 2mm in one case of piezocision.

5.3. Indications

Indications for these treatments depend on age, skeletal maturity and the complexity of the case.

In general terms, MARPE would be more suitable for young adults with less ossified sutures and lower bone density, like mentioned in Salmoria(33) and Marín(34) studies, while SARPE would be recommended in cases of greater expansion, advanced age or

failure of expansion by other methods like said by De Oliveira(43) Han(44) and Behnia(48).

Finally, corticotomy would therefore be indicated in cases of moderate or severe crowding in adults to accelerate the movement. Accelerating treatment time and thus improving patient compliance like seen in Alfawal(49) and Sirri(57) studies.

5.4. Treatment duration

Treatment duration is crucial for patients who want faster results and inducing fewer complications.

MARPE enables expansion to take place in a relatively short time, usually within a few weeks or months. Chen's 2025 study(40) shows an average expansion period of 32 days, and Winsauer's 2021 study(32) around 81 days. Expansion is generally rapid, but depends on the extent of expansion required, the number of turns in the protocol and the patient's characteristics.

SARPE, although quite invasive, allows significant expansion in a short period of time, but must be followed by a retention period for ossification of the suture, as seen in Han's case report in 2022(44). In general, treatment with SARPE lasts several months, preceded and followed by orthodontic treatment as seen in Behind's case report in 2019(48).

Piezocision and corticotomy therefore make it possible to reduce the duration of treatment, especially in the early stages like mentioned in Jahanbakhshi article(51). Charavet's 2016 study(53) showed that piezocision reduced treatment time by 43%, and Gibreal's 2019 study(56) by 59%, the active retraction period generally lasting a few months. This systematic review(67) coincides with our results showing that the groups treated with corticotomy showed reduced treatment times compared with conventional treatments.

5.5. Limitations and Future Perspectives

This review presents certain limitations. First, some of the included studies were case reports and are therefore less reliable. In addition, some studies presented very small samples and short follow-up times, which may affect the results. In addition, differences between devices, treatment protocols and miniscrews placement can lead to differences in results and complications. Further research should be performed on larger populations with standardized protocols and longer follow-up periods, to gain a better understanding of the stability and side-effects of these treatments.

Finally, new technologies and digital planning may improve the precision and personalization of treatments. Allowing orthodontists to improve results and reduce complications.

6.CONCLUSION

The aim of this study was to evaluate the efficacy of modern orthodontic solutions available to treat adult patients, more precisely MARPE, SARPE and corticotomy. The secondary objectives were to evaluate side effects, treatment duration and indications.

1.Firstly, the results of this review showed that MARPE is an effective alternative to surgery, allowing a significant skeletal expansion with few complications and no additional periodontal damage. This technique is highly effective in patients with less advanced skeletal maturity. SARPE therefore remains an essential solution for patients with more advanced skeletal maturity or requiring significant expansion.
Corticotomy has been shown to be an effective solution for facilitating and accelerating orthodontic movement in adults, thereby reducing treatment time. This technique is indicated for moderate to severe crowding, improving treatment time despite adult bone density.

2.Complications vary from one treatment to another and from one individual to another. MARPE presents only a few possible complications, such as slight tilting and minor bone loss, although there is a higher failure rate with advanced age or high bone density. SARPE seems to present more risks, such as greater tooth tilt or alveolar resorption in some patients. Corticotomy, on the other hand, seems to lead only to minor complications such as slight gingival recession or bone sequestration. All techniques appear to be periodontally safe for patients as long as they are monitored during treatment.

Indications for these different treatments are therefore based on age, case complexity and skeletal maturity. Marpe seems to be more recommended for young adults, with less ossified sutures, while SARPE would be a more invasive solution reserved for older patients, requiring greater expansion, or in the event of failure with other techniques.
Corticotomy is therefore indicated to accelerate tooth movement in cases of overcrowding and very often canine traction.

Treatment times vary greatly between patients, influenced by the complexity of the case, the expansion required and the patient's characteristics. But these techniques remain a fast solution for adult patients, with treatment generally taking several months. These techniques are usually combined with other orthodontic treatments, such as aligners, to resolve the entire case, thus extending the treatment period.

MARPE, SARPE and corticomy are modern techniques which, combined with conventional techniques, offer promising solutions to orthodontic challenges in adult patients. But even if these techniques offer important advantages, it's important to note that their application needs to be personalized to patient needs and characteristics. That is why the integration of digital diagnosis and planning is becoming an essential aspect in performing more effective results with fewer complications. Finally, future researches need to refine these methods and explore the long term effects of these techniques, while further integrating new technologies to improve the care of adult patients.

7.SUSTAINABILITY

Modern orthodontic treatments to treat adult patients such as SARPE, MARPE or corticotomy meet several sustainable development objectives.

Economic: these techniques represent more cost-effective alternatives, reducing the need for more invasive surgical techniques and thus lowering health costs associated with post-operative care and long hospital stays. This could help making advanced orthodontic treatments more accessible.

Environmental: Digital technologies like CBCT and the use of 3D imaging can reduce waste and radiation exposure. It could also improve dentists' precision for diagnosis.

Social: Improving orthodontic care for adult’s patients boosts patients' self-esteem and their quality of life, therefore helping to reduce social inequalities. And by offering less invasive and more comfortable treatment options, we're responding to the needs of adult patients, improving the inclusivity of our services.

In conclusion new orthodontic innovations make it possible to provide effective, inclusive care while reducing their environmental impact and promoting a positive economical and social aspect.

8.ANNEXES

P	adult patients
I	use of MARPE, SARPE or corticotomy
C	left open to broaden the study and collect more information
O	Primary: efficacy Secondary: side effects, duration, indications

Annex 1: Table with the terms of the PICO question used.

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