Systematic Review and Meta-analysis Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)

Med J Islam Repub Iran. 2025 (14 May);39.68. https://doi.org/10.47176/mjiri.39.68

Effectiveness of Transpalatal Arch (TPA) in Molar Movement: A Systematic Review and Meta-analysis

Matine Gharavi[1], Alireza Jafari-Naeimi[2]*, Seyyed Amir Yasin Ahmadi[3]

Received: 8 Dec 2024 Published: 14 May 2025

Abstract

Background: Molar movement control is a fundamental aspect of orthodontic treatment, particularly in managing anchorage and achieving desired occlusal outcomes. The transpalatal arch (TPA) is a commonly used passive or active appliance designed to provide anchorage reinforcement and facilitate specific molar movements. Despite its widespread application, there is limited consensus regarding its quantitative effectiveness. This systematic review and meta-analysis assesses the effectiveness of the TPA in molar movement during orthodontic treatment.

Methods: An extensive search of major electronic databases was conducted up to the year 2023 to identify studies evaluating the application of the TPA in molar movement. Data regarding study design, participant characteristics, types of TPA used, and numerical outcomes related to molar displacement were systematically extracted. For each outcome, point estimates and corresponding 95% confidence intervals were computed to assess pre- and post-treatment changes.

Results: Fourteen studies underwent detailed qualitative synthesis, with 2 classified as low risk, 7 with some concerns, and 5 as high risk of bias. Nine studies were included in the meta-analysis. The pooled change in mesial movement U6-PTV (mm) for the TPA group was 2.73 (95% CI: 1.90-3.50), vertical movement U6-PP (mm) was 1.24 (95% CI: 0.96-1.52), vertical movement U6-FH (mm) was 1.34 (95% CI: 0.36-2.32), and mesial tipping U6-FH (°) was 2.94 (95% CI: 1.51-4.37).

Conclusion: This review underscores the TPA's versatility and effectiveness as an anchorage device. Evaluating TPA's full range of applications, beyond comparisons with skeletal devices, is crucial. Future research should incorporate three-dimensional digital models and consider pubertal growth stages for more accurate assessments.

Keywords: Tooth Movement Technique, Orthodontic Anchorage Procedures, Palatal Expanders, Orthodontic Appliances, Corrective Orthodontic Appliances

Conflicts of Interest: *None declared*
Funding: *None*

Cite this article as: Gharavi M, Jafari-Naeimi A, Ahmadi SAY. Effectiveness of Transpalatal Arch (TPA) in Molar Movement: A Systematic Review and Meta-analysis. *Med J Islam Repub Iran.* 2025 (14 May);39:68. https://doi.org/10.47176/mjiri.39.68

Introduction

Orthodontic treatment requires precise management of tooth movement while maintaining stable anchorage. The transpalatal arch (TPA) has been widely utilized for its ability to control molar movement and provide anchorage dur-

Corresponding authors: *Dr Alireza Jafari-Naeimi, ar.jafari@iau.ac.ir*

1. Department of Pediatrics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
2. Department of Orthodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
3. Preventive Medicine and Public Health Research Center, Psychosocial Health Research Institute, Iran University of Medical Sciences, Tehran, Iran

↑What is "already known" in this topic:
The transpalatal arch (TPA) is a well-established orthodontic device for anchorage and molar movement. Its applications include space maintenance, molar rotation correction, and posterior segment control. While comparisons with other devices like miniscrews and Nance appliances have been made, the TPA's full range of capabilities has not been comprehensively evaluated.

→What this article adds:
This systematic review and meta-analysis assesses the TPA's effectiveness in various orthodontic treatment phases, revealing its versatility compared to other anchorage devices. It emphasizes the need for further research using three-dimensional digital models and consideration of pubertal growth stages for more accurate evaluations of TPA's role in orthodontic practice.

ing various stages of orthodontic treatment (1, 2). Compared to other anchorage methods, such as headgear or miniscrews, TPAs offer a noninvasive, patient-friendly approach with minimal reliance on compliance (3). Their capability to provide three-dimensional control over molar position, including transverse stability and rotational control, makes them a preferred choice in many clinical scenarios (4, 5).

The role of TPAs in preventing mesial molar movement, particularly during space closure after premolar extraction, remains an area that requires further study. Although TPAs are traditionally employed to stabilize the maxillary arch and manage anchorage during initial alignment, their function in later phases, such as space closure, is equally critical (6).

While the influence of TPAs on molar stabilization has been investigated, much of the existing research focuses on their effects during initial alignment or canine retraction, with limited attention to mesial molar movement during space closure. Some studies have assessed stress distribution and anchorage loss with and without TPAs, but primarily emphasize overall molar displacement rather than mesialization during space closure (7, 8). The absence of direct assessments on this aspect highlights a gap in the literature.

The ability of TPAs to control molar rotations is well documented, yet their effectiveness in preventing mesial movement during anterior space closure has received less attention (9). Studies have described their role in maintaining transverse stability, but their impact on mesial movement during space closure is not well quantified (10). Comparisons with skeletal anchorage devices, such as miniscrews, have consistently demonstrated superior anchorage control with miniscrews (11). However, direct evaluations of TPAs in mitigating mesial molar movement remain insufficient.

Despite the advantages of skeletal anchorage, TPAs remain a viable option for clinicians seeking a nonsurgical, cost-effective, and reliable method for anchorage management, especially in cases where skeletal anchorage is not feasible or preferred (12).

This systematic review aims to consolidate evidence from randomized clinical trials and retrospective studies to assess the role of TPAs in various orthodontic stages, particularly during space closure following premolar extraction. By evaluating mesial molar movement, different TPA designs, patient cooperation, and operator expertise, this review seeks to clarify the effectiveness of TPAs in controlling molar movement. Addressing these gaps will provide clinically relevant insights that may improve treatment strategies and optimize orthodontic outcomes.

Methods

Protocol Registration

The present systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparent and standardized reporting. The protocol was prospectively registered in PROSPERO (International Prospective Register of Systematic Reviews) with the ID No. CRD420251001743.

Search Strategy

A structured literature search was performed in the PubMed, Embase, Scopus, Web of Science, and the Cochrane Library databases, using a strategy collaboratively developed with input from dental specialists and clinical epidemiologists. Search terms, including both MeSH and free-text keywords, were organized according to a tailored population, intervention, comparison, outcome (PICO) framework to improve precision and relevance.

Population (P): Patients undergoing orthodontic treatment requiring maxillary molar anchorage control, including children, adolescents, and young adults (ages 8-33 years). Included patients exhibited Class I or Class II malocclusions and were in different treatment phases, such as leveling and aligning, space closure, or en-masse retraction.

