Systematic Review Article

Maxillary molar distalization with miniscrew-supported appliances in Class II malocclusion: *A systematic review*

Roshan Noor Mohamed[a]; Sakeenabi Basha[b]; Yousef Al-Thomali[c]

ABSTRACT

Objectives: To evaluate the quantitative effects of miniscrew supported appliances for maxillary molar distalization in Class II malocclusion.

Materials and Methods: The systematic search included MEDLINE, EMBASE, CINAHL, PsychINFO, Scopus, and key journals and review articles. The date of the last search was January 30, 2017. Methodological quality of the retrospective studies was graded by means of the Quality Assessment Tool for Quantitative Studies, developed for the Effective Public Health Practice Project (EPHPP) and prospective studies by means of Newcastle–Ottawa Scale.

Results: In total, 298 studies were identified for screening, and 14 studies were eligible. The Quality Assessment Tool for Quantitative Studies rated all of the four included retrospective studies as moderate. The Newcastle–Ottawa Scale rated seven studies as high quality and three studies as low quality. The mean molar distalization values varied from 1.8 mm to 6.4 mm. Mean distal tipping of molars varied from 1.65° to 11.3°. The mean distal movement of premolars and incisors varied from 1.75 mm to 5.4 mm and 0.1 mm to 2.7 mm, respectively.

Conclusions: Miniscrew-supported appliances are effective in molar distalization with distal movement of premolars with minimal anchorage loss and distal tipping of the molar teeth. (*Angle Orthod.* 2018;88:494–502.)

KEY WORDS: Systematic review; Miniscrew; Molar distalization; Class II malocclusion

INTRODUCTION

Maxillary molar distalization is the most frequently used nonextraction treatment in the correction of Class II malocclusion to establish a Class I molar and canine relationships. Distalization of the molars may be achieved either by extraoral[1,2] or intraoral[3] forces. The main disadvantages with extraoral anchorage is the need for patient compliance and it is esthetically unacceptable.[1,2] To overcome these limitations, many intraoral methods were used to distalize molars such as the use of magnets,[4] pendulum appliance,[5] distal jet appliance,[6,7] nickel–titanium open coil springs[3,4] and several other methods. The common and unwanted side effect of these intraoral methods is the mesial shift of premolars and incisors leading to anchorage loss.[3]

To prevent anchorage loss, intraoral distalization methods use support from the surrounding skeletal structures with the help of temporary anchorage devices such as endosseous implants,[8] miniplates,[9] and miniscrews.[10] The main limitations of implants and miniplates is that they need additional surgery for placement and removal, and they are expensive.[8,9] To overcome these limitations, miniscrews were developed, which are less invasive, cheaper, require less total treatment time, and need minimal patient compliance compared to implants and miniplates. The miniscrew was developed in 1998 by Costa et al.[11] and featured a bracket-like head. Since the time of their invention, these screws were used in a wide array of cases including: correction of deep overbites, closure of extraction spaces, extrusion and

[a] Assistant Professor, Department of Pedodontics, Faculty of Dentistry, Taif University, Taif, Kingdom of Saudi Arabia.

[b] Assistant Professor, Department of Preventive and Community Dentistry, Faculty of Dentistry, Taif University, Taif, Kingdom of Saudi Arabia.

[c] Associate Professor, Department of Orthodontics, Faculty of Dentistry, Taif University, Taif, Kingdom of Saudi Arabia.

Corresponding author: Sakeenabi Basha, MDS, PhD, Assistant Professor, Department of Preventive and Community Dentistry, Faculty of Dentistry, Taif University, Taif, Kingdom of Saudi Arabia
(e-mail: reachdocsaki@gmail.com; sakeena@tudent.edu.sa)

Accepted: February 2018. Submitted: September 2017.
Published Online: April 17, 2018

uprighting of impacted molars, distalization of maxillary and mandibular molars, correction of vertical skeletal discrepancies that would otherwise require orthognathic surgical procedures, etc.[10]

For the correction of Class II malocclusion, miniscrews play an important role because their use avoids premolar extraction in the case of Class II camouflage, and laboratory procedures in the case of noncompliance alternative treatments such as use of the distal jet.[10] In searching the literature, there were a few systematic reviews[12,13] and a meta-analysis[14] conducted on the success rate and anchorage quality of miniscrew implants. Except for several studies that showed the effectiveness of the miniscrew-supported appliance in molar distalization,[6,7,15–27] there was no systematic review synthesizing the evidence for the use of a miniscrew in molar distalization. To address this, a systematic review of the literature was conducted to evaluate the quantitative effects of the miniscrew-supported appliance in maxillary molar distalization in Class II malocclusion.

MATERIALS AND METHODS

This review was planned, conducted, and reported in adherence to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards of quality for reporting systematic reviews and meta-analyses.[28] Institutional review board approval was not required. The present review was registered in PROSPERO (international prospective register of systematic reviews) with registration number CRD42017065808.

