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ORIGINAL ARTICLE

Pendulum and modified pendulum appliances for maxillary molar distalization in Class II malocclusion – a systematic review

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ABSTRACT

Objective: The main purpose of the present systematic review was to evaluate the quantitative effects of the pendulum appliance and modified pendulum appliances for maxillary molar distalization in Class II malocclusion.

Materials and methods: Our systematic search included MEDLINE, EMBASE, CINAHL, PsychINFO, Scopus and key journals and review articles; the date of the last search was 30 January 2017. We graded the methodological quality of the studies by means of the Quality Assessment Tool for Quantitative Studies, developed for the Effective Public Health Practice Project (EPHPP).

Results: In total, 203 studies were identified for screening, and 25 studies were eligible. The quality assessment rated four (16%) of the study as being of strong quality and 21 (84%) of these studies as being of moderate quality. The pendulum appliances showed mean molar distalization of 2–6.4 mm, distal tipping of molars from 6.67° to 14.50° and anchorage loss with mean premolar and incisor mesial movement of 1.63–3.6 mm and 0.9–6.5 mm, respectively. The bone anchored pendulum appliances (BAPAs) showed mean molar distalization of 4.8–6.4 mm, distal tipping of molars from 9° to 11.3° and mean premolar distalization of 2.7–5.4 mm.

Conclusions: Pendulum and modified pendulum appliances are effective in molar distalization. Pendulum appliance with K-loop modification, implant supported pendulum appliance and BAPA significantly reduced anchorage loss of the anterior teeth and distal tipping of the molar teeth.

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Class II malocclusion; bone anchored pendulum; molar distalization; pendulum appliance; systematic review

Introduction

The distalization of maxillary molars is the frequently used non-extraction treatment in Class II malocclusion to establish a Class I molar and canine relationships. Several techniques have been developed to distalize maxillary molars, by means of extraoral [1,2] or intraoral forces [3]. The pendulum device is one of the most commonly used intraoral conventional distalizing devices. This device was developed in 1992 by Hilgers, which consisted of two pendulums springs anchored to the dorsal portion of the button, made of 0.032-inch titanium, molybdenum alloy (TMA) wire, which are inserted in the pre-activated state into palatal sheaths of the molar bands [4]. Since then, several studies evaluated the efficacy of the pendulum appliance, relative to dentoalveolar and skeletal changes in the correction of Class II molar relationship [5–16]. The use of pendulum appliance for correction of Class II molar relationship has an advantage that the correction is accomplished through dentoalveolar changes rather than maxillary growth restriction [4]. The main limitation with this appliance is, anchorage loss, which may cause increased treatment time and round tripping of the anchor teeth unless reinforcement with skeletal anchorage is used [4–10]. Recently, many modifications were done to limit the anchorage loss with pendulum appliance. Sequential distalization of the second molar through segmented pendulum appliance and simultaneous distalization of second and first molar through quad pendulum has been documented by Caprioglio et al. [17]. The bone anchored pendulum appliance (BAPA) which minimizes the round tripping of the anchor teeth bone by the elimination of palatal arms on the premolar has been used by few authors [18–22]. Other modifications in original pendulum appliance tried by various researchers include K-loop combination [23–25], Pendulum K with uprighting bend, toe-in bend, incorporation of a distal screw [26–29] and Pendulis [30] where dental support is replaced by a single mini screw to which a device is fixed by means of welded cap making it easier in positioning and removal by the practitioner. When we searched the literature we came across three recent reviews [3,31,32] which compared the effectiveness of noncompliance intraoral devices in molar distalization and one meta-analysis, which compared the effectiveness of conventional and bone anchorage devices in molar distalization [33]. Irrespective of several studies, which showed the effectiveness of the pendulum appliance in molar distalization [4–30], we could not identify a systematic review synthesizing the evidence for the use of a pendulum appliance in molar distalization. To address this gap,

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we conducted a systematic review of the literature to evaluate and compare the quantitative effects of the pendulum appliance and modified pendulum appliances for maxillary molar distalization in Class II malocclusion.

Materials and methods

This review was planned, conducted and reported in adherence to PRISMA standards of quality for reporting systematic reviews and meta-analyses [34]. IRB approval was not required.