Intervention (I): Use of a transpalatal arch (TPA) for anchorage reinforcement, including both conventional and modified TPAs with or without additional activation protocols (e.g., soldered extensions, loops, or omega designs).

Comparison (C): Alternative anchorage strategies, including Nance appliances, headgear, interarch elastics, miniscrews, temporary anchorage devices (TADs), or no additional anchorage reinforcement. Studies that included a TPA in the control group were analyzed separately.

Outcome (O): Changes in maxillary first molar position, including mesial and distal movement, vertical displacement, buccal-lingual tipping, and rotational changes. Measurements were assessed using cephalometric analysis, digital models, or clinical evaluations, with time points ranging from initial placement to completion of the anchorage-requiring treatment phase.

These criteria were applied to each database to ensure consistency and comprehensiveness in the literature search. Additionally, the Cochrane Highly Sensitive Search Strategy was used to identify relevant studies.

Inclusion Criteria

The following were the study's inclusion criteria: studies comparing TPA with no treatment or other anchorage devices (Nance appliance, headgear, interarch elastics, miniscrews, TADs, etc.); peer-reviewed publications published between 1990 and 2023; full-text articles available in English; studies reporting specific orthodontic treatment phases and measurable outcomes.

Exclusion Criteria

The exclusion criteria were as follows: animal studies, in vitro research, case reports, case series, abstract-only publications, studies with incomplete data or unclear methodology, and articles written in languages other than English.

Study Selection and Data Extraction Process

The literature search and study selection were conducted in August 2023 by two independent reviewers (M.G. and A.J.). Title and abstract screening were performed initially, followed by full-text assessment. Any disagreements were resolved through discussion with a third reviewer (Y.A.). Before final submission, an independent investigator (Y.A.) double-checked each entry to ensure consistency.

[DOI: 10.47176/mjiri.39.68]

Quality Assessment of Included Studies

The methodological quality and risk of bias of included studies were evaluated using established tools:

The Newcastle-Ottawa Quality Assessment Scale (NOS) for cohort and case-control studies. Scores of 7 to 9 were considered low risk, 4 to 6 moderate risk, and 0 to 3 high risk of bias.

The Risk of Bias 2 (RoB2) tool for randomized controlled trials (RCTs), assessing five domains: randomization, deviations from the intended intervention, missing data, outcome measurement, and selective reporting. RCTs were categorized as low risk, some concerns, or high risk of bias.

Sensitivity analyses were conducted to determine the impact of high-risk studies on pooled outcomes.

Synthesis of Results and Meta-analysis

Pooled means (point estimation) with a 95% confidence interval were calculated for each of the measurement changes. According to the results of the I^2 test for heterogeneity, the random effects model was used for $I^2 > 50\%$, and the fixed-effects model was used for $I^2 \leq 50\%$. A funnel plot was used to investigate publication bias. Sensitivity analysis was performed with a leave-one-out approach. The Metan package was used for meta-analysis in Stata 17 (Stata Corp).

Results

Study Selection

Figure 1 illustrates the process of searching for and selecting studies. Initially, 3764 records were identified through electronic database searches. Duplicates were manually removed using a reference management program, resulting in 1230 unique records. Following a review of titles and abstracts, 1186 records were excluded. A total of 44 full-text articles were assessed for eligibility, and 30 articles were excluded with documented reasons. The remaining 14 publications underwent full-text screening and were deemed eligible for qualitative synthesis.

Tables 1 to 3 present the risk of bias assessment for all 14 included studies.

In this systematic review, we assessed the risk of bias using appropriate tools based on study design. For cohort and case-control studies, we applied the Newcastle-Ottawa Scale (NOS), which evaluates studies across three domains: selection of participants, comparability of groups, and assessment of outcomes or exposures. Studies scoring 7 to 9 points were categorized as having a low risk of bias, those scoring 4 to 6 points as having a moderate risk of bias, and those scoring 0 to 3 points as having a high risk of bias.

For RCTs, we used the Risk of Bias 2 (RoB 2) tool, which assesses five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Based on the overall judgment from RoB 2, RCTs

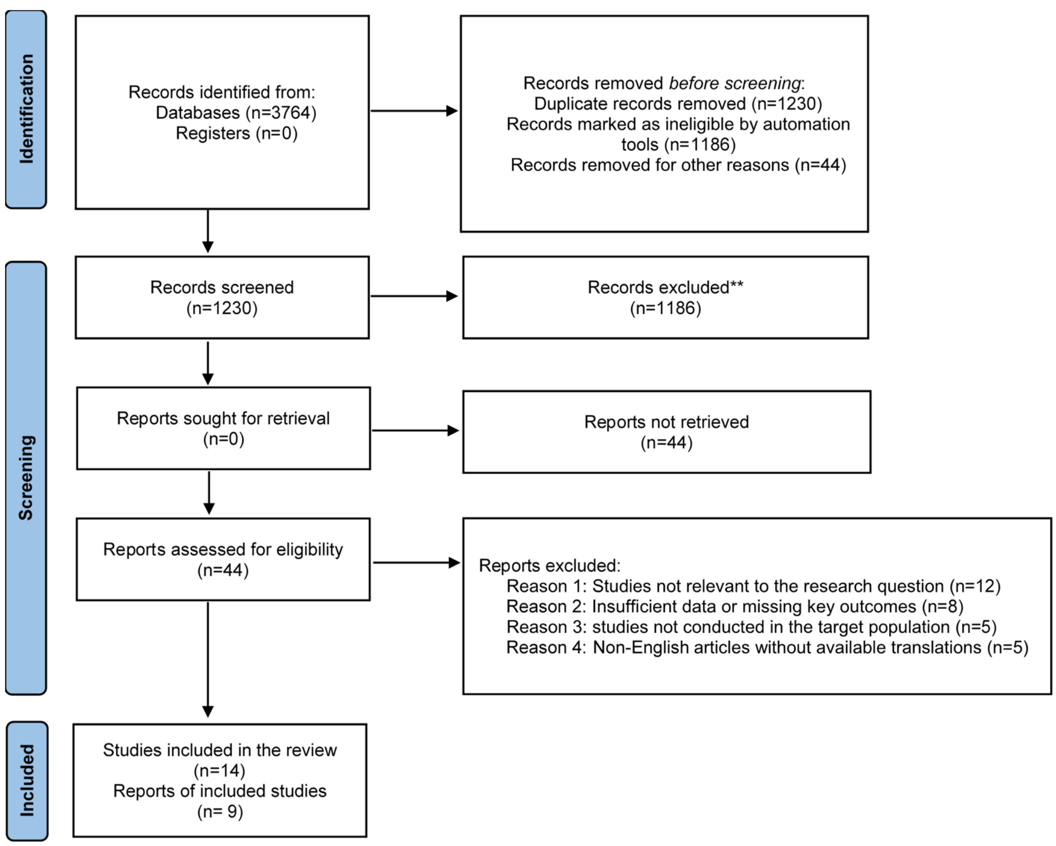

Figure 1. PRISMA Flow Diagram

[DOI: 10.47176/mjiri.39.68]

