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ORIGINAL ARTICLE



# Anchorage effectiveness of orthodontic miniscrews compared to headgear and transpalatal arches: a systematic review and meta-analysis

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**ABSTRACT**

**Background:** Anchorage in orthodontics can be provided through several extra- and intra-oral sources including headgear, teeth, cortical bone and soft tissue.

**Objective:** The aim of this review was to systematically review the effectiveness of miniscrews in reinforcing anchorage during en-masse retraction of anterior teeth in comparison to conventional anchorage appliances.

**Search method:** Comprehensive searching of the electronic databases was undertaken up to March 2018 in the Cochrane Database of Systematic review, Cochrane Central Register of Controlled Trials, MEDLINE via PubMed and Scopus databases. Additional searching for ongoing and unpublished data and hand search of relevant journals were also undertaken, authors were contacted, and reference lists screened.

**Eligibility criteria:** Searches were restricted to randomized clinical trials (RCTs) published in English, which compared anchorage reinforcement using mechanically-retained miniscrews (diameter of 2 mm or less) to conventional anchorage appliances during en-masse retraction of anterior teeth in participants of any age treated with fixed appliances combined with extraction of maxillary premolars.

**Data collection and analysis:** Blind and induplicate study selection, data extraction and risk of bias assessment were undertaken. The primary outcome was the amount of mesial movement of the upper first permanent molar (anchorage loss) while secondary outcomes included treatment duration, number of visits, adverse effects and patient-centered outcomes. The risk of bias was assessed using Cochrane risk of bias tool. A random-effects model with its corresponding 95% confidence interval (CI) were generated for comparable outcomes. Statistical heterogeneity across the studies were assessed using the $I^2$ and $Chi^2$ test. Additional sensitivity tests were implemented.

**Results:** Seven RCTs met the inclusion criteria, however, data of 241 participants from 6 RCTs (250 miniscrews and 134 conventional anchorage appliances) were meta-analyzed. Qualities of the included RCTs varied from low to high. The standardized mean difference (SMD) of the anchrage loss between the two intervention groups was 2.07 mm ((95% CI (–3.05) to (–1.08), $p < .001$, $I^2 = 88\%$, 6 RCTs)) in favour of miniscrews, which was also preserved after excluding the high risk of bias studies (SMD 1.94 mm, 95% CI (–2.46) to (–0.42) $p < .001$, $I^2 = 93\%$, 3 RCTs)). Information on overall treatment duration, space closure duration, quality of treatment, patient-reported outcomes, adverse effects and number of visit were limited.

**Conclusion:** The result of the meta-analysis suggested that there is moderate quality of evidence that miniscrews are clinically and statistically more effective in preserving orthodontic anchorage than conventional appliances. However, this conclusion is supported by a small number of studies with variable qualities. High-quality RCTs would give a better understanding of miniscrews effectiveness in providing orthodontic anchorage.

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## Introduction

Orthodontic anchorage by definition is the resistance to unwanted tooth movement [1], and it is conventionally provided by different methods including incorporating multiple teeth, the use of headgear, face masks, chin caps, transpalatal arches (including Nance buttons), lingual arches or intermaxillary elastics [2].

More recently orthodontic skeletal anchorage devices have been suggested as a reliable method for providing maximum to absolute anchorage [3,4]. Skeletal anchorage devices could be in the form of implants, plates, screws or

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screw-retained devices which inserted into the bone to provide resistance to unwanted tooth movement (indirect anchorage) or a point from which orthodontic traction can be applied (direct anchorage) [5]; they can broadly be divided into two categories: osseointegrated implants such as mid-palatal implants [6] and onplants [7], and mechanically retained devices such as titanium mini-plates [8], zygomatic wires and miniscrews [9,10]. The use of miniscrews has been increased recently due to their ease of insertion and removal, reasonable cost, biocompatibility and capability to withstand orthodontic forces [11,12].

Recent reviews investigated the effectiveness of all types of skeletal anchorage devices in anchorage provision in comparision to conventional methods [13,14]. However, the findings of these reviews were not specific to the most commonly used skeletal anchorage device, the mechanically-retained miniscrews. The aim of this review therefore, was to systematically review the effectiveness of miniscrews in reinforcing anchorage during en-masse retraction of anterior teeth.

## Methods

### Protocol registration, conflict of interest, and funding

This review received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The study protocol was registered a priori with the International Prospective Register of Systematic Reviews (PROSPERO) under protocol number (CRD 42017071439). The study was planned and reported according to the preferred reporting items for systematic review and meta-analysis [15] and Cochrane Guidelines for Systematic Reviews [16].

### Eligibility criteria

Participants: Participants of any age or gender required en-masse retraction of anterior teeth, using fixed orthodontic appliances combined with extraction of maxillary premolars, treated in general practitioner/specialist offices or hospital settings were included.

Interventions: Participants who required orthodontic anchorage reinforcement by mechanically-retained miniscrews of any length but a diameter of 2 mm or less.

Comparators: Participants required orthodontic anchorage reinforcement using headgear, Nance appliance, transpalatal arch appliances or any other conventional anchorage appliances.

Outcome measures: The primary outcome was the anchorage loss defined as amount of mesial movement of the upper first permanent molar, measured in millimetres [17]. Secondary outcomes including the treatment and space closure durations, number of visits, quality of treatment, adverse effects and patient-reported outcomes were collected from the studies when available.