Questions

The purpose was to examine the effectiveness of miniscrew-supported appliances for maxillary molar distalization in Class II malocclusion. The research question of the present systematic review was defined according to the PICO format as:

P (Population / Patients): Subjects with Class II malocclusion treated by maxillary molar distalization, only humans.
I (Intervention): Miniscrew appliance in maxillary molar distalization.
C (Comparison): Subjects not receiving any treatment or treated with other molar distalizing appliance.
O (Outcome): Molar distalization in mm.

Study Eligibility

Included studies were published in the English language only and investigated the effectiveness of miniscrew-supported appliances for maxillary molar distalization in Class II malocclusion. Papers were excluded at this stage if they were editorial letters, case reports, in vitro, or not investigating the effectiveness of miniscrew-supported appliances for maxillary molar distalization in Class II malocclusion.

Study Identification

Research databases were searched including: Cochrane library (Cochrane review, Trails), Medline (PubMed, Ovid MEDLINE, and EBSCO), Embase (European studies, pharmacological literature, conference abstract), Web of Knowledge (Social science, conference abstract), Scopus (Conference abstracts, scientific web pages), CINAHL (Nursing and allied health), PsycINFO (Psychology and psychiatry), ERIC (Education) using key terms focused on the specific search strategy (Molar distalization, molar distal shift, Class II malocclusion, miniscrew, miniscrew implants, temporary anchorage device [TAD], intraoral extradental anchorage system, mini implants, screw, and orthodont). For gray literature, the following databases were searched: Google scholar, Open Grey, National Library of Medicine, Social science research, For thesis (EThOS, DART-Europe), Institutional repositories (OpenDOAR, Bielefeld Base, Lenus, RIAN, e-publications@RCSI). To supplement the searches, the tables of content of four key orthodontic journals (American Journal of Orthodontics and Dentofacial Orthopedics, The Angle Orthodontist, European Journal of Orthodontics, and Journal of Clinical Orthodontics) were searched for relevant articles. No beginning date was used, and the last date of the search was January 30, 2017. Additional studies were searched in the reference lists of all articles included.

Study Selection

All titles and abstracts were screened independently and in duplicate for inclusion. In the event of disagreement or insufficient information in the abstract, the full text of potential articles was reviewed independently and in duplicate. The interrater agreement for study inclusion, as assessed using an intraclass correlation coefficient, was 0.75. Conflicts were resolved by consensus discussion between the two reviewers. For retrospective studies, risk of bias was evaluated using the Quality Assessment Tool for Quantitative Studies,[29,30] and, for prospective studies, risk of bias was evaluated using the Newcastle–Ottawa Scale.[31]

Data Extraction

Data were extracted independently and in duplicate for all variables and conflicts were resolved by consensus. The methodological quality of the retro-

Table 1. Search Strategy of the Databases

Citation Screened From Electronic	Number of Articles Screened (n = 286)
Cochrane library (Cochrane review, Trails)	12
Medline (PubMed, OVID Medline, and Ebsco)	125
EMBASE (European studies, pharmacological literature, conference abstract)	56
Web of Knowledge (Social science, conference abstract)	7
SCOPUS (Conference abstracts, scientific web pages)	23
CINAHL	34
PsycInfo (Psychology and psychiatry)	1
ERIC (Education)	1
Google scholar, Open Grey, National Library of Medicine, Social science research,	26
EthOS, DART-Europe	1
Institutional repositories (OpenDOAR, Bielefeld Base, Lenus, RIAN, e-publications@RCSI	0

spective studies was graded by means of the Quality Assessment Tool for Quantitative Studies developed for the Effective Public Health Practice Project (EPHPP), Canada, as adapted by Thomas et al.[29,30] This tool consists of six criteria: selection bias, study design, confounders, blinding, data collection method, and withdrawals/dropouts. Each criterion was rated as strong, moderate, or weak according to the dictionary of the tool; the overall assessment of the study is determined by assessing these ratings. According to the guidelines for the tool, studies with no weak rating and four strong ratings are classified as "strong;" studies with fewer than four strong ratings and one weak rating are classified as "moderate;" and studies with two or more weak ratings are classified as "weak." Two reviewers independently performed the assessment of the quality of the included studies. Any discrepancies in quality ratings were resolved by discussion and consensus. The methodological quality of the prospective studies was assessed by means of the Newcastle–Ottawa Scale.[31,32] Using this "star system," the quality of each included prospective study was assessed using the following criteria: study group selection (it included four items, with a maximum of one star for each item), the comparability (one item with two stars maximum), and outcome and follow-up (three items with a maximum of one star for each item). If the total quality score was 0 to 5, the article was rated as low quality and if the total quality score was 6 to 9, the article was rated as high quality.

Data Synthesis

Two reviewers did data extraction independently for the included studies, and any discrepancies were resolved by discussion and consensus. The following data were extracted from each included study: first author, publication year, study type, study quality, length and diameter of the miniscrew used, screw number, site of placement, duration of treatment, sample size, statistical analysis used, the authors' conclusion, molar distal movement, premolar mesial movement, incisor mesial movement, molar distal tipping, premolar vertical movement, and incisor vertical movement.

RESULTS

Trial Flow

Using the search strategy, 286 articles were identified (Table 1) with an additional 12 identified from the review of references and journal indices. From these, 14 articles were identified for inclusion in the present systematic review (Figure 1).

