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Original Research Article

A systematic review of anchorage loss in distalization appliances: Current evidence and clinical implications

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ABSTRACT

Background: A comprehensive search of key databases, including MEDLINE/PubMed, Scopus, Cochrane, and EMBASE. Studies published from the year 2000 to 2023 were considered with no language restriction. Aim was to include all the recent studies to make this review more relevant to current paradigm of orthodontic distalization mechanics. Relevant keywords were used, and risk of bias evaluated for included studies. Adults or adolescent patients exhibiting Angle's Class II molar relationship formed the study population with a minimum sample size of 10 patients. Patients with periodontal compromise and those treated with mini-plates and extraoral appliances were excluded. Various distalization appliances including mini-screw supported appliances were examined.
Objective: This systematic review aimed with the primary goal to analyse recent evidence on anchorage loss, amount of distalization, distal tipping in distalization appliances
Materials & Methods: A search across databases yielded a total of 284 records. Additionally, 17 records were identified through other sources, resulting in a combined pool of 301 records. 11 studies met the inclusion criteria and were included in this review. The studies include both the conventional distalization appliances as well as the skeletally anchored appliances.
Results: Qualitative analysis and results of the included studies have been highlighted.
Conclusion: Bone-anchored supported distalization appliances were found to offer significant advantages over conventional appliances in terms of better anchorage control, reduced treatment time and favourability in critical anchorage cases. Modification of pendulum and distal jet appliances by incorporation of micro implants significantly preserves anchorage and reduces overall treatment time

1. Introduction

The foundational concept of anchorage emerges as an essential mark for the success of therapeutic interventions.[1] Anchorage in orthodontic practice denotes the preservation of stability and immobility in specific teeth or dentition, acting as steadfast reference points within the oral cavity.[2] The significance of anchorage becomes apparent when delving into the multifaceted treatment goals of orthodontic therapy.[3] The primary objective is to facilitate regulated tooth movement, aligning teeth and jaws in a harmonious manner. Anchorage serves as the linchpin for achieving intended tooth motions while averting unintended shifts in adjacent or anchored teeth.

Orthodontic forces, when applied, inherently impact not only the targeted teeth but also adjacent ones. Inadequate management of anchorage can lead to adverse outcomes, such as tooth tilting, rotation, or undesired dental displacement.[4–6]. Moreover, anchorage control significantly enhances treatment effectiveness.[7] While anchorage holds importance across all orthodontic procedures, it takes on a distinctive relevance within the realm of distalization

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approaches.[8]

The effective attainment of distalization often requires the application of significant magnitudes of force, owing to the vast distance between posterior teeth and the targeted destination.[9] If these forces are not carefully controlled, they can unintentionally impact anchorage teeth, resulting in undesired tooth displacement.[10]

To address the nuanced particulars of anchorage loss during distalization, this systematic review offers a thorough analysis of the associated difficulties and evidence-based perspectives and strategic planning of orthodontic intervention.

This systematic review not only aims to bridge the existing gaps in knowledge but also aspires to provide a nuanced understanding of the current evidence surrounding anchorage loss in distalization appliances.

2. Materials and Methods

This systematic review adhered to the recommendations outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses(PRISMA) guidelines. Before initiating the review process, a methodology was devised in accordance with the guidelines provided by the Cochrane Handbook for Systematic Reviews of Interventions.

2.1. Protocol and registration

The protocol for a systematic review of anchorage loss in distalization appliances was registered on the National Institute of Health Research Database(www.crd.york.ac.uk/prospero, Protocol: (CRD42024492776).

2.2. Focused question

"What is the current evidence regarding anchorage loss in different distalization appliances, and what are the clinical implications?" By meticulously examining data through a synthesis of randomized controlled trials(RCTs) and non-randomized prospective and retrospective clinical trials, our review aimed to provide a comprehensive understanding of these appliances

2.3. Search strategy

To conduct a thorough and comprehensive search for our systematic review of anchorage loss in distalization appliances, we employed a meticulous search strategy. Our interdisciplinary approach involved blending cohort studies, case-control studies, and randomized clinical trials(RCTs) to gather a diverse range of evidence. We conducted a comprehensive search of key databases, including MEDLINE/PubMed, Scopus, Cochrane, and EMBASE, to ensure broad coverage of relevant literature.

Inclusion criteria were defined in accordance with the PRISMA Checklist. To identify potential articles, initial search was only by title and abstract. No limitations were imposed on language and studies published from the year 2000 to 2023 were taken into consideration. This was done to include all the recent studies to make this review more relevant to current paradigm of orthodontic distalization mechanics. MeSH terms and relevant keywords were strategically chosen to capture the essence of the anchorage loss in distalization appliances. The following terms were employed: "distalization appliances”, “anchorage loss”, “orthodontic anchorage", "molar distalization", "Class II malocclusion", "orthodontic treatment outcomes". Articles published between 2000 to 2023 were considered to encompass the most recent and relevant literature. In addition to the electronic database searches, a manual search of the reference sections of the included studies was conducted. This step aimed to ensure comprehensive coverage of the available literature and identify any additional relevant studies.

By employing this well-defined search strategy, we aimed to gather a robust collection of evidence to contribute to the understanding of anchorage loss in distalization appliances, with adherence to PRISMA statement guidelines.

The inclusion and exclusion criteria were determined based on the aspects of Study design, Participants, Interventions, Comparisons, and Outcomes(PICOS).

1. **Population:** Adults or adolescent patients exhibiting Angle’s Class II molar relationship formed the study population with a minimum sample size of 10 patients, with orthognathic mandible, benefitting from distalization of maxillary teeth. Use of miniplates and adjunctive orthodontic treatment were among the other factors in the exclusion criteria.
2. **Intervention:** Various distalization appliances including mini-screws were examined, and other intraoral devices or other appliances designed for the displacement of posterior teeth.
3. **Comparision:** Different approaches to anchorage preservation during distalization and intra oral appliances
4. **Outcome:** Primary outcomes included distalization amount, distal tipping, and anchorage loss focusing on understanding the effectiveness of distalization appliances and their impact on anchorage. Secondary outcomes included the mandibular rotation with these appliances.Additional outcomes included effects of second and third molars on the rate and amount of distalization.

