Efficacy of Bone Anchored Pendulum Appliance Over Conventional Pendulum Appliance during Molar Distalization in the Orthodontic Management of Class II Malocclusion : A Systematic Review

Nazleen Valerie Vas[1] , Navaneethan R[2]

[1]Postgraduate student, Department of Orthodontics and Dentofacial Orthopaedics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University Email: 152108002.sdc@saveetha.com
[2]Professor, Department of Orthodontics and Dentofacial Orthopaedics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University navaneethan@saveetha.com

KEYWORDS
Pendulum appliance, Molar distalization, Anchorage, Intraosseous screw

ABSTRACT
Background: Pendulum appliance used commonly used to achieve molar distalization in the management of borderline class II malocclusion is associated with mesial tipping of the maxillary premolars and proclination of maxillary incisors post-distalization, resulting in round tripping and increased treatment time. Bone Anchored Pendulum Appliance (BAPA) is one of the modifications of the pendulum that could effectively prevent anchorage loss. Aim: To evaluate the effectiveness of Bone Anchored Pendulum Appliance(BAPA) over the Conventional Pendulum Appliance(CPA) for the distalization of maxillary molar in the management of Class II malocclusion. Materials and Methods: A web search was done in Google Scholar, MEDLINE, Web of Science, LILAC and COCHRANE Library databases using PRISMA guidelines. The search included RCTs and Non RCTs (Both Prospective and Retrospective studies) comparing distalization achieved by BAPA with CPA in Class II malocclusion. The Risk of bias was assessed using the ROBINS - I tool. Results: Of the initial 745 articles, 5 studies met the inclusion criteria and were included to the systematic review. The BAPA showed between 4.8 -6.4 mm of molar distalization and between 9 °-11.3° of distal tipping of molars while the distalization achieved with CPA was between 2mm -6.4mm with 6.67° -14.50° of distal tipping. While CPA groups showed mesial tipping of premolars, distal tipping of premolars was observed with the BAPA appliances. Conclusions: BAPA were found to significantly reduce anterior anchorage loss, distalise the premolars and molars. There is moderate evidence that BAPA provides greater distalization with reduced incidence of unwanted tooth movements.

1. Introduction

Molar Distalization is the preferred treatment of choice for correction of borderline Class II malocclusions. A multitude of modalities are available to achieve this - the use of headgears, molar distalization appliances, Infrazygomatic screws etc.[1] The pendulum appliance developed by Hilgers in 1992, conventionally consisted of an anteriorly placed Nance palatal button which anchors two “pendulum” springs from its distal aspect. The springs are fabricated using 0.032’’ Titanium Molybdenum Alloy (TMA) wire. The springs are pre activated before they are engaged into palatal sheaths of the molar bands.[2] The pendulum appliance can effectively distalize the maxillary molars, provided there is sufficient anchorage reinforcement. Loss of anchorage with pendulum appliance manifesting as anterior proclination, mesial movement and extrusion of premolars which inherently increases treatment time.[3] Skeletal anchorage is the most effective method of anchorage reinforcement irrespective of the type of tooth movement planned in orthodontics.[4] To this effect many appliances have been modified to include TADs to improve anchorage.[5,6,7] CPA has had many modifications since its introduction.[8] One such modification, designed to prevent loss of anchorage was the Bone anchored Pendulum Appliance by relying on skeletal anchorage. Its application has previously been studied by Sar et al, Kircelli et al among others.[9,10] There is extensive literature on conventional pendulum appliances (CPA) and their modifications. In 2017, Al Thomali et al conducted a systematic review on molar distalization achieved by CPA and its various modifications. While this review illustrated a comprehensive picture of the efficacy of various appliances, there is a lack of concrete evidence on the effectiveness of BAPA over CPA.[11] This systematic review gathers recent evidence to study and compare the effectiveness of BAPA over

CPA. The present study thus was aimed to compare and assess the effectiveness of BAPA over CPA during molar distalization in management of Class II malocclusion.