Table 1. Risk of Bias Assessment for Case-Control Studies

Study	Selection Domain	Comparability Domain	Outcome Assessment Domain	Overall NOS Score	Overall Quality
Kecik et al. (2016)	****	-	**	6/9	Moderate risk of bias

Table 2. Risk of Bias Assessment for Cohort Studies

Study	Selection Domain	Comparability Domain	Outcome Assessment Domain	Overall NOS Score	Overall Quality
EYÜBOĞLU et al. (2004)	**	**	**	6/9	Moderate risk of bias
Zablocki et al. (2006)	***	**	**	7/9	Low risk of bias
Liu et al. (2009)	***	**	*	6/9	Moderate risk of bias
Sharma et al. (2012)	**	*	**	5/9	Moderate risk of bias
Alhadlaq et al. (2015)	*****	*	**	8/9	Low risk of bias

Table 3. Risk of Bias Assessment for Randomized Controlled Trials

Study	Randomization Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of the Outcome	Selection of the Reported Result	Overall Risk of Bias
Feldmann et al. (2008)	LR	SC	SC	HR	SC	HR
Stivaros et al. (2009)	LR	SC	SC	LR	LR	SC
Basha et al. (2010)	HR	SC	SC	HR	SC	HR
Borsos et al. (2011)	SC	SC	SC	SC	SC	SC
Borsos et al. (2012)	HR	SC	SC	LR	SC	HR
Al-Sibaie et al. (2014)	LR	SC	SC	LR	SC	SC
Nor et al. (2019)	HR	SC	SC	LR	SC	HR
Wilmes et al. (2009)	HR	SC	LR	LR	SC	HR

LR, low risk; HR, high risk; SC, some concern.

were categorized as having a low risk of bias, some concerns, or a high risk of bias.

In summary, our analysis identified two studies with a low risk of bias, seven with a moderate risk of bias, and five with a high risk of bias. Most of the high-risk studies were RCTs (4 out of 5), primarily due to concerns related to outcome measurement and deviations from intended interventions. These high-risk studies could have influenced the pooled results, particularly in areas where heterogeneity was observed. Sensitivity analyses were conducted to assess the impact of high-risk studies on the overall findings, and results remained consistent after excluding these studies.

Heterogeneity and Potential Sources of Variation

Statistical heterogeneity was assessed using the I^2 statistic, and a high level of heterogeneity ($I^2 > 50\%$) was observed in some analyses. Several factors likely contributed to this variability:

Differences in Study Design: The included studies varied in methodology, with some being RCTs, while others were cohort or case-control studies. The level of control over confounding variables differed between these study designs, potentially influencing the pooled effect size.

Variation in TPA Types: Some studies examined conventional TPAs, while others included modified TPAs or TPAs combined with other anchorage devices. These variations in appliance design and function may have contributed to inconsistencies in anchorage outcomes.

Differences in Measurement Methods: The assessment of molar movement and anchorage loss varied between studies. Some used cephalometric analysis, while others relied on digital model measurements or clinical observations, leading to differences in reported outcomes.

Sample Characteristics: Variability in patient demographics, initial malocclusion type, and treatment protocols across studies may have contributed to observed heterogeneity.

Follow-up Duration: Studies differed in the length of follow-up periods, which could affect the extent of reported anchorage loss and the interpretation of TPA effectiveness over time.

To address these sources of variation, we conducted subgroup analyses based on study design and TPA type, which partially reduced heterogeneity. Additionally, a random-effects model was used in meta-analyses to account for variability between studies.

Study Characteristics

The study included patients <33 years. The intervention involved the use of a TPA device compared to no treatment, other auxiliary appliances like Nance, Headgear, Utility arch, fixed orthodontics, interarch elastics, miniscrews, TADs, or any other group that included a TPA. The outcomes are presented in Tables 4, 5, and 6.

Studies Using Cephalometric Analysis to Evaluate Molar Displacement

Zablocki et al examined the effect of the TPA during extraction treatment and found no significant differences in maxillary first molar displacement between the TPA and no-TPA groups. Specifically, the net difference in mesial and vertical displacement was minimal (0.4 mm), with the no-TPA group showing slightly more forward and downward movement. The study concluded that the TPA does not significantly impact molar positioning during extraction (6).

Feldmann et al compared the anchorage capacities of various systems during leveling/aligning and space closure phases post-premolar extractions. They found that while

[DOI: 10.47176/mjiri.39.68]

Table 4. Studies Comparing Anchorage TPA with Other Devices (Lateral Cephalometric Analysis)