Study design: Cohort studies, case-control studies, and randomized controlled trials(RCTs).

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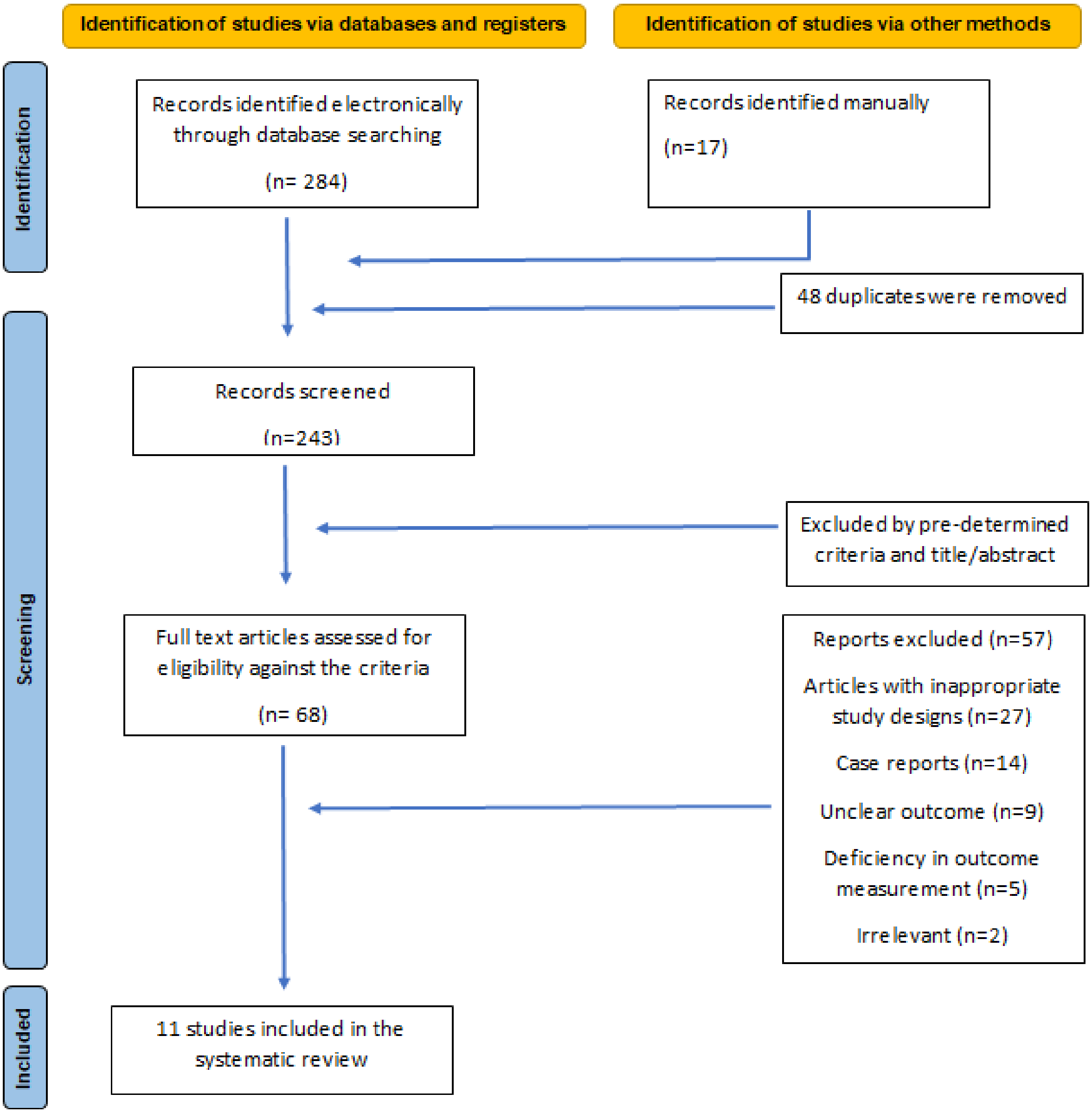

Figure 1: Flow diagram summarizing literature search

Table 1: : Data extraction sheet

Study	Population	Type of study	Mean age of patients	Parameters checked	Intervention	Comparison	Outcome	Time period
Marure et al., 2016[11]	66 children	Prospective design	14.13 years	anteroposterior skeletal measurements, vertical skeletal assessments, interdental measurements, maxillary dentoalveolar changes, and soft tissue parameters.	Three different molar distalization appliances - pendulum, K-loop, and distal jet	Three groups (Group I - pendulum, Group II - K-loop, Group III - distal jet) served as the basis for comparison in assessing the effects of different distalization appliances.	All three molar distalization techniques in growing children produced significant effects on the anchor unit. FMA increased by 1.79° ± 2.25° Reduction of overbite 2.38 ± 1.83 mm Maxillary 1^{st} molars were distalized by average of 4.70 ± 3.01 mm Maxillary central incisor labial tipping increased to an average of 1.61 ± 2.73 mm	5-month period of molar distalization
Rosa et al., 2020[12]	Class II division 1 malocclusion, focusing on growing individuals.	prospective and comparative design	Not mentioned	parameters examined included ANB, GoGn.SN, AO-BO, S'-ANS, S'-A, S'-B, S'-Pog, and S'-U6(maxillary first molar).	exclusive use of cervical headgear for 15 ± 4 months.	The Control Group served as a reference for comparison, consisting of untreated individuals with similar malocclusions and chronological age.	Significant differences were observed in ANB, S'-U6, AO-BO, S'-ANS, S'-A, S'-B, and S'-Pog variables between T1 and T2 in both the Experimental and Control Groups. No statistically significant variation regarding the GoGn.Sn angle	15 ± 4 months