Study design: The included studies in this systematic review were human RCTs published in English. There was no limitation in terms of publication's year, publication status, or publication type. All *in vitro* studies, animal studies, case reports, case series, review articles and studies investigating participants with systemic diseases were excluded. Language exclusion criteria was applied following the primary search to avoid bias in the search protocol.

### Information sources and search strategy

A comprehensive search using a combination of controlled vocabulary and free text terms was designed to identify published, ongoing and unpublished studies (Supplementary Appendix 1). The following electronic databases were searched up to 16 March 2018: MEDLINE via PubMed, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (searched via the Cochrane Library) and Scopus. Up to 7 March 2018, a manual search in the leading orthodontic journals and other bibliographic databases were also undertaken for ongoing and unpublished data. Reference lists of the included articles and other relevant systematic reviews were screened for any additional relevant literature and to include additional controlled vocabulary and free text terms, if present. We assumed that adverse effects are described in included studies only.

### Study selection

Electronic database searching was performed independently and in duplicate by two reviewers (FA and MA). A manual search and additional bibliographic databases search were undertaken by one reviewer (MA). Duplicate removal was undertaken using EndNote reference manager software. First, relevant articles were identified through their titles and abstracts. In cases of unclear study design, corresponding authors were contacted for further information. Then, the full text of the potential articles was assessed for eligibility by two reviewers (FA and DB). In the case of disagreement between the reviewers, a consensus was made through open discussion with the third reviewer (MA). All excluded studies were listed with their exclusion justification (Supplementary Appendix 2).

### Data extraction

Two reviewers (FA and MA) extracted the data using a pre-piloted standardized data extraction form and the following information was collected: [1] authors, [2] year of publication, [3] study setting, [4] number and age of the participants, [5] miniscrew number and dimensions, [6] types of conventional anchorage appliance, [7] amount of anchorage loss in miniscrew and control group; and [8] any secondary outcomes. In the case of disagreement between the reviewers, a consensus was made through open discussion with the third reviewer (DB). Authors were contacted where any missing data needed clarification.

### Assessment of risk bias in the included studies

The included RCTs were assessed for risk of bias by two reviewers (FA and DB), using the Cochrane collaboration's tool, a domain-based tool [18]. Each included study was assessed regarding the risk of bias in [1] random sequence generation; [2] allocation concealment; [3] blinding of participants and personnel; [4] blinding of outcome assessors; [5] incomplete outcome data; [6] selective reporting; [7] other sources of bias. In the case of disagreement between the reviewers, a consensus was made through open discussion with the third reviewer (MA).

The overall risk of bias of individual studies was categorized as being at low (if all domains were at low risk of bias), unclear risk of bias (if one or more domains were at unclear risk of bias) or high (if one or more domains were at high risk of bias).

### Data synthesis

For continuous data, the standard mean difference (SMD) with its 95% confidence intervals (95% CI) was chosen as a summary effect. Statistical aggregation of the results was carried out using a random-effects model as it takes into its consideration the possible existence of heterogeneity. The heterogeneity across the studies was assessed using the $I^2$ and $Chi^2$ statistics. A 25%, 50% and 75% statistic accounts for low, moderate and high levels of heterogeneity respectively.

For meta-analyzing outcomes from studies with more than two arms, we undertook pair-wise comparison separately in which the number of the participants in the intervention groups (miniscrews group) divided out approximately among the comparisons (conventional anchorage groups) while the means and standard deviations left unchanged [16]. The statistical tests were performed using the Review Manager (RevMan) Version 5.3 (Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration, 2014). The net confidence in the effect estimates and any subsequent clinical recommendations was enhanced by rating the overall quality of the resultant evidence using the GRADE approach. For comparisons where a meta-analysis could not be carried out, we provided a narrative reporting of the treatment effects.

### Additional analysis

The protocol of this review included a visual inspection of a generated contour-enhanced funnel plot if 10 or more studies met the inclusion criteria. Besides, Egger's linear regression tests [19] were pre-planned to examine publication bias. To investigate the robustness of this review, further sensitivity tests were performed examining the impact of removing low-quality studies on the overall outcome [16].

## Results

### Results of the search

The initial search strategy identified 751 records (Figure 1). As a result of the initial screening and duplicate removal, 717 records were excluded. The full texts of the remaining 34 articles were assessed which led to the exclusion of another 27 studies (Supplementary Appendix 2).

The final sample included seven RCTs; [17,20–25], all of them were single-centre parallel two-arm trials except the RCT by Sandler and colleagues [23] which was a multicentre three-arms parallel trial. Three trials were performed in India [20,24,25], two in China [21,22], one in Syria [17], and one in the UK [23]. All of the included RCTs were performed in university settings.

### Characteristics of the interventions

Four studies compared miniscrews to transpalatal arch [17,21,24] and two compared miniscrews to headgear (HG) [22,23], the three-arm trial [23] also included an additional comparison between miniscrews and Nance appliance. The last study compared miniscrews with other methods of conventional anchorage provision including HG, transpalatal arch, differential moments and the banding of a second molar [25] (Table 1). The overall number of the participants analyzed in the 7 included RCTs were 271 who had been treated using 310 miniscrews and 149 conventional anchorage appliances, however, the outcomes of 241 participants treated using 250 miniscrews and 134 conventional anchorage appliances were meta-analyzed.