Study Characteristics and Study Quality

The Newcastle–Ottawa Scale rated seven studies as high quality and three studies as low quality (Table 2). The Quality Assessment Tool for Quantitative Studies rated all the four included retrospective studies as moderate (Table 3). The studies were fairly recent, with the oldest study published in 2004. All of the included studies were published in English. From the 14 studies selected for this review, a self-drilling placement method was used in seven (50%) studies and a self-tapping method in seven (50%) studies (Table 4). The number of miniscrews per subject ranged from one to two. Miniscrews with various brand names were used in the present review, with thread diameters from 1.3 to 2.2 mm and thread lengths from 7.0 to 14.0 mm. The number of study participants ranged from 10 to 57 (total n = 414), with a mean of 29.57. The mean treatment duration varied from 4.6 months to 11.27 months. Distalization force applied/quadrant varied from 200 g to 400 g. In the majority (85.71%) of the studies, the paramedian palate was used to place the miniscrews (Table 5).

Table 6 shows the results of the included studies. The mean molar distalization values varied from 1.8 mm to 6.4 mm. The largest distalization effects (6.4

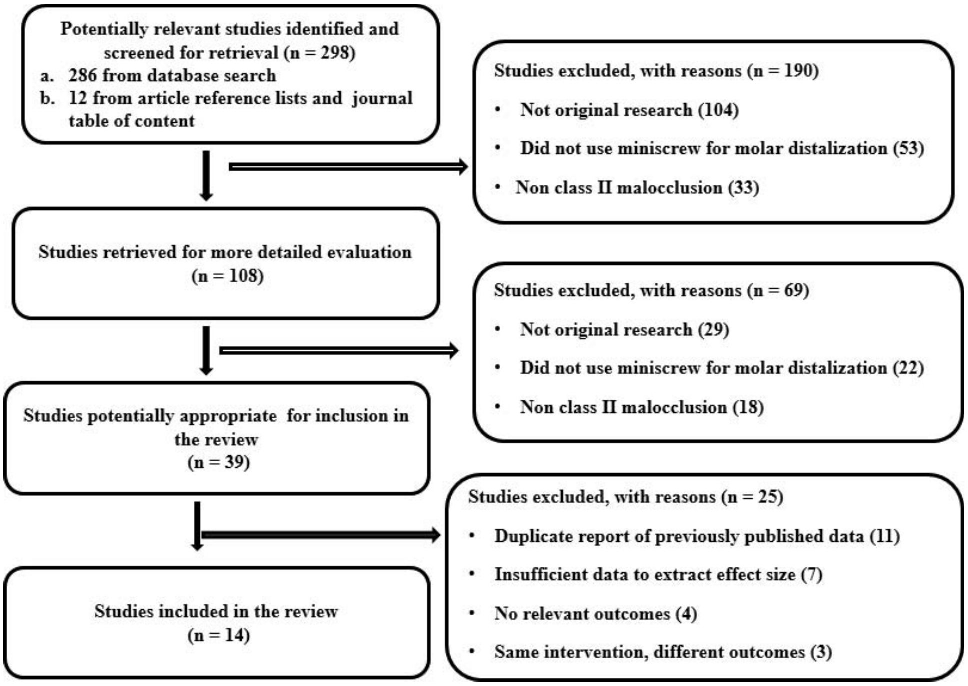

Figure 1. Study selection flow diagram of the systematic review.

mm) were achieved by Kircelli using the miniscrew-supported pendulum appliance. The shortest linear distalization (1.8 mm) measurements were reported by Bechtold et al. with one miniscrew in the interradicular area. The mean distal tipping of molars varied from 1.65° degrees to 11.3°. The highest extent of distal tipping (11.3°) was recorded by Escobar et al. The mean distal movement of premolars and incisors varied from 1.75 mm to 5.4 mm and 0.1 mm to 2.7 mm, respectively (Table 6).

DISCUSSION

Miniscrew-supported appliances have experienced widespread clinical use and various studies have demonstrated their skeletal and dentoalveolar effects.[6,7,10,15–27] The present systematic review was conducted to examine the effectiveness of miniscrew-supported appliances for maxillary molar distalization in Class II malocclusion.

Table 2. Risk of Bias Assessment of Included Prospective Studies Using The Newcastle–Ottawa Scale[a]

	Study									
Quality Evaluation	Duran et al., 2016[23]	Cozzani et al., 2014[6]	Sar et al., 2013[18]	Bechtold et al., 2013[27]	Kinzinger et al., 2009[26]	Yamada et al., 2009[21]	Escobar et al., 2007[19]	Gelgor et al., 2007[25]	Kircelli et al., 2006[17]	Gelgor et al., 2004[24]
Selection										
Representativeness of miniscrew group	*	*	*	*	*	*	*	*	*	*
Selection of control group		*	*						*	
Ascertainment of miniscrew group	*	*	*	*	*	*	*	*	*	*
Demonstration that outcome of interest not present at the start of study	*		*	*		*	*		*	*
Comparability										
Comparability of participants in treatment groups and control groups		*	**						*	
Outcome and follow-up										
Assessment of outcome with independent blinding	*	*	*	*		*	*	*	*	*
Adequacy of follow-up	*	*	*	*	*	*	*		*	*
Lost to follow-up acceptable (<10% and reported)	*	*	*	*			*		*	*
Total quality score	6 (H)	7 (H)	9 (H)	6 (H)	3 (L)	5 (L)	6 (H)	3 (L)	8 (H)	6 (H)

[a] H indicates high quality; L, low quality.