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Table 1 continued

Kircali & Yuksel, 2018 [13]	20 patients with the Angle Class II molar relationship	prospective clinical study	Mean age of the patients in the study was 14.05±2.4 years.	Cephalometric angles such as SNA, SNB, SN/GoGn, as well as specific measurements related to the maxillary first molars, maxillary second premolars, maxillary first premolars, and maxillary incisors	use of a mini-screw-anchored pendulum appliance for maxillary molar distalization.	evaluate changes in various cephalometric angles and dental measurements before and after the intervention with the mini-screw-anchored pendulum appliance.	mini-screw-anchored pendulum appliance was effective for maxillary molar distalization, controlling undesired anchorage loss typically observed in 1^{st} premolar and incisor regions in conventional methods. 4.2 mm distalization of maxillary 1^{st} molars Distal tipping of 8.9°	8.4 months
Ömür Polat-Ozsoy et al., [14]	22 patients with Angle's class II malocclusion(15 girls and 7 boys)	comparative retrospective study	mean age was 13.61 ± 2.07 years	Sagittal skeletal, dental and soft tissue changes achieved after molar distalization with BAPA and compare it patients treated with conventional pendulum appliance	use of 2 anterior paramedian intraosseous titanium screws in the anterior area of the palate	assessing the predicted maxillary molar distalization movement with the achieved clinical outcome using Invisalign.	significant difference in the amount of distalization, distal tipping of first molar, changes in premolar and treatment duration between the 2 groups	6.8 months for BAPA and 5.1 months for conventional pendulum appliance

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Table 1 continued

Serafin et al., 2021[15]	24 patients with Class II malocclusion	prospective observational design	mean age was 12.1 years	incisor buccal tipping, first and second molar distal tipping, as well as the movement of maxillary molars and premolars.	use of a pendulum appliance for molar distalization in patients with Class II malocclusion.	analyzing cephalograms at baseline (T1) and after molar distalization (T2) to assess changes in various dental and skeletal parameters.	changes in angular and linear dental parameters, anchorage loss, and the effects on the occlusal plane after molar distalization using the pendulum appliance. Significant incisor buccal tipping of 5°±3.6° 1^{st} molar distal tipping of 8.9°±8.3° 2^{nd} molar distal tipping of 8.2°±8.1° Premolar showed statistically significant anchorage loss of 2.7±3.3 mm Overjet increased by 1.3±1.2 mm	8±2 months
Kinzinger et al., 2009[16]	10 patients	interventional study design	Not mentioned	parameters related to molar distalization, including translatory movement, mesial inward rotation, and anchorage loss.	placement of two paramedian miniscrews in the anterior area of the palate	effectiveness of the skeletonized distal jet appliance with paramedian mini screw anchorage	suitability of the skeletonized distal jet appliance for translatory molar distalization by 3.92±0.53 mm Mesial inward rotation of 1^{st} molar by 8.35°±7.66° 1^{st} premolar mesialization of 0.72±0.78 mm	Not mentioned

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Table 1 continued

Reis et al., 2020[17]	44 patients with Class II malocclusion	comparative observational design	mean age of patients in Group 1(experimental) was 12.7 years, while the mean age in Group 2 (control) was 12.2 years.	changes in the mandibular plane angle, inclination, distalization, and extrusion of maxillary second molars, distalization of maxillary first molars, mesialization of maxillary first premolars, proclination, and protrusion of maxillary incisors	use of the Distal Jet appliance for the treatment of Class II malocclusion	compared the outcomes of the experimental group treated with the Distal Jet appliance (Group 1) to the control group (Group 2), which did not receive the intervention.	increased by 1.5±1.1 mm	changes over a specific time period, including before treatment (T0) and at the end of the distalization (T1).
Caruso et al., 2019[18]	10 subjects, comprising 8 females and 2 males,	retrospective observational study	mean age of the study participants was 22.7 ± 5.3 years	measurements included SN-GoGn, linear position of upper molars(6-PP, 7-PP), molar class relationship parameter(MR), and upper incisive inclination	upper molars sequential distalization using orthodontic aligners, specifically Invisalign.	evaluating the changes in cephalometric parameters from T0 (initial) to T1 (post-distalization) within the same group of subjects treated with orthodontic aligners.	impact on the vertical dimension, molar class relationship, incisive inclination, and other relevant parameters during the orthodontic procedure. Statistically significant differences were found in linear position of upper molars	two time points: T0 (before treatment) and T1 (after upper molars sequential distalization).

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Table 1 continued

Cozzani, M et al., 2014[19]	36 subjects, with 18 treated using the bone-anchored distal screw(DS) and 18 as controls treated with the traditional tooth-supported distal jet(DJ).	comparative study design	Not mentioned	parameters included molar distalization, treatment time, spontaneous distalization of the first premolar, anchorage loss, distal tipping, extrusion, and skeletal changes.	primary interventions in the study were the bone-anchored distal screw (DS) for the experimental group and the traditional tooth-supported distal jet (DJ) for the control group.	efficiency of the bone-anchored distal screw (DS) and the traditional tooth-supported distal jet (DJ) for molar distalization.	Maxillary 1st molars distalized by 4.7±1.6 mm in experimental group and 4.4±2.5 mm in control group Maxillary 1st premolars in experimental group distalized by 2.1±1.8 mm and slightly mesialized by 0.9±1.6 mm At the end of treatment, 1st molar distal tipping were slightly lower in experimental group (-2.8°;-3.1 to 1.3 mm), as compared to the control group (-5.0°;-9.0 to 2.0 mm) Molar extrusion was similar in both the groups Maxillary first premolars instead (PP-U4) presented a lower extrusion in the DS group (1.1 mm; 0.1 to 1.9) in comparison to the controls (3.5 mm; 1.0 to 4.0) and the difference was statistically significant	9.1±2.8 months in distal screw group 10.5±4.2 months

