Review Article

Evaluation of Treatment Outcomes of *En masse* Retraction with Temporary Skeletal Anchorage Devices in Comparison with Two-step Retraction with Conventional Anchorage in Patients with Dentoalveolar Protrusion: A Systematic Review and Meta-analysis

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Abstract

Objective: The main objective is to evaluate the effectiveness of *en masse* retraction with temporary skeletal anchorage devices (TSADs) versus two-step retraction with conventional anchorage (CA) in terms of the skeletal, dental, and soft-tissue variables, as well as the duration of retraction or overall orthodontic treatment. **Materials and Methods:** An electronic search of PubMed and nine other major databases for prospective, randomized controlled trials (RCTs) and clinical controlled trials (CCTs) was carried out between January 1990 and April 2018. The bibliography in each identified article was checked out. In addition, manual searching was performed in the same time frame in five major orthodontic journals. Adult patients undergoing fixed orthodontic treatment with extraction of maxillary premolars followed by an *en masse* retraction in the experimental group and two-step retraction of upper anterior teeth in the control group. Methodological index for nonrandomized studies for CCTs and Cochrane's risk of bias tool for RCTs were applied. **Results:** Four articles (two RCTs and two CCTs) were included in this review and all articles were appropriate for the quantitative synthesis. There was no significant difference between the *en masse* retraction and two-step retraction groups in terms of SNA, SNB, ANB, and MP-SN angles. Using TSADs gave significantly better results in terms of posterior anchorage and incisors inclination, and greater anterior teeth retraction in comparison with CA (standardized mean difference [SMD] = –3.03 mm, $P < 0.001$; SMD = 0.74°, $P = 0.003$; SMD = –0.46 mm, $P = 0.03$, respectively). *En masse*/TSAD combination caused a significantly greater increase in nasolabial angle, higher decrease in facial convexity angle, and greater lower lip retraction in comparison with two-step/CA combination (weighted mean difference = 4.73°, $P = 0.007$; $P = 0.0435$; SMD = –0.95 mm, $P = 0.01$, respectively). **Conclusion:** There is weak-to-moderate evidence that using either *en masse*/TSAD combination or two-step/CA combination would lead to similar skeletal improvement. There is a very weak-to-moderate evidence that using TSADs with *en masse* retraction would cause better posterior anchorage and incisors inclination, and greater anterior teeth retraction than using CA with two-step retraction. There is weak-to-moderate evidence that using *en masse*/TSAD combination would lead to a better improvement in the facial profile. According to the quality of evidence, we confirm the need for more well-conducted RCTs in the *en masse* retraction field.

Keywords: *Anchorage, anterior teeth, en masse, extraction, meta-analysis, orthodontic, protrusion, retraction, systematic review, two-step*

Introduction

The problem of bimaxillary protrusion of the dental arches is widespread across the world.[1] In addition, the maxillary dentoalveolar protrusion is one of the most prevalent cases seen in the orthodontic clinics.[2] Treatment of these types of malocclusion often requires extraction of maxillary or bimaxillary first or second premolars and the use of maximum anchorage.[3,4] When treating patients with an excessive dentoalveolar protrusion, anchorage control is necessary to obtain the good results.[3,5] To reinforce anchorage, various auxiliary methods can be used such as the transpalatal arch, Nance button, headgear, intermaxillary elastics, and bonding of second molars.[3,6] Lately, temporary skeletal anchorage devices (TSADs) have been offered as an alternative method for anchorage control.[4]

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Closing extraction spaces can be performed by a one-step technique (*en masse* retraction) with anchorage reinforcement or by a two-step technique involving canines' retraction followed by the incisors' retraction.[7] The one-step technique is preferred on the two-step technique because when canines are retracted individually, they tend to tip and rotate more than when the six anterior teeth are retracted as one unit, thus requiring more time and effort to relevel and realign the dental arch.[8]

The *en masse* retraction of the anterior teeth after the premolar extraction has been practiced in the Begg and Tip-Edge edgewise techniques for several years.[9] In the straight-wire appliances, the *en masse* retraction of upper anterior teeth was first presented by Andrews, and then it has been used routinely by Bennett and McLaughlin in their preadjusted appliance system.[9]

There are three systematic reviews that have evaluated the *en masse* retraction technique, but several points could be raised regarding these reviews. The systematic review carried out by Xu and Xie[3] and Antoszewska-Smith *et al*.[10] merged between *en masse* retraction and two-step retraction in the control group, so there was no concentration on one retraction technique. The systematic reviews carried out by Antoszewska-Smith *et al*.[10] and Rizk *et al*.[11] did not evaluate the skeletal and soft-tissue variables and focused only on some dental variables. It should be noted that Xu and Xie[3] and Antoszewska-Smith *et al*.[10] systematic reviews had included retrospective studies, which is known to suffer from a high risk of bias, rather than confining the results to prospective randomized controlled trials (RCTs) and clinical controlled trials (CCTs).