Table 3. Risk of Bias Assessment of Included Retrospective Studies[a]

Study	Risk Assessment Criteria						Overall Grade
	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals/ Dropouts	
Cozzani et al., 2016[7]	M	M	M	M	M	W	M
Caprioglio et al., 2015[22]	S	M	M	W	M	M	M
Mariani et al., 2014[16]	M	M	W	M	M	M	M
Polat-Ozsoy et al., 2008[20]	M	M	M	M	W	M	M

[a] M indicates moderate; W, weak.

Table 4. Descriptive Data of Included Studies[a]

Study	Study Design/MS per Subject (Total Screw)	Type of Distalizing Appliance Used
Duran et al., 2016[23]	Prospective 2 MS/subject (42)	Hyrax screw
Cozzani et al., 2016[7]	Retrospective MGBM/DS, 2 MS/Subject (106)	MGBM and DS
Caprioglio et al., 2015[22]	Retrospective DS/HP, 2 MS/subject (38)	HP and DS
Cozzani et al., 2014[6]	Prospective DS/DJ, 2 MS/subject (36)	Bone anchored DS and tooth supported DJ
Mariani et al., 2014[16]	Retrospective MGBM/HP, 2 MS/Subject (60)	MGBM/HP
Sar et al., 2013[18]	Prospective MISDS/ retrospectiveBAPA, 2 MS/subject (56)	MISDS and BAPA
Bechtold et al., 2013[27]	Prospective Group A one MS /Group B two MS (38)	Miniplates fixed with multiple bone screws
Kinzinger et al., 2009[26]	Prospective 2 MS/subject (20)	Skeletonized distal jet appliance
Yamada et al., 2009[21]	Prospective 2 MS/Subject (24)	Miniscrews placed in the interradicular space
Polat-Ozsoy et al., 2008[20]	Retrospective BAPA/HP one or 2 MS/subject (31)	BAPA/HP
Escobar et al., 2007[19]	Prospective BSP, 2 MS/subject (30)	BSP
Gelgor et al., 2007[25]	Prospective MSV/MSP one per subject (40)	VFV/PFV
Kircelli et al., 2006[17]	Prospective BAPA, 1 MS/Subject (10)	BAPA
Gelgor et al., 2004[24]	Prospective /One per subject (25)	Intramaxillary fixation screw

[a] MS indicates miniscrew; SD, self drilling; ST, self tapping; SDJ, skeletonized distal jet; MD, molar distalization; PMD, premolar distalization; AL, anchorage loss; MISDS, miniscrew implant-supported distalization system with two miniscrews per subject; BAPA, bone-anchored pendulum appliance; MGBM, MGBM system with interradicular miniscrew; DS, distal screw appliance with palatine miniscrew; DJ, distal jet appliance; HP, Hilgers Pendulum; MSV, miniscrew with vestibular force; MSP, miniscrew with palatal force; VFV, vestibular force vector appliance; PFV, palatinal force vector appliance; BSP, bone-supported pendulum.

Table 5. Summary of Dimensions of Miniscrew Used for Distalization, Sample Size, Treatment Duration, Distalization Force Used, Skeletal Anchorage Site, and Analysis Used[a]

Author	MS Dimension, Diameter/Length in mm	Sample Size/Mean Age in Years	Mean Treatment Duration
Duran et al., 2016[23]	1.7/8	21/13.6	5.3 ± 1.46 M
Cozzani et al., 2016[7]	1.5/8–10 in MGBM 1.5–2/11 in DS	29/12.3 in MGBM 24/11.3 in DS	6 M/9M
Cozzani et al., 2016[7]	2.2/11	19/11.3 in DS, 24/12.2 in HP	9 M/7 M
Caprioglio et al., 2015[22]	1.5/11	18/11.5 in DS, 18/11.2 in DJ	9.1 M in DS, 10.5 M in DJ
Mariani et al., 2014[16]	1.5/10	30/13.3 in MGBM, 27/12.8 in HP	7 M/9 M
Sar et al., 2013[18]	2/8	14 in each group/14.8	10.2 M/8.2 M
Bechtold et al., 2013[27]	1.8/7	Group A 12/23.58, Group B 13/22.92	9.08 M /11.27 M
Kinzinger et al., 2009[26]	1.6/8-9	10/12.1	6.7 M
Yamada et al., 2009[21]	1.3 or 1.5/8 or 9	12/28.2	8.4 M
Polat-Ozsoy et al., 2008[20]	2/8	22/13.61 in BAPA, 17/13.62 in P	6.8 M in BAPA/5.1 M in P
Escobar et al., 2007[19]	2/11	15/13	7.8 M
Gelgor et al., 2007[25]	1.8/14	20/11.6-15.1 MSV and 20/12.3-15.4 MSP	4.6 M in MSV, 5.4 M in MSP
Kircelli et al., 2006[17]	2/8	10/13.5	7 M
Gelgor et al., 2004[24]	1.8/ 14	25/11.3-16.5	4.6 M