### Characteristics of the participants

Two RCTs recruited adolescent participants [20,23–25] while the rest recruited adults and young adults. Female participants were dominant in four studies [17,21,22,24] and one study recruited more males than females [23]. Two studies included only female participants [20,25].

### Characteristics of the outcomes

#### Primary outcome

The primary outcome of this review was the anchorage loss i.e. the amount of mesial movement in the upper first permanent molar at different time points. In one study [23], it was measured from the start to the end of the anchorage phase. Another RCT [17] measured maxillary molar movement from the start of the treatment until a Class I canine relationship was achieved. Two trials [20,25] measured the degree of mesial movement of the molar during space closure phase i.e. before the commencement of space closure up to the end of space closure phase. The primary outcome was measured from the beginning of the treatment to the end of space closure phase in one study [24]. In the last trial [22], the amount of mesial molar movement of the upper first permanent molar was not reported. In five trials [17,20,21,24,25], anchorage loss as primary outcome was measured cephalometrically. However, in one trial [23], left and right mesial molar movements were measured individually using three-dimensional study model analysis, however, the average means of both sides were combined for the ease of meta-analysis.

**Table 1.** Characteristics of studies included in the systematic review.

| Trial number | Author | Settings | Participants analyzed | Number of participants in the miniscrews arm/arm 1 (total number, length, diameter of the miniscrews analyzed) | Control arm 2 (total number of participants analyzed) | Control arm 3 (total number of participants analyzed) | Primary outcome (s) | Secondary outcome (s) | Mean of the mesial movement of the molar in miniscrews (arm 1) mm (SD) | Mean of the mesial movement of the molar in control group (arm 2 and/ or arm 3) mm (SD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alsibaie and Hajeer [17] | University | 56 ( mean: 22.4 years) | 28 (56 miniscrews, 7 mm, 1.6 mm) | TPA [28] | NA | Mesial molar movement measured on cephalometric radiograph | NA | –0.89 (0.59) | 1.50 (1.25) |
| 2 | Basha et al. [20] | University | 14 (Mean: 16 years, SD: 1.41) | 7 (14 miniscrews, 8mm, 1.3 mm) | TPA [7] | NA | Mesial molar movement measured on cephalometric radiograph | Space closure duration (in days)<br>• 182.43 (SD9.64) for arm 1<br>• 181 (SD 32.07) for arm 2 | 0.00 (0.00) | 1.73 ( 0.43) |
| 3 | Liu et al. [21] ws | University | 34 (mean: 20.68 years) | 17 (34 miniscrews, 8 mm, 1.2 mm) | TPA [17] | NA | Mesial molar movement measured on cephalometric radiograph | Total treatment duration:<br>• 25.65 (SD5.06) months for arm 1<br>• 26.88 (SD 6.54) months for arm 2<br>Adverse effect (8 TADs, in 5 participants, failed and replaced without complication) | –0.06 (1.4) | 1.47 (1.15) |
| 4 | Ma et al. [22] | University | 30 (Range: 18–22 years) | 15 (60 miniscrews, 5 mm for mandibular and 6 mm for maxillary miniscrews, 1.2 mm) | Headgear [15] | NA | Cephalometric measurements (molar movement not reported) | NA | NA | NA |
| 5 | Sandler et al. [23] | University | 71 (mean: 14.22 years) | 22 (44 miniscrews, 8 mm, 1.6 mm) | Headgear [23] | Nance [26] | Mesial molar movement measured on 3D models | Total treatment<br>• 26.83 (8.5–45.16) for arm 1<br>• 28.01 (17.46–38.51) for arm 2<br>• 27.43 (15.03–39.83) for arm 3<br>Number of visits<br>• 18.38 (5.8–30.04) for arm 1<br>• 19.24 (6.66–31.8) for arm 2<br>• 21.77 (13.13–30.41) for arm 3<br>PARS score reduction<br>• 26.59 (SD13.82) for arm 1<br>• 21.26 (SD10.61) for arm 2<br>• 25.69 (SD11.47) for arm 3<br>Patient perceptions (6-point Likert scale) and questionaries'<br>• Similar score for arm 1 and 2 on placement and on removal<br>• Minor problems in arm 3 and very minor problems in arm 1<br>• Poor compliance in arm 2<br>• Comfort and convenience were poor in | Right 0.8 (1.6)<br>Left 0.99 (1.15) | - Arm 2<br>Right 1.36 (1.83)<br>Left 1.99 (2.09)<br>- Arm 3<br>Right 1.84 (1.32)<br>Left 2.09 (1.32) |

(*continued*)

Table 1. Continued.

| Trial number | Author | Settings | Participants analyzed | Number of participants in the miniscrews arm/arm 1 (total number, length, diameter of the miniscrews analyzed) | Control arm 2 (total number of participants analyzed) | Control arm 3 (total number of participants analyzed) | Primary outcome (s) | Secondary outcome (s) | Mean of the mesial movement of the molar in miniscrews (arm 1) mm (SD) | Mean of the mesial movement of the molar in control group (arm 2 and/ or arm 3) mm (SD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Sharma et al. [24] | University | 30 ( 17.4 years) | 15 (30 miniscrews, 8 mm, 1.2 mm) | TPA [15] | NA | Mesial molar movement measured on cephalometric radiograph | arm 2<br>Adverse effect: one miniscrew fractured without complications<br>NA | –0.00(0.02) | 2.48 ( 0.71) |
| 7 | Upadhyay et al. [25] | University | 36 (17.5 years) | 18 (72 miniscrews, 8 mm, 1.3 mm) | Conventional anchorage group including headgear, TPA, banding the second molar and application of differential moments [18] | NA | Mesial molar movement measured on cephalometric radiograph | Space closure duration (in months)<br>• 8.61 (SD2.2) for arm 1<br>• 9.94 (SD2.44) for arm 2 | –0.78 (1.35) | 3.22 (1.06) |

Minus sign (–) for the mesial movement of the molar indicates that the molar moved distally (anchorage gain) as a result of dynamic friction during space closure.
NA: Not Available; SD: Standard deviation; TPA: Transpalatal arch; mm: millimetre.