PICOS analysis

P (Population): Patients with a Class II malocclusion in the permanent dentition

I (Intervention): Bone-Anchored Pendulum Appliance (BAPA) for Distalization of maxillary molars

C (Comparison):): Conventional Pendulum Appliance (CPA) for maxillary molar distalization

O (Outcome): Distal movement of molars in Millimeters (millimeters, mm), Distal Tipping of molars in degrees, mesial movement of premolars (mm) and mesial tipping of premolar in degrees

S (Study design): Randomized clinical trials and non-randomised trials - both prospective and retrospective studies.

2. Materials And Methods

The systematic review was registered with PROSPERO with ID CRD42023416488 in April 2023 and followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guidelines. The Cochrane Handbook for Systematic Reviews of Interventions was used to design the methodology for this study.

Search Strategy and Databases:

The search was performed to find articles published before May 2023 in various electronic databases namely PUBMED, COCHRANE, LILAC, ScienceDirect, Google Search and Medline using the search terms mentioned in Table 1. Articles describing Non-Randomised Prospective and Retrospective studies, Randomised Control Trials (RCTs) were included for review, while in silico, systematic or narrative reviews, animal studies, and studies published in languages other than English were excluded. The studies were assessed for eligibility according to inclusion criteria by two independent reviewers

Selection Criteria:

Inclusion Criteria:

- RCT or Non RCT, Prospective or Retrospective studies
- Patients with Class II malocclusion,
- Studies comparing distalization achieved by Pendulum appliance and Bone Anchored Pendulum appliance.
- Studies in English language
- Studies published until March 2023

Exclusion Criteria:

- Case reports,
- Case series,
- In silico studies
- Animal studies,

- Reviews of studies wherein distalization was achieved with appliances other than BAPA and CPA.

Screening And Selection:

Two reviewers independently screened the papers on the basis of Title, abstract and keywords. For the articles fulfilling the preliminary search, full text was retrieved and was assessed on the basis of the selection criteria. To find additional literature cross references of included articles were searched. In order to determine if the articles that were first reviewed indeed contained information relevant to the present systematic review, both examiners double-checked them. In case of discrepancies, a third reviewer would act as arbitrator.

Data Extraction:

The required data for our review were extracted from the final articles by 2 reviewers. The data were collected according to the headings as characteristics table and summation of findings table.

- Author, Year Of Publication,
- Place Of Study,
- Study Design,
- Total Sample Size, Number Of Samples Included In Control And Intervention Group
- Activation protocol
- Type Of Temporary Anchorage Device Used, Site Of Placement Of Implant
- Method Of Outcome Assessment,
- Molar Distal Tipping And Molar Distalization Values
- Anchorage loss of Incisor and Premolar
- Changes in Maxillary Transverse Dimension

Assessment Of Risk Of Bias:

Risk of Bias was assessed using the ROBINS-I tool suggested by Cochrane Training[12]. Independent evaluations of the quality of the studies included were conducted by two reviewers separately and any disagreements were settled through discussions.The overall risk of Bias was decided by taking into account the highest level of bias in any of the domains.

3. Results And Discussion

As illustrated in Figure 1, the preliminary search resulted in a total of 745 articles, of which 21 articles were identified on PUBMED, 720 identified on Google Scholar and 4 articles on ScienceDirect.[13] Searches on LILACS and Cochrane library yielded no results. From the 745 identified articles 25 duplicates were first removed. On screening the titles 70 articles were found irrelevant and were excluded. On screening the abstracts, 645 articles were found to not match the inclusion criteria after reading the abstract and were excluded. Full texts were then retrieved for the remaining 5 studies and all the 5 studies were considered eligible for review.