Questions

We sought to examine the effectiveness of pendulum and modified pendulum appliances for maxillary molar distalization in Class II malocclusion.

Study eligibility

We included studies published in the English language only that investigated the effectiveness of pendulum and modified pendulum appliances for maxillary molar distalization in Class II malocclusion. Papers were excluded at this stage if they were editorial letter, case report, *in vitro*, not investigating the effectiveness of pendulum and modified pendulum appliances for maxillary molar distalization in Class II malocclusion.

Study identification

We searched MEDLINE, EMBASE, CINAHL, PsychInfo, Educational Resources Information Center (ERIC), ISI Web of Science and Scopus using search terms designated by an experienced research librarian, focused on the search strategy (molar distalization, molar distal shift, Class II malocclusion, pendulum, pendulum appliance, pendulum device, modified pendulum appliance, bone anchored pendulum appliance, pendulum with K-loop, implant supported pendulum). To supplement the searches, the tables of content of four key orthodontic journals (American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontics, 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 30 January 2017. We searched for additional studies in the reference lists of all articles included.

Study selection

We screened all titles and abstracts independently and in duplicate for inclusion. In the event of disagreement or insufficient information in the abstract, we independently and in duplicate reviewed the full text of potential articles. The inter-rater agreement for study inclusion, as assessed using an intra-class correlation coefficient, was 0.65. Conflicts were resolved by consensus discussion between the two reviewers. Risk of publication bias was assessed using quality assessment tool for quantitative studies [35].

Data extraction

We extracted data independently and in duplicate for all variables and resolved conflicts by consensus. We graded the methodological quality of these studies 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. [35]. The EPHPP tool has been judged suitable to be used in systematic reviews of effectiveness, and it can be used to assess a variety of intervention designs, including randomized controlled trials, quasi-experimental studies and uncontrolled studies. It has been found to have content and construct validity and excellent inter-rater reliability [35–37]. 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.

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, type of pendulum device used, duration of treatment, tool used to measure distalization, sample size, statistical analysis used, molar distal movement, premolar mesial movement, incisor mesial movement, molar distal tipping, premolar vertical movement and incisor vertical movement.

Results

Trail flow

Using our search strategy, we identified 177 articles with an additional 26 identified from our review of references and journal indices. From these, we identified 25 articles for inclusion in the present systematic review (Figure 1).

Study characteristics and study quality

The studies were fairly recent, with oldest study published in 1996. All of the included studies were published in English. Fourteen studies used Hilgers pendulum appliance, five studies used pendulum with bone anchorage, four studies used pendulum appliance with pre-activated springs and toe in bend, one study used pendulum with expansion screws and one study used segmented and quad pendulum appliances. The quality assessment rated four (16%) of the studies as