[a] MS, indicates miniscrew; REM, reverse engineering method; M, months; NA, not available; DSC, digital sliding caliper; MISDS, miniscrew implant-supported distalization system; BAPA, bone-anchored pendulum appliance; MGBM system with interradicular miniscrew; DS, distal screw appliance with palatine miniscrew; DJ, distal jet; HP, Hilgers Pendulum; MSV, miniscrew with vestibular force; MSP, miniscrew with palatal force; IM, first molar; IPM, first premolar; IIPM, second premolar.

Effects on Molar Distalization, Tipping, and Vertical Movement

In the present review, the molars were distalized with a mean value varying from 1.87 mm to 6.4 mm, with the highest (6.4 mm) distalization observed by Kircelli et al.[17] Distal tipping of the molars varied from 1.65° to 11.3°. Distal tipping of the molar was minimal when the distalizing force was applied palatally as the reactive forces were located gingivally, close to the center of resistance of the molar.[24,25] Cozzani et al. compared the distal screw appliance with the MGBM system[7] and distal jet appliance.[6] The results showed that distal tipping of the molars was minimal with the distal screw with more bodily movement of the molars. This might possibly be related to the rigidity of the distalizing arms and the point of the force application with respect to the center of resistance of

Table 4. Extended

Manufacturer	Method of MS Placement	Statistical Analysis	Study Conclusion
MS Forestadent	SD	Spearman rank correlation	Effective MD without AL
Spider screw, HDC/M.A.S., Micerium	SD / ST	*t*-test	Effective MD in MGBM. Less molar tipping in DS
S.p.A., Micerium	ST	Mann-Whitney *U*-test	Effective MD in both groups. Greater distal molar tipping and premolar AL (36.5%) in Pendulum group
M.A.S., Micerium	ST	*t*-test	Effective MD with spontaneous PMD in DS
Spider screw, HDC	SD	Paired *t*-test	Effective MD in both groups, but more AL in HP
MS Stryker	SD	Paired and un-paired *t*-test	Effective MD in both groups. Significant distal tipping of molars in BAPA group
MS Orlus 18107	SD	Two-tailed paired *t*-test	Effective MD with 86.5% of success rate
SDJ with MS Forestadent	SD	*t*-test	91.71% MD with 8.29% AL
AbsoAnchor and Gebruder	ST	Wilcoxon sign rank	Effective MD with no AL
MS IMF Stryker	ST	*t*-test	Effective MD in both groups, high AL (46%) with HP
MS Mondeal	SD	Wilcoxson test	Effective MD with no AL
MS IMF Stryker	ST	Correlation	Effective MD in both group
MS IMF Stryker	ST	Spearman's coefficients	Effective MD and PMD without AL
MS IMF Stryker	ST	Mean and standard deviation	88% of MD with 12% AL

Table 5. Extended

Distalization Force Applied/ Teeth With Bands	Skeletal Anchorage Site	Analysis Used
NA/ 2 IM	Paramedian Palate	Three-Dimensional REM
200 g/240 cN/2 IM and 2 IPM in MGBM, 2 IM in DS	Interradicular, palate between IIPM and IM/ Paramedian palate	Cephalometric
240 g/230 g/2 IM	Paramedian palate	Cephalometric
240 cN/2 IM in DS, 2 IM and 2 IPM in DJ	Paramedian palate	Cephalometric
200 cN/2 IPM, 2 IM	Interradicular, palatal, between IM and IIPM	Cephalometric and dental cast
230 g/2 IM	Paramedian palate	Cephalometric
200g/400g 2IM	Interradicular Buccal, 45° between, IPM and IIPM	Cephalometric
200 cN/2 IPM, 2 IM	Paramedian palate	DSC
200 g/2 IM	Interradicular Buccal, 20° to 30°, between IPM and IM	Cephalometric
230 g/2 IM	Paramedian palate	Cephalometric
250 g/2 IM	Paramedian palate	Cephalometric
250 g/2 IM, 2 IPM	Paramedian palate	Cephalometric and dental cast
NA/2 IM	Paramedian palate	Cephalometric and dental cast
250 g/2 IM, 2 IPM	Paramedian Palate	Cephalometric and dental cast

Table 6. Summary of Results of Included Studies (Molar Distal Movement and Distal Tipping; Premolar and Incisor Mesial Movement; and Mesial Tipping, Molar, Premolar, and Incisor Vertical Movement)[a]