### *Secondary outcomes*

Two studies [21,23] reported the overall duration of treatment. Duration of the space closure was reported in two trials, in days [20] and months [25]. Only one RCT [23] reported on the number of visits, PARS score reduction and patient perception. Two studies [21,23] provided brief reports about the adverse effect of interventions.

## *Risk of bias*

In summary, out of the seven studies included in this review, four studies were assessed as having an overall high risk of bias [20–22,25], while three studies were assessed as having an overall low risk of bias [17,23,24]. The assessment of the risk of bias in the RCTs is presented and summarized in Figure 2.

The random sequence generation was adequate in all studies except for one study [20]. Allocation concealment was graded as unclear in two studies [21,22] and a high risk of bias in one study [20]. In four studies [17,22–24], the outcome assessors were blinded. The remaining three studies were graded as having either a high risk of bias [20,21] or an unclear risk of bias [25]. The risk of bias in the completion of the outcome data reporting domain (Attrition bias) was low in all included studies except one trial [25]. Selective reporting bias was assessed as being of low risk in three studies [17,23,24] while the remaining studies were graded as having a high risk of selective reporting bias [20–22,25]. In all the included studies no other potential sources of bias were identified.

## *Meta-analysis*

### *Mesial movement of the upper first molars (anchorage loss)*

Six RCTs [17,20,21,23–25] appropriately reported the primary outcome, but at variable time point, and they were included in the meta-analysis analysis (Figure 3). Data from 241 participants were included in a random-effects meta-analysis to assess the anchorage effectiveness of 250 miniscrews when compared with 134 conventional anchorage devices. The conventional methods included headgear, transpalatal arch, Nance appliances, banding of second molar and differential anchorage methods. The overall standard mean difference (SMD) of the anchorage loss between the main two groups was –2.07 mm in favour of miniscrews ((95% CI (–3.05) to (–1.08), $p < .001$, $I^2$=88%, 6 RCTs)) which was higher when subgroup analysis comparing the miniscrews and TPA groups was undertaken ((SDM = (–3.13), 95% CI (–4.72) to (–1.55), $p < 0.001$, $I^2$ 88%, 4 RCTs)). Sensitivity analysis indicated that, after exclusion of the studies with a high risk of bias [20,21,25], the SMD was preserved at –1.94 mm in favour of miniscrews ((95% CI (–3.46) to (–0.42), $p < .001$, $I^2$ 93%, 4 RCTs)) (Figure 4).

### Overall duration of treatment

The overall duration of the treatment was reported in two RCTs; one trial [21] had high risk of bias and it showed that there is statistically non-significant ($p > .05$) difference in terms of total treatment duration between miniscrews (25.65 ± 5.06 months) and TPA device (26.88 ± 6.54 months). Similarly, the second trial [23] which has low risk of bias concluded that difference in the overall treatment duration was almost equal ($p > .05$) in those treated using miniscrews (26.83 months, 95% CI: 8.5–45.16), Nance appliance (27.43 months, 95% CI: 15.03–39.83) or Headgear appliance (28.01 months, 95% CI: 17.46–38.51). Results from 105 participants (total of 78 miniscrews and 66 conventional anchorage appliances) were pooled in a fixed-effect meta-analysis. The difference in the means of the treatment duration was −1.10 month (95% CI (–3.98) to 1.79, $p = 0.98$, $I^2 = 0\%$) in favour of miniscrews (Figure 5). It was not possible to undertake a subgroup analysis as there was only two RCTs which measured this outcome.

### Duration of space closure phase

The duration of space closure phase was reported in two RCTs [20,25], both with high risk of bias, hence, the data was assessed narratively. The first trial [20] calculated the number of days required to close extraction spaces using miniscrews (182.43, SD 9.64 days) and TPA (181, SD 32.07 days) while the second trial [25] used month as a unit of time, 8.61 (SD 2.2) month and 9.94 (SD 2.44) month in miniscrews and TPA groups respectively. Both trials found that there is no statistically significant ($p > .05$) difference in terms of time required to close extraction spaces.

### Number of visits

Only one study [23] reported on the number of visits required to complete the treatment using different anchorage systems. Participants from the miniscrews arm completed their treatment within 18.38 (SD 5.95) visits, this was shorter than those from the headgear and Nance appliance arms, 19.24 (SD 6.42) and 21.77 (SD 4.41) visits respectively.

