FINAL DEGREE PROJECT

Degree in Dentistry

EFFECTIVENESS OF EXTRA-ALVEOLAR MINISCREWS IN ORTHODONTIC TREATMENT.

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RESUMEN

Introducción: El control del anclaje es fundamental en el tratamiento ortodóntico y los mini-tornillos extraalveolares han ampliado las posibilidades terapéuticas al proporcionar anclaje esquelético independiente de las unidades dentarias y de la cooperación del paciente.

Objetivos: Evaluar si los mini-tornillos extraalveolares permiten manejar eficazmente las alteraciones del espacio en la arcada durante el tratamiento ortodóntico e identificar las situaciones clínicas en las que su uso aporta mayores beneficios.

Metodología: Se realizó una revisión exhaustiva siguiendo criterios de elegibilidad previamente definidos. Se efectuaron búsquedas en MEDLINE y en bases de datos académicas complementarias. La estrategia de búsqueda combinó términos libres, terminología controlada y operadores booleanos relacionados con ortodoncia, anclaje esquelético, distalización, cresta infra-cigomática y estante bucal. La selección siguió las directrices PRISMA y los datos relativos a efectividad, estabilidad, tasas de éxito y complicaciones fueron sintetizados cualitativamente.

Resultados: Se incluyeron trece estudios. La evidencia muestra distalización maxilar y mandibular predecible, corrección eficaz de maloclusiones de Clase II y casos seleccionados de Clase III, altas tasas de éxito y estabilidad y complicaciones generalmente menores y manejables. Los hallazgos fueron relevantes en casos que requerían distalización significativa o un anclaje reforzado durante el tratamiento ortodóntico. Se observó recaída limitada cuando existían datos de seguimiento disponibles.

Conclusiones: Los mini-tornillos extraalveolares constituyen un método de anclaje eficaz y fiable, especialmente en tratamientos que requieren distalización significativa y menor dependencia de la cooperación del paciente, ampliando las posibilidades de tratamiento ortodóntico no quirúrgico.

PALABRAS CLAVE

Odontología, Ortodoncia, Anclaje esquelético, Mini-tornillos extraalveolares, Distalización.

ABSTRACT

Introduction: Anchorage control is fundamental in orthodontic treatment and extra-alveolar mini-screws have expanded therapeutic possibilities by providing skeletal anchorage independent of dental units and patient cooperation.

Objectives: To evaluate whether extra-alveolar mini-screws effectively manage orthodontic arch space alterations and to identify clinical situations in which their use provides maximum benefit.

Methods: A comprehensive review was performed following predefined eligibility criteria. Searches were conducted through MEDLINE and complementary academic databases. The search strategy combined free-text terms, controlled terminology and Boolean operators related to orthodontics, skeletal anchorage, distalization, infra-zygomatic crest and buccal shelf. Study selection followed PRISMA guidelines and data regarding effectiveness, stability, success rates and complications were qualitatively synthesized.

Results: Thirteen studies were included. Evidence shows predictable maxillary and mandibular distalization, effective correction of Class II and selected Class III malocclusions, high success and stability rates and generally minor and manageable complications. Findings were relevant in cases requiring significant distalization or reinforced anchorage support during orthodontic treatment. Limited relapse was reported where follow-up data were available.

Conclusions: Extra-alveolar mini-screws constitute an effective and reliable anchorage method, particularly in treatments requiring significant distalization and decreased dependence on patient compliance, expanding non-surgical orthodontic treatment possibilities.

KEYWORDS

Dentistry, Orthodontics, Skeletal anchorage, Extra-alveolar mini-screws, Distalization.

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1. INTRODUCTION

1.1 Acquaintance with key concepts.

This comprehensive review covers the issue of the extra-alveolar (in Greek “extra-“ signifying outside, “alveol” referring to air sac and “-ar” designating “pertaining to”, taken together, these roots refer to an entity being outside the alveolus, which will be explained in more detail later) titanium mini-screws (1) (devices embedded in the maxillary bones to ultimately support a kind of oral orthodontic device) (2) assessing their effectiveness (here, ability to deliver absolute/near-absolute anchorage) (3).

1.2 Key factor in biomechanics.

Anchorage in Orthodontics is a decisive factor for many treatments, especially because mechanical principles are central in this field (4).

Anchorage refers to the ability to counteract undesired tooth movement caused by orthodontic forces. According to Newton’s third law, any force applied to move a tooth produces an equal opposite reaction on the anchorage unit. Effective anchorage is therefore essential to avoid anchor loss, which could negatively affect treatment progress and final outcomes (4).

1.2.1 A step in therapeutic evolution.

Orthodontic treatments have progressed from conventional dental and extraoral devices to the implementation of skeletal Temporary Anchorage Devices (TADs) (5), particularly mini-screws, providing a new treatment approach that may now be essential in more advanced cases, where a conventional relative anchorage (anchorage by the adhesion/friction of a device in the oral cavity), might not be sufficient (4).

1.2.2 The orthodontist's best ally.

Many treatments, such as anchorage-based removable devices, rely heavily on patient cooperation. When patient compliance is irregular, insufficient or completely absent, treatment progression can be significantly delayed, the planned biomechanics may not evolve as expected and unwanted complications may arise (2,5).

This adds to the limitation imposed by the anatomical references which directly influence treatment quality. This includes restrictions on force application, sometimes requiring extraoral devices, along with the volume and minimal thickness required by certain materials (2).

When mini-screws are used instead, several of these previously mentioned constraints can be considerably reduced and, in some cases, become clinically insignificant.