Given the shortfalls listed above, a new systematic review seemed desirable to answer the following explicit focused review question: "What is the overall effectiveness of *en masse* retraction versus two-step retraction of the upper anterior teeth in adult patients with maxillary or bimaxillary dentoalveolar protrusion?"

Materials and Methods

A PubMed scoping search was done to verify the existence of similar systematic reviews and to explore potentially eligible articles before writing up the final systematic review protocol. The protocol was registered during the first stages of this review in PROSPERO (CRD42018085596). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[12] checklist and the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0[13] were used for writing and submitting this systematic review and meta-analysis.

Eligibility criteria

The PICOS framework was as follows:

Participants: Healthy adult patients, both males and females, the minimum age is 14 years old to minimize the effects of growth, with Class I or II dentoalveolar protrusion, undergoing fixed orthodontic treatment with maxillary or bimaxillary first or second premolar extraction and retraction of upper anterior teeth. Intervention: *En masse* retraction of the upper anterior teeth associated with TSADs for anchorage reinforcement. Comparison: Two-step retraction of the upper anterior associated with conventional anchorage (CA). Outcome measures: Skeletal, dental, and soft-tissue variables, and retraction or overall treatment duration.

Study design

Prospective RCTs and CCTs that were published from January 1990 to April 2018 in the English language only.

Exclusion criteria

Retrospective studies, studies performing *en masse* retraction or two-step retraction in both evaluated groups, non-English language trials, animal studies, finite element analysis studies, *in vitro* studies, split-mouth-design studies, editorials, personal opinions, case reports or case series reports, articles without a reported sample, reviews and technique description articles, absence of a control group or the presence of a control group of nontreated participants, fewer than 10 patients in the experimental group, a control group of patients being treated on a nonextraction basis, and/or age range >15 years.

Information sources

An electronic literature search was done using PubMed, Medline, Embase, OVID SP, EBSCO, Scopus, Google Scholar, the Cochrane Central Register of Controlled Trials, OpenGrey, and Web of Science. The databases were searched between January 1990 and April 2018. Electronic searching was supplemented with reviewing the bibliography in each included article. In addition, manual searching was carried out in the same time frame in the American Journal of Orthodontics and Dentofacial Orthopedics, the European Journal of Orthodontics, Orthodontics and Craniofacial Research, the Angle Orthodontist, and the Journal of Orthodontics. ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform Search Portal were also checked electronically to identify any clinical trials in progress and those that have been completed but not published yet.

Search strategy and study selection

The search strategy for PubMed is presented in Table 1. Keywords used in the search strategy are shown in Supplementary Table 1. Two reviewers (HNK and MYH) assessed the articles for eligibility independently, and in the event of any discrepancy, the reviewers resolved it by discussion until consensus was reached. First, the two reviewers checked titles and abstracts of articles during the search by using the eligibility criteria. Second, the same two reviewers evaluated the full text of all articles that

Table 1: Search strategy of PubMed

Publication date: From January 1990 to April 2018	#1 orthodontic treatment OR orthodontic therapy
Language: English	#2"Skeletal class 2 " OR "Class 2 Div 1" OR "Maxillary protrusion" OR "Dentoalveolar protrusion" OR "Maxillary dentoalveolar protrusion" OR "Bimaxillary protrusion" OR "premolar extraction"
Species: Human	#3 "enmasse retraction" OR "en-masse retraction" OR "en masse retraction" OR "One step retraction" OR "anterior teeth retraction" OR "six anterior teeth retraction" OR "maxillary anterior teeth retraction" OR "two-step retraction " OR " two step retraction " OR "two step " OR "retraction"
Article types: Clinical trial	#4 anchorage OR "skeletal anchorage" OR "maximum anchorage" OR "absolute anchorage" OR "traditional anchorage" OR tpa OR "transpalatal arch" OR "transpalatal bar" OR "nance button" OR headgear OR "mini plate" OR mini-plate OR miniplate OR "mini screw" OR miniscrew OR mini-screw OR micro screw OR mini-implant OR "mini implant" OR micro-implant OR microimplant OR tads OR toads OR tisads OR "temporary anchorage devices" OR "titanium microscrew" OR "titanium mini-implant" OR "ortho implant"
Ages	#5 #1 AND #2 AND #3 AND #4
Adolescent: 13-18 years	
Young adult: 19-24 years	
Adult: 19-44 years	

might be included in the review. Articles were discarded from the review when they did not fulfill one or more of the eligibility criteria.