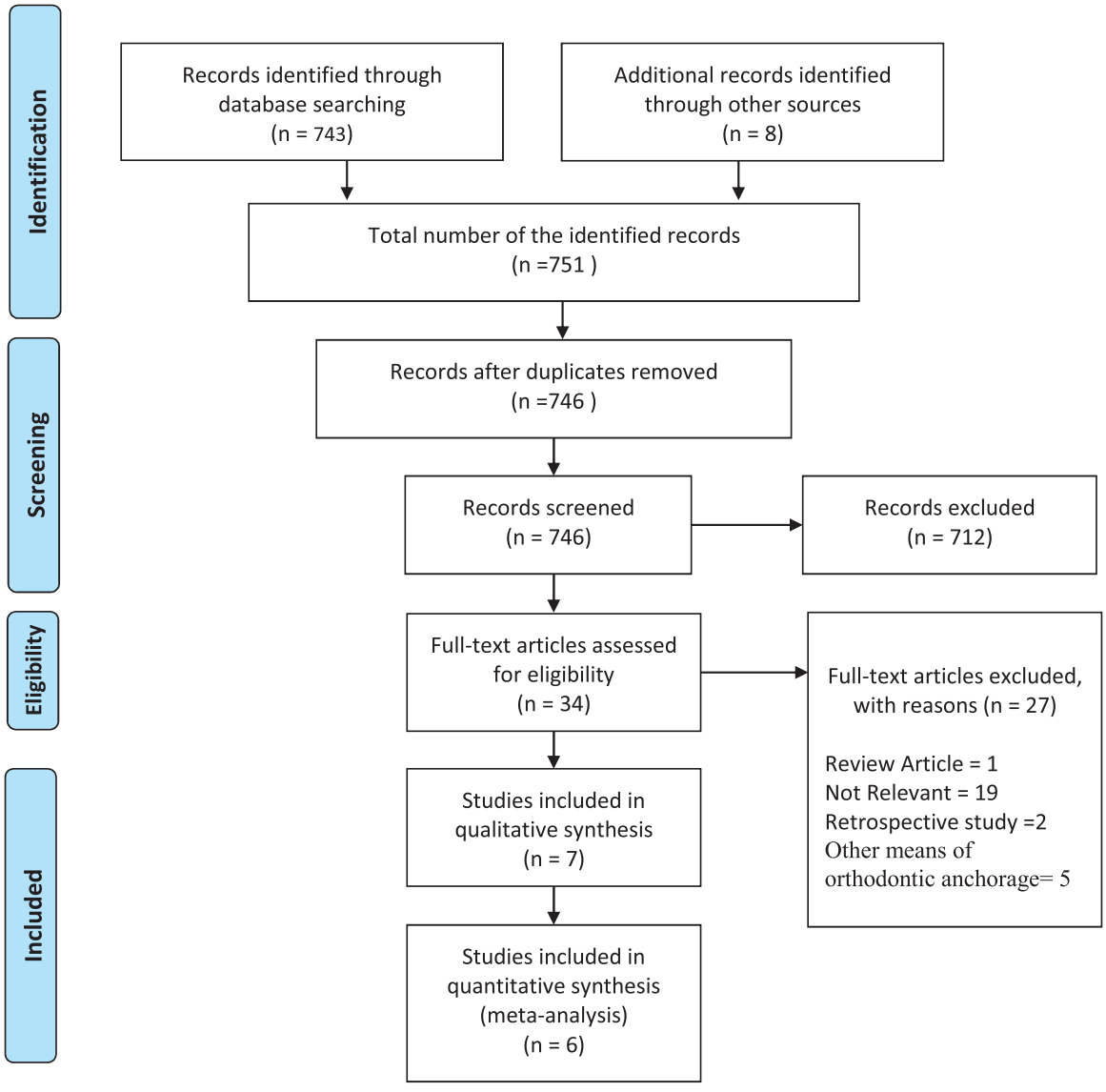


**Figure 1.** Flow chart of the selection of studies.

### *Quality of the treatment*

The quality of the treatment was assessed in one trial [23] using Peer Assessment Rating index (PAR index). Participants treated using miniscrews as an anchorage appliance had the highest PAR score (26.59, SD 13.82), followed by those treated by Nance appliance (25.69, SD 11.47) and headgear (21.26, SD 10.61). In comparison with headgear group, there was −3.97 and −1.24 PAR points in favour of miniscrews and Nance appliance groups respectively. The difference in PAR scoring between headgear and miniscrews groups was significant ($p < .05$).

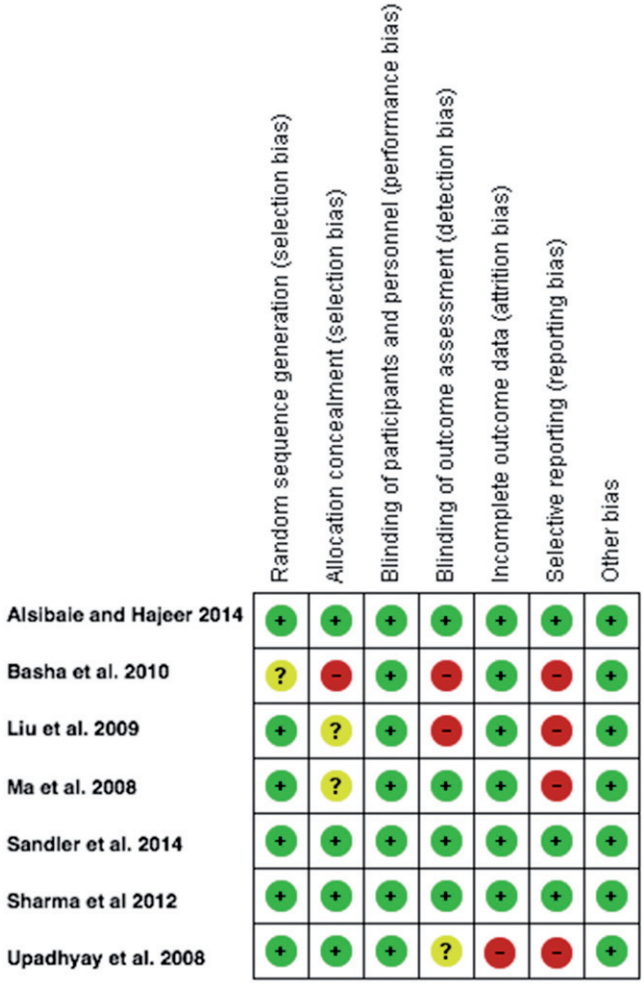


Figure 2. Risk of bias summary.