1.2.3 The practical foundation of mini-screws.

The insertion of mini-screws is done through a minimally invasive clinical procedure. It requires a precise prior bone morphology and surrounding anatomical structures assessment to ensure safe placement and sufficient mechanical stability, and, in case of an inconclusive preliminary study at the selected site, complementary clinical examination and radiographic evaluation may be needed.

After the standard antiseptic preparation, local anesthesia is then administered at the target site (4).

The screw is then introduced directly through the mucosa, unlike conventional implant surgery that generally need soft tissue flaps. In high-density cortical bone areas, a small initial perforation can be performed to facilitate insertion and decrease the risk of screw fracture, or self-drilling screws can often be inserted without prior drilling (4).

The mini-implant is then progressively advanced using a hand driver until firm engagement with cortical bone, providing the primary stability (early stability achieved by an implant at the insertion time) required for orthodontic anchorage. The insertion direction should be meticulously monitored, since an oblique

trajectory increases bone contact while reducing the risk of damage to dental roots or adjacent anatomical structures. This leads to the final orientation of the screw head being adjusted according to the biomechanics required for the planned tooth movement (4).

Because stability is more directly related to mechanical principles than to osseointegration, orthodontic forces can usually be applied shortly after placement. As any surgical procedure, maintenance of adequate oral hygiene and clinical follow-up is very important, especially to prevent soft tissue inflammation and maintain anchorage stability throughout treatment. (4)

The placement sites of extra-alveolar mini-screws involve high site discrimination according to anatomical regions offering greater cortical bone support. In the maxilla, one important site is the Infra-Zygomatic Crest (IZC), corresponding to a reinforced bone area extending from the zygomatic process toward the posterior teeth, presenting increased cortical thickness favourable for anchorage stability (4). Similarly, at the mandibular level, one of the most commonly used sites is the Mandibular Buccal Shelf (MBS) region, that represents a bone plateau located buccally to the molar roots and along the external oblique line, where bone width generally increases toward the posterior region. It presents adequate cortical thickness and attached gingiva, facilitating screw placement, although anatomical variations may occur among individuals showing the importance of a previous adequate clinical palpation and radiographic examination. (4)

Among extra-alveolar insertion sites, the IZC and the MBS are widely used because of their favourable bone characteristics, although other anatomical regions can also be considered and will be further discussed in the following sections.

1.2.4 A whole new spectrum of clinical applications.

As mentioned previously, at certain points in the clinical workflow, the placement of orthodontic titanium mini-screws can be compared to prosthetic implants: they are placed precisely within a specific spatio-temporal framework, subsequently to the treatment planning, with the purpose of providing useful support for the main treatment plan.

The development of orthodontic skeletal enhanced-anchorage screws in orthodontics had enabled their progressive integration into a wide range of treatment modalities.

This field includes anchorage that can be considered direct (the forces are directly transferred between the anchorage unit and the tooth or dental segment being moved, the most commonly used) or indirect (synergy with the adhered tooth) (6). Various auxiliary devices can be connected to them for different mechanical purposes, such as tooth intrusion, extrusion, space closure, molar distalization and up-righting: some are individual auxiliary elements such as elastic chains, elastic threads and coil springs, while others are fixed appliances themselves, such as Hilger's pendulum (6), Hyrax expanders for which the biomechanics have been so profoundly enhanced by this interplay that it gave rise to "MARPE" (Mini-implant Assisted Rapid Palatal Expansion) (7) and even removable appliances, giving rise to hybrid treatments such as mini-screws-coupled aligner procedures (8).

Regarding the removable appliance coupling, although there is no direct anchorage, through elastics or the previously mentioned devices, we can easily imagine that this TAD can even lead to mechanisms similar to hybrid fixed-removable dentures (9) as screw-supported (relationship between appliance base and supporting structures, oppose intrusive movements directed to the appliance) or screw-retained (dental prosthesis inherent quality to resist the dislodgement forces, oppose extrusive movements, by adhesion and cohesion) (10) therapeutic approaches in the future, if the need arises, due to its high versatility leading to a very broad therapeutic range.

1.3 Comparison with other treatment options.

The advantages of mini-screws, which contribute to an improved mechanical environment, are particularly relevant in orthodontic cases with greater biomechanical demands.

However, like any therapeutic approach, its efficacy must be critically evaluated and compared with other treatment options across multiple clinical contexts to gain clinical validity and be indicated in cases offering the greatest therapeutic benefits.

1.3.1 Mini-screws design diversity.

Considering now the implantation sites for those titanium anchors, three main types can be distinguished.

Palatal screws are used in the previously mentioned MARPE procedures (7) focusing more on the transverse (medio-lateral oral dimension done by a horizontal section) plane of the mouth (11).

Interradicular mini-screws are the most commonly used configuration (4) as indicated in the name being introduced between two roots or more, focusing more on the vertical plane (supero-inferior axis done by a frontal section).

Extra-alveolar mini-screws are implanted in areas such as the IZC area, retromolar pad, anterior ramus border, or the MBS (3,12) and are mainly used for sagittal (antero-posterior field by medial section) correction that is the one studied in this work.

1.3.2 Increasing the scope.

As mentioned previously, the main focus of the extra-alveolar type of mini-screws, that are the ones studied here, is the sagittal plane and particularly intra-quadrant movements. Their specificity is that they are introduced at some anatomical points parallel to the roots of the teeth (12).

Tooth migration is a very frequent phenomenon after a space alteration in the dental arches, as a compensatory mechanism aiming to establish a new occlusal stability avoiding increased occlusal forces on the remaining teeth (13).