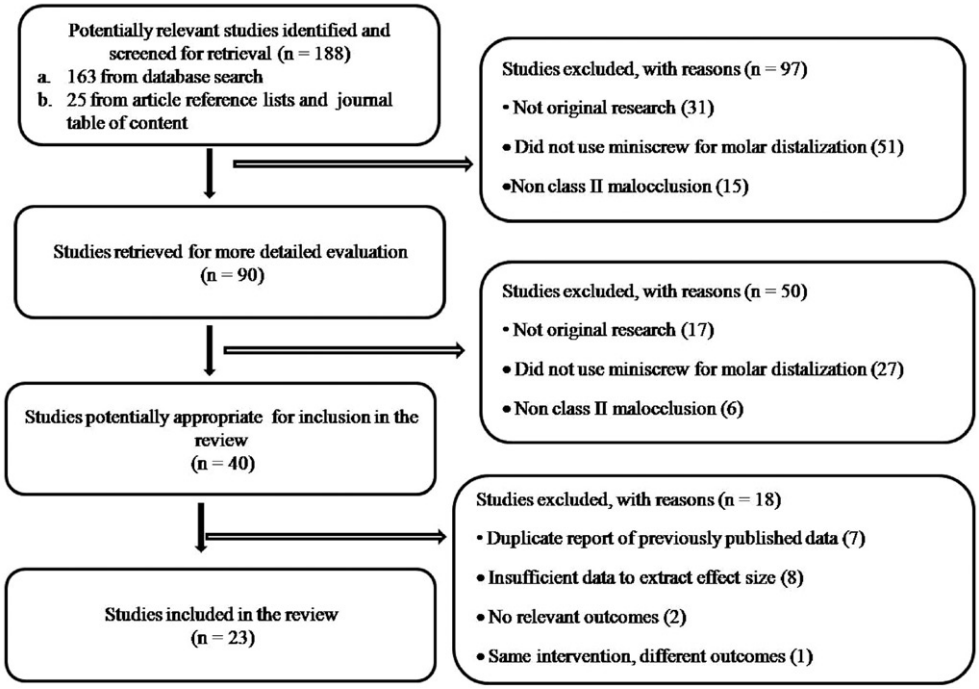

Figure 1. Study selection flow diagram of the systematic review.

being of strong quality and 21 (84%) of these studies as being of moderate quality (Table 1). The number of study participants ranged from 10 to 101 (total $n = 985$), with a mean of 39.4. The mean treatment duration varied from 12 weeks to 10.2 months. Distalization force applied/quadrant varied from 180 to 500 g. The majority (88%) of the studies used four premolars with wires as dental anchorage units (Table 2).

Table 3 shows the results of the included studies. The mean molar distalization values varied from 2.2 to 6.4 mm. The pendulum appliances showed mean molar distalization of 2–6.4 mm, distal tipping of molars from 6.67° to 14.50° and anchorage loss with mean premolar and incisor mesial movement of 1.63–3.6 mm and 0.92–6.5 mm, respectively. The BAPAs showed mean molar distalization of 4.8–6.4 mm, distal tipping of molars from 9° to 11.3° and mean premolar distalization of 2.7–5.4 mm.

Discussion

The pendulum appliance has experienced widespread clinical use and various studies have demonstrated its skeletal and dentoalveolar effects [4–29]. The present systematic review was conducted to examine the effectiveness of pendulum and modified pendulum appliances for maxillary molar distalization in Class II malocclusion.

Effects on molar distalization, tipping and vertical movement

In the present review, 14 studies [5–16,24,25] used Hilgers pendulum appliances and molars were distalized with a mean value varying from 2 to 6.4 mm, with the highest distalization noticed by Marure et al. [24]. The distal tipping of the molars was varying from 8.36° to 14.50°. This shows that purely distalization force application to the maxillary molars is not possible with Hilgers pendulum appliances and that this is built into their design. Byloff et al. [15] in a second treatment stage used uprighting activators, in the area of the pendulum springs, which substantially reduced the side effects of molar tipping, but it took more treatment time. Kinzinger et al. [26–29] showed specific modifications to the pendulum appliance like uprighting bend, toe-in bend and incorporation of a distal screw allowed immediate molar distalization with low distal tipping effects. Kircelli et al. [19], Sar et al. [20] and Polat et al. [21] used BAPA and noticed a distal movement of 4.8–6.4 mm, and distal tipping of 9°–10.9°. Both the authors noticed that the pendulum appliance with skeletal anchorage from inter-maxillary fixation screws could present a more reliable anchorage compared to the Hilgers pendulum appliance.

Vertical movement of maxillary molar was minimal and the standard pendulum appliance caused the maxillary molar intrusion. Mean intrusion values varied from 0.10 to 1.68 mm. This may be due to the fact that the dentoalveolar vertical growth was prevented by the rigid bonded appliance or by the intrusive force exerted by the tongue. The study by Kinzinger et al. [26–29] who used modified pendulum appliance and Kircelli et al. [19] and Sar et al. [20] who used BAPA showed extrusion of maxillary molars and the mean values varied from 0.1 to 1.75 mm.

Second molar status on distalization effect

Kinzinger et al. [26] noticed that, with pendulum treatment, distal tipping of the first molars was less in subjects with erupted second molars than in those whose second molars were not yet erupted. If a second molar has not erupted,

Table 1. Descriptive data and qualitative assessment of included studies.