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Table 1 continued

Sodagar et al., 2011[20]	16 patients, consisting of 12 girls and four boys.	prospective clinical study design	Not mentionned	parameters to evaluate the dental and skeletal effects of the Bonded Molar Distalizer(BMD).	The primary intervention in the study was the use of the Bonded Molar Distalizer (BMD) for bilateral distalization of maxillary molars.	outcomes were likely compared to baseline measurements before treatment.	During the 11 weeks of activation of the Bonded Molar Distalizer, mean maxillary 1^{st} molar distalization was 1.22±0.936 mm with a distal tipping of 2.97±3.74°. Rate of distal movement per month was 0.48 mm Reciprocal mesial movement of 1^{st} premolar was 2.26±1.12 mm with a mesial tipping of 4.25±3.12° Maxillary incisors moved 3.55±1.46 mm and tipped by 9,87±5.03°	11 weeks

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Table 1 continued

Papadopoulos et al., 2010[21]	26 consecutive patients with bilateral Class II molar relationships.	randomized controlled trial(RCT)		distalization of maxillary first molars, molar movement rate, distal tipping of the first molars, anchorage loss in terms of overjet increase, mesial movement and inclination of the first premolars or first deciduous molars, buccal movement of maxillary first molars, and distal rotation of the molars.	use of the First Class Appliance (FCA) for the distalization of maxillary first molars in patients with Class II malocclusion and mixed dentition.	comparison in the study was between the treatment group, which received the First Class Appliance (FCA), and the untreated control group.	mean treatment period required to achieve a full Class I molar relationship, the extent of distalization of maxillary first molars produced by the FCA was compared with the untreated group. The rate of molar movement was 1.00 mm per month Distal tipping of 1^{st} molar by 8.56° and anchorage loss in terms of overjet increased by 0.68 mm Mesial movement of 1^{st} premolar by 1.86 mm and tipping by 1.85°. Maxillary 1^{st} molar moved buccally by 1.37 mm	mean treatment period to achieve a full Class I molar relationship was 17.2 weeks.

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Table 1 continued

Fuziy et al., 2006[22]	31 patients with Angle Class II molar relationships	clinical trial design	mean age of the patients was 14.58 years.	extent of maxillary first molar distalization, mesial movement of maxillary first premolars, space opening, rate of molar movement, distal crown tipping of maxillary molars, expansion effects on the molars, and the symmetry of expansion on the right and left sides.	use of the pendulum appliance for the distalization of maxillary molars.	study involved assessing the changes produced by the pendulum appliance before and after the intervention.	outcomes included the percentage of space opening attributed to molar distalization and premolar movement, the mean space opening on lateral cephalograms, the rate of molar movement, the extent of distalization, and the collateral effects such as distal crown tipping and expansion of the maxillary molars. Establishment of Class I molar relationship by 5.87 months. Rate of molar distalization was 1.04 mm and 1.10 mm for right and left sides respectively. Molar distalization accounted for 63.5% of the space opening, and 36.5% was due to maxillary 2^{nd} premolar mesialization	5.87 months

Table 2: Details of studies included in the analysis

Author	Mean age group for the study	Appliance used	Treatment time	Sample size	Malocclusion
Marure et al., 2016[11]	14.13 years	Pendulum, K loop and Distal jet	5 months	n= 66	Class II malocclusion
Kircali & Yuksel, 2018[12]	14.05±2.4 years	mini-screw-anchored pendulum appliance	8.4 months	n= 20	Class II malocclusion
Ömür Polat-Ozsoy et al., 2007[13]	13.62 ± 2.01 years	Conventional pendulum appliance and bone anchored pendulum appliance	6.8 months for BAPA and 5.1 months for conventional pendulum appliance	n=22 (BAPA group) n=17 (CPA group)	Class II malocclusion
Serafin et al., 2021[14]	12.1 years	Pendulum appliance	8 ± 2 months	n=24	Class II malocclusion
Kinzinger et al., 2009[15]	12 years and 1 months	Mini-screw supported distal jet appliance	6.7 months	n=10	Class II malocclusion
Reis et al., 2020[16]	12.7 years	Distal jet appliance	Not mentioned	n=44	Class II malocclusion
Caruso et al., 2019[17]	22.7 ± 5.3 years	Orthodontic aligners	1.9 ± 0.5 years	n=10	Class II malocclusion
Cozzani, M et al., 2014[18]	11.5 ± 1.7 years(Test group) 11.2 ± 1.3 years (Control group)	Tooth supported distal jet v/s implant supported distal jet	9.1 ± 2.8 months	n=36	Class II malocclusion
Sodagar et al., 2011[19]	Not mentioned	Bonded molar distalizer	11.25 ± 3.44 weeks	n=16	Class II malocclusion
Papadopoulos et al., 2010[20]	Not mentioned	First Class appliance	17.2 weeks	n=26	Class II malocclusion
Fuziy et al., 2006[21]	14.58 years	Pendulum appliance	5.87 months	n=31	Class II malocclusion

Table 3: Study characteristicsof included studies

Publication: Year/ Author	Distalization appliance	Treatment time	First molar tipping (Mean)	First molar distalization (Mean)	Second molar tipping (Mean)	Second molar distalization (Mean)	Anchorage loss (Mean)		Mandibular rotation (Mean)
							Premolar tipping and movements (Mean)	Incisor proclination (Mean)	
Marure et al., 2016[11]	Pendulum(Group I), K loop (Group II) and distal jet (Group III)	5 months	Group I: –7.3° Group II: - 2.66° Group III: 2.9°	Group I: 6.4 mm Group II: 2.25 mm Group III: 3.9 mm	Not mentioned	Not mentioned	Not mentioned	Group I: 1.09 mm with no significant proclination Group II: 6.08° Group III: 6.7°	Group I: -1.59° Group II: -0.25° Group III: -4.1°
Kircali & Yuksel, 2018[12]	Mini screw anchored pendulum appliance	8.4 months	8.9°	4.2 mm	8.3°	3.5 mm	First premolars distalized by 2.2 mm and distally tipped by 3.4° Second premolars distalized by 0.4 mm and tipped by 0.8° (non-significant)	Changes in upper incisor proclination was insignificant and protrusion was very small	Slight anticlockwise rotation of mandible by 0.3° (statistically significant)