Distalization is defined as the movement of teeth within a quadrant in a distal direction (in other words, pulling them in the midline antithetical direction), can, on the other hand, only be induced by orthodontic forces application (14), and it is the most common procedure for this screw system.

Mesialization, meaning the application of force in the opposite direction, thus, toward the midline (15), can either be physiologic after dentition eruption, also referred to as mesial drift or “driftodontics”, or induced by space alterations such as tooth avulsion (13,16). However, therapeutically, it is usually achieved with palatal screws that will not be discussed here.

Based on this, the main target population includes patients with Angle Class II molar malocclusions (12), in which the lower molar is positioned more distally compared to the upper molar (17), in contrast to the ideal occlusal relationships described by Andrews' six keys of normal occlusion (18), as well as patients with Class III malocclusions (19), here identified as cases in which the lower molar is positioned more mesially than the upper molar (17). These may be dental (resulting from tooth misalignment), skeletal (related to bone growth and position of the jaws) (20) or functional (also called pseudo-Class III, of neuromuscular origin or related to premature occlusal contacts, having a highly better prognosis but need to be treated before evolving to skeletal classes) (21), the last one will not be discussed here since the mini-screws are not indicated for this type, which usually relies on occlusal adjustment and myofunctional therapy (22).

1.4 The patient's best friend.

One of the main strengths of this procedure is that it may represent an alternative to orthognathic surgery (19) which offers several advantages.

First of all, psychological considerations. Patients may experience apprehension and/or recall previous traumatic procedures, sometimes even subconsciously (23). Another aspect is the social impact of convalescence, particularly because of facial inflammation (23).

Another consideration is pro-operatory metabolic alteration or toxicity: general anaesthesia adds some adverse effects and complications by causing cellular imbalance contributing to apoptosis (a term designating physiological programmed cell death, but here, we have an induced process caused by their inactivity). (24)

This is in addition to the typical complications associated with surgeries of this magnitude as post-operatory pain, pro-operatory and post-operatory haemorrhage, nausea and vomiting and post-operatory infections (23).

1.4.1 Potential hindrances in the therapeutic workflow.

Despite being a promising emerging innovation, Orthodontic mini-screws, like any therapeutic approach, present certain drawbacks and possible complications that can be distinguished between pro-operatory, post-operatory and post-treatment. At the time of mini-screw insertion, possible complications include compromised primary stability, persistent post-anaesthesia pain, local haemorrhage, nasal cavity penetration, mucosal breakdown and alteration of adjacent nerve pathways (25). Then, during the postoperative healing phase, we can include pain, soft-tissue scarring with persistent granulation tissue, delayed bleeding, acute and chronic mucositis, soft tissue outgrowth, anchorage loss and adjacent root perforation (25).

Finally, among post-treatment complications occurring during the "explantation" of the device, the following can be distinguished: wound healing alteration, implant fracture (depending on the diameter, material selection and angulation during the insertion), bone loss and pulp necrosis of adjacent teeth (25,26).

2. OBJECTIVES

2.1 Primary objective.

To determine whether arch space discrepancies can be effectively managed with extra-alveolar mini-screws.

2.2 Secondary objective.

To identify the clinical situations in which their use provides the greatest clinical benefit.

3. MATERIAL AND METHODS

3.1 Review design

This investigation relies on a structured documentary review to identify, select and analyse existing scientific evidence on the use of extra-alveolar mini-screws in orthodontic anchorage and their associated characteristics.

All methodological steps were defined in advance and described in sufficient detail to ensure that the review process can be replicated by other researchers.

3.2 Information sources.

The bibliographic search was conducted through the Bibliotheca CRAI Dulce Chacón (CRAI Dulce Chacón Library) and the MEDLINE electronic database providing access to various scientific resources. Additional relevant articles were acquired from complementary online scientific platforms.

3.3 Exploration route across the literature.

The literature exploration procedure combined free keywords with Boolean operators (AND, OR, NOT) to identify studies focusing on extra-alveolar mini-screws and orthodontic anchorage. Controlled terminology was applied across the MEDLINE database when available, while free-text terms were applied through CRAI Dulce Chacón Library portal and complementary platforms.

The main terms used in the search included: Orthodontics, Mini-screws, Skeletal anchorage, Extra-alveolar mini-screws, Absolute anchorage, Distalization, Buccal shelf, Infra-zygomatic crest, Effectiveness, Stability and Success rate.

When available, MeSH (Medical Subject Headings) were applied in the MEDLINE database to increase search precision and ensure that relevant indexed concepts related to extra-alveolar mini-screws and orthodontic anchorage were captured.

The final search equation applied in MEDLINE combined Orthodontic and skeletal anchorage terminology as: “(orthodontic OR orthodontics) AND (miniscrew OR “mini-screw” OR “temporary anchorage device” OR TAD) AND (“infrazygomatic crest” OR “buccal shelf” OR extra-alveolar).”

This equation was adjusted, when necessary, across platforms to maintain search sensitivity while ensuring relevance to extra-alveolar mini-screw anchorage. Additional filters were applied to refine the research, restricting studies to human subjects with full-text availability and publication dates were limited to the last ten years to ensure strict inclusion of modern clinical evidence.

3.4 Eligibility conditions.

This investigation is designed to assess, in orthodontic populations seeking enhanced anchorage reinforcement, whether the use of extra-alveolar mini-screws offers improved effectiveness, stability and clinical safety compared with conventional anchorage techniques including dental anchorage during orthodontic treatment.

The inclusion criteria were defined in advance to ensure appropriate study selection. These included studies involving orthodontic patients requiring anchorage reinforcement or anchorage-based treatment strategies, the use of extra-alveolar mini-screws (including MBS, IZC and similar locations), comparative or descriptive clinical studies, studies reporting results on effectiveness, stability, success rate and clinical safety, studies written in English or Spanish and full-text availability.