### *Patient perception and adverse effects*

Only one study [23] reported on pain perception using miniscrews, Nance and headgear appliances. Using a 6-point Likert scale, Sandler and colleagues [23] found that participants had very mild level of dis-comfortability during placement and on removal of both miniscrews and Nance appliances. The authors also found that the participants' free text comments were almost always positive toward miniscrews, unlike Nance and headgear. Nine out of ten participants (90%) recommended miniscrews to their peers. For those who had been treated using headgear and Nance appliance, the figures were 77% and 57% respectively. Comfort, compliance and convenience with the headgear appliance was poor among adolescent patients.

Two trials reported briefly on the adverse effects [21,23]. Both reported no serious harms secondary to interventions. However, in one trial [21], eight miniscrews failed throughout the treatment which were replaced two months later without complications. In the second trial [23], only one miniscrews fractured during its insertion but it was left it *in situ* without complications, the authors did not report whether replacement was undertaken immediately or at later stage. Table 2 represents the summary of findings table for the main outcomes of this systematic review.

## Discussion

Overall, the findings from this review suggest that there is moderate quality evidence that reinforcement of anchorage

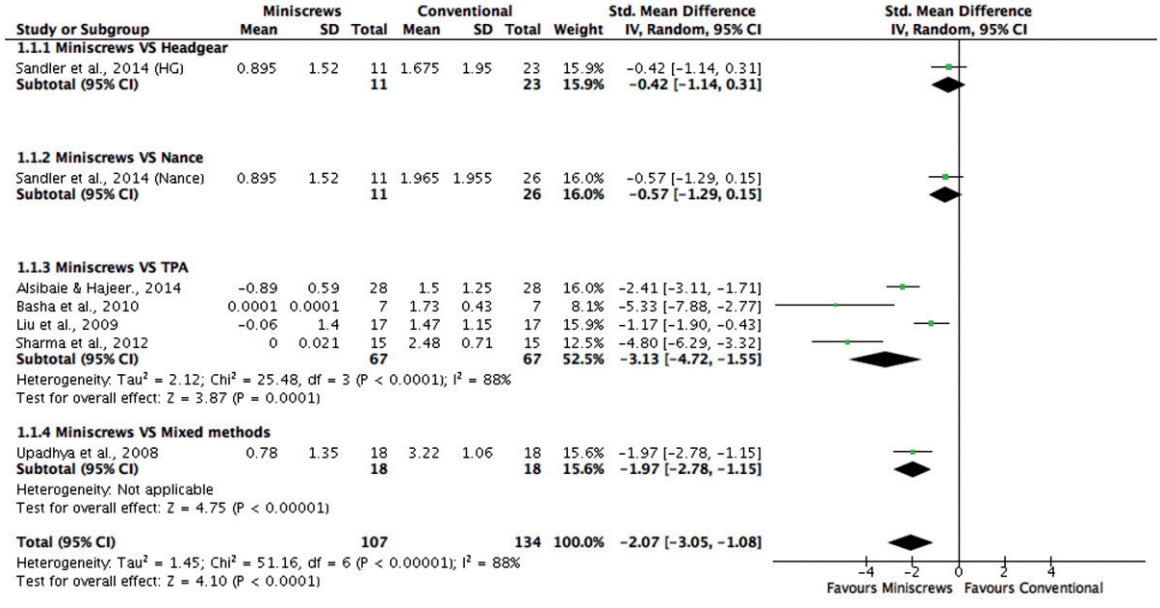


Figure 3. Forest plot of anchorage loss (all studies).