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Table 3 continued

Ömür Polat-Ozsoy et al., 2007 [13]	Bone anchored pendulum appliance and conventional pendulum appliance	6.8 months for BAPA (Group I) and 5.1 months for conventional pendulum appliance (Group II)	Group I: 9.1° Group II: 5.3°	Group I: 4.8 mm Group II: 2.7 mm	Group I: 9.5° Group II: 5.5°	Group I: 3.3 mm Group II: 2.7 mm	Group I: Distalization of first and second premolars by 2.7 ± 1.6 mm and 4.1± 2.1 mm) respectively Group II: Mesialization of first and second premolars by 4.0 ± 2.7 mm and 2.3 ± 2.1 mm respectively	Group I: Incisors retroclined by 1.7° and distalized by 0.1 mm Group II: Proclined by 0.9° and mesialized by 1.2 mm	Group I: 0.8° ± 1.4° Group II: 0.6° ± 1.1°
Serafin et al., 2021 [14]	Pendulum appliance	8 ± 2 months	8.9°±8.3°	2.8±3.2 mm	8.2°±8.1°	3.7±2.7 mm	Premolars showed mesial movement by 2.7±3.3 mm and mesial tipping of 2.5°±5.1°	Anchorage loss of incisors in the study was 1.5±2.8 mm and tipping by 5°±3.6°	0.8°±3°
Kinzinger et al., 2009 [15]	Miniscrew supported distal jet appliance	6.7 months	2.79 ± 2.51°	3.92 ± 0.53 mm (of first molar)	Not mentioned	Not mentioned	First premolars distalized by 0.72 ± 0.78 mm and tipped distally by 1.15° ± 2.98° in relation to palatal plane The second premolars also drifted distally by 1.87 ± 0.74 mm and tipped by 3.21° ± 2.86°	Central incisors slightly proclined by 0.36 ± 0.32 mm and labial tipping of 0.57° ± 0.79° in relation to palatal plane	No significant change in the mandibular plane in relation to the anterior cranial base

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Table 3 continued

Reis et al., 2020[16]	Distal jet appliance (Group I: experimental group receiving distal jet appliance Group II: control group not receiving any treatment	Not mentioned	Statistically non-significant distal tipping	Group I: 1.2 ± 1.4 mm Group II: Mesialization by a mean of 1.1 ± 1.6 mm	Group I: distal tipping by 6.6° ± 3.8° Group II: Mesial tipping by 1.6° ± 5.2°	Group I: 1.1 ± 1.1 mm Group II: mesialization by 0.9 ± 1.8 mm	The first premolars mesialized in both groups, but it was greater in Group I: 3.4 ± 1.1 mm than Group II: 0.9 ±1.6 mm	Group I: Labial tipping of maxillary incisors by 4.3° ± 4.7° Group II: Lingual tipping of 0.3° ± 3.0° Protrusion of incisors was observed in both groups	Group I: significant increase by 0.7° ± 2.0° Group II: Reduction in mandibular plane angle by 0.7° ± 1.5°
Caruso et al., 2019[17]	Orthodontic aligners	1.9 ± 0.5 years	1.3°	2.0 ± 3.0 mm	0.6°	3.0 ± 3.0 mm	Anchorage loss by premolar mesialization not mentioned	Reduction in incisor inclination by 13.2°	No significant changes in mandibular rotation; variation of Sn-GoGn was lower than 1%
Cozzani, M et al., 2014[18]	Tooth supported distal jet(DJ group- control group) vs implant supported distal jet (DS group- test group)	9.1 ± 2.8 months in DS- test group 10.5 ± 4.2 months in DJ- control group	DS- test group: -2.8° DJ- control group: -5.0°	DS- test group: 4.7 ± 1.6 mm DJ- control group: 4.4 ± 2.5 mm	Not mentioned	Not mentioned	DS- test group: Maxillary first premolars distalized spontaneously by 2.1 ± 1.8 mm and mean distal tipping of -3.0° DJ- control group: Mesialization of first premolar by 0.9 ± 1.6 mm and mean tipping of -1.0°	Not mentioned	Not mentioned

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Table 3 continued

Sodagar et al., 2011[19]	Bonded molar distalizer	11.25 ± 3.44 weeks	2.97±3.74°	1.22±0.936 mm	2.62 ± 0.85°	1.034±0.854 mm	Mesial tipping of first premolars by 4.25±3.12° and mesialization by 2.26±1.12 mm	Mesial tipping of upper incisors by 9.78±5.04° and mesialization by 3.55 ± 1.46 mm	Reduction of mandibular plane angle by 1.03±1.38°
Papadopoulos et al., 2010[20]	First class appliance Treatment group (n=16) Control group(n=16)	17.2 weeks	Treatment group: 8.56° Control group: Mesial tipping by 1.45°	Treatment group: 4.00 mm Control group: Slight mesialization which was not significant	Not mentioned	Not mentioned	Treatment group: mesial tipping of second premolars by 1.86° Control group: Slight mesial tipping and mesialization which was not significant	Treatment group: upper incisor labial tipping of 1.60° Control group: Non-significant mesialization and proclination of upper incisors	Treatment group: clockwise rotation of mandible of 2.06° Control group: no significant changes in mandibular rotation
Fuziy et al., 2006[21]	Pendulum appliance	5.87 months	Distal tipping of 18.5°	Distal movement of 4.6 mm	Not mentioned	Not mentioned	Mesial tipping of first premolars by 2.50° and mesial movement of 2.65 mm	Labial tipping of upper incisors by 3.4° and protrusion of 1.11 mm	Clockwise rotation of mandible by 0.47°

2.4. Screening and selection

The search and screening process was conducted collaboratively by two researchers, and the degree of agreement between them was quantified using a κ coefficient of 0.83, indicating a substantial level of concordance. The identified articles underwent a comprehensive evaluation in four distinct stages, following a structured framework. In Stage 1, search was conducted through titles and abstracts and citations lacking relevance were excluded. Progressing to Stage 2, two reviewers meticulously assessed the titles and abstracts to determine the alignment with predefined criteria. Articles outside the inclusion parameters were promptly excluded, while ambiguous cases underwent thorough full-content scrutiny. In cases of uncertainty, a second reviewer provided input for the evaluation.