Study	MDM in mm (SD)	MDP in Degrees	Premolar MM in mm (SD)	Premolar MT in Degrees (SD)	Incisor MM in mm (SD)	Incisor MT in Degrees (SD)	Molar VM in mm (SD)	Premolar VM in mm (SD)	Incisor VM in mm (SD)
Duran et al., 2016[23]	4.10 (1.57)	11.02 (5.32)	−2.90 (1.08)	−6.21 (3.49)	−0.59 (0.37)	−1.59 (0.91)	−0.59 (0.50)	0.70 (0.40)	0.38 (0.32)
Cozzani et al., 2016[7]									
MGBM	5.2 (6.2)	10.4 (12.5)	1.8 (1.1)	4.3 (1.6)	NA	1.8 (0.1)	−1.2 (1.5)	1.4 (0.7)	NA
DS	2.6 (3.2)	3.1 (6.3)	−1.9 (2.7)	−8.1 (10.6)	NA	0.3 (1.2)	0.3 (0.1)	1.1 (0.3)	NA
Caprioglio et al., 2015[22]									
DS	4.2 (1.4)	3.2 (3.0)	−1.9 (1.7)	−5.1 (2.0)	−0.1 (1.5)	0.1 (3.5)	0.3 (0.8)	1.3 (2.0)	0.5 (0.6)
HP	4.7 (2.0)	9.0 (4.1)	2.7 (3.3)	3.6 (1.6)	1.7 (2.7)	5.0 (3.6)	−0.1 (1.6)	1.4 (1.9)	0.5 (1.4)
Cozzani et al., 2016[7]									
DS	4.7 (1.6)	2.8 [a]	−2.1 (1.8)	−3.0[a]	NA	NA	0.7 (1.9)	1.1[a]	NA
DJ	4.4 (2.5)	5	0.9 (1.6)	−1.0	NA	NA	0.4 (2.5)	3.5	NA
Mariani et al., 2014[16]									
MGBM	4.9 (3.1)	10.5 (6.2)	1.1 (2.4)	2.5 (4.3)	1.6 (2.0)	1.4 (2.5)	1.3 (0.9)	1.1 (1.9)	0.5 (1.1)
HP	2.5 (2.1)	10.3 (8.4)	1.0 (2.0)	1.9 (6.6)	2.9 (2.0)	4.7 (3.9)	0.1 (1.6)	1.4 (1.7)	0.5 (1.4)
Sar et al., 2013[18]									
MISDS	2.81 (2.70)	1.65 (7.29)	−1.75 (1.14)	−9.65 (6.92)	0.31 (1.75)	−1.38 (3.08)	2.73 (2.03)	−1.77 (1.86)	0.31 (1.75)
BAPA	2.93 (1.74)	9.0[a] (6.74)	−2.73 (2.03)	−6.04 (6.01)	1.07 (2.53)	1.96 (5.49)	1.75[a] (1.14)	−0.93 (1.300	1.07 (2.53)
Bechtold et al., 2013[27]									
A	1.83 (1.23)	3.19 (4.61)	NA	NA	−1.29 (0.66)	1.72 (2.22)	−0.84 (1.09)	NA	0.49 (0.88)
B	2.91 (0.96)	1.55 (1.32)	NA	NA	−2.41 (1.80)	2.41 (7.40)	−1.40 (0.99)	NA	−1.56 (1.19)
Kinzinger et al., 2009[26]	3.92 (0.53)	2.79 (2.51)	0.72 (0.78)	1.15 (2.98)	0.36 (0.32)	0.57 (0.79)	−0.16 (0.26)	0.14 (0.14)	0.14 (0.29)
Yamada et al., 2009[21]	2.8 (1.6)	4.8 (4.5)	NA	NA	−2.7 (2.1)	−4.3 (7.7)	−0.6 (1.0)	NA	0.2 (1.4)
Polat-Ozsoy et al., 2008[20]									
BAPA	4.8 (1.8)	9.1 (4.6)	−2.7 (1.6)	−7.7 (5.1)	−0.1 (1.7)	−1.7 (2.9)	NA	NA	NA
HP	2.7 (1.7)	5.3 (3.8)	4.0 (2.7)	6.9 (4.1)	1.2 (1.7)	0.9 (2.4)	NA	NA	NA
Escobar et al., 2007[19]	6 (2.27)	11.3 (6.2)	−4.85 (1.96)	−8.6 (5.08)	−0.5 (1.33)	−2.5 (2.98)	0.04 (2.25)	−0.46 (1.61)	1.15 (1.69)
Gelgor et al., 2007[25]									
MSV	3.95 (1.68)	9.05 (4.67)	NA	3.15 (3.36)	0.52 (0.61)	1.08 (1.46)	NA	NA	NA
MSP	3.88 (1.47)	0.75 (0.72)	NA	0.10 (0.38)	0.10 (0.16)	0.07 (0.21)	NA	NA	NA
Kircelli et al., 2006[17]	6.4 (1.3)	10.9 (2.8)	−5.4 (1.3)	−16.3 (6.5)	−0.2 (0.7)	−0.6 (1.8)	0.1 (0.5)	0.1 (0.6)	0 (0.6)
Gelgor et al., 2004[24]	3.9 (1.61)	8.7 (4.8)	NA	2.8 (3.1)	0.5 (0.6)	1.0 (1.3)	NA	NA	NA

[a] DM indicates distal movement; DP, distal tipping; MM, mesial movement; MT, mesial tipping; VM, vertical movement; SD, standard deviation; mm, millimeter; NA, not available; A, Group A with single miniscrew; B, Group B with dual miniscrew; MISDS, miniscrew implant-supported distalization system; BAPA, bone-anchored pendulum appliance; MS, miniscrew; HP, Hilgers Pendulum; MSV, miniscrew with vestibular force; MSP, miniscrew with palatal force; DS, distal screw appliance with palatine miniscrew; DJ, distal jet.