The exclusion criteria included in vitro, ex vivo and animal in vivo studies, purely technical descriptions without clinical data and articles published more than 10 years ago.

Case reports were generally excluded due to their low level of evidence, but some specific ones were retained when they provided clinically relevant data regarding extra-alveolar mini-screw placement techniques as a complement to higher-level clinical studies.

3.5 Article selection workflow.

The selection process followed a three-stage screening strategy.

Initially, all records were reviewed by title to eliminate clearly irrelevant publications.

They were then filtered at the abstract level according to predefined eligibility criteria.

Finally, full-text versions of the remaining articles were examined in detail and those meeting inclusion criteria were retained.

The exclusion reasons at the full-text stage were systematically documented and the overall workflow of the selection process has been illustrated using a PRISMA 2020 diagram in the results section.

3.6 Data extraction.

The collection of data was performed using a structured template adapted to the characteristics of each study.

For every included article, the following information was collected when available: author, year of publication, sample characteristics, type of extra-alveolar mini-screw used with its anatomical placement site and when applicable comparison groups as conventional anchorage methods.

Outcome measures related to effectiveness, stability, success rate, reported complications, safety aspects and the main conclusions of each study were also recorded.

All extracted information was organised in tabulated format to allow comparison of the findings.

4. RESULTS

4.1 PRISMA study selection flow diagram.

The literature research conducted on MEDLINE and the Dulce Chacón University Library identified fifty-one records. After the removal of two duplicates, forty-nine records remained for title and abstract screening.

Twenty records were directly excluded due to irrelevant titles despite containing keywords and sixteen others were excluded at this stage as they did not meet the predefined eligibility criteria, mainly due to language limitations (title in English only at the homepage), non-clinical or simulation-based study designs, absence of clinical outcomes data or lack of relevance to extra-alveolar mini-screw effectiveness.

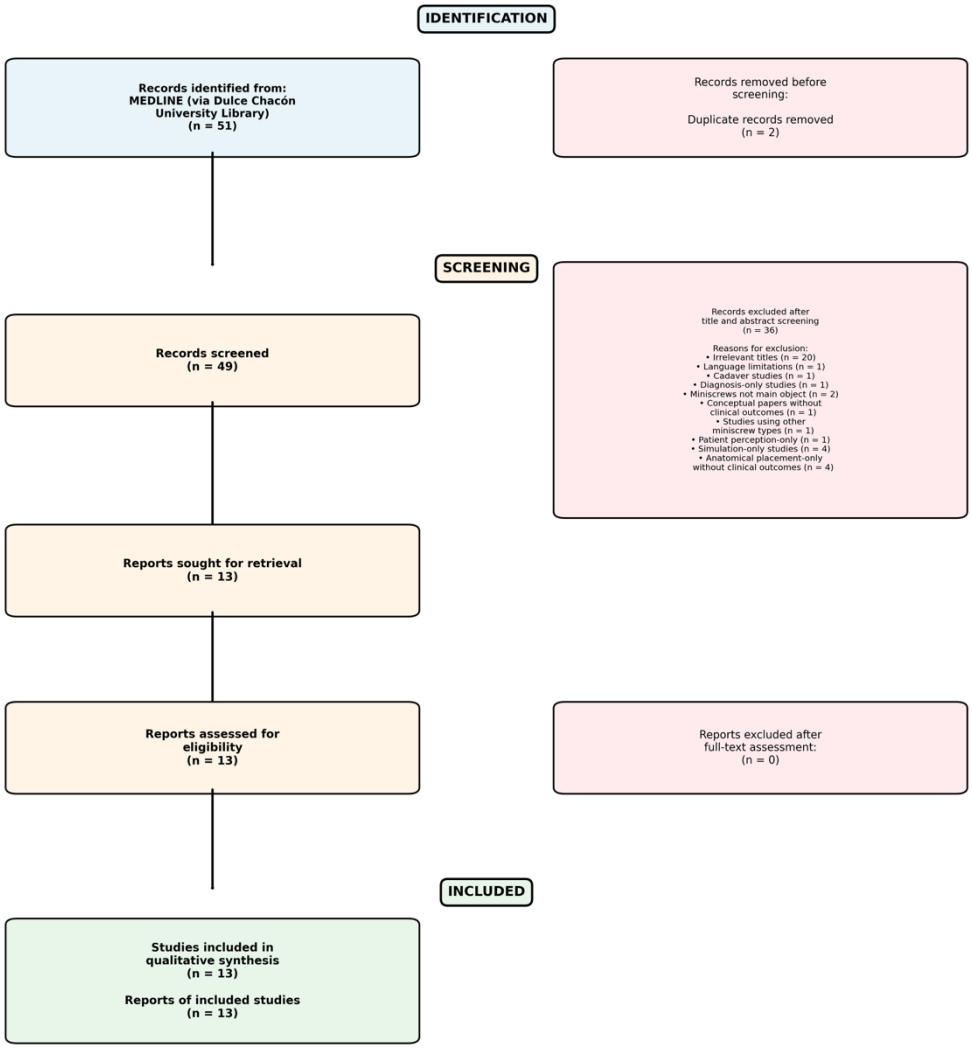
Thirteen full-text articles were subsequently evaluated for eligibility.

All studies met the inclusion criteria and none were excluded after full-text evaluation. Consequently, thirteen studies were included in the qualitative synthesis of this comprehensive review.

The whole study selection process has been illustrated according to the PRISMA 2020 flow diagram.