In Stage 3, the articles selected in Stage 2 underwent meticulous assessment by two independent reviewers to validate alignment with eligibility criteria. This phase involved excluding articles with inappropriate study designs or deficiencies in outcome measurement at baseline and endpoint. Articles with referencing deficiencies were also excluded. During Stage 4, articles suitable for inclusion underwent thorough examination, with pertinent data extraction. Clinical methodologies in scrutinized studies were critically appraised, focusing on intervention specifics and explored outcomes.

This rigorous process ensures the methodological robustness and relevance of the selected articles for inclusion in the medical journal. The κ coefficient reflects the reliability of the collaborative screening process, enhancing the validity of the systematic review's findings.

2.5. Data extraction

During the initial phase of data extraction, the corresponding author undertook the process, and subsequent reviews and refinements were reviewed by the second author. Independent data extraction was meticulously conducted for each full-text article that met the predetermined inclusion criteria. This process adhered to a standardized format facilitated by digital tools, specifically Microsoft Corporation's Office Excel 2013 software(Table 1). The collected data were systematically organized into distinct sections, including authorship and year of publication, study design, population, mean age, particulars of interventions, comparator elements, and the resultant outcomes along with time period. This comprehensive approach ensured precision and consistency in the extraction and organization of pertinent information from each included article.

3. Results

3.1. Search and selection

The systematic review initiated with a comprehensive search across databases, yielding a total of 284 records(Figure 1). Additionally, 17 records were identified through other sources, resulting in a combined pool of 301 records. Following the removal of duplicates, 253 unique records underwent screening. During this process, 185 records were excluded based on predetermined criteria. The remaining 68 records underwent a thorough assessment of full-text articles for eligibility, leading to the exclusion of 56 articles with specific reasons outlined. Ultimately, 11 studies met the inclusion criteria and were included in the systematic review(Table 2). This meticulous selection process, involving rigorous screening and eligibility assessments, ensures that the studies incorporated into the review are of high quality and relevance.

3.2. Qualitative analysis

How the characteristics and results of the included studies.All the results obtained from the included articles were reported by using lateral cephalometry as the method of evaluation. The included studies include both the conventional distalization appliances as well as the skeletally anchored distalization appliances.

3.3. Risk of bias in included studies

To address potential sources of bias, the assessment incorporated *ROBINS-I criteria*[23], particularly relevant for cohort and case control studies used in our study. Those presenting comprehensive information in all evaluated domains were categorized as demonstrating a commendable level of methodological accuracy which was described as low risk of bias. Studies with two to three factors which were acknowledged as maintaining a reasonable standard of quality were described as moderate risk of bias. Studies lacking substantial data on the majority of factors were described as manifesting a serious risk of bias. As per this tool, there were no studies with serious risk of bias whereas nearly 5 studies showed low and 5 studies showed moderate risk(Table 4)**.** For the Randomised Controlled Trial included in our study, given their experimental nature, we preferred the Cochrane collaboration tool for assessing risk of bias(Higgins and Altman)[22] (Table 5). The risk of bias tool was undertaken in duplicate and independently.

4. Discussion

4.1. Primary outcome

In conducting a systematic review on anchorage loss in distalization appliances, this article covered a diverse range of studies, each contributing unique insights into

Table 4: Robins: risk of biasin non-randomized studies tool

Domain	Marure et al., 2016[11]	Kircali & Yuksel, 2018[12]	Saif et al., 2022[13]	Serafin et al., 2021[14]	Kinzinger et al., 2009[15]	Reis et al., 2020[16]
Bias due to confounding	Low	Low	Moderate	Low	Low	Low
Bias in selection of participants into the study	Low	Low	Low	Moderate	Low	Low
Bias in classification of interventions	Low	Moderate	Moderate	Moderate	Moderate	Low
Bias due to deviations from intended interventions	Low	Moderate	Moderate	Low	Moderate	Low
Bias due to missing data	Low	Moderate	Moderate	Low	Serious	Low
Bias in measurement of outcomes	Moderate	Low	Low	Low	Moderate	Moderate
Bias in selection of reported result	Low	Low	Moderate	Low	Moderate	Moderate
Overall	Low	Low	Moderate	Low	Moderate	Low
Domain	**Caruso et al., 2019[17]**	**Cozzani, M et al., 2014[18]**	**Sodagar et al., 2011[19]**	**Fuziy et al., 2006[21]**		
Bias due to confounding	Low	Moderate	Moderate	Low		
Bias in selection of participants into the study	Low	Moderate	Moderate	Low		
Bias in classification of interventions	Moderate	Low	Moderate	Moderate		
Bias due to deviations from intended interventions	Moderate	Moderate	Moderate	Low		
Bias due to missing data	Moderate	Moderate	Moderate	Moderate		
Bias in measurement of outcomes	Low	Low	Low	Low		
Bias in selection of reported result	Low	Moderate	Low	Low		
Overall	Moderate	Moderate	Moderate	Low		

Table 5: Risk of bias(cochrane collaboration tool for assessing risk of bias (higgins and atman)

Domain	Papadopoulos et. al., 2010[20]
Random sequence generation	1
Allocation concealment	1
Blinding of Participants and Personnel	2
Blinding of outcome assessment	1
Incomplete outcome data	2
Selective reporting	1
Other bias	1
Total	9

the effectiveness of various techniques. In the included articles for the study, there were many different distalization appliances used, including conventional tooth borne appliances and skeletally anchored appliances.

All the patients that were included in the study presented with an Angle's Class II malocclusion that would benefit from maxillary molar distalization. The highest success rate with the fewest complications occurs when molars are moved distally in the mixed dentition stage of development .[18]Most of the studies that were included in the review initiated the treatment in late mixed or early permanent dentition, except for the study by Caruso et al.,(2019),[17] that had a mean average age of 22.7 ± 5.3 years.

Most of the articles did not describe the severity of the malocclusion before the treatment, and therefore the information in our study was limited in this aspect. Also, the studies mention Class II malocclusion as a prerequisite for inclusion in the study, but the extent of severity might not be mentioned.

