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SYSTEMATIC REVIEW

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The effectiveness of temporary anchorage devices (TADs) in the orthodontic management of impacted canines: a systematic review

A eficácia dos dispositivos de ancoragem temporária (DATs) no manejo ortodôntico de caninos impactados: uma revisão sistemática

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ABSTRACT

Background: Orthodontic traction of impacted canines is challenging, requiring precise biomechanical planning to prevent complications like root resorption. **Objective:** The systematic review aims to assess the efficiency of skeletal anchorage devices in orthodontic traction of these canines. **Material and Methods:** Following PRISMA 2020 guidelines, this review searched databases such as Medline and Scopus for clinical trials from 2016 onwards. It focused on studies from 2016 in English or French, specifically on orthodontic traction of impacted canines, excluding literature reviews, case reports and non-comparative studies. **Results:** Of the 2396 articles initially identified, 4 met the inclusion criteria. These studies compared outcomes of anchorage techniques, primarily TADs versus transpalatal arches, examining aspects like root resorption, traction duration, and force efficiency. Each study's assessment for bias risk (RoB) was evaluated based on its design-type. **Conclusion:** TADs are advantageous for the orthodontic management of impacted canines, offering significant benefits in terms of stability and reduced side effects.

KEYWORDS

Anchorage procedures, orthodontic; Canine tooth; Impacted teeth; Orthodontic extrusions; Technique, Orthodontic Anchorage.

RESUMO

O tracionamento ortodôntico de caninos impactados é desafiador, exigindo um planejamento biomecânico preciso para evitar complicações como a reabsorção radicular. **Objetivo:** O objetivo desta revisão sistemática é avaliar a eficiência dos dispositivos de ancoragem esquelética no tracionamento ortodôntico desses caninos. **Material e Métodos:** Seguindo as diretrizes PRISMA 2020, esta revisão pesquisou bancos de dados como Medline e Scopus para ensaios clínicos a partir de 2016. Ela se concentrou em estudos de 2016, em inglês ou francês, especificamente sobre o tracionamento ortodôntico de caninos impactados, excluindo revisões de literatura, relatos de casos e estudos não comparativos. **Resultados:** Dos 2.396 artigos inicialmente identificados, 4 atenderam aos critérios de inclusão. Esses estudos compararam os resultados das técnicas de ancoragem, principalmente DATs versus arcos transpalatais, examinando aspectos como reabsorção radicular, duração da tração e eficiência da força. A avaliação do risco de viés (RoB) de cada estudo foi avaliada com base em seu tipo de desenho. **Conclusão:** Os DATs são vantajosos para o tratamento ortodôntico de caninos impactados, oferecendo benefícios significativos em termos de estabilidade e redução dos efeitos colaterais.

PALAVRAS-CHAVE

Dente canino; Dente impactado; Extrusão ortodôntica ;Procedimentos de ancoragem ortodôntica; Técnica, Ancoragem Ortodôntica.

INTRODUCTION

Canines play a major role in maintaining dental arches integrity, and facial harmony [1]. Recent studies highlighted an important role of genetic factors in canine eruption and impaction. Genetic variations could influence the position and eruption pattern of canines; therefore, these genetic factors must be considered in treatment plans [2,3].

However, these teeth can also be impacted due to various environmental factors, such as barriers along the eruptive path, soft tissue lesions, or developmental pathologic conditions [2]. Furthermore, palatally impacted maxillary canines are attributed to hereditary influence, whereas buccally impacted maxillary canines have been attributed to arch length tooth size discrepancies [3]

Impacted maxillary canines are the second-most frequently impacted teeth in the dental arch following the third molars—with a prevalence of 1 to 3%. They primarily occur palatally (85%) rather than labially (15%). These impactions can lead to serious adverse effects, including resorption of adjacent incisors and the development of cysts [4].

The preferred management strategy for impacted canines typically involves surgical exposure followed by guided orthodontic eruption. However, this approach is complex and requires careful consideration of several factors: the selection of an appropriate surgical technique and orthodontic traction modality is critical for achieving satisfactory periodontal health and aesthetic outcomes; additional space must be created within the arch to align the canine properly; precise anchorage preparation is essential; and, the treatment of the impaction must be integrated into the comprehensive treatment planning for the entire malocclusion [5,6].