PRISMA 2020 Flow Diagram

Systematic Review on Extra-Alveolar Miniscrews for Orthodontic Anchorage



Flow diagram depicts the flow of information through the different phases of the systematic review. It maps out the number of records identified, included and excluded, and the reasons for exclusions.

Adapted from: Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.

4.2 Comparative overview of the included studies.

A tabulated format was adopted to provide a clearer visual comparison of the selected studies.

As mentioned previously, specific points were recorded: the main characteristics, treatment approaches, mini-screw placement sites, clinical applications, success rates, complications and follow-up durations of the included studies, all of which have been summarized in **Table 1**. Moreover, the studies were organized within the table according to the main clinical themes to facilitate the analysis from the results to the discussion section.

Table 1. Characteristics and outcomes of studies included in the comprehensive review.

Study	Years	Sample size	Screw site	Treatment goal	Clinical application	Placement technique	Success/Stability	Reported complications	Follow-up duration
Ceratti et al. (27)	2024	n = 1182 patients (40 studies)	Palatal, buccal and IZC TAD sites	Maxillary molar distalization for Class II correction	Mini-screw-supported distalization	TAD-supported appliances with rigid or non-rigid mechanics	Effective molar distalization with comparable stability across sites	Complications varied among included studies	Variable among included studies
Bechtold et al. (28)	2020	n = 38 patients	Inter-radicular mini-screws (not strictly extra-alveolar)	Evaluate long-term stability of total arch distalization	Mini-screw-supported total arch distalization	Elastomeric chains applied from mini-screws to anterior hooks	Mean molar distalization: 4,2 mm with minimal relapse during retention	No major complications reported	Mean follow-up: 42 months
Afify et al. (29)	2021	n = 22 patients	IZC (extra-alveolar)	Maxillary molar distalization in growing patients	Distalization using IZC mini-screw or headgear	Two IZC mini-screws with coil springs delivering force	Class II correction achieved in both groups, mini-screws effective without compliance requirement	No complications reported	No post-treatment follow-up reported

Wu et al. (30)	2018	n = 20 patients	IZC (extra-alveolar)	Evaluate effects of maxillary distalization	Maxillary distalization for Class II correction	IZC mini-screws placed with immediate loading and sliding mechanics	Class II corrected with mean molar distalization 3-4 mm	Minor soft tissue swelling reported	No post-treatment follow-up reported
Rosa et al. (31)	2023	n = 25 patients	IZC (extra-alveolar)	Evaluate effectiveness of total arch distalization	Maxillary distalization	Two IZC mini-screws with elastomeric chains	Class II correction achieved, mean molar distalization 4 mm with intrusion control	No complications reported	No post-treatment follow-up reported
Sarul et al. (32)	2022	n = 92 patients (184 mini-screws)	MBS (extra-alveolar)	Evaluate screw size influence on stability	Mandibular distalization in Class III camouflage treatment	MBS mini-screws placed lateral to molars	Larger screws demonstrated higher stability than smaller screws	Inflammation and screw mobility reported	No post-treatment follow-up reported
Nguyen et al. (33)	2025	n = 1 patient	MBS (extra-alveolar)	Non-surgical correction of skeletal class III	Mandibular arch distalization	MBS mini-screws placed lateral to molars	Successful distalization achieved, mild relapse at 24 months	No complications reported	24 months
Nguyen & Vo. (34)	2025	n = 1 patient	Palatal and MBS (extra-alveolar)	Correction of unilateral Class III subdivision	Asymmetric distalization and space closure	Palatal and MBS mini-screws allowing controlled asymmetric distalization	Successful correction achieved with stable occlusion	No complications reported	12 months post-treatment
Katyal et al. (35)	2025	1683 IZC mini-screws	IZC (extra-alveolar)	Evaluate success rate and stability factors of IZC mini-screws	Anchorage for retraction, intrusion and distalization	Various clinical insertion protocols through studies	Overall success rate approximately 92%	Screw mobility and inflammation reported in some studies	Variable among included studies
Basafa et al. (36)	2024	n = 744 patients (2619 mini-screws)	Multiple extra-alveolar sites	Evaluate success rate according to placement site and screw size	Skeletal anchorage for orthodontic tooth movement	Extra-alveolar mini-screws placed and immediately loaded	Overall success rate 79%, highest success in palate and MBS	Screw mobility requiring removal reported	Mean use duration 17 months

Song et al. (37)	2022	n = 32 patients	IZC (extra-alveolar)	Determine optimal IZC insertion sites and angles	Anatomical guidance for mini-screw placement	CBCT bone thickness measurements at different insertion angles	Optimal bone thickness observed at recommended insertion heights and angles	No complications reported	Not applicable
Tavares et al. (38)	2022	n = 58 patients (116 sites)	IZC (extra-alveolar)	Evaluate bone availability for IZC insertion	Anatomical guidance for mini-screw placement	Tomographic measurements at various insertion angles	Optimal bone availability identified at recommended insertion sites	No complications reported	Not applicable
Shyagali et al. (39)	2021	n = 32 patients	Alveolar mini-screws	Evaluation of soft-tissue changes after anterior retraction	Anterior retraction	Mini-screws used for anchorage vs conventional reinforcement	Mini-screw group showed greater soft-tissue improvement compared to conventional	No complications reported	No long-term follow-up reported

5. DISCUSSION

5.1 Effectiveness of maxillary distalization.

Since correction of arch space alteration constitutes the primary objective of this review, evaluation of distalization effectiveness is therefore fundamental to determine if skeletal anchorage truly improves arch space management in clinical practice.