Characteristics of Included Studies:

As illustrated in Table 2, a total of 5 studies (3 retrospective studies and 2 prospective studies) that were published between 2007 and 2020, were considered for the present systematic review. In all the articles, the study sample consisted of Class 2 malocclusion patients between the ages of 11 to 17 years, who had presented with moderate crowding in the upper arch and minimally crowded lower arches. The study by Soans et al had the smallest sample size (n=10) and the one by Bozkaya et al had the largest sample size (n=43).[14,15] Polat et al and Gahalla et al used Titanium Intraosseous screws to gain skeletal anchorage.[16,17] Oncag et al used Camlog cylinder screw osseointegrated implants and the loading of the implant was allowed only after 10 weeks of placement.[18] Bozkaya et al used mini-screws as anchorage devices.[19] Soans et al did not specify the anchorage device used, nor the site of placement.[20] The authors had placed the anchorage devices posterior to the incisive foramen, in the anterior paramedian region (APR) of the midpalatal suture (MS). Activation of the spring ranged from 60 degrees to 70 degrees to deliver a distalising force of 230 g in the study by Polat et al, while 300 g was used by Oncag et al and Gahalla et al.[16,17,18] All the authors carried out the cephalometric analysis(CA) on pre-distalization and post distalization lateral cephalograms. In addition, Gahalla et al, Soans et al and Bozkaya et al also carried out Dental Cast Analysis (DCA) to analyze changes in the transverse dimension. [15,17,20]

Risk of Bias Assessment

ROBINS-I tool for non-randomised trials was used to analyze the 5 studies for risk of bias. Of these, 4 studies were deemed to have a moderate risk of bias while 1 article was graded as having a serious risk of bias as illustrated in Figure 2 and Figure 3. [21] Critical judgment in Domain 4 for the study by Soans et al was due to lack of disclosure of the activation protocol of the CPA, the type of skeletal anchorage device used, nor the site of placement of the anchorage devices.[20] CPAs showed molar distalization in the range between 2 mm to 6.4mm. The molars were found to be distally tipped by 6.67° to 14.50°. The BAPA displayed mean distalization of molars between 4.8 - 6.4 mm while the molars were distally tipped by 9° - 11.3°. This shows that CPAs have been designed such that exertion of a pure translatory distalizing force is not possible. In CPA treated patients, mesialization of the premolars and the incisors occurred in the range of 1.63 to 3.6 mm and 0.92 - 6.5 mm respectively. However in the BAPA groups, mean premolar distalization by 2.7 mm –5.4 mm was observed, the maxillary incisors retracted by 0.1 - 2.6mm and a distal inclination change by 1.6° to 6.6°.In the CPA groups, Oncag et al noted a reduction in nasolabial angle, and Soans et al noted increased lip prominence, both attributed to increased proclination of the Maxillary central incisors. 9,12 In both groups, significant increases were observed in inter-premolar and inter-molar distances. Gahalla et al observed an increase in the intercanine width which was statistically significant in the BAPA group.11

Distalization in orthodontics can be achieved using various appliances. In 1892, Norman Kingsley described the headgear, an appliance that requires to be worn for 14 to 16 hours and hence is heavily dependent on patient compliance. Thus a need arose for a noncompliance appliance to achieve distalization. In 1992 the pendulum appliance was described by Hilgers which proved to be an efficient method for distalization of the upper molars.[2] The main advantages of the pendulum appliance over other appliances such as the headgear or Wilson distalizing arch was the minimal compliance required from the patient as only a single activation is necessary in most cases to achieve distalization. The pendulum appliance has experienced widespread clinical success in correction of Borderline Class II malocclusion by bringing about distalization of maxillary first molar. However, the pendulum appliance had some unwanted effects namely mesial tipping of the premolars and the incisors which primarily arose when anchorage was insufficient Kircelli et al designed the bone-anchored pendulum appliance (BAPA) to achieve an effective and compliance-free molar distalization without the undesired mesial tipping and/or forward movement of the premolars and incisors. [10] Despite its advantages, the BAPA also had a disadvantage which was that its activation was difficult. In addition breakages can occur during activation of the springs or

while engaging the springs into the lingual sheaths of the molar bands with BAPA. This systematic review compares the effectiveness of CPAs with that of BAPAs in Class II malocclusion for distalization of maxillary molar.