Data collection process

Initially, data extraction tables were developed, then the first reviewer (HNK) retrieved the data from the included articles according to the data extraction tables, and the second reviewer (MYH) checked the extracted data. Any conflict was resolved by discussion between the two reviewers and reexamination of the original article. If no consensus could be reached, a third reviewer (OH) was asked to decide and resolve the controversy. In the event of lack of information, the authors of the included studies were E-mailed and asked for more data.

In this systematic review, the following data were extracted from the included studies: Author's name, year and country of publication, study design, malocclusion type, types of devices used for anchorage reinforcement, gender of the patients, sample size, age of the patients at the start of the treatment, magnitude and source of force applied during the retraction, length and diameter of miniscrews, retraction or overall treatment duration, brackets' prescription, slots' size, and working archwire.

Lateral cephalometric measurements were also extracted from the included articles to evaluate the skeletal, dental, and soft-tissue variables. These measurements are presented in Supplementary Table 2.

Assessment of Risk of Bias in Individual Studies and Strength of Evidence

The Methodological index for nonrandomized studies (MINORS) Index[14] was applied to assess the risk of bias for CCTs. The Cochrane Collaboration tool[15] was used to assess the risk of bias for RCTs, and it was evaluated as a judgment (high, low, or unclear) for individual elements from seven domains. An additional summary of the reliability of the conclusions and strength of the evidence was developed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.[16] The strength of evidence was evaluated as high, moderate, low, or very low for seven outcomes.

Summary Measures, Synthesis of Results, Additional Analysis, and Risk of Bias Across Studies

Meta-analysis was carried out using Review Manager, Version 5.3. Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration. The random-effects model was used for the continuous outcomes, in which studies were weighted with the inverse of their variance and the heterogeneity parameter.[13] The mean, standard deviation, and sample size of the included studies were used to combine the results into a weighted mean difference (WMD) with 95% confidence intervals when the outcome measurements in all included articles were made on the same scale; but when the same outcome was measured in a variety of ways, the standardized mean difference (SMD) was used as a summary statistic in meta-analysis.[13]

The P value was used to discover any significant heterogeneity when $P < 0.05$. I^2 index was used to describe the percentage of heterogeneity across the studies.[13] The forest plots were applied to present a graphical assessment of the analysis results. Sensitivity analysis was conducted by tracing sensitivity plots to

investigate the influence of the CCTs on the results and discarding them when appropriate. The publication bias was not evaluated because we did not collect 10 studies. Therefore, the funnel plots were not used in this meta-analysis.

Results

Study selection

Initially, 2925 articles were found from all the searches combined. After taking off the duplicates, 572 articles remained. After reviewing the titles and abstracts, 540 articles were discarded because they failed to meet the eligibility criteria. The full text of the 32 remaining articles was examined in depth. Twenty-eight articles did not meet the inclusion criteria as described. A summary of the excluded articles along with reasons for exclusion is shown in Supplementary Table 3. Finally, four articles (two RCTs[1,7] and two CCTs[17,18]) met the inclusion criteria and were included in the systematic review. The PRISMA flow diagram of the study selection process is shown in Figure 1.

Study characteristics

Baseline characteristics of the patients in the retrieved articles are shown in Table 2. Characteristics of the included studies are shown in Tables 3 and 4. The skeletal, dental, and soft-tissue measurements are shown in Supplementary Tables 4-7, respectively. All included studies were of a two-arm parallel-group design. Extraction-based treatments were supplied in the two groups in all the retrieved studies. The experimental group (G1) consisted of an *en masse* retraction of the upper anterior teeth associated with TSADs for anchorage reinforcement, whereas the control group (G2) consisted of a two-step retraction of the upper anterior teeth associated with CA devices.