As mentioned previously, extra-alveolar mini-screws are mainly indicated for this distal movement, which, from a maxillary point of view, correlates perfectly with the correction of Class II malocclusion.

Several included studies, such as those conducted by Ceratti et al. (27), Afify et al. (29), Wu et al. (30) and Rosa et al. (31), were then precisely selected due to their relevance in the evaluation of the effectiveness of extra-alveolar mini-screw

anchorage in achieving controlled molar or total arch distalization without dependence on conventional dental anchorage.

The included studies showed that extra-alveolar anchorage allows predictable molar and even total arch distalization, while reducing unwanted movements seen with conventional anchorage. In addition, clinically significant Class II correction can be achieved without dependence on patient compliance or extraoral appliances, and when follow-up data were available, treatment results showed minimal relapse suggesting acceptable post-treatment stability.

Ceratti et al. (27), in their study, reported that mini-screw-supported distalization achieved effective molar movement with stability comparable across different anchorage sites, supporting its clinical applicability for Class II correction.

Similarly, Afify et al. (29), Wu et al. (30) and Rosa et al. (31) each showed that the use of IZC mini-screws enabled successful maxillary distalization, resulting in clinically significant Class II correction without dependence on extraoral appliances. The reported distalization values from those studies were generally in the range of approximately 3-4 mm, sufficient to achieve sagittal correction while preserving treatment control. In addition, Bechtold et al. (28), although involving inter-radicular rather than extra-alveolar mini-screws, demonstrated that mini-screw-supported total arch distalization remained stable during retention, with only minimal relapse observed over follow-up periods, providing complementary evidence on post-treatment stability.

Together, available evidence supports the use of extra-alveolar skeletal anchorage in the maxillary arch as a reliable method for posterior tooth movement, directly contributing to correction of arch space discrepancies.

5.2 Effectiveness of mandibular distalization.

To correctly analyse the distalization effect of the mini-screws, it is important to verify the hypothesis at the level of all the components of the jaw, the focus now shifts to the mandible, especially as space management and sagittal correction in the lower arch traditionally remain more limited due to anatomical and biomechanical constraints.

For this purpose, the studies of Sarul et al. (32), Nguyen et al. (33) and Nguyen & Vo. (34) were therefore included because they primarily focused on mandibular distalization achieved through extra-alveolar skeletal anchorage placed in the MBS, allowing assessment of whether this approach can represent a reliable alternative to extraction or surgical treatment in selected Class III and asymmetric cases. However, patient selection remains critical due to anatomical limitations and variability in distalization potential.

Similarly, Nguyen et al. (33) demonstrated that skeletal anchorage permits distal movement of the mandibular dentition with acceptable control of tooth movement and minimal dependence on patient compliance, enabling sagittal correction without surgical intervention.

Nguyen & Vo. (34) further showed that controlled asymmetric distalization combined with space closure can successfully correct unilateral Class III subdivision cases while achieving functional occlusal relationships.

Additionally, Sarul et al. (32) contributed evidence that MBS mini-screw stability was sufficient to support distalization mechanics, with larger screw dimensions associated with improved anchorage stability, reinforcing the predictability of this approach.

Two of the included publications corresponded to case reports, which represent lower levels of evidence due to limited sample sizes. Nevertheless, they were retained due to their direct clinical relevance, as they provide detailed documentation of treatment mechanics, indications and post-treatment outcomes in situations where mandibular distalization was successfully performed using MBS anchorage. These reports illustrate practical applications of the technique in complex or asymmetric malocclusions and provide useful clinical information, complementing data obtained from studies with larger populations, such as that of Sarul et al. (32).

Across those studies, mini-screw-related complications were minimal or absent. Nguyen et al. (33) and Nguyen & Vo. (34) reported no significant complications, while Sarul et al. (32) mainly observed minor inflammatory reactions and occasional screw mobility, highlighting the need for careful clinical monitoring during treatment.

Follow-up data, when available, indicated acceptable post-treatment stability, with Nguyen et al. (33) reporting only mild relapse after 24 months and Nguyen & Vo. (34) demonstrating stable occlusal outcomes at 12 months post-treatment. Current evidence suggests that extra-alveolar anchorage expands treatment options by making mandibular distalization achievable in selected patients, thereby increasing camouflage treatment possibilities and supporting non-surgical management of arch space discrepancies.

5.3 Success and stability.

Beyond demonstrating the feasibility of distalization mechanics, evaluating treatment success and long-term stability remains essential to determine whether mini-screw-supported distalization, particularly extra-alveolar skeletal anchorage, provides predictable clinical outcomes. This complements the previous sections by examining if results obtained with mini-screw-supported mechanics remain stable over time while maintaining acceptable complication rates.

Bechtold et al. (28) evaluated the long-term stability of inter-radicular mini-screw-supported total arch distalization and reported a mean molar distalization of approximately 4,2 mm. Minimal relapse was observed during retention, suggesting that this amount of distalization is clinically sufficient to maintain sagittal correction after treatment. With a mean follow-up of 42 months, their results suggest that skeletal anchorage-supported distalization can remain stable over extended periods, with no major complications reported, supporting the long-term reliability of this approach.

Similarly, Katyal et al. (35) analysed success rates and factors influencing stability of IZC mini-screws across a large clinical sample including 1,683 screws. An overall success rate of about 92% was reported, indicating that IZC anchorage provides reliable support for orthodontic movements such as distalization, retraction and intrusion. Although screw mobility and local inflammation were occasionally observed, these events were generally manageable and rarely compromised treatment progress. Yet, variability in success rates across studies suggests that operator experience and insertion protocols remain decisive factors.