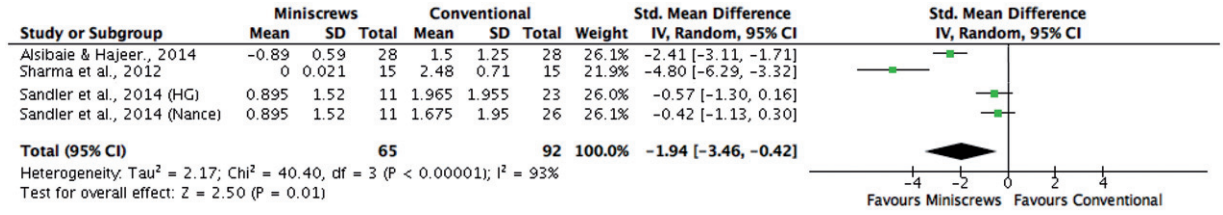


**Figure 4.** Forest plot.

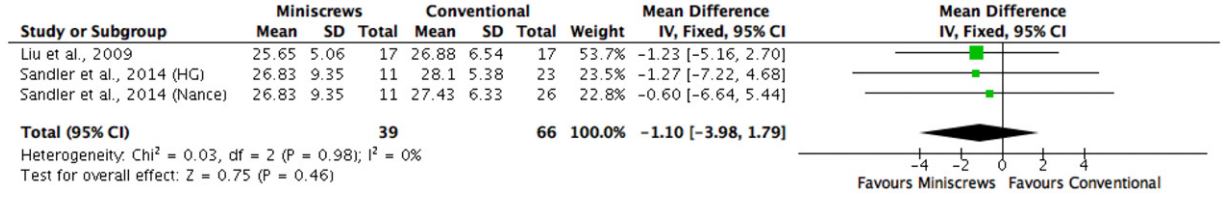


**Figure 5.** Forest plot of treatment duration.

using mechanically retained miniscrews are more clinically efficient than any conventional anchorage devices.

A meta-analysis of the pooled data found a significant difference between miniscrews and conventional anchorage devices/mechanics of 2.07 mm in favour of miniscrews, excluding studies with low risk of bias from the data synthesis still showed a similar finding. Jambi and colleagues [13] in their review found that surgical anchorage devices resulted in less anchorage loss (1.68 mm, 95% CI: 2.27–1.09) than conventional approaches; although they included in their review osseointegrated implants, their estimate did not differ significantly from our review estimate. Similarly, in Jambi et al. study [13], the pooled data from the high-quality RCTs showed a mean difference of 2.17 mm (95% CI: 2.58–1.77) in favour of skeletal anchorage which is very close to our findings. A similar systematic review was undertaken by Papadopoulos and co-workers [26], included five cohort studies and three RCTs, they concluded that miniscrews were more effective than conventional anchorage methods (2.4 mm, 95% CI: 1.8–2.9 in favour of miniscrews). However, Papadopoulos and colleagues included studies with high risk of bias which could affect robustness of their findings. Another systematic review that investigated anchorage effectiveness of orthodontic implants (not mechanically miniscrews) and headgear was undertaken by Li and colleagues [27]. The result of their search included four RCTs, one prospective cohort study and three retrospective studies; however, they pooled the data from two studies only and the estimated mean difference was 1.34 mm (95% CI: 2.02–0.67) in favour of implants which is slightly lower than that in our findings.

In our review, some of the secondary outcomes (adverse effects) were reported in two studies with variable quality [21,23]. The adverse effects of the different anchorage appliances were briefly reported in these two trials, both found that there was no serious adverse effect with any of the reviewed anchorage appliances apart from few failed/fractured miniscrews which were replaced or left *in situ* without complications [21,23]. The failure rate of the miniscrews was variable among the included studies but overall it was low and comparable to the published data [28]. However, in Liu and colleagues trial [21], eight miniscrews were failed and the operator waited for two months before replacing them to allow bone healing at the insertion site; this could increase both overall treatment duration, space closure phase duration and the overall cost of treatment. Nevertheless, the data extracted from these two studies [21,23] revealed that treatment duration was shorter when miniscrews as anchorage device were used, though, this was not statistically significant. Likewise, duration of space closure phase was almost identical among those treated with miniscrews or other means of anchorage provision as reported by two low-quality trials [20,25]. It is worth mentioning that the loss of anchorage in the conventional anchorage samples resulted in a smaller amount of extraction space left for incisor retraction, hence, the time required for space closure could be shortened. If the above-mentioned point and the extra waiting time required to replace failed miniscrews were taken in consideration, theoretically, miniscrews implication on treatment duration would be accentuated. Jambi and co-workers [13] found similar outcome and they indicated that orthodontic treatment reinforced with surgical anchorage was on average shorter by 0.15 year (0.37 years shorter to 0.07 years longer) compared to the group treated with conventional anchorage, however, it is worth noticing that the pooled the data in that review were collected from three studies, two of them used palatal implants [29,30] and only one study used miniscrews [21].

In our review, participants treated using miniscrews attended 2–3 visits fewer than those treated using other anchorage approaches [23]. This is contradicting with the findings of the Cochrane review [13] in which the outcomes of one study [30] indicated that treatment takes 7 visits more to be completed by surgical anchorage, although visits required for surgical healing of mid-palatal implants (osseointegration) were not counted.

In our review, one study [23] reported on patients' perception and found that patients had positive perception about miniscrews, unlike headgear and Nance appliance. This is unlike the outcomes of Jambi et al. review [13], in which two trials [30,31] reported that participants experienced more discomfort with bone anchorage devices, however,

**Table 2.** Summary of findings table for the main outcomes of this systematic review.

SUMMARY OF THE FINDINGS FOR THE MAIN COMPARISON

Miniscrews anchorage compared to conventional anchorage for patients undergoing orthodontic treatment