In total, 150 adult patients were included: 74 patients in G1 (57 female and 17 male patients), and 76 in G2 (59 female and 17 male patients). Three papers[1,7,18] evaluated the skeletal, dental and soft-tissue variables and one paper[17] studied the dental variables only. Two papers[1,17] mentioned the retraction duration, one paper[7] presented the overall treatment duration, and one paper[18] did not give these details.

Risk of bias of the included studies

The risk of bias in the RCTs is shown in Figure 2, and the overall risk of bias for each domain is shown in Figure 3. The two included RCTs[1,7] were of low risk of bias (quality assessment is shown in Supplementary Table 8). Methodological quality assessment of the CCTs[17,18] is presented in Table 5. The global ideal score was 24 when using the MINORS scale. Studies'scores were both 17 points, which showed that the included CCTs were of fair quality.

Results of individual studies, synthesis of results, and additional analysis

En-masse retraction with temporary skeletal anchorage devices (G1) versus two-step retraction with conventional anchorage (G2)

Two studies[1,7] measured skeletal variables and the related forest plots are shown in Supplementary Figure 1. There was no significant difference between the two groups in the SNA, SNB, ANB, and MP-SN angles (WMD = 0.03°,

Table 2: Baseline characteristics of the patients in the included studies

Study ID: Author and year	Experimental group (G1)				Control group (G2)			
	Female	Male	*n*	Age at start of treatment (years)	Female	Male	*n*	Age at start of treatment (years)
Upadhyay *et al*., 2008[1]	20	0	20	17.6±3.2	20	0	20	17.3±3.2
Upadhyay *et al*., 2008[17]	10	5	15	17.16	11	4	15	17.16
Solem *et al*., 2013[18]	8	3	11	27.4±7.9	12	1	13	21.6±7.1
Al-Sibaie and Hajeer, 2014[7]	19	9	28	23.02±6.23	16	12	28	20.46±4.84

Table 3: Characteristics of the included studies (Part I)

Study ID: Author and year	Country	Study design	Type of malocclusion	Anchorage type		Diameter/length of miniscrew (mm)	Magnitude of force (g)
				G1	G2		
Upadhyay *et al*., 2008[1]	India	RCT	Class I bialveolar protrusion	Mini-implant	Various conventional anchorage methods	1.3/8	150
Upadhyay *et al*., 2008[17]	India	CCT	Class II or I with bimaxillary protrusion	Mini-implant	Various conventional anchorage methods	1.3/8	150
Solem *et al*., 2013[18]	Korea	CCT	Bimaxillary dentoalveolar protrusion	C-tube miniplates	TPA	-	NR
Al-Sibaie and Hajeer, 2014[7]	Syria	RCT	Class II division 1	Mini-implant	TPA	1.6/7	150

RCT: Randomized clinical trial; CCT: Controlled clinical trial; G1: Experimental group; G2: Control group; NR: Not reported; TPA: Transpalatal arch

Table 4: Characteristics of the included studies (Part II)

Study ID: Author and year	Bracket's type or prescription	Slot's size (inches)	Working archwire (inches)	Force source	Retraction/treatment duration (months)	
					G1	G2
Upadhyay *et al*., 2008[1]	Roth	0.022	G1: SS 0.017×0.025 + crimpable hook distal to the lateral incisors	G1: Closed NiTi coil spring	(R) 9.94±2.44	(R) 8.61±2.2
Upadhyay *et al*., 2008[17]	Roth	0.022	G1: SS 0.017×0.025 + crimpable hook distal to the lateral incisors	G1: Closed NiTi coil spring	(R) 10.6	(R) 9.2
Solem *et al*., 2013[18]	Twin brackets	0.018	G1: SS 0.016×0.022 passing through the labial c-tube miniplates	G1: Elastomeric chains from hooks on the archwire to the C-tube	NR	NR
			G2: SS 0.016×0.022	G2: Elastomeric chains		
Al-Sibaie and Hajeer, 2014[7]	MBT	0.022	G1: SS 0.019×0.025 with 8 mm height soldered hooks distal to the laterals	G1: Elastic chains attached between the mini-implants and the soldered hooks	(T) 12.90	(T) 16.97
			G2: SS 0.019×0.025	G2: Closed elastic chains		

SS: Stainless steel; NiTi: Nickel-titanium; G1: Experimental group; G2: Control group, NR: Not reported; R: Retraction duration; T: Overall treatment duration; MBT: McLaughlin, Bennet and Trevisi