Effective planning of orthodontic traction is crucial for clinical success. Various methods are available, including cantilevers, power chains, ligature wires, springs, and double archwires. However, meticulous biomechanical planning is essential to avoid root contact, preserve anchorage, and maintain periodontal health of the affected teeth. Furthermore, it is important that the magnitude of the force applied remains within a physiological range to ensure optimal outcomes [7].

Although there are several types of studies, case reports and some reviews on this topic, it is still difficult for the clinician to find reliable data regarding impacted canine management. The purpose of this systematic review is to evaluate the effectiveness of anchorage devices in managing the impacted canines.

MATERIAL AND METHODS

Registration of protocol

Registration of the research protocol was carried out at PROSPERO to avoid any duplication (Registration # CRD42024575877). All the phases of this systematic was conducted with a strict respect of PRISMA 2020 guidelines for reporting items [8].

Study selection and search strategy

Meticulous electronic research was carried out extending from 2016 to 2024 by exploring the following databases:

- PUBMED (MEDLINE)
- SCIENCE DIRECT
- COCHRANE LIBRARY
- GOOGLE SCHOLAR

The research was aiming mainly clinical trials extending from 2016 up to now

The medical subject heading terms were gathered by a Boolean operator AND forming the following search equations:

1 – impacted teeth AND canine AND orthodontic anchorage

2 – impacted teeth AND canine AND orthodontic extrusion

3- impacted canine AND orthodontic anchorage

4- impacted canine AND orthodontic extrusion

A well-defined research question using PICO principle: Population, Intervention, Comparator, and outcome was established and followed. Characteristics of PICO question are all summarized in Table I.

Inclusion and exclusion criteria

The inclusion and exclusion criteria used for selecting articles for the analysis are summarized in Table II.

Table I - PICO question

Population	Patients with unilateral or bilateral impacted maxillary canine
Intervention	Guided orthodontic eruption
Comparison	Orthodontic traction devices
Outcome	Amplitude of movement, traction duration, root resorption

Data extraction method

Two independent reviewers, A.A and H.N, conducted a qualitative synthesis by discussing the results obtained from evaluating the titles and abstracts of the studies. They excluded those that did not meet our inclusion criteria and eliminated duplicate articles.

Subsequently, A.A and H.N independently extracted data from the selected studies using a data extraction sheet, which included:

- Author name
- Year of publication
- Study design
- Aim of the study
- Intervention group
- Types of appliances used for anchorage reinforcement
- Method of evaluation
- Results

A third researcher, A.H, then reevaluated the collected data. Our selection process is illustrated in the flow chart (Figure 1).

Methodological and risk of bias assessment (RoB)

Search evaluation and risk of bias assessment were conducted independently by two researchers, A.A and N.H. In the event of any disagreement, a third reviewer, A.H, reexamined the results.

The assessment of RoB was completed in each study, depending upon its type and design:

- RoB2 tool was used to assess the quality of included randomized controlled trials [9];
- Risk of Bias in Non-randomised Studies of Interventions (ROBINS-I) tool was used to assess the quality of included non-randomized trials [9];
- Joanna Briggs Institute (JBI) tools was used to assess the quality of included retrospective case-control and cohort studies [10].

RESULTS

Study selection

We identified 2,396 studies from the initial search, of which 2,348 were duplicates or did not meet our inclusion criteria. We retained 48 studies for pre-selection to undergo abstract screening. After eliminating irrelevant studies and assessing the full text, 4 studies were included in our systematic review.

The overview of the study selection process is illustrated in the flow chart (Figure 1).

Study characteristics and RoB

The included studies consisted of a combination of a randomized clinical trial published in 2021 [5], a non-randomized clinical trial published in 2016 [11], a retrospective cohort study and a retrospective case–control study published in 2018 [4,12]. The four studies shared a common objective: to evaluate the effectiveness of orthodontic traction devices in guiding the eruption of impacted canines.

Three studies compared by using CBCT records the outcomes before and after canine orthodontic traction with the same anchorage technique, while the fourth study compared results using 2 anchorage techniques (temporary anchorage devices TADS and transpalatal arch TPA).

Using the RoB2 tool, the randomized clinical trial was assessed to have a moderate risk of bias (Table III). In contrast, the ROBIN I tool for non-randomized clinical trials indicated that the study was classified as low risk (Table IV). Additionally, based on the JBI critical appraisal checklist for retrospective case-control and cohort studies, both studies were categorized as moderate risk (Tables V and VI).