Author	Age-range (year)	Study type	Sample size (n)	Tooth movement		Mean (SD)	*P* value
Zablocki 2008 Italy	12-14	Cohort study	60	Mesial movement	U6-PTV (mm)	TPA: 4.1 (1.5) no-TPA: 4.5 (2.0)	NS
				Vertical movement	U6-PP (mm)	TPA: 1.4 (1.7) no-TPA: 1.8 (1.1)	NS
				Mesial tipping	U6-FH (°)	TPA: 3.2 (2.9) no-TPA: 2.4 (3.6)	NS
Feldmann 2008 Sweden	mean age=14.3	Randomized clinical trial	113	Mesial movement Alignment (T0-T1)	Ms-OLp minus A-Olp (mm)	A. Onplant: 0.1 (0.42) B. Orthosystem: -0.1 (0.42) C. HG: -0.4 (1.57) D. TPA: 1.0 (1.08)	A/D: .004 B,C/D: .001
				Mesial tipping Alignment (T0-T1)	inclination: Ms/NL (°)	A. Onplant: 0.7 (1.69) B. Orthosystem: 0.5 (1.65) C. HG: 1.0 (4.05) D. TPA: 4.1 (3.51)	A,B,C/D: <.001
				Mesial movement Space-Closure (T1-T2)	Ms-OLp minus A-Olp (mm)	A. Onplant: 0.0 (0.42) B. Orthosystem: 0.1 (0.74) C. HG (mm): 1.6 (1.59) D. TPA (mm): 1.0 (0.96)	A/D: .005 B/D: .007
				Mesial tipping Space-Closure (T1-T2)	inclination: Ms/NL (°)	A. Onplant: -0.2 (1.36) B. Orthosystem: 0.7 (1.55) C. HG (°): 0.8 (2.38) D. TPA (°): 0.7 (3.34)	NS
				Mesial movement Total observe period (T0-T2)		A. Onplant: 0.1 (0.42) B. Orthosystem: -0.1 (0.82) C. HG (mm): 1.2 (1.96) D. TPA (mm): 2.0 (1.39)	A,B: NS C,D: .001
Liu 2009 China	18-33	Cohort study	34	Mesial movement	U6-PTV (mm)	mini-screw implants: -0.06 (1.40) {& P=0.905} TPA: 1.47 (1.15) {& P<0.001}	P=0.001
				Vertical movement	U6-FH (mm)	mini-screw implants: -1.42 (2.55) {& P<0.05} TPA: 1.91 (1.75)	P=0.000
Basha 2010 India	TPA: 16.00 ±1.41 Mini-Implant: 17.36 ±3.5	Randomized clinical trial	14	Mesial Movement (Anchor Loss)	Distance pterygoid vertical to maxillary molars	TPA = 1.73 mm ±0.4 Mini-Implant = 0.0 mm	?
Borsos 2011 Hungary	mean age: 14.0 (12.6–17.5)	Randomized clinical trial	18	Mesial Movement	U6-PTV (mm)	TBA [TPA] (mm): 1.51 (1.88) BBA [Implant] (mm): 0.68 (0.59)	P=0.241 (NS)
Borsos 2012 Hungary	14.22 ±1.37	Randomized clinical trial	30	Mesial Movement U6-PTV (mm)	(T1-T2) Canine retraction	TPA+ utility arch= 1.48 (1.56) Orthosystem = 1.57 (1.06)	NS
					(T2-T3) Incisor retraction	TPA only = 1.26 (0.93) Orthosystem= 0.59 (0.74)	P=0.039
					(T3-T4) Finishing	TPA only = 0.89 (0.77) Orthosystem= 1.52 (1.69)	NS
					(T0-T4) Overall	TPA (+ utility arch) = 4.28 (1.50) Orthosystem= 4.19 (2.70)	NS
Sharama 2012 India	mean age=17.4	Cohort study	30	Mesial movement	U6-PTV (mm)	TPA: 2.49 (0.71) {P<0.001} Mini-screw implants: -0.001 (0.021) {P=0.90}	P<0.001

*NS, not significant.

molars remained stable in the Onplant, Orthosystem implant, and headgear groups, the TPA group experienced a significant anchorage loss (1 mm) and greater mesial tipping (mean, 4.1°) during the leveling/aligning phase. During space closure, Onplant and Orthosystem implants showed better stability compared to headgear and TPA, which had losses of 1.6 mm and 1 mm, respectively (13).

Liu et al compared cephalometric changes with miniscrew implants versus TPA in adults with bialveolar protrusion. They found that molars in the TPA group were mesialized (1.47 mm), while miniscrew implants caused minimal distalization (–0.06 mm). The study concluded that miniscrew implants provided superior anchorage in both vertical and sagittal directions (14).

Basha et al compared en-masse retraction using mini-implants versus molar anchorage, finding significant anchor-

Table 4. Studies Comparing Anchorage TPA with Other Devices (Lateral Cephalometric Analysis)

Author	Age-range (year)	Study type	Sample size (n)	Tooth movement		Mean (SD)	P value
Al-Sibaie 2014 Syria	22.34 ±4.56	Randomized clinical trial	56	Mesial Movement DUM-H (mm)	T1-T2 (Post-levelling changes)	TPA= 0.26 (0.06) {P=0.120} Mini-Impl= 0.14 (0.61) {P=0.615}	0.053
					T2-T3 (Re-traction changes only)	TPA= 1.50 (1.25) {P=0.001} Mini-Impl= -0.89 (0.59) {P<0.001}	<0.001
					T1-T3 (Over-all changes)	TPA= 1.76 (1.01) {P<0.001} Mini-Impl= -0.75 (0.63) {P=0.001}	<0.001
				Vertical Movement DUM-V (mm)	T1-T2 (Post-levelling changes)	TPA= 0.32 (0.80) {P=0.052} Mini-Impl= 0.27 (0.73) {P=0.131}	0.414
					T2-T3 (Ré-traction changes only)	TPA= 0.06 (0.68) {P=0.825} Mini-Impl= -0.25 (0.83) {P=0.191}	0.231
					T1-T3 (Ove-rall changes)	TPA= 0.38 (0.74) {P=0.009} Mini-Impl= 0.02 (0.93) {P=0.984}	0.044
Alhadlaq 2015 Canada	not men-tioned	Cohort study	20	Mesial movement	U6-PTV (mm)	TPA+ segmented arch me-chanics: 0.7 (1.4)	P=0.01
						TPA+ continuous arch me-chanics: 4.5 (3.0)	P=0.01
Kecik 2019 Turkey	14-22	Case-control study	50	Mesial movement	U6-PTV (mm)	TPA: 2.4 (1.8) TAD: 0.0 (0.0)	P<0.01
				Vertical movement	U6-FH (mm)	TPA: 0.9 (1.1) TAD: 0.0 (0.0)	NS*
					U6-PP (mm)	TPA: 1.2 (0.8) TAD: 0.0 (0.0)	NS
				Mesial tip-ping	U6-FH (°)	TPA: 1.8 (1.6) TAD: 0.0 (0.0)	P<0.05
					U6-PP (°)	TPA: 2.3 (1.4) TAD: 0.0 (0.0)	P<0.01

*NS, not significant.

age loss in the TPA group (1.73 mm) compared to the implant group (0.0 mm). They concluded that mini-implants offered better anchorage for significant anterior retraction, though mean retraction times were similar between groups (15).

Borsos et al investigated osseointegrated palatal implants versus conventional tissue-borne anchorage. They found no significant difference in mesial molar displacement (1.51 mm for TPA vs. 0.68 mm for implants) during canine retraction (16).

Borsos et al evaluated osseointegrated palatal implants versus conventional dental anchorage in adolescents. They noted significant differences in mesial molar movement during incisor retraction, with the implant group exhibiting less movement compared to the dental anchorage group. Overall differences were statistically insignificant (17).

Sharma et al conducted an RCT comparing miniscrew implants versus TPA for canine retraction. The TPA group experienced a significant mesial movement of 2.49 mm, while the miniscrew group showed negligible change. The study highlighted mini-screw implants' superior anchorage but noted potential bias from cephalometric magnification, suggesting future use of three-dimensional models (18).

Al-Sibaei et al compared en-masse retraction with mini-implants versus TPA. They found significant differences in molar movement, with TPA showing forward displacement (1.50 mm) and mini-implants showing minimal movement (–0.89 mm). The mini-implant group had better outcomes in speed, anchorage loss, and aesthetics (19).