Author/year	Study design/ follow-up	Distalization appliance used	Second molar status	Tool to measure distalization	Statistical analysis	Study conclusion	Study quality
Ghos/1996	R	Hilgers P	Y	CA and DCA	Paired *t*-test and Pearson's correlation	Effective MD with 40% AL	M
Byloff/1997a	P	Hilgers P	Y	CA with Bjork super imposition	Paired *t*-test	70% of MD with 29% of AL	M
Byloff/1997b	P	Hilgers P with uprighting activation	Y	CA with Bjork super imposition	Paired *t*-test	64% of MD with 36% of AL	M
Kinzinger/2000	P	PK	N	CA and DCA	Wilcoxon test	72.5% of MD with 27.8% of AL	M
Bussick/2000	R	Hilgers P	Y	CA	Paired *t*-test and ANOVA	76% of MD with 24% of AL	M
Chaques/2001	R	Hilgers P	Y	CA	Paired *t*-test	Effective MD with 30% AL	M
Taner/2003	P	PX/CHG	N	CA with Ricketts super imposition	Mann–Whitney *U* test	Effective MD with AL in PX group with shorter treatment time	M
Kinzinger/2004	P	PK	Y	CA and DCA	ANOVA with Tukey *post hoc*	70.25% of MD with 29.75% AL and distal tipping of first molars less in subjects with erupted second molar	M
Kinzinger/2005a	P	PK	N	CA	ANOVA	57% of MD with less AL	M
Kinzinger/2005b	P	PK	Y	CA and DCA	Paired *t*-test	73.53% of MD with 26.47% AL	M
Chiu/2005	R/Follow-up for 24 months	Hilgers P/Distal Jet	Y	CA	*t*-test with ANOVA	90% of MD with significantly less AL (19%) in pendulum group, high relapse in P group	M
Kircelli/2006	P	BAPA	Y	CA and DCA	Spearman's coefficients	Effective MD and PMD without AL	M
Fuziy/2006	P	Hilgers P	Y	CA and DCA	Paired *t*-test	63.5% of MD with 36.5% of AL	M
Angelieri/2006	P/Follow-up for 3.6 years	Hilgers P	Y	CA	Paired *t*-test	Effective MD, but AL and high relapse during follow-up	M
Oncag/2007	P	Hilgers P/OIP	Y	CA	Paired *t*-test and ANOVA	Mean MD more in pendulum group but AL significantly low in OIP group	M
Escobar/2007	P	BSP	Y	CA and DCA	Wilcoxson test	Effective MD with no AL	M
Polat/2008	R	Hilgers P/BAPA	Y	CA	*t*-test	Effective MD in both groups, high AL (46%) with HP	S
Acar/2010	P	Hilgers P with K loop modification/CHG	Y	CA and DCA	Paired *t*-test	Effective MD in both groups. Distal tipping of molars and AL less with pendulum appliance with K-loop	M
Sar/2013	R/P	BAPA/MISDS	Y	CA	Paired *t*-test with Bonferroni	Effective MD in both groups. Significant distal tipping of molars in BAPA group	S
Caprioglio/2013	R/Follow-up for 5 years	Hilgers P	Y	CA	Paired *t*-test	Effective MD with AL. 43% relapse on 5-year follow-up	S
Mariani/2014	R/Follow-up for 2.7 years	Hilgers P/MGBM	Y	CA with Pancherz's super-imposition	Paired *t*-test	Effective MD in both groups, but more AL in P	M
Caprioglio/2014	R/Follow-up for 30 months	SP/QP	Y	CA	Mann–Whitney *U* test	Both SP and QP effective in MD, but SP with more tipping of molars. Less relapse in SP	M
Caprioglio/2015	R	Hilgers P/Distal screw	Y	CA	Mann–Whitney *U* test	Effective MD in both groups. Greater distal molar tipping and premolar AL (36.5%) in Pendulum group	M
Marure/2016	P	Hilgers P/K-loop/DJ	Y	CA	Paired *t*-test	Effective MD with significant AL in P group	S
Shashidhar/2016	P	K-loop/Hilgers P	Y	CA	Paired *t*-test	Effective MD in both groups, more AL in P	M

Y: permanent second molar present; N: permanent second molar absent; R: retrospective; P: prospective; ANOVA: analysis of variance; MD: molar distalization; PMD: premolar distalization; AL: anchorage loss; PK: pendulum appliance with distal screw and pre-activated springs with toe-in bend; P: Hilgers pendulum; SP: segmented pendulum; QP: quad pendulum; DS: distal screw; BAPA: bone-anchored pendulum appliance; MISDS: mini screw supported distalization system; OIP: osseo-integrated implants with pendulum springs; PX: Hilgers pendulum appliance with expansion screw; BSP: bone supported pendulum appliance; CHG: cervical head gear; CA: cephalometric analysis; DCA: dental cast analysis; M: study quality moderate; S: study quality strong.