[b] Indicates intrusion, or distal tipping, or distal movement.

the molar. Vertical movement of the maxillary molar was minimal and the miniscrew-supported appliance caused both maxillary molar intrusion and extrusion. The mean rate of intrusion varied from 0.1 mm to 1.4 mm. This may be due to the fact that dentoalveolar vertical growth was prevented by the rigid bonded appliance or by the intrusive force exerted by the tongue. The studies by Kircelli et al.,[17] Escobar et al.,[19] and Sar et al.,[18] who used a miniscrew-supported pendulum appliance, showed extrusion of the maxillary molars with mean values from 0.1 mm to 2.7 mm.

Single Screw vs Dual Miniscrew Effect on Molar Distalization

In the present review, studies[20,27] which compared single vs dual miniscrews for molar distalization showed greater molar distalization in the dual screw group compared to the single screw group. Polat-Ozsoy et al.[20] used one screw in nine subjects and two screws in 12 subjects, and showed overall success was greater in subjects with two screws. This may be attributed to the double magnitude of force from using a dual screw.

Miniscrew in Interradicular Area vs Midpalatine

The paramedian palate is a favored site for miniscrew placement because it has an adequate bone mass which in-turn reduces the risk of damage to anatomic structures such as dental roots, nerves, and blood vessels.[23] In the present review, 11 studies used the paramedian region of the palate to place miniscrews. Appliances with miniscrews placed in the paramedian palate caused distal movement of the molars by more than 5 mm without undesirable side effects on the premolars and incisors. The main limitation with the placement of miniscrews in the anterior part of the palate is that this procedure is complex to place and remove the screws. Extensive molar distal movement is difficult to achieve with interradicular miniscrews because the screws would come in contact with the surrounding root during tooth movement.[21,27]

Effects on the Premolars and Incisor/Anchorage Unit

The conventional anchorage setup in noncompliance molar distalization includes the use of acrylic buttons on the palatal mucosa by using the periodontium of anchorage teeth.[10] The disadvantages of this kind of anchorage include, in particular, restrictions to hygiene and contraindications based on certain dentition stages and local situations. Alternative anchorage components for molar distalization appliances include titanium miniscrews of small diameter and orthodontic implants of short length. In comparison to mini implants, miniscrews are less expensive and less invasive.[6,7] Miniscrew anchorage not only causes distal movement of premolars, but also prevents flaring of maxillary incisors, an undesirable side effect of molar distal movement, but could also cause significant distal movement of the incisors. In the present systematic review, eight out of 14 studies showed distalization of premolars and incisors and the mean distal movement of premolars and incisors varied from 1.75 mm to 5.4 mm and 0.1 mm to 2.7 mm, respectively. This may be attributed to the fact that the reactive forces arising from the appliances were directly resisted by an intraosseous screw, the premolars were free from any attachment, and they drifted distally via transseptal fibers during the distalization period.

Limitations

The limitations of the present review were due to heterogeneity across the studies a meta-analysis of the included studies could not be performed. Therefore, no forest plots or funnel plots were constructed. Due to the disparate nature of the studies, only simple descriptive and stratified comparisons were reported.

CONCLUSIONS

- Despite the limitations related to the heterogeneity of the studies included in the review, it can be concluded that miniscrew-supported appliances are effective in molar distalization with minimal distal tipping.
- Along with molar distalization, miniscrew-supported appliances lead to premolar distalization without anchorage loss.

REFERENCES

1. Shpack N, Brosh T, Mazor Y, et al. Long- and short-term effects of headgear traction with and without the maxillary second molars. *Am J Orthod Dentofacial Orthop*. 2014;146:467–476.
2. Patel MP, Henriques JF, Freitas KM, Grec RH. Cephalometric effects of the Jones Jig appliance followed by fixed appliances in Class II malocclusion treatment. *Dental Press J Orthod*. 2014;19:44–51.
3. Kinzinger GS, Eren M, Diedrich PR. Treatment effects of intraoral appliances with conventional anchorage designs for non-compliance maxillary molar distalization: a literature review. *Eur J Orthod*. 2008;30:558–571.
4. Erverdi N, Koyuturk O, Kuçukkeles N. Nickel-titanium coil springs and repelling magnets: a comparison of two different intra-oral molar distalization techniques. *Br J Orthod*. 1997;24:47–53.
5. Fuziy A, Rodrigues de Almeida R, Janson G, Angelieri F, Pinzan A. Sagittal, vertical, and transverse changes consequent to maxillary molar distalization with the pendulum appliance. *Am J Orthod Dentofacial Orthop*. 2006;130:502–510.
6. Cozzani M, Pasini M, Zallio F, et al. Comparison of maxillary molar distalization with an implant-supported distal jet and a traditional tooth-supported distal jet appliance. *Int J Dent*. 2014;2014:937059.
7. Cozzani M, Fontana M, Maino G, Maino G, Palpacelli L, Caprioglio A. Comparison between direct vs indirect anchorage in two miniscrew-supported distalizing devices. *Angle Orthod*. 2016;86:399–406.
8. Onçag G, Seçkin O, Dinçer B, Arikan F. Osseointegrated implants with pendulum springs for maxillary molar distalization: a cephalometric study. *Am J Orthod Dentofacial Orthop*. 2007;131:16–26.
9. Cornelis MA, De Clerck HJ. Maxillary molar distalization with miniplates assessed on digital models: a prospective clinical trial. *Am J Orthod Dentofacial Orthop*. 2007;132:373–377.