Kecik compared conventional anchorage systems with TADs. TPA showed a mean mesial movement of 2.4 mm, while TADs showed no change. TADs provided better control for achieving absolute anchorage (20).

Studies Using Study Models to Evaluate Molar Displacement

Wilmes et al compared traditional TPA to skeletal anchorage using mini-implants. Their three-dimensional scans showed greater anchorage loss with TPA (4.21 mm) compared to mini-implants (2.05 mm). The study indicated that TPA was less effective, particularly in cases with heavy retraction loads (21).

Table 5. Studies Comparing Anchorage TPA with Other Devices (Study Model Analysis)

Author	Age-range (year)	Study type	Sample size (n)	Type of evaluation	Tooth movement		Mean (SD)	*P* value
Wilmes 2009 Germany	Mean age: 20.9	Randomized clinical trial	20	3D digital Cast measurement	Mesial migration of maxillary molars	3D superimpositions (mm)	TPA : 4.21 (1.17) mm Implants : 2.05 (1.39) mm	0.013
					Intermolar distance (Transverse displacement)	Mini-implant coupled with (a) simple horseshoe arch or (b) addition of reinforcement arch wire	TPA= 0.4 mm (0.91) Implant (a): 1.73 (0.39) Implant (b): 0.36 (0.11)	0.002
Stivaros *2010* England	10-17	Randomized clinical trial	49	Model	Mesial movement (mm)		TPA: 0.98 (1.02) Nance: 0.72 (1.33)	0.50
					Mesial tipping (°)		TPA: 2.09 (4.29) Nance: 2.75 (6.04)	0.72
					Distal (disto-palatal) rotation (°)		TPA: 4.43 (3.74) Nance: 2.11 (2.68)	0.02
Mat Nor 2019 Malaysia	TPA =24.8 (3.0) TPA & Nance =23.0 (2.5) Mini-implant =22.8 (2.8)	Randomized clinical trial	36	Study Cast Photographed & measured using Viewbox	Mesial Movement (T0 – T1)	Right side 1st Molar	A – TPA= 2.19 (0.53) B – Nance= 1.23 (0.22) C – Mini-Imp= 0.33 (0.23)	A/B, A/C = <0.001
					Mesial Movement (T0 – T1)	Left side 1st Molar	A – TPA= 2.25 (0.56) B – Nance= 1.25 (0.21) C – Mini-Imp= 0.11 (0.17)	A/B, A/C = <0.001

Table 6. Studies Using Active TPA

Author	Age-range (year)	Study type	Sample size (n)	Type of evaluation	Tooth movement		Mean (SD)	*P* value
Eyüboğlu 2004 Turkey	10.8-12.1	Cohort	15	Cephalometric	Mesial movement	*AnM-PtV (mm)	0.37 (0.44)	< 0.01
					Distal movement	**DiM-PtV (mm)	2.07 (0.70)	< 0.001
					Vertical movement (extrusion)	AnM-FH (mm)	0.27 (0.42)	< 0.05
						DiM-FH (mm)	0.53 (0.58)	< 0.01
					Mesial tipping	AnM/FH (°)	0.40 (0.60)	< 0.05
					Distal tipping	DiM/FH (°)	3.73 (0.96)	< 0.001
				Model	Buccal movement	*^IpAn-ML (mm)	0.20 (0.41)	NS
						IpDi-ML (mm)	0.47 (0.64)	< 0.05
					Mesio-buccal rotation	*+MB-DPAn/ML (°)	9.40 (2.75)	< 0.001
						MB-DPDi/ML (°)	4.80 (1.94)	< 0.001

*AnM, anchorage molar; **DiM, distallized molar.
+*Rotation of the first molars was found by measuring the angle between the midline (ML) and the diagonal line passing through the mesiobuccal (MB) and distopalatinal (DP) cusptips.
*^The changes in the intermolar distance were found by measuring the perpendicular distances from IPAn to ML and from IPDi to ML

Stivaros et al compared Goshgarian TPA and Nance arches over 6 months. Both groups had similar mesial movements (0.98 mm for TPA, 0.72 mm for Nance) and tipping (2°-3°), but TPA caused significantly more disto-palatal rotation (4.5°) compared to Nance (2°) (22).

Mat Nor et al evaluated TPA, TPA-Nance, and mini-implants in treating malocclusion. Mini-implants showed the least anchorage loss (0.33 mm) compared to TPA (2.19 mm) and TPA-Nance (1.23 mm). Mini-implants provided superior anchorage reinforcement (23).

Studies on Asymmetrical Molar Displacements

Eyüboğlu et al assessed the effects of a Goshgarian TPA on unilateral maxillary first molar distalization. They found significant distalization of the first molars (2.07 mm) and a slight mesial movement of the anchorage molar (0.37 mm). The study indicated successful asymmetric distalization with TPA (24).

Overall, the evidence suggests that while TPA can be effective, it often results in greater anchorage loss compared to modern alternatives like mini-implants. Future studies

[DOI: 10.47176/mjiri.39.68]

should use three-dimensional models and consider treatment phases for a comprehensive evaluation of anchorage efficacy.

Meta-analysis

According to the extracted results, pooled means were calculable for four outcomes—including mesial movement U6-PTV (mm) in the TPA group, vertical movement U6-PP (mm) in the TPA group, vertical movement U6-FH (mm) in the TPA group, and mesial tipping U6-FH (°) in the TPA group. There were eight studies for mesial movement U6-PTV (mm), three studies for mesial tipping U6-FH (°), and two studies for each of the other outcomes.

According to the forest plots, the pooled change in mesial movement U6-PTV (mm) in the TPA group was 2.73 (95% CI: 1.90-3.50, random effects), the pooled change in vertical movement U6-PP (mm) in the TPA group was 1.24 (95% CI: 0.96-1.52, common effect), the pooled change in vertical movement U6-FH (mm) in the TPA group was 1.34 (95% CI: 0.36-2.32, random effects), and the pooled change in mesial tipping U6-FH (deg) in the TPA group was 2.94 (95% CI: 1.51- 4.37, random effects) (Figure 2).