Table 2. Summary of appliance used for distalization, sample size, treatment duration, distalization force used and dental anchorage used.

First Author/year	Distalization appliance used	Soft tissue rest	Sample size (male, female)/ mean age in years	Sample size for error of method	Mean treatment duration	Distalization force/ quadrant in cN/g	Dental/skeletal anchorage
Ghos/1996	Hilgers P	NAB	41 (15, 26)/12.5	20	6.21 ± 1.44 m	230	Four occlusal rests with wires
Byloff/1997a	Hilgers P	NAB	13 (4, 9)/11.1	NA	16.6 ± 7 w	200–250	Four premolars or primary molars with wires
Byloff/1997b	Hilgers P with uprighting activation	NAB	20 (12, 8)/13.11	NA	27.25 ± 7.12 w	200–250	Four premolars or primary molars with wires
Kinzinger/2000	PK	NAB	50 (21, 29)/11.2	NA	22.49 w	200–250	Four occlusal rests with wires
Bussick/2000	Hilgers P	NAB	101 (45, 56)	NA	7 ± 2 m	200–250	Four premolars or primary molars with wires
Chaques/2001	Hilgers P	NAB	26 (10, 16)/11.2	10	6.5 m	NA	Two first premolars, wire soldered to bands
Taner/2003	PX/CHG	NAB	PX – 13 (3, 10)/10.6 CHG – 13 (5, 8)/10.5	7	7.31 m/11.38 m	230–250/500	Four occlusal rests with wires
Kinzinger/2004	P with distal screw and preactivated springs	NAB	36 (11, 25)/12.5	36	21.86 w	180–200	Four occlusal rests with wires
Kinzinger/2005a	PK	NAB	30 (16, 14)/11.5	NA	22.2 w	180–200	Four premolars or primary molars with wires
Kinzinger/2005b	PK	NAB	66 (27, 39)/11.8	NA	22 w	180–200	Four occlusal rests with wires
Chiu/2005	Hilgers P/distal Jet	NAB	P – 32 (13, 19)/12.6 DJ – 32 (13, 19)/12.3	NA	7 m/10 m	230/240	Four occlusal rests with wires/2-s premolars with bands
Kircelli/2006	BAPA	IMF screw at palatal suture	10 (1, 9)/13.5	NA	7.0 ± 1.8 m	NA	Skeletal anchorage with two IMF screws
Angelieri/2006	Hilgers P	NAB	22 (7, 15)/14.5	20	5.85 ± 1.82 m	400–500	Four premolars with bands
Fuziy/2006	Hilgers P	NAB	31 (9, 22)/14.5	20	5.87 m	250	Four premolars with bands
Oncag/2007	Hilgers P/OIP	NAB	Hilgers P – 15 (6, 9) OIP – 15 (5, 10)	15/15	29 w/27 w	300	Four premolars with bands/OI with occlusal rest on premolar
Escobar/2007	BSP	NAB	15 (9, 6)/13.2	NA	7.8 ± 1.7 m	250	Two endosseus screws in palatal area
Polat/2008	BAPA/Hilgers P	NAB	P – 17 (7, 10)/13.6 BAPA – 22 (7, 15)/13.6	NA	P – 5.1 m BAPA – 6.8 m	230	P – Four premolars with bands BAPA – Two miniscrew in palatal area
Acar/2010	Hilgers P with K loop modification/CHG	NAB	HP with K – 15 (8,7)/15 CHG – 15 (5, 10)/14.2	10	12 ± 2.9 w	200/400	Four premolars with wires
Sar/2013	BAPA/MISDS	IMF screw at palatal suture	BAPA – 14 (5, 9)/14.5 MISDS – 14 (6, 8)/14.8	10	10.2 m/8.2 m	230	Skeletal anchorage with two IMF screws
Caprioglio/2013	Hilgers P	NAB	76 (35, 41)/ 12.11	25	8 ± 2 m	NA	Four premolars with wires
Mariani/2014	Hilgers P/MGBM[a]	NAB	P – 27/12.8 MGBM – 30/13.3	NA	9 m/8 m	200	Four occlusal rests on premolar with bands/ trans palatal bar
Caprioglio/2014	SP/QP	NAB	SP – 24 (13, 11)/12.9 QP – 11 (6, 5)/13.2	15	10 m/11 m	300	Four occlusal rests on premolar with wires
Caprioglio/2015	Hilgers P/distal screw	NAB	Hilgers P – 24 (10, 14/12.2 DS – 19 (9, 10)/11.3	15	7 m/9 m	230/240	Four occlusal rests on premolar with wires/ mini screws at palatal vault
Marure/2016	Group I – P, Group II – K-loop, Group III –DJ	NAB	GI – 22 (14, 8)/14.3 GII – 24 (4, 20)/ 13.3 GIII – 20 (8, 12)/14.8	20	NA	230/200/240	Four occlusal rests on first premolar and molars with wires
Shashidhar/2016	Group I –K-loop, Group II – P	NAB	GI – 15 (6, 9)/16.2 GII – 15 (8, 7)/15.4	15	5–6 m	NA	Four occlusal rests on first premolar and molars with wires