From our study, it appears that both conventional and skeletally anchored appliances are effective in achieving the distalization of molars. However, in conventional distalization appliances like pendulum[11–14,21] distal jet[11,15,16,18], K-loop,[11]bonded molar distalizer,[19] first class appliance,[20] the distalization achieved was a combination of tipping movement and anchorage loss in form of premolar and incisor movements.

In pendulum appliance, the study by Fuziy et al.[21] reported that the distalization of first molars was accompanied with significant distal tipping along with significant amount of anchorage loss. Another study reported similar results with successful distal movement of maxillary first molars but there was unfavourable premolar mesialization and incisor proclination during the active phase of the treatment[16]. Marure et. al.[11] however reported insignificant change in the upper incisor proclination at the termination of active treatment, but reported distal tipping of molars.

Bone Anchored Pendulum Appliance(BAPA) was reported to prevent the adverse effects of the Conventional Pendulum Appliance(CPA) and achieved greater amount of distalization.[13] The characteristic finding in the study was the spontaneous distalization of the premolars in the BAPA group as compared to the CPA group where the premolars showed labial tipping and mesialization. The percentages of space opening in the CPA group were 56% by distalization of first molars and 44% due to the mesialization of the premolars. The distal movement of the premolars was attributed to the trans-septal pull of the gingival fibres.

The effects of skeletally anchored pendulum appliance were further emphasised in study by Kircali & Yuksel[12], where they reported similar distalization of the premolars along with the molars. The study also reported statistically insignificant changes in the upper incisor proclination, suggesting a major 17.

As regards to the Distal Jet appliance, out study shows that the first and second molars showed significant distalization with distal tipping in the group receiving the distal jet appliance as compared to the control group with mesialization of the premolars along with greater labial tipping of the incisors, compared to the untreated group.[16] Similar effects of the distal jet appliance were concluded by Marure et al.[11] in which the distal jet group was shown to be effective in distalization of the molars but with significant anchorage loss. The study however, did not report the quantification of anchorage loss of premolars or the amount of distalization of second molars.

The advantages of implant supported distal jet appliances was highlighted in the study by Cozzani, M et al.[18], in his comparative study between the bone anchored distal screw(DS) and tooth supported distal jet(DJ). The amount of distalization of the first molars was similar in both the groups, but there was significantly less mesialization of premolars the DS group as compared to DJ group. Yet another study on efficacy of skeletonized distal jet appliance supported by miniscrew anchorage reported the suitability of the appliance for translatory molar distalization[15] They reported that the miniscrew supported anchorage although, does not allow anchorage of stationary quality, but offers essential advantages over the conventional appliances by limiting the number of occlusal rests and useful in cases with lower anchorage quality in the supporting zone, and distalization of the premolars along with the molars.

Sodagar et al.[19] introduced a fixed bonded appliance for the distalization of molars called the Bonded Molar Distalizer(BMD). Over a period of 11.25 ± 3.44 weeks, they reported greater bodily movement of the molars coincident with less distal tipping as compared to the other conventional appliances.

Our study also includes the First Class Appliance(FCA) that reported successful bodily distalization of the first molars with minimal, statistically non-significant proclination of the incisors.[20] However, distal tipping of the molar crowns and anchorage loss was associated with its use, which were similar or even smaller as compared to the other non-compliance distalization appliances. They concluded that 68.3% of the space created by the distalization was attributed to molar distalization, whereas 31.7% of the space created was attributed to the mesial movement of the premolars.

Lastly, our study also included the effects of orthodontic aligners on distalization[17]. Significant amount of molar distalization, with absence of distal tipping and no anchorage loss on upper incisors was reported. The aligner design that allows 3-dimensional control over tooth movements was attributed to the reduction of incisor inclination in the study.

In our study, we have also found that in order to control the unfavourable effects of the conventional appliances, the articles have reported either skeletally anchored appliance as an alternative[20] or by using first molars as an anchorage unit after the active phase of distalization[13] The control of anchorage loss, reduced patient compliance and possibility of reduced treatment time make skeletonized distalization appliances a viable alternative to the conventional appliances, with only major downside reported in our study to be difficulty in maintaining oral hygiene and possible failure of implants.[12,13,18]

4.2. *Secondary outcome*

Owning to the distal tipping and extrusive effects of appliances on maxillary molars, our study found that the use of pendulum appliance had a statistically significant effect on clockwise mandible rotation[11,13,14,21] However, one article reported no significant effects on the mandibular rotation.[12]

Regarding the distal jet appliance, our study reports that there was clockwise mandibular rotation.[11,16] In one study however, there was no mention about the rotation of the mandible.[18]

Papadopoulos et al.[20] reported clockwise rotation of the mandible in the treatment group whereas Sodagar et al.[19] reported anticlockwise rotation of the mandible, which was attributed to the intrusion of molars because of the bite plane effect of the bonded appliance. Although the sample size of the study was very small, aligners highlighted a major advantage over the other conventional appliances, in terms of vertical control·[17]

4.3. *Additional outcomes*

An additional outcome in our study was related to the amount of distalization and presence of the second and third molars. A few articles reported that lesser amounts of distalization was achieved in the presence of fully erupted second molars and/or presence of third molar tooth germs[18,21]. The presence of completely erupted second molars might require increased treatment time and higher forces, leading to greater anchorage loss and less efficiency.[14]

Maxillary molar distalization might be effective in early treatment during the mixed dentition.[20] This however, may lead to a prolonged treatment time and possible anchorage loss after the active phase of distalization. Third molar germectomy might be useful in achieving a more bodily distalization of the molars[12] and one of the studies reported extraction of third molars before the initiation of treatment.[13]

Future research on this aspect of presence of molars and rate of distalization is required and will be welcome.

5. Limitations

While the systematic review provides valuable insights into anchorage loss in distalization appliances, there were certain limitations inherent in the included studies and the review process.

Firstly, the diverse range of distalization appliances, diverse population and study designs may contribute to variability in outcome. Standardization in the outcome measurements and assessment protocol is crucial for validity and reliability of the overall findings.