Q1: Q11 refers to questions 1–11 derived from the JBI risk assessment. The risk of bias was classified as high when the study achieved up to 49% of “yes” responses, moderate for 50 to 69% of “yes” responses, and low for over 70% of “yes”

Table II - Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
- Articles in English or French	- Animal studies
- Full text accessible	- Simulation or virtual study methods
- Published from 2016	- Case reports
- Prospective and retrospective studies	- Literature reviews and opinion articles
- Randomized and non-randomized clinical trials	- Studies assessing interceptive treatment for managing impacted maxillary canines
- Clinical trials focusing exclusively on successful orthodontic-surgical methods for treating impacted maxillary canines	- Studies that include patients with clefts in their sample
- Studies that clearly describe the anchorage strategies employed	- Articles introducing new anchorage systemsor devices for treating impacted maxillary canines

Table III - Risk of bias assessment using the RoB2 tool

	D1	D2	D3	D4	D5	Overall risk
Migliorati et al. [5]	+	-	-	+	+	-

Domains: D1: Bias arising from the randomization process; D2: Bias arising from deviations from the intended interventions provided; D3: Bias from missing outcome data; D4: Bias in measurement of the outcome; D5: Bias in selection of the reported result. (-) = Some concerns; (+) = Low.

Table IV - Risk of bias assessment using ROBIN-I tool

Study	D1'	D2'	D3'	D4'	D5'	D6'	D7'	Overall risk
Herav et al. [11]	Moderate	Low	Moderate	Low	Low	Low	Moderate	Low

Domains: D1': Bias due to confounding; D2': Bias in the selection of study participants; D3': Bias in classification of interventions; D4': Bias due to deviations from intended interventions; D5': Bias due to missing data; D6': Bias in measurement of outcomes; D7': Bias in selection of the reported result.

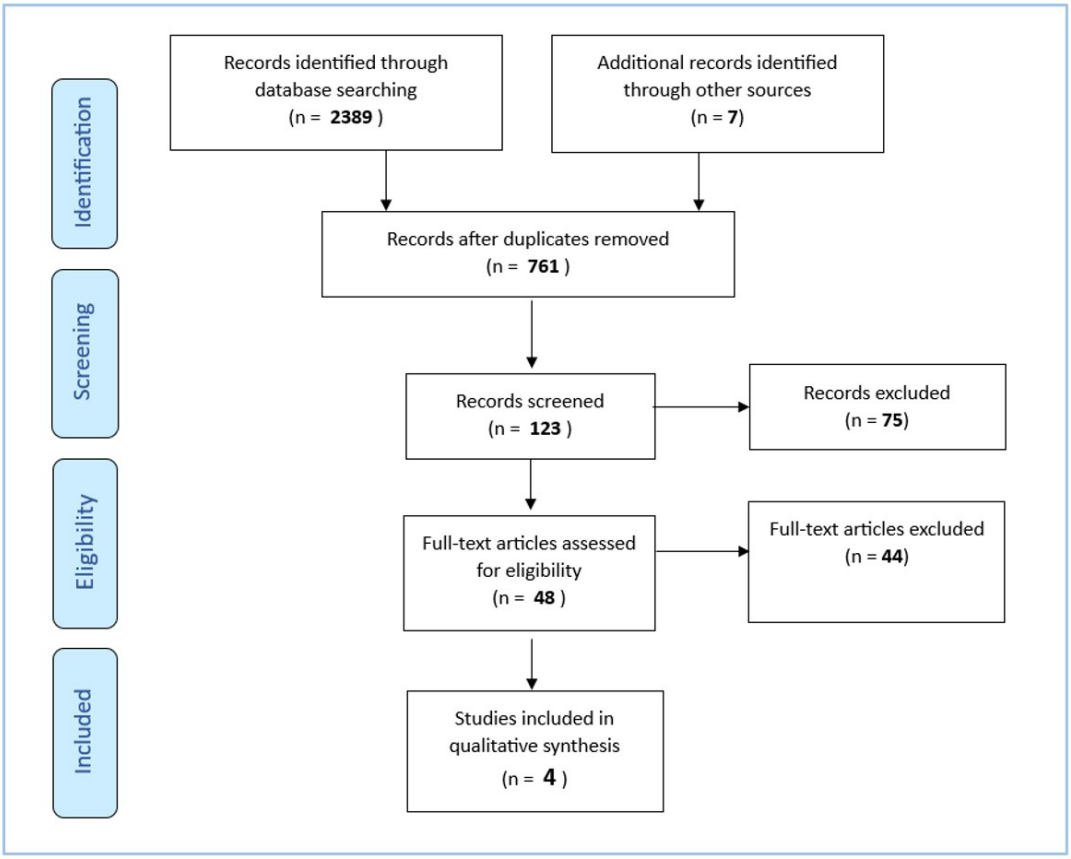

Figure 1 - Flow chart.