P: pendulum; m: months; w: week; CHG: cervical head gear; BAPA: bone-anchored pendulum appliance; MISDS: mini screw supported distalization system; IMF: intermaxillary fixation; G: group; SP: segmented pendulum with two titanium-molybdenum alloy (TMA) springs and two distal screws; QP: quad pendulum with four TMA springs; NAB: Nance acrylic button; OIP: osseo-integrated implants with pendulum springs; PX: Hilgers pendulum appliance with expansion screw; BSP: bone supported pendulum appliance; DJ: distal jet appliance.
[a]MGBM with skeletal, anchorage.

Table 3. 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).

Author/year	Molar DM in mm (SD)	Molar DP in degrees (SD)	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)
Ghosh/1996	3.37 (2.10)	8.36 (8.37)	2.55 (1.90)	1.29 (7.52)	NA	2.40 (4.57)	−0.10 (1.29)	1.70 (1.36)	0.65 (1.07)
Byloff/1997a	3.39 (1.25)	14.50 (8.33)	1.63 (1.370	NA	0.92 (0.670	1.71 (1.48)	−1.68 (1.33)	0.78 (1.23)	0.45 (0.81)
Byloff/1997b	4.14 (1.61)	6.07 (5.15)	2.22 (0.98)	NA	1.54 (0.88)	3.20 (3.20)	−1.42 (0.87)	1.41 (1.19)	0.54 (0.87)
Kinzinger/2000	2.88 (1.59)	3.24 (4.28)	NA	NA	1.06 (1.03)	3.93 (5.66)	0.37 (0.56)	NA	NA
Bussick/2000	5.70 (1.90)	10.60 (5.60)	1.80 (2.00)	1.50 (4.30)	1.40 (1.50)	3.60 (8.40)	0.10 (1.30)	1.10 (1.20)	0.90 (1.20)
Chaques/2001	5.31 (1.52)	13.06 (7.52)	2.21 (1.3)	4.84 (3.84)	2.09 (0.72)	5.14 (4.01)	−1.20 (1.37)	1.18 (1.36)	0.75 (1.12)
Taner/2003									
PX	3.81 (2.25)	11.77 (11.1)	0.73 (3.53)	4.08 (8.63)	2.00 (1.54)	6.08 (3.670	0.00 (0.960	1.77 (0.90)	0.19 (0.780
CHG	3.15 (1.94)	6.96 (6.05)	−1.88 (1.12)	−3.46 (7.52)	−0.42 (1.59)	1.73 (3.12)	1.42 (0.98)	2.12 (1.76)	0.12 (0.92)
Kinzinger/2004	3.14 (0.92)	3.07 (4.02)	NA	NA	1.33 (0.85)	4.51 (3.60)	0.63 (0.70)	NA	NA
Kinzinger/2005a	3.85 (1.24)	4.65 (3.45)	1.08 (1.19)	−0.50 (5.19)	1.33 (0.74)	3.40 (5.39)	0.25 (0.70)	0.62 (0.82)	0.61 (0.71)
Kinzinger/2005b	3.46 (1.80)	4.24 (4.67)	NA	NA	1.26 (0.71)	3.74 (5.11)	0.39 (0.80)	NA	NA
Chiu/2005									
P	6.1 (1.8)	10.7 (5.5)	1.4 (1.9)	−1.70 (4.7)	1.1 (1.2)	3.1 (4.1)	0.5 (1.1)	1.20 (1.1)	−0.1 (0.9)