The possibility of publication bias was assessed for mesial movement U6-PTV (mm) using; accordingly, the distribution of the effect sizes was approximately symmetric (Figure 3). The results of leave-one-out sensitivity analysis

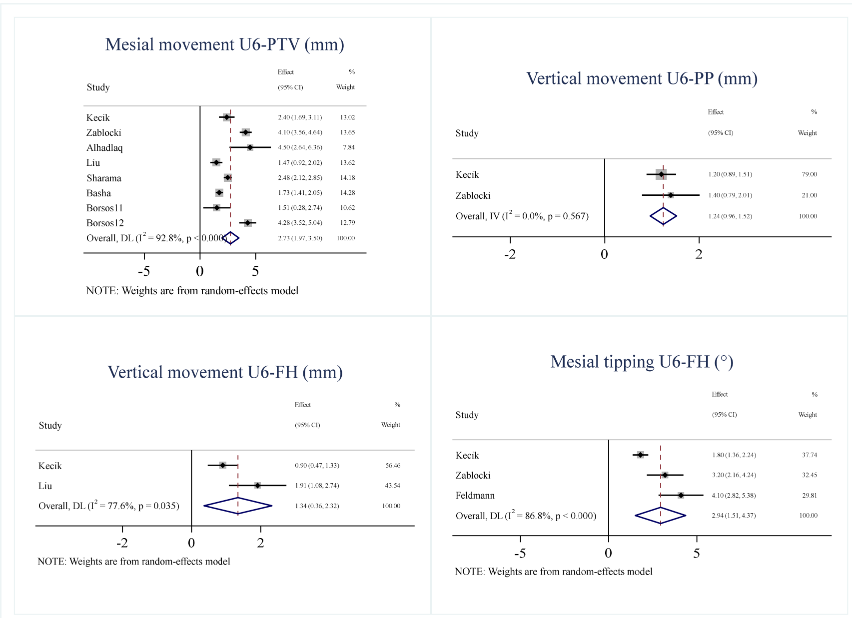

Figure 2. Forest plots for the pooled changes of some measurements (before and after TPA).

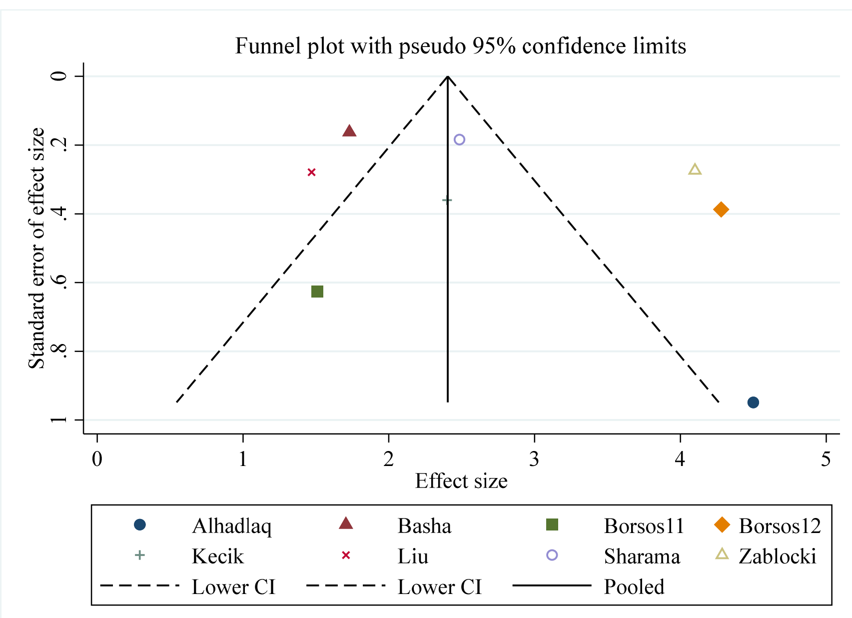

Figure 3. Funnel plot for the pooled mean of Mesial movement U6-PTV (mm).

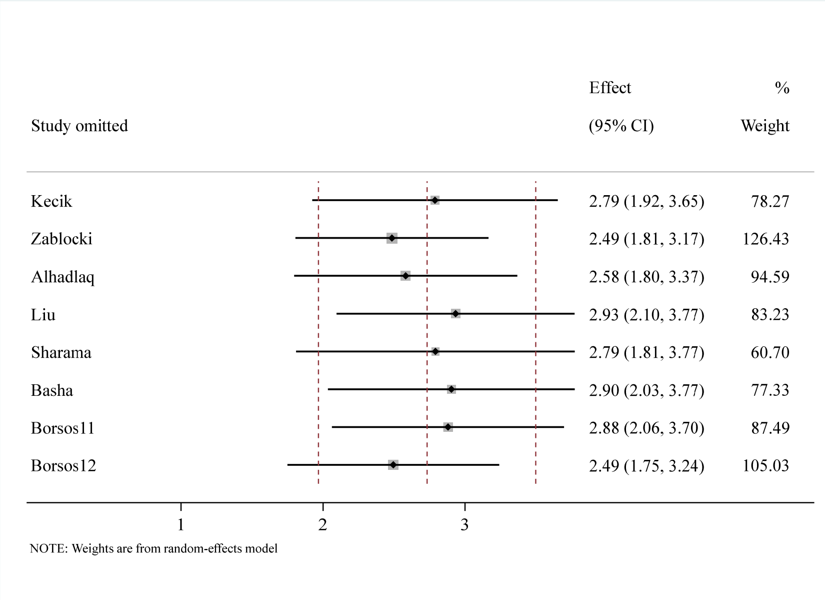

Figure 4. Sensitivity analysis for the pooled mean of Mesial movement U6-PTV (mm).

are also shown for mesial movement U6-PTV (mm) (Figure 4).

Discussion

The TPA is a versatile orthodontic device, renowned for its multiple applications despite its relatively simple design (1, 25). Beyond its well-researched role as an anchorage tool, the TPA has demonstrated efficacy in various clinical scenarios. These include maintaining spaces during dentition transition, correcting molar rotation and mesiodistal inclination, expanding or contracting posterior segments, controlling molar torque, and intruding one or both molars (6, 13, 23). Due to its straightforward design, ease of fabrication, and simplicity in application, the TPA has been widely utilized as an anchorage device. Its compatibility with other treatment systems further underscores its versatility (25, 26).

While comparisons between the TPA and devices designed for singular tasks are common, they often fail to account for the multifaceted utility of the TPA. These comparisons, typically focusing on a single characteristic, do not diminish the value of the TPA but rather highlight the need for comprehensive evaluations that consider all its capabilities.

In contrast to skeletal anchorage devices like miniscrews, which provide absolute anchorage by engaging the bone directly, the TPA offers a noninvasive alternative that relies on dental support. Miniscrews have been shown to achieve superior anchorage control, particularly in cases requiring extensive distalization or intrusion (9, 27). However, their placement involves surgical intervention, potential risks of root proximity, and a success rate influenced by patient-specific factors such as bone density (28). The TPA, while less rigid in anchorage, provides sufficient control in many clinical scenarios without the need for surgical placement, making it a preferable option in cases where moderate anchorage is sufficient or where patient preference limits invasive procedures.