Table V - The JBI (Joanna briggs institute) critical appraisal for retrospective case control studies

Checklist questions	1	2	3	4	5	6	7	8	9	10	%yes	Risk
Arriola-Guillén et al. [12]	✓	✓	✓	X	✓	X	X	X	✓	✓	60%	Moderate

Table VI - The JBI critical appraisal for retrospective cohort studies

Check list questions	1	2	3	4	5	6	7	8	9	10	11	% yes	Risk
Potrubacz et al. [4]	X	✓	✓	✓	X	?	✓	✓	✓	X	✓	64%	Moderate

responses. A "✓" signifies yes, an "X" denotes no, and a "?" indicates unclear. JBI: Joanna Briggs Institute.

We provide a summary of the included articles in Table VII.

DISCUSSION

Orthodontic anchorage can be defined as the means to resist unwanted reactive forces and moments related to movements of teeth. This, tropes well into the third law of Newton, namely, every action has an equal reaction back towards the opposite direction [13].

Maxillary canine impactions are a very frequently seen clinical problem. The cause of impaction of the canine could be attributed to localized, systemic, or genetic factor(s). Thus, the most important step in management of impacted canines, according to both clinical and radiographic examinations, is a precise diagnosis and the 3D localization of the tooth [14].

Orthodontic treatment of impacted maxillary canines requires an interdisciplinary approach involving meticulous surgical techniques as well as orthodontic biomechanical considerations in light of the 3D force system that will be applied to the canines along the horizontal, vertical, and sagittal planes.

The anchorage strategy should adapt to various changes in traction direction to achieve alignment of the canine in the dental arch, either vertical or oblique in the first phase for straightening its axis while moving away from the roots of the neighboring teeth, before moving to a second phase of traction that is most often horizontal toward its place in the dental arch [13,15].

Becker et al. [16] in his study stated that poor anchorage is the leading cause for failure of treatment in the impacted maxillary canines (approximately 48.6% cases).

When comparing conventional anchorage systems such as transpalatal arches (TPAs) and temporary anchorage devices (TADs) in the management of impacted maxillary canines, several critical aspects must be considered, including their effectiveness in controlling tooth movement, the risk of side effects such as root resorption, treatment time, and overall stability.

Effectiveness in controlling tooth movement

Arriola-Guillén et al. [12] investigated the changes in interpremolar width following traction of maxillary impacted canines (MICs) with a reinforced conventional anchorage device (a transpalatal arch).

This study shows similar maxillary premolar expansion change without significative differences of the impaction type (unilateral/bilateral) or impaction location (palatal/buccal). It could be explained by the fact that heavy anchorage plays a significant role in helping to control Newton's third law.

Moreover, in cases of unilateral impaction, transversal asymmetry was reported after traction of MICs. These changes were greater on the affected side than the unaffected side (2 mm of expansion vs. <1 mm, respectively, $P < 0.05$). In other words, despite the application of a reinforced transpalatal arch, the authors still recognized a loss of the transversal anchorage in the cases of unilateral impaction [12].

Furthermore, vertical anchorage control plays an essential role in managing MICs ; loss of anchorage is common wherever traction biomechanics are not respected or not well-planned. Clinically, this produces mesial tipping of the maxillary molars, occlusal plane alterations, and poor treatment outcomes. It also gives the appearance of an anterior or lateral open bite [11].

One study by Migliorati et al. [5] investigated the mesial tipping of permanent teeth under