DJ	4.1 (5.4)	5.0 (3.6)	2.6 (1.1)	0.3 (4.9)	3.7 (1.7)	13.7 (8.0)	0.6 (1.2)	1.3 (1.2)	−1.5 (1.6)
Kircelli/2006	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)
Angelieri/2006	2	9.4	3.6	6.5	2.2	4	NA	1.8	2.2
Fuziy/2006	4.6	18.5	2.65	2.50	1.51	3.4	−1.17	1.71	1.14
Oncag 2007									
P	4.96 (1.44)	7.06 (5.86)	1.56 (1.69)	2.83 (3.84)	2 (1.52)	1.76 (5.23)	NA	NA	NA
OIP	3.4 (1.18)	10 (3.29)	− 2.8 (0.94)	−7.26 (4.54)	0.06 (1.09)	−1 (1.13)	NA	Na	NA
Escobar/2007	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)
Polat/2008									
P	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
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
Acar/2010									
P	4.53[a] (1.46)	5.13[a] (4.90)	0.23 (1.86)	−1.67 (3.44)	−0.50 (1.64)	−1.07 (2.96)	−0.90 (1.04)	−0.43 (1.50)	0.33 (1.63)
CHG	2.23 (1.68)	−0.8 (2.27)	−1.20 (1.51)	0.27 (1.98)	−1.13 (2.09)	1.33 (1.59)	−0.20 (1.48)	0.17 (2.83)	−1.57 (1.37)
Sar/2013									
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)
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)
Caprioglio/2013	5.1 (0.9)	9.9 (1.5)	1.1 (0.8)	1.2 (1.4)	NA	NA	0.6 (0.3)	0.3 (0.5)	−1.4 (0.5)
Mariani/2014									
P	2.5 (2.1)	10.3 (8.4)	1.0 (2.0)	1.9 (6.6)	2.9 (2.0)	4.7[a] (3.9)	0.1 (1.6)	1.4 (1.7)	0.5 (1.4)
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)
Caprioglio/2014									
SP	4.0 (0.90)	9.6[a] (1.60)	1.50 (1.20)	1.60 (0.90)	1.7 (0.70)	4.1[a] (0.9)	0.20 (0.20)	0.30 (0.20)	−0.4 (1.0)
QP	3.50 (0.7)	4.6 (1.1)	1.80 (0.9)	2.0 (0.7)	2.1 (0.9)	6.6 (1.2)	1.1 (0.9)	0.8 (0.9)	−1.6 (1.2)
Caprioglio/2015									
P	4.7 (2.0)	9.0[a] (4.1)	2.7[a] (3.3)	3.6[a] (1.6)	1.7 (2.7)	5.0[a] (3.6)	0.1 (1.6)	−0.1 (1.6)	0.5 (1.4)
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)	0.3 (0.8)	0.5 (0.6)
Marure/2016									
P	6.4[a] (2.5)	7.3[a] (7.6)	NA	NA	0.9 (2.0)	1.1 (3.0)	0.6 (1.9)	NA	2.3 (2.2)
K	2.2 (2.09)	2.7 (9.9)	NA	NA	4.1[a] (2.0)	6.1 (8.1)	−0.5 (1.7)	NA	2.1 (1.8)
DJ	3.9 (2.9)	−2.9 (3.0)	NA	NA	0.1 (2.9)	6.7 (4.7)	−1 (1.2)	NA	2.8 (0.9)
Shashidhar/2016									
P	4.9 (1.7)	5.2 (1.4)	NA	NA	1.6 (0.6)	5.5 (3.4)	2.5 (1.9)	NA	1.7 (2.1)
K	5.1 (0.8)	5.3 (2.3)	NA	NA	1.3 (0.6)	5.7 (4.7)	2.3 (2.06)	NA	1.6 (1.1)