Treatment Duration

Correction of Distocclusion by use of CPA had been achieved in 5 months as reported by Polat-Ozsoy et al and Soans et al while a duration of 9 months was reported by Bozkaya et al. [16,19,20] The shorter treatment time in the study by Soans et al could be attributed to the smaller sample size. This treatment duration is about the same as described for BAPA which has been described to have achieved the same correction between 6 months and 8 months.[20] Previously Escobar et al reported an average treatment time of 7.8 +/- 1.7 months while Kircelli et al reported correction of Class II malocclusion in 7.0 +/- 1.8 months.[10,22] Farag et al compared distalization between BAPA and Lever-Arm Mini-Implant System(LAMS), with distalization achieved in a duration of 7.2 ± 2.43 months and 10.5 ± 3.14 months respectively.[23] Sesham et al achieved distalization of 4.12 ± 0.069 months using BAPA and in 4.39 ± 0.38 months using a Bone- Anchored Intraoral Bodily Molar Distalizer.[24] Caprioglio et al used a distalising screw appliance to achieve distalization in 9 ±2 months.[25] A comparison was drawn between BAPA and Zygoma Anchorage System(ZAS) by Burcak Kaya et al.[26] The authors reported completion of distalization within 8.1 ± 4.2 months and 9.0 ± 2.4 months respectively. The BAPA group in a study by Cagla Sar et al took 10.2 months, which was more than the group treated using Miniscrew Implant Supported Distalization System (MISDS)- an appliance designed by Papadopoulos- which took 8.2 months.[9] Kircali et al noted a treatment duration of 8.4 months using Miniscrew-Supported Pendulum Appliance. [27]

Effects on Incisors

In the present systematic review, in all 5 studies, the CPA was constructed with an acrylic palatal button anchored to prefabricated bands or occlusal rests on the primary molars or permanent premolars. The palatal button alone cannot bear reciprocal mesially directed counter force of the the springs of the appliance, resulting in consequent mesial movement of the premolars and maxillary incisors.

The CPA groups showed that anchorage loss occurred more distinctly in the region of the incisors when compared with that of the premolars. This has been also described by Ghosh and Nanda, and Bussick et al.[3, 28] However, the converse has been noted in the use of BAPA, where 4 of the 5 studies reviewed reported palatal tipping of the Incisors. This is a favorable movement that could help to reduce the overall treatment time. Escobar et al described Incisor distalization and palatal tipping to be 0.5 +/- 1.33 mm and 2.5 degrees +/- 2.98 degrees respectively, however significant changes did not occur at the incisor (0.1°) in the BAPA group in the study by Caprioglio.[22,25]

Effects on the Maxillary Premolars

Premolar tipping, mesialization and extrusion had been found in the CPA groups. With the aid of skeletal anchorage by placement of implants/screws the distalization of the first and second premolar was seen in the BAPA groups. Oncag et al. found proclination of incisors and mesial tipping of premolars in the CPA group while retraction of the incisors along with distal tipping of premolars occured in the BAPA group.[13] Similarly Ghosh and Nanda described reciprocal mesial movement and mesial tipping of the first premolars on use of CPA. [3] Previously studies employing BAPA reported distalization of premolars by 1.75–5.4 mm along with distal tipping in the range of 6.04° – 16.3°.[9,10,22,23] In BAPA, counter forces produced by the appliance springs are borne by the temporary anchorage device. Thus the premolars are free to move distally with the pull produced by the transseptal fibers during the period of distalization. Bussick and McNamara reported anterior movement 1.8-mm of the upper first premolars, with a mesial tipping of 1.5° in the CPA group.[3] Caprioglio et al reported that in the BAPA group, the maxillary premolar tended to tip

distally rather than be bodily distalized, suggesting that transseptal fibers have a larger influence over the crown of the premolar, than the root.[25]