Basafa et al. (36) further evaluated extra-alveolar mini-screw success across different insertion sites and reported an overall success rate of approximately 79%, with higher success observed in palatal and MBS regions. While screw mobility sometimes required removal, the results indicate that mini-screw-supported anchorage generally provides sufficient stability when appropriate placement protocols and site selection are respected.

The extra-alveolar studies indicate that extra-alveolar mini-screw anchorage offers high clinical success rates with acceptable long-term stability, supporting its use in complex orthodontic mechanics, including distalization procedures. Thus, when proper placement and biomechanical control are ensured, treatment outcomes are generally reliable.

5.4 Anatomical placement guidance.

Beyond evaluating treatment effectiveness and stability, successful application of extra-alveolar mini-screws also depends on appropriate anatomical placement, as explained previously, since inadequate insertion sites or incorrect angulation may compromise screw stability and increase complication risk. Assessment of anatomical conditions for safe and predictable mini-screw placement is essential for translating skeletal anchorage mechanics into reliable clinical practice.

The studies conducted by Song et al. (37) and Tavares et al. (38) were therefore included as they specifically investigated anatomical parameters guiding IZC mini-screw insertion using tomographic imaging.

Song et al. (37) analyzed CBCT measurements to determine optimal insertion heights and angulations and showed that bone depth in the IZC region ranged between approximately 6 and 9 mm, with greater bone availability observed closer to the cementoenamel junction and progressively reduced thickness toward more apical levels. Their results further demonstrated that insertion at smaller angulations, particularly around 60°, provided greater bone engagement compared with more acute angulations, which showed reduced available bone depth. These findings highlight the importance of individualized imaging assessment before screw placement in order to optimize stability and reduce placement-related risks.

Similarly, Tavares et al. (38) evaluated bone availability through different skeletal patterns and confirmed that bone thickness decreases at more apical insertion levels and at larger insertion angles. They also showed that Class II and mesofacial subjects tend to present lower bone availability in apical regions, suggesting that insertion sites located farther from the cementoenamel junction may offer reduced mechanical support and increased risk of sinus proximity.

Both studies reported absence of major complications in the evaluated insertion parameters, reinforcing the clinical feasibility of these placement protocols when proper planning and imaging assessment are performed.

Significantly, the findings indicate that selecting insertion sites closer to the cervical region and using smaller insertion angles may improve bone engagement and help achieve bi-cortical stabilization while reducing risks related to excessive sinus penetration.

Although extra-alveolar mini-screws are also widely used in other regions such as the MBS or palatal areas in the included studies, dedicated tomographic analyses of anatomical conditions in these sites were not specifically evaluated here.

Therefore, anatomical placement guidance in the present review relies primarily on IZC evidence, while other insertion regions are mainly supported by clinical success data rather than quantitative anatomical measurements.

Consequently, anatomical evaluation emerges as a key element for ensuring predictable anchorage performance, directly supporting treatment strategies aimed at efficient arch space management while minimizing placement-related risks.

5.5 Secondary outcomes and treatment impact.

A treatment should not be considered fully effective if the objectives are achieved at the expense of functional stability or patient well-being. Therefore, beyond mechanical correction of malocclusion and space management, evaluation of secondary outcomes such as soft-tissue response and overall treatment impact remains clinically relevant when assessing the effectiveness of mini-screw-supported anchorage.

This is why the study conducted by Shyagali et al. (39) was included, having its particular focus on soft-tissue changes following anterior retraction supported by mini-screw anchorage compared with conventional reinforcement methods. The findings demonstrated that patients treated with mini-screw-supported mechanics showed greater soft-tissue improvement, reflecting enhanced profile changes associated with improved control of anterior tooth movement.

More importantly, no complications directly related to mini-screw use were reported in this study, suggesting that skeletal anchorage can achieve favourable aesthetic and functional outcomes without increasing treatment-related risks. However, the absence of long-term follow-up data limits conclusions regarding the stability of these soft-tissue changes over time. Furthermore, limited data are available regarding patient-reported outcomes, which restricts evaluation of overall treatment perception.

These findings indicate that mini-screw-supported anchorage not only facilitates effective orthodontic tooth movement but also contributes positively to treatment impact by improving soft-tissue outcomes without evidence of increased treatment-related risks. Consequently, consideration of secondary outcomes further supports the clinical value of skeletal anchorage in managing arch space discrepancies while maintaining overall treatment quality and patient well-being.

5.6 Clinical implications for anchorage management.

Apart from the soft-tissue impact discussed previously, the studies included in this review predominantly evaluated treatment outcomes obtained using extra-alveolar mini-screw anchorage rather than providing direct comparisons with conventional dental anchorage techniques. Nevertheless, the reported results consistently demonstrate that skeletal anchorage allows effective distalization and space management while minimizing dependence on patient compliance and extraoral appliances.

These findings suggest that extra-alveolar mini-screws represent a valuable clinical alternative when conventional dental anchorage is insufficient or greater control of tooth movement is required. And appears particularly beneficial in cases requiring

significant distalization or in complex sagittal and asymmetric malocclusions where traditional anchorage methods may present limitations.

However, because direct comparative studies remain limited, conclusions regarding superiority over conventional anchorage techniques should be interpreted cautiously.

In some patients, this may help avoid more invasive procedures or reduce the complexity of treatment and limit the use of more compliance-dependent or bulkier mechanics, which is relevant, not only from a clinical point of view, but also from an ethical and professional one.

Indeed, providing a treatment that is effective, more conservative and appropriately managed is consistent with the professional duty to protect patient well-being, minimize harm and use healthcare resources responsibly.