Patient or population: Patients undergoing orthodontic treatment

Setting: University settings

Intervention: Miniscrew anchorage

Comparison: Conventional anchorage

| | Illustrative comparative risks* (95% CI) | | | | | |
|---|---|---|---|---|---|---|
| Outcomes | Assumed risk with conventional anchorage | Corresponding risk with miniscrews | Relative effect (95% CI) | No of participants (studies)** | Quality of the evidence (GRADE) | Comments |
| Mesiodistal movement of the upper first permanent molar (mm) | The mean mesiodistal movement of the upper first permanent molar across the control groups ranged from 1.47 to 3.22 | The standardized mean mesiodistal movement of the upper first permanent molar in the intervention groups was 2.07 mm lower (3.05 lower to 1.08 lower) | – | 241 (6 RCTs) | ⊕⊕⊕◯ Low[a,b] | A total of 250 miniscrews and 134 conventional anchorage appliances were assessed for this outcome. Lower scores indicate less molar movements (greater reinforcement of anchorage). A change of 1.5 mm or greater is clinically important |
| Duration of overall treatment (months) | The mean overall duration of treatment (months) across the control groups ranged from 26.88 to 28.01 months | The mean total duration of treatment (months) in the intervention groups was −1.10 months shorter (3.98 months shorter to 1.79 months longer) | – | 105 (2 RCTs) | ⊕⊕◯◯ LOW[c,d] | Lower scores indicate a shorter duration of overall treatment. Duration estimated using a standardized mean difference. |

*The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95%CI); CI: confidence interval; SD: standard deviation mm: millimetre; minus sign (–) for the mesial movement of the molar indicates that the molar moved distally (anchorage gain) as a result of dynamic friction during space closure. **RCT: Randomized controlled trial. GRADE Working Group grades of evidence High quality: We are very confident that the true effect lies close to that of the estimate of the effect. Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect. Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[a]Downgraded one level for bias: 6 studies at overall high (3), unclear (0) and low (3) risk of bias.

[b]Downgraded one level for inconsistency: Substantial heterogeneity 88%, although standardized mean difference (SMD) of all studies in favour of miniscrews intervention.

[c]Downgraded one level for imprecision: Only two small RCTs are included.

[d]Downgraded one level for bias: 1 study at high risk of bias, 1 study at low risk of bias.

both studies used surgical implants which makes the comparison with our review not possible. Furthermore, there is limited evidence that the quality of the occlusal outcomes is better when miniscrews were used as an anchorage device in comparison to other anchorage appliances [23].

### Strengths and limitations of this review

The authors attempted to minimize bias being introduced into this systematic review by undertaking a comprehensive search of multiple databases and literature sources aiming to identify every single research that matched the inclusion criterion. Two reviewers independently evaluated and retrieved database results and articles in duplicate, while a third reviewer mediated any unresolved disagreement. Furthermore, studies eligible for quantitative synthesis were conducted in three different regions of the world; hence, generalizability of the obtained results is good.

On the other hand, the body of evidence was generally of low to moderate quality, mainly due to the unclear domains presented in many included trials. Furthermore, findings of this review should be interpreted with caution due to the substantial heterogeneity across the studies. This high level of heterogeneity could be a result of discrepancies in clinical and statistical methodologies, variation in the assessment tools, age/gender variations and small sample size among the included studies. The mean age of participants in the included studies ranged from 14.22 years to 22.4 years and they have variable failure rate of miniscrews ranging from 1 to 8 miniscrews; this might have had an impact of the anchorage effectiveness provided by miniscrews as well as on the total cost of the treatment.

Within the included trials, measurement of the anchorage losses was performed at four different time points, this could affect the pooled effects, therefore, the data should be interpreted with caution.

Several options were recommended by the Cochrane handbook for meta-analysing outcomes from studies with more than two arms [16]. Although the recommended method is to combine groups to create a single pair-wise comparison, we decided to undertake pair-wise comparison separately in which the number of the participants in the intervention groups (miniscrews group) divided out approximately evenly among the comparisons (conventional anchorage groups) while the means and standard deviations left unchanged. This is because it will be unwise to combined different conventional anchorage appliances with different anchorage capabilities into single group. Moreover, this method partially overcomes the unit-of-analysis error and it would be that approximate investigations of heterogeneity across intervention arms are possible [16].

The limited data on the secondary outcomes do not allow conclusive findings on the miniscrews or conventional anchorage regarding the total treatment duration, serious adverse effect or patient-reported outcomes. None of the included trials reported on the cost-effectiveness of the different anchorage devices, although our research indicated an ongoing trial in Sweden (registration number NCT02644811). Statistical analysis of the publication bias was not performed in this review as only a few studies were included.

### Recommendations for clinical practice

Overall, data analysis of this review shows that there is moderate evidence favouring miniscrews in providing anchorage over conventional methods. There is also a limited evidence suggesting that treatment with miniscrews provides better occlusal outcomes and is better tolerated by patients than headgear or Nance appliances. Limited evidence suggesting that there is no significant difference in terms of overall treatment duration, space closure duration, adverse side effect, space closure duration and number of orthodontic visit. None of the included trials reported on the cost-effectiveness of the different anchorage devices.

### Implications for research

There is a need for further long-term and high-quality RCT to report on number of the required orthodontic appointments, failure rate of different anchorage devices, cost efficiency, discomfort and related quality of life issues.

## Conclusion

There is a moderate quality evidence suggesting that miniscrews are statistically more effective than conventional anchorage devices, preserving 2.207 mm of space, this effect might be considered clinically significant. Limited evidence suggesting that there is no significant difference in terms of overall treatment duration, space closure duration, adverse side effect, space closure duration and number of orthodontic visit. Additionally, there is limited evidence suggesting that the occlusal outcomes and patient perception secondary to anchorage reinforcement using miniscrews as anchorage appliance are better than any other anchorage appliances. However, due to the high level of statistical and clinical heterogeneity, this finding should be interpreted with caution. High-quality RCTs with large sample size would give more conclusive evidence.

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No potential conflict of interest was reported by the authors.

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