Compared to the Nance appliance, the TPA offers similar anchorage benefits but with key differences. The Nance appliance utilizes an acrylic button resting on the palatal mucosa, which enhances anchorage but can lead to soft tissue irritation and hygiene challenges (29). The TPA, on the other hand, provides effective anchorage without direct palatal contact, reducing the risk of mucosal irritation and plaque accumulation. While the Nance appliance is often preferred for greater anchorage reinforcement, particularly in cases involving premolar extractions, the TPA remains advantageous for patients who require a more hygienic and less bulky alternative (30).

When compared to headgear, which relies on extraoral forces for anchorage reinforcement, the TPA offers a more compliance-independent solution. Headgear is highly effective in distalizing maxillary molars and controlling vertical dimension, but requires patient cooperation for optimal results (31). The TPA, being fixed intraorally, eliminates the reliance on compliance while still providing effective molar stabilization, albeit with less distalization potential (32). For patients with poor adherence to extraoral appliance use, the TPA serves as a practical alternative, particularly when combined with other intraoral mechanics to enhance anchorage control.

In recent years, skeletal anchorage devices, such as microimplants, miniscrews, and TADs, have increasingly replaced the TPA in the maxilla (6). These bone anchors have been extensively researched for their effectiveness, often in comparison with traditional devices like the TPA. Such comparisons, however, may be problematic due to the essential distinctions between skeletal anchoring devices and TPAs.

Many aspects of the TPA are incomparable to those of skeletal anchorage devices and are therefore often overlooked.

This review addresses this gap by evaluating the TPA's role as an auxiliary anchorage device across different stages of orthodontic treatment. Studies on the TPA generally fall into 2 primary categories based on the type of evidence used: lateral cephalometry studies, which primarily offer a two-dimensional evaluation of molar position and angulation, and studies using dental casts, which are further divided into those employing three-dimensional assessments and those utilizing two-dimensional evaluations from cast images (21, 23). Most cephalometric studies averaged right and left images, with only 1 study reporting them separately (23). Linear cephalometric magnification, although reported in only a few studies, can subtly impact treatment outcomes.

For instance, Feldmann et al and Sharma et al mentioned a 10% linear enlargement, although only the latter made the necessary corrections. Another study by Zalbocki et al reported an 8% magnification without correction (2,13,18). Given the inconsistent reporting of radiographic magnification effects, this review disregarded its potential influence. Future research should consider using three-dimensional digital study models to eliminate magnification bias.

The versatility of the TPA allows it to be used in various orthodontic treatment phases. This review compared the effectiveness of the TPA as an anchorage device during different treatment phases, including the leveling/alignment phase, canine retraction phase, incisor/anterior retraction phase, and the overall treatment duration (16,20). Additionally, the TPA's impact on molar transverse and rotational displacements was evaluated, providing a comprehensive assessment of its role throughout treatment.

However, several limitations must be acknowledged. One of the primary concerns is the small sample size in many studies, which may affect the generalizability of findings. Many investigations included limited patient cohorts, making it difficult to draw definitive conclusions regarding the long-term effectiveness of the TPA. Additionally, study designs varied considerably, with differences in methodology, patient selection criteria, and treatment protocols, further complicating direct comparisons.

Another critical limitation is the lack of long-term follow-up data in many studies. Most evaluations focus on short- to medium-term outcomes, providing little insight into the stability of TPA-assisted anchorage over extended periods. Given that anchorage loss and molar movement may continue beyond active treatment, future research should include longer follow-up durations to assess post-treatment stability.

Study durations varied due to concerns over repeated X-ray exposures. Many studies relied on pre- and post-treatment radiographs, while a few took radiographs at specific treatment phases (2, 20). In contrast, study casts allowed for well-defined measurement periods and independent assessment of molar mesial migration in each quadrant, free from the limitations of two-dimensional cephalograms (21, 23). To minimize growth-related variability, studies often selected female patients who had completed growth (ages 13-16), as determined by cervical maturity indicators in lateral cephalograms (2, 13, 16, 17). Although forward growth of the maxilla was anticipated in headgear groups, similar growth patterns were observed across all groups, likely due to normal growth processes (13).

Few studies accounted for posterior maxillary growth when calculating displacement from reference planes such as PTV, although such calculations are crucial in evaluating anchorage loss and treatment efficacy. Some studies suggested that the design of the TPA, such as whether it was square or round, could influence anchorage efficacy (16). However, these differences were considered negligible in the context of the present study.

The review also compared the TPA to various other devices, including Nance appliances, headgear, utility arches, inter-arch elastics, miniscrews, and TADs, across different conditions to comprehensively evaluate its anchorage properties.

Conclusion

This review highlights the versatility and effectiveness of the TPA as an anchorage device across various orthodontic treatment phases. While comparisons with skeletal anchorage devices often overlook the TPA's multifaceted applications, this review underscores the importance of evaluating the TPA within the context of its full range of capabilities. As orthodontic research progresses, the incorporation of three-dimensional digital study models and consideration of pubertal growth stages will be essential in providing more accurate and comprehensive evaluations of the TPA's role in orthodontic treatment.

Authors' Contributions

All authors contributed to the conception and design of the study. Matine Gharavi conducted the literature search and data extraction. Seyyed Amir Yasin Ahmadi performed the statistical analysis. Matine Gharavi and Alireza Jafari-Naeimi drafted the manuscript. All authors read and approved the final manuscript.

Ethical Considerations

Not applicable.

Acknowledgment

The authors received no support or assistance to acknowledge.

Conflict of Interests

The authors declare that they have no competing interests.

References

1. Diar-Bakirly S, Feres MFN, Saltaji H, Flores-Mir C, El-Bialy T. Effectiveness of the transpalatal arch in controlling orthodontic anchorage in maxillary premolar extraction cases: A systematic review and meta-analysis. Angle Orthod. 2017;87(1):147-158.
2. Almutairi T, Al-Maflehi N, Almuzian M, Bearn D. Anchorage effectiveness of orthodontic miniscrews compared to headgear and transpalatal arches: A systematic review and meta-analysis. Acta Odontol Scand. 2018;76(6):434-445.
3. Sandler J, Murray A, Thiruvenkatachari B, Gutierrez R,

[DOI: 10.47176/mjiri.39.68]