Effect of Unerupted Second Molar on Distalization

Distal tipping of the first molars was found to be reduced in subjects with erupted second molars when compared to those with unerupted second molars as first reported by Kinzinger et al.[29] An unerupted second molar acts as a fulcrum to cause tipping of the first molar. Kircali et al suggested the germectomy of the third molars to achieve a more bodily distalization of both molars.[28] In the present systematic review, aside from the study by Polat-Ozsoy et al, which included patients with unerupted second molars, all the other studies included only patients who had fully erupted second molars.[1]7 And as such it was not possible to determine the individual effect of the eruption status of the second molar as a variable on the distalization produced by CPA and BAPA. The status of eruption of the third molar was not discussed, and therefore its role in causing tipping of the molars cannot be outlined with certainity.

Effect on the Maxilla in Transverse Dimension

Gahalla et al noted that there was a significant increase in the upper intercanine widths in the BAPA group. The maxillary arch perimeter also increased significantly in both groups (CPA group-11.7 mm and BAPA group-9 mm.) There was also a significant increase in the maxillary intermolar width in both groups with the CPA group showing a slightly greater increase.[17] Soans et al noted significant disto-palatal rotation of the maxillary first molars and also a significant increase in the arch perimeter of both groups post distalization ($p<0.05$). The intermolar distance in particular was significantly increased in the BAPA group ($p<0.05$).[20] A similar increase in the intermolar width was also reported by Bozkaya et al al in both the groups.[22] Farag et al also reported a similar increase in the maxillary intermolar width which was slightly greater in the LAMS group (5.4mm) when compared to the BAPA group (3.4mm). They attributed this increase in the intermolar width to the distalization of the first molar through the wide area of the dental arch.[23]

Table 1 - Search strategy

Database	Search Terms
Pubmed	((Class II Malocclusion) OR (Class 2 Malocclusion))) AND ((((((((Bone-anchored) OR (Bone Anchorage)) OR (Skeletal anchorage)) OR (Temporary Anchorage Device)) OR (TAD)) OR (Miniplate)) OR (mini-screw)) OR (mini-implant))) AND (((Pendulum Appliance) AND ((Distalization) OR (Distalization))
Science Direct	((Class II Malocclusion) OR (Class 2 Malocclusion))) AND ((((((((Bone-anchored) OR (Bone Anchorage)) OR (Skeletal anchorage)) OR (Temporary Anchorage Device)) OR (TAD)) OR (Miniplate)) OR (mini-screw)) OR (mini-implant))) AND (((Pendulum Appliance) AND ((Distalization) OR (Distalization))
Google Scholar	Distalization AND Class II malocclusion AND mini implant OR bone anchored OR skeletal anchorage OR miniplate OR miniscrew AND Pendulum appliance
Cochrane	Class II malocclusion AND Pendulum Appliance AND bone anchored AND Distalization
LILACS	Pendulum Appliance AND bone anchored AND Distalization

Conclusions

Conventional Pendulum Appliance and Bone Anchored Pendulum Appliance are effective in molar distalization. Anchorage loss in the form of mesial premolar tipping, proclination of the incisors was observed on use of CPA. Significant distalization of the premolars and palatal tipping of the maxillary incisors was achieved by BAPA. There is moderate evidence that BAPA provides greater distalization with less tipping of the premolars and anterior teeth. However studies with higher levels of evidence are required to ascertain the efficacy of distalization by BAPA in comparison with CPA.

Limitations

With advancements in clear aligner technology, the modern orthodontist is lesser likely to choose non-compliance Class II correctors for the purpose of distalization.[30,31] This review includes a small sample size. Furthermore, one of the five studies reported serious risk of bias, and four articles with moderate risk of bias.[20] Each of the 5 studies have heterogeneity in their methodologies, having referenced different cephalometric landmarks and hence a meta-analysis, hence a meta analysis cannot be performed to quantify distalization achieved by CPA and BAPA Studies with higher evidence need to be planned to ascertain the effectiveness of distalization on using BAPA.

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