10. Crismani AG, Bertl MH, Celar AG, Bantleon HP, Burstone CJ. Miniscrews in orthodontic treatment: review and analysis of published clinical trials. *Am J Orthod Dentofacial Orthop*. 2010;137:108–113.
11. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. *Int J Adult Orthod Orthognath Surg*. 1998;13:201–209.
12. Schatzle M, Mannchen R, Zwahlen M, Lang NP. Survival and failure rates of orthodontic temporary anchorage devices: a systematic review. *Clin Oral Implants Res*. 2009;20:1351–1359.
13. Chen Y, Kyung HM, Zhao WT, Yu WJ. Critical factors for the success of orthodontic mini-implants: a systematic review. *Am J Orthod Dentofacial Orthop*. 2009;135:284–291.
14. Papageorgiou SN, Zogakis IP, Papadopoulos MA. Failure rates and associated risk factors of orthodontic miniscrew implants: a meta-analysis. *Am J Orthod Dentofacial Orthop*. 2012;142:577–595.e7.
15. Maino G, Mariani L, Bozzo I, Maino G, Caprioglio A. Maxillary molar distalization with MGBM-system in class II malocclusion. *J Orthod Sci*. 2013;2:101–108.
16. Mariani L, Maino G, Caprioglio A. Skeletal versus conventional intraoral anchorage for the treatment of class II malocclusion: dentoalveolar and skeletal effects. *Prog Orthod*. 2014;15:43.
17. Kircelli BH, Pektaş ZO, Kircelli C. Maxillary molar distalization with a bone-anchored pendulum appliance. *Angle Orthod*. 2006;76:650–659.
18. Sar C, Kaya B, Ozsoy O, Ozcirpici AA. Comparison of two implant-supported molar distalization systems. *Angle Orthod*. 2013;83:460–467.
19. Escobar SA, Tellez PA, Moncada CA, Villegas Ca, Latorre CM, Oberti G. Distalization of maxillary molars with the bone-supported pendulum: A clinical study. *Am J Orthod Dentofacial Orthop*. 2007;131:545–549.
20. Polat-Ozsoy O, Kircelli BH, Arman-Ozçirpici A, Pektaş ZO, Uçkan S. Pendulum appliances with 2 anchorage designs: conventional anchorage vs bone anchorage. *Am J Orthod Dentofacial Orthop*. 2008;133:339.e9–339.e17.
21. Yamada K, Kuroda S, Deguchi T, Takano-Yamamoto T, Yamashiro T. Distal movement of maxillary molars using miniscrew anchorage in the buccal interradicular region. *Angle Orthod*. 2009;79:78–84.
22. Caprioglio A, Cafagna A, Fontana M, Cozzani M. Comparative evaluation of molar distalization therapy using pendulum and distal screw appliances. *Korean J Orthod*. 2015;45:171–179.
23. Duran GS, Gorgulu S, Dindaroglu F. Three-dimensional analysis of tooth movements after palatal miniscrew-supported molar distalization. *Am J Orthod Dentofacial Orthop*. 2016;150:188–197.
24. Gelgor IE, Buyukyilmaz T, Karaman AI, Dolanmaz D, Kalayci A. Intraosseous screw-supported upper molar distalization. *Angle Orthod*. 2004;74:838–850.
25. Gelgor IE, Karaman AI, Buyukyilmaz T. Comparison of 2 distalization systems supported by intraosseous screws. *Am J Orthod Dentofacial Orthop*. 2007;131:161.e1–8.
26. Kinzinger GS, Gulden N, Yildizhan F, Diedrich PR. Efficiency of a skeletonized distal jet appliance supported by miniscrew anchorage for noncompliancemaxillary molar distalization. *Am J Orthod Dentofacial Orthop*. 2009;136:578–586.
27. Bechtold TE, Kim JW, Choi TH, Park YC, Lee KJ. Distalization pattern of the maxillary arch depending on the number of orthodontic miniscrews. *Angle Orthod*. 2013;83:266–273.
28. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol*. 2009;62:1006–1012.
29. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews Evid Based Nurs*. 2004;1:176–184.
30. Deeks JJ, Dinnes J, D'Amico R, et al. Evaluating non-randomized intervention studies. *Health Technol Assess*. 2003;7:1–173.
31. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol*. 2010;25:603–605.
32. Yang X, Li C, Bai D, et al. Treatment effectiveness of Frankel function regulator on the Class III malocclusion: a systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop*. 2014;146:143–154.