In this context, extra-alveolar mini-screws can support a more responsible treatment strategy when they are indicated correctly, when the patient is adequately informed and if the expected benefits clearly justify their use.

It also reinforces the idea that clinical benefit must be weighed against procedural demands, resource use and the need for additional monitoring throughout treatment. Its indication should remain limited to situations in which the expected clinical benefit clearly justifies these additional requirements for both the patient and the clinician.

It should also be kept in mind that failure, inflammation or instability may lead to replacement or additional interventions, which can in turn reduce the expected benefit.

5.7 Limitations.

Despite the encouraging findings reported in this review, several limitations should be considered when interpreting the results. First, important heterogeneity exists among the included studies in terms of study design, sample size, treatment mechanics and reported outcomes. The literature included prospective and

retrospective studies, descriptive clinical studies and a small number of case reports, which makes direct comparison between studies difficult.

Sample sizes varied considerably, ranging from single-patient case reports to large observational cohorts. While larger studies provided robust data, case reports, as indicated previously, were retained mainly because they illustrated clinically relevant treatment approaches and placement techniques. Nevertheless, results derived from limited samples should be, again, interpreted with cautiously.

Another limitation concerns the variability of treatment protocols. Differences in insertion sites, screw dimensions, loading protocols and biomechanical strategies were observed across studies, which may influence treatment outcomes. This variability makes it challenging to attribute results only to extra-alveolar anchorage. In addition, some included studies did not focus strictly on extra-alveolar mini-screw placement although they remained relevant to the broader evaluation of skeletal anchorage strategies.

Follow-up duration also represented a limitation in several studies, as some investigations reported short or absent post-treatment observation periods. This restricts the ability to draw firm conclusions regarding long-term stability and relapse, even though some studies did provide encouraging long-term data.

In addition, randomized controlled trials directly comparing extra-alveolar mini-screws with conventional dental anchorage remain limited, decreasing the strength of comparative conclusions. Moreover, patient-reported outcomes were rarely evaluated, making it difficult to fully assess treatment impact from the patient's perspective.

Finally, factors related to the operator and the patient, such as clinical experience, patient age, bone quality and anatomical variability may also have influenced the reported outcomes, even though their impact remains difficult to assess.

This should be considered when assessing the consistency and transferability of clinical outcomes.

Therefore, these limitations suggest that available evidence should be interpreted with carefully, even though current results support the clinical usefulness of extra-alveolar mini-screw anchorage.

5.8 Synthesis of findings.

This review suggests that extra-alveolar mini-screws are an effective and reliable option for the management of arch space discrepancies. The included studies showed that both maxillary and mandibular distalization can be achieved with mean molar movements of around 3-4 mm and relatively few reported side effects when appropriate planning and biomechanical control are applied, with acceptable post-treatment stability when follow-up data were available.

From a clinical point of view, skeletal anchorage expands the treatment possibilities for the management of Class II malocclusions, selected Class III cases and asymmetric discrepancies, while reducing dependence on patient compliance and limiting the need for more invasive approaches in selected cases where conventional anchorage may be insufficient or as a non-surgical alternative. Their reported success rates appear favourable, especially in IZC and MBS regions which appear to be among the most favourable locations. Moreover, the available anatomical evidence suggests that appropriate site selection and insertion angulation remain important to optimize stability and reduce placement-related risks. Their contribution therefore does not rely only on the device itself, but also on the way it is integrated into a careful, evidence-based and ethically sound treatment plan.

When complications occur, they are usually minor and manageable, mainly involving local inflammation or temporary screw mobility and can generally be controlled through proper placement protocols and careful follow-up.

However, these findings should still be interpreted with caution because of the heterogeneity of the included studies, the variability of treatment protocols and the lack of long-term follow-up in several reports and the small number of high-quality comparative studies which reduces the strength of the available evidence. Despite these limitations, the overall results largely support the clinical usefulness of extra-alveolar mini-screws in modern orthodontic treatment and suggest that further standardized research could help improve patient selection, refine treatment protocols and better define their role in orthodontic practice.

6. CONCLUSIONS

1) Extra-alveolar mini-screws are an effective and reliable option for the management of orthodontic arch space discrepancies, supporting controlled distalization with acceptable stability.
2) They appear particularly useful in cases requiring reinforced anchorage, reduced dependence on patient compliance and a non-surgical alternative to extractions or orthognathic surgery. Although complications are generally minor and manageable, further standardized studies are needed to better define their indications and long-term outcomes.

7. SUSTAINABILITY

In oral healthcare, sustainability should not be understood only as an environmental concept, but also as the search for care that is ethically justified, clinically safe, of high-quality and based on the appropriate use of available resources. In Orthodontics, this means choosing treatment approaches that are effective, proportionate to the patient's needs and able to improve oral health while avoiding unnecessary procedures.

From this perspective, extra-alveolar mini-screws may contribute to viable orthodontic approach in selected cases. Their value lies in their clinical effectiveness, in their potential to support a more proportionate and less aggressive treatment strategy in selected cases.

This dimension is linked to professional ethics. Treatment decisions should not be guided only by technical feasibility, but also by beneficence, non-maleficence, fairness, truthfulness and respect for patient's autonomy. A treatment approach cannot be considered responsible or sustainable if it is used without careful case selection.

However, their clinical usefulness should not be overstated, as their benefits remain conditional and context-dependent. Sustainability in this field should be understood as a balance between treatment efficacy, patient well-being,

professional responsibility and rational use of clinical resources. Within these limits, extra-alveolar mini-screws may support a more efficient, more proportionate and ethically responsible orthodontic treatment.

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