Secondly, smaller sample sizes may be prone to more random variations, affecting the robustness of the conclusions drawn from these studies.

Thirdly, long term effects of the anchorage loss of different distalization appliances and anchorage preservation have been less exposed.

Future research on longitudinal studies with extended follow up periods and retentive protocols to comprehensively understand the sustainability of anchorage in the context of orthodontic interventions will be welcome.

6. Conclusion

The following conclusions can be drawn from our study:

1. All different conventional distalization appliances are associated with unfavourable anchorage loss and distal tipping of molars, and increased overall treatment time, which might not be favourable for critical anchorage cases or cases with already proclined upper incisors before treatment.
2. The Bonded Molar Distalizer and the First Class Appliances show evidence of more bodily distal movement as compared to the pendulum and distal jet appliance.
3. Modification of pendulum and distal jet appliances by incorporation of micro implants significantly preserves anchorage and reduces overall treatment time.
4. There is clinical evidence reported in the included studies of difference in the rate of distalization in presence of second and third molars, but further studies are required to give a definite conclusion about the same. In this study, we can assume that presence of second and third molars affects the rate of molar distalization.

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8. Conflict of Interest

None.

References

1. Soejima U, Motegi E, Nomura M, Yamazaki M, Sueishi K. Change in proportion of extraction and non-extraction in orthodontic patients. *Bull Tokyo Dent Coll*. 2014;55(4):225–31.
2. Chiu PP, Mcnamara JA, Franchi L. A comparison of two intraoral molar distalization appliances: distal jet versus pendulum. *Am J Orthod Dentofacial Orthop*. 2005;128(3):353–65.
3. Fontana M, Cozzani M, Caprioglio A. Soft tissue, skeletal and dentoalveolar changes following conventional anchorage molar distalization therapy in class II non-growing subjects: a multicentric retrospective study. *Prog Orthod*. 2012;13(1):30–41.
4. Cambiano AO, Janson G, Fuziy A, Garib DG, Lorenzoni DC. Changes consequent to maxillary molar distalization with the bone-anchored pendulum appliance. *J Orthod Sci*. 2017;6(4):141–6.
5. 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(2):266–73.
6. Cornelis MA, Clerck H. Maxillary molar distalization with miniplates assessed on digital models: a prospective clinical trial. *Am J Orthod Dentofacial Orthop*. 2007;132(3):373–7.
7. Oh YH, Park HS, Kwon TG. Treatment effects of microimplant aided sliding mechanics on distal retraction of posterior teeth. *Am J Orthod Dentofacial Orthop*. 2011;139(4):470–81.
8. Chung KR, Choo H, Kim SH, Ngan P, Am J Orthod Dentofacial Orthop 2010 Dec;138(6):839-49 . Timely relocation of mini-implants for uninterrupted full-arch distalization. *Am J Orthod Dentofacial Orthop*. 2010;138(6):839–49.
9. Han S, Bayome M, Lee J, Lee YJ, Song HH, Kook YA. Evaluation of palatal bone density in adults and adolescents for application of skeletal anchorage devices. *Angle Orthod*. 2012;82(4):625–31.
10. Papadopoulos MA. Efficient Distalization of Maxillary Molars with Temporary Anchorage Devices for the Treatment of Class II Malocclusion. *Turk J Orthod*. 2020;33(3):197–201.
11. Marure PS, Patil RU, Reddy S, Prakash A, Kshetrimayum N, Shukla R, et al. The effectiveness of pendulum, K-loop, and distal jet distalization techniques in growing children and its effects on anchor unit: A comparative study. *J Indian Soc Pedod Prev Dent*. 2016;34(4):331–40.
12. Kircali M, Yuksel AS. Evaluation of Dentoalveolar and Dentofacial Effects of a Mini-Screw-Anchored Pendulum Appliance in Maxillary Molar Distalization. *Turk J Orthod*. 2018;31(4):103–9.
13. Polat-Ozsoy Ö, Kırcelli BH, Arman-Özçırpıcı A, Pektaş Z, Uçkan S. Pendulum appliances with 2 anchorage designs: conventional anchorage vs bone anchorage. *Am J Orthod Dentofacial Orthop*. 2008;133(3):339–48.
14. Serafin M, Fastuca R, Castellani E, Caprioglio A. Occlusal plane changes after molar distalization with a pendulum appliance in growing patients with class II malocclusion: a retrospective cephalometric study. *Turk J Orthod*. 2021;34(1):10–17.
15. Kinzinger GS, Gülden N, Yildizhan F, Diedrich PR. Efficiency of a skeletonized distal jet appliance supported by miniscrew anchorage for noncompliance maxillary molar distalization. *Am J Orthod Dentofacial Orthop* . 2009;136(4):578–86.
16. Reis RS, Henriques JFC, Janson G, Freitas KMS, Moura W, Dental Press J Orthod 2019 Nov-Dec;24(6):56–64 doi. Dental, skeletal and soft tissue effects of the Distal Jet appliance: A prospective clinical study. *Dental Press J Orthod*. 2019;24(6):56–64.
17. Caruso S, Nota A, Ehsani S, Maddalone E, Ojima K, Tecco S, et al. Impact of molar teeth distalization with clear aligners on occlusal vertical dimension: a retrospective study. *BMC Oral Health*. 2019;19(1):182.
18. Cozzani M, Pasini M, Zallio F, Ritucci R, Mutinelli S, Mazzotta L. 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.
19. Sodagar A, Akhoundi MSA, Rafighii A, Arab A, S. Fabrication and evaluation of a noncompliant molar distalizing appliance: bonded molar distalizer. *J Dent (Tehran)*. 2011;8(3):107–16.
20. Papadopoulos MA, Melkos AB, Athanasiou AE. Noncompliance maxillary molar distalization with the first class appliance: a randomized controlled trial. *Am J Orthod Dentofacial Orthop*. 2010;137(5).
21. Fuziy A, Almeida RRD, 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(4):502–10.
22. Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *Bmj*. 2011;343.
23. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. 2016;355.

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