DM: distal movement; DP: distal tipping; MM: mesial movement; MT: mesial tipping; VM: vertical movement; SD: standard deviation; mm: millimetre; NA: not available; P: Hilgers pendulum; SP: segmented pendulum; QP: quad pendulum; DS: distal screw; DJ: distal jet; K: K-loop; CHG: cervical head gear; BAPA: bone-anchored pendulum appliance; MISDS: mini screw supported distalization system; OIP: osseo-integrated implants with pendulum springs; PX: Hilgers pendulum appliance with expansion screw.

'−' indicates intrusion, or distal tipping, or distal movement.

[a]p Value <0.05 (statistically significant difference).

it acts as a fulcrum and causes first molar tipping. But other authors concluded that second molars do not affect linear and angular changes in molar distalization [9,10,16].

Effects on the premolars and incisor/anchorage unit

The present systematic review showed, 23 out of 25 studies used an acrylic button placed on to the palatal mucosa in the area of the palatal rugae and anchored to two or four primary molars or permanent premolars, occlusally attached to rests or prefabricated bands. The forces and the movements exercised by the activators of the distalization appliance caused movement of anchored teeth with anchorage loss and mesial movement, with intrusion or extrusion of incisors. In the investigated studies, anchorage loss occurred more markedly in the areas of the incisors compared with that of the premolars, leading to proclination of the maxillary incisors. This might be related to the fact that the reciprocal force reacting to the distalization force is directed to the anterior teeth from premolars as all the premolars will be used as anchor units, because of this the acrylic button in palatal depth is insufficient to resist the reciprocal mesial force of the appliance. To minimize this side effect, palatal implants were used along with pendulum appliance. Oncag et al. [22] noticed labial tipping of incisor in the pendulum group and palatal tipping in the implant group. Premolars tipped mesially in the pendulum group, with significant loss of anchorage and distally in implant group, with no anchorage loss. Kircelli et al. [19], Sar et al. [20] and Polat et al. [21] used BAPA and reported premolar distalization of 1.75–5.4 mm and distal tipping of 6.04°–16.3°. Escobar et al. [18] used bone supported pendulum (BSP) appliance and showed premolar distalization of 4.85 mm with a distal inclination of 8.6°. Because reactive forces arising from the pendulum springs were directly resisted by an intra-osseous screw, the premolars were free from any attachment, and they drifted distally *via* transeptal fibres during the distalization period.

Limitations

Compared with previous systematic reviews our study included the larger number of published studies. Because of heterogeneity across the studies, we could not do the meta-analysis of included studies. Therefore, no forest plots or funnel plots were constructed. The low inter-rater agreement (0.65) itself increased the risk of bias in the present review. The limited number of studies in relation to BAPAs might provide a biased estimate of its effect on molar distalization. Further studies are needed in this regard to establish the significant conclusion.

Conclusions

1. Pendulum and modified pendulum appliances are effective in molar distalization.
2. Molar distalization, as well as premolar distalization, was achieved with BAPA without anchorage loss.
3. A pendulum appliance with K-loop modification, implant supported pendulum appliance and bone supported pendulum appliance (BSP) significantly reduced anchorage loss of the anterior teeth and distal tipping of the molar teeth.
4. As the number of studies with BAPAs are less, more studies are still needed to evaluate the effects of modified pendulum appliances on molar distalization in Class II malocclusion treatment.

Effective molar distalization in Class II malocclusion can be achieved with pendulum appliances. The efficiency of these appliances in a clinical application depends on a stabilizing anchorage unit. With the modification of Hilgers pendulum appliance, bodily molar distalization can be achieved with minimal anchorage loss.

Disclosure statement

No potential conflict of interest was reported by the authors.

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