Speight P, O'Brien K. Effectiveness of 3 methods of anchorage reinforcement for maximum anchorage in adolescents: A 3-arm multicenter randomized clinical trial. Am J Orthod Dentofacial Orthop. 2014;146(1):10-20.
4. Antoszewska-Smith J, Sarul M, Łyczek J, Konopka T, Kawala B. Effectiveness of orthodontic miniscrew implants in anchorage reinforcement during en-masse retraction: A systematic review and meta-analysis. Am J Orthod Dentofacial Orthop. 2017;151(3):440-455.
5. Raucci G, Pachêco-Pereira C, Grassia V, d'Apuzzo F, Flores-Mir C, Perillo L. Maxillary arch changes with transpalatal arch treatment followed by full fixed appliances. Angle Orthod. 2015;85(4):683-689.
6. Zablocki HL, McNamara JA Jr, Franchi L, Baccetti T. Effect of the transpalatal arch during extraction treatment. Am J Orthod Dentofacial Orthop. 2008;133(6):852-860.
7. Parate AS, Singh P, Shrivastava S, et al. Anchorage. Dentomed Publication House; 2023.
8. Kojima Y, Fukui H. Effects of transpalatal arch on molar movement produced by mesial force: A finite element simulation. Am J Orthod Dentofacial Orthop. 2008;134(3):335.e1-335.e7.
9. Gabada D, Reche A, Saoji KP, Deshmukh R, Rathi N, Mantri A. Accelerated Orthodontics: Stepping Into the Future Orthodontics. Cureus. 2023;15(10):e46824.
10. Andrade I Jr, Sousa AB, da Silva GG. New therapeutic modalities to modulate orthodontic tooth movement. Dental Press J Orthod. 2014;19(6):123-133.
11. Al-Moghrabi D, Johal A, Fleming PS. What are the impacts of orthodontic treatment on caries and periodontal health? A systematic review. Am J Orthod Dentofacial Orthop. 2016;150(1):15-24.
12. Sfondrini MF, Gandini P, Alcozer R, Vallittu PK, Lassila LV, Scribante A. Failure load and stress analysis of orthodontic miniscrews with different transmucosal collar length. J Mech Behav Biomed Mater. 2018;87:132-137.
13. Feldmann I, Bondemark L. Anchorage capacity of osseointegrated and conventional anchorage systems: A randomized controlled trial. Am J Orthod Dentofacial Orthop. 2008;133(3):339.e19-339.e28.
14. Liu YH, Ding WH, Liu J, Li Q. Comparison of the differences in cephalometric parameters after active orthodontic treatment applying mini-screw implants or transpalatal arches in adult patients with bialveolar dental protrusion. J Oral Rehabil. 2009;36(9):687-695.
15. Basha AG, Shantaraj R, Mogegowda SB. Comparative study between conventional en-masse retraction (sliding mechanics) and en-masse retraction using orthodontic micro-implant. Implant Dent. 2010;19(2):128-136.
16. Borsos G, Jianu R, Vegh A. Comparison of bone-borne and tooth tissue-borne anchorage during the maxillary canine retraction in growing patients: A randomized clinical trial. Timisoara Med J. 2011;61:98-101.
17. Borsos G, Vokó Z, Gredes T, Kunert-Keil C, Vegh A. Tooth movement using palatal implant-supported anchorage compared to conventional dental anchorage. Ann Anat. 2012;194(6):556-560.
18. Sharma M, Sharma V, Khanna B. Mini-screw implant or transpalatal arch-mediated anchorage reinforcement during canine retraction: A randomized clinical trial. J Orthod. 2012;39(2):102-110.
19. Al-Sibaie S, Hajeer MY. Assessment of changes following en-masse retraction with mini-implants anchorage compared to two-step retraction with conventional anchorage in patients with class II division 1 malocclusion: A randomized controlled trial. Eur J Orthod. 2014;36(3):275-283.
20. Kecik D. Comparison of temporary anchorage devices and transpalatal arch-mediated anchorage reinforcement during canine retraction. Eur J Dent. 2016;10(4):512-516.
21. Wilmes B, Olthoff G, Drescher D. Comparison of skeletal and conventional anchorage methods in conjunction with pre-operative decompensation of a skeletal class III malocclusion. J Orofac Orthop. 2009;70(4):297-305.
22. Stivaros N, Lowe C, Dandy N, Doherty B, Mandall NA. A randomized clinical trial to compare the Goshgarian and Nance palatal arch. Eur J Orthod. 2010;32(2):171-176.
23. Mat Nor NF, Sinniah SD, Md Dasor M. Comparison of three methods of orthodontic anchorage: A prospective study. J Int Dent Med Res. 2019;12(1):185-191.
24. Eyüboğlu S, Bengi AO, Gürton AÜ, Akın E. Asymmetric maxillary first molar distalization with the transpalatal arch. Turk J Med Sci. 2004;34(1):Article 10.
25. Alrehaili R, Alhujaili A, Almanjhi W, et al. How Effective Are the Nance Appliance and Transpalatal Arch at Reinforcing Anchorage in Extraction Cases?. Cureus. 2024;16(5):e61171. Published 2024 May 27.
26. Kharche A, Durkar S, Kawale P, Yerawadekar S, Jethe S. Transpalatal arch: An overview of literature. J Adv Med Dent Scie Res. 2019;7:26-32.
27. Casaña-Ruiz MD, Bellot-Arcís C, Paredes-Gallardo V, García-Sanz V, Almerich-Silla JM, Montiel-Company JM. Risk factors for orthodontic mini-implants in skeletal anchorage biological stability: a systematic literature review and meta-analysis. Sci Rep. 2020;10(1):5848.
28. Thiruvenkatachari B, Pavithranand A, Rajasigamani K, Kyung HM. Comparison of mini-implant anchorage with conventional anchorage in the maxillary anterior region: A meta-analysis. Am J Orthod Dentofacial Orthop. 2018;153(3):318-328.
29. Santmartí-Oliver M, Jorba-García A, Moya-Martínez T, de-la-Rosa-Gay C, Camps-Font O. Safety and Accuracy of Guided Interradicular Miniscrew Insertion: A Systematic Review and Meta-Analysis. J Clin Med. 2024;13(24):7697.
30. Duske K, Turan B, Prinz C, Lenz JH, Stahl F, Warkentin M. Functionality testing of an innovative biomechanically optimized and surface-modified orthodontic mini-screw-a comparative study. Funktionsprüfung einer innovativen biomechanisch optimierten und oberflächenmodifizierten kieferorthopädischen Minischraube – eine vergleichende Studie. J Orofac Orthop. Published online January 15, 2024.
31. Almeida MR, Farias ACR, Bittencourt MAV, et al. Evaluation of the Nance appliance: Effects and indications. J Clin Orthod. 2019;53(2):75-82.
32. Adeloye AY, Egbunah UP, Utomi IL. Iatrogenic fibrotic encapsulation of NANCE palatal arch appliance in the hard palate and its surgical management: a case report. J Surg Case Rep. 2023;2023(3):rjad120.

[DOI: 10.47176/mjiri.39.68]