Table VII - Studies characteristics and results

Author	Aim	Study design	Intervention group	Comparison	Mean of comparison	Outcome	Results
Migliorati et al. [5]	To compare the effectiveness of two different anchorage systems for the traction of impacted maxillary canines.	Randomized clinical trial	16 patients mean age: 13.4 years, undergoing orthodontic treatment for impacted maxillary canines (both labial and palatal)	Group 1: n 8 mm long miniscrew Group 2: transpalatal arch as anchorage a calibrated traction force of 50 g	- CBCT -Before and after 3 months of guided eruption	- Crown movement - Root movement - Crown velocity - Root velocity - Duration of guided eruption	-No statistically significant difference between the two groups about the amount and speed of canine's crown and apex movement. -In the TADs group, no miniscrews were lost during the traction period - In the transpalatal arch group, there was significant loss of anchorage and mesialization of the molars.
Potrubacz [4]	To assess the time required for orthodontic traction of impacted teeth with varying severity levels, utilizing a device capable of consistently applying forces below 0.6 N.	Retrospective study	Twenty-two patients were treated for unilateral or bilateral palatally impacted canines using a stainless-steel cantilever soldered onto a transpalatal arch.	Intervention group before and after treatment	Panoramic	- Force applied by the traction device - Duration of traction	-Force generated by the system close to the recommended 0.6 N. -Guided eruption achieved in an average duration of 3.5 months.
Arriola-Guillén et al. [12]	to compare the root resorption of maxillary incisors after traction of unilateral vs bilateral impacted canines with temporary anchorage devices (TADs)	Retrospective longitudinal study	Two groups: 15 patients with unilateral maxillary impacted canines and 15 with bilateral maxillary impacted canines.	Before and after orthodontic traction	CBCT: scans before and after orthodontic traction	Root resorption of maxillary insisors	-The reinforced anchorage minimizes undesirable side effects and reduces the risk of root resorption.
Herav et al. [11]	To asses the movement of impacted canines away from the roots of adjacent teeth using TADs before to full-mouth bracket placement.	non-randomized parallel-designed clinical controlled trial study	26 patients (15 in the experimental group and 11 in the control group) with 34 palatally impacted canines with axial inclinations<45°	Group 1: n = 15 with two miniscrews for anchorage reinforcement, along with a cantilever spring inserted into the miniscrew slot (0.018 x 0.025). Group 2: n = 11 with a 0.016 x 0.022-inch stainless steel arch and a transpalatal arch.	CBCT: scans before and after orthodontic traction	-Incisor and canine root resorption -Traction duration	-Higher pain levels in group 2 in the first weeks of traction (p = 0.012) -The volume of lateral incisor root resorption in group 2 was significantly greater than group -No statistically significant difference according to traction duration between the two groups

CBCT = Cone Beam Computed Tomography; TADs = Temporary Anchorage Devices.

traction with transpalatal arch, showing that this movement caused significant mesial tipping of the first permanent molars. Nevertheless, this study did not give details about molars displacement or quantity of anchorage loss in the vertical dimension.

This could explain why other authors had included a palatal acrylic button to the transpalatal arch [17-20], in which the anterior palatine vault serves as additional anchorage. These studies did not mention any anchorage loss in the vertical dimension nor molar movement;

however, further studies must be done to draw consistent conclusions.

On the other hand, it has been stablished that a transpalatal arch connecting upper first molars, experiences intrinsic forces generated by tongue action during swallowing and mastication. At the same time, the extrusive force, applied to the impacted canines, produces reactive intrusive forces that in turn cause a moment, leading to mesial tipping of the molars. These findings enhance the need of further anchorage techniques to a better vertical dimension control during canine traction [21,22].

In contrast, TADs, such as mini-screws, offer significantly better control over tooth movement. Mini-screws, by providing absolute anchorage directly to the bone, eliminate forces on adjacent teeth and avoiding unwanted tooth movements. Several studies have highlighted the advantages of TADs in providing more predictable and controlled 3D movement of impacted canines [18,22].

Herav et al. [11], inserted two 8 mm mini-screws with a 1.4 mm diameter in the palatal region for each impacted maxillary canine prior to the initiation of orthodontic treatment. Later, a palatal cantilever spring of TMA was used to apply traction force thereby obtaining extrusive and distal forces on canines. The cantilever spring was activated to upright and expose the canine's crown by applying a mainly extrusive force before the erupted canine is moved bucally using NITI overlay. The results of this study show that skeletal anchorage allows for controlled movement of the impacted tooth in both the vertical and sagittal dimensions with no need to bracket maxillary arch before total canine correction [11].

Migliorati et al. [5] in their study used 8mm long mini-screws as anchorage in a "canine first" approach where no anchorage preparation was done. Traction biomechanics included beta-titanium cantilever spring applying 3D forces on the canines. The insertion sites for the mini-screws varied depending on the positional representation of the canine within the human mouth. The results showed no anchorage loss nor any considerable differences with respect to the apical and tip dislocation of canines.

Risk of root resorption

Root resorption is a major concern when treating impacted canines. Arriola-Guillén et al. [12] in their work compared the root resorption of maxillary incisors pre- and post-orthodontic treatment of impacted unilateral or bilateral maxillary canines using transpalatal arch and concluded no significant differences on the basis that root resorption in both groups was less than 2 mm and 5 mm, which was clinically not significant. The approach employed to maintain a greater space between the impacted canines and the roots of the neighboring teeth, as well as the substantial anchors used to regain direct dental support, were the main causes of the decrease in root resorption.

Conversely, TADs offer even greater advantage, by providing more direct control over the forces applied, reducing the risk of root resorption and minimizing unwanted tooth movement of the adjacent teeth. Herav et al. [11] indicated that TADs, such as mini-screws, could effectively control direction and magnitude of force applied to extrude impacted canines and cause no damage to adjacent roots. For instance, Kocsis et al. [23] noted that mini-screws caused less root resorption as compared to the conventional anchorage methods.

Treatment duration

Treatment time is another important factor to consider and has been a subject of controversy.

The transpalatal arch with a cantilever system allows for easy and efficient procedure, according to Potrubacz et al. [4]. The orthodontic extrusion took on average of 3.5 months to complete. Tepedino et al.'s [24] findings, which show an average extrusion time of 3.6 months, are in good agreement with this investigation.

The average treatment time was correlated to patient´s age. That is, a younger patient will need less time for tooth extrusion. No statistically significant correlation was drawn between the canine's position and treatment time.

The authors found, also, an effect of gender on treatment time: Males required a shorter time for tooth extrusion. This can be explained by the differential timing of skeletal maturation between the two genders .Males typically mature later than females, and this delayed maturation could allow their skeletal bones to respond more efficiently to orthodontic forces, leading to faster tooth extrusion [4].

This interval of time is shorter than reported in other studies [25] but similar to that reported

by Becker and Chaushu [26] for adolescent patients.

On the other hand, Kocsis et al. [23] studied the traction of impacted maxillary canines using 1.5 mm LEONE TM mini-screws in a sample of 69 canines. The sample included unilateral and bilateral buccal or palatal impaction with different levels of impaction. Success of 88.41% was reported with a mean traction time of 6.8 months, which is a relatively a long period compared to other studies [11,12].

In contrast, Migliorati et al. [5] didn't find evidence that skeletal anchorage using miniscrews could make canine disimpaction faster than anchorage on a TPA. The rate of canine eruption was on average 1.08 and 1.96 mm in 1 month in the TADs and TPA groups respectively by applying always a 50–60 g force.

Management of impacted maxillary canines remains challenging. Both conventional anchorage devices and TADs have their respective advantages and limitations.

Our findings indicate that while conventional anchorage is a more recognized method, the evidence supporting TADs presents a trend towards controlled and predictable treatments. As we advance in our practice as orthodontists, it is essential to integrate the conventional approach and innovations that TADs offer, in order to create the most effective treatment plan customized to each individual case. Recent studies on advanced techniques provide valuable insights into expected improvements for patients with impacted canines.

CONCLUSION

Orthodontic management of impacted canines relies on surgical exposure and guided orthodontic traction; hence, it requires an appropriate treatment protocol. Plus, it is important for both patients and clinicians to be aware of the expected time of the whole treatment, degree of predictability of success, and side effects that could arise.

Anchorage is crucial to the effective control of canine traction. A transpalatal arch, is usually used as an anchorage device for stabilizing the upper arch during canine traction, it protects adjacent teeth and soft tissues from reaction forces.

TADs such as mini-screw represent an alternative method to the conventional anchorage strategy; they became increasingly popular because of ease of placement and removal, as well as for decreasing patient compliance.

By maintaining relatively good stability in the bone and enhancing anchorage effectiveness with fewer negative effects on neighboring teeth or problems that could affect treatment outcomes, this systematic study shows that TADs are advantageous in clinical practice. Further studies are necessary to make more definitive findings about their 3D effectiveness.

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Author's Contributions

AA: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Ressources, Writing – Original Draft Preparation. NH: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Supervision. ZF: Conceptualization, Supervision, Writing – Review & Editing. HA: Conceptualization, Supervision, Writing – Review & Editing.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Regulatory Statement

The systematic review was conducted through a search strategy in electronic databases. The search was restricted to publications in peer-reviewed journals, in which approval for ethics committee were obtained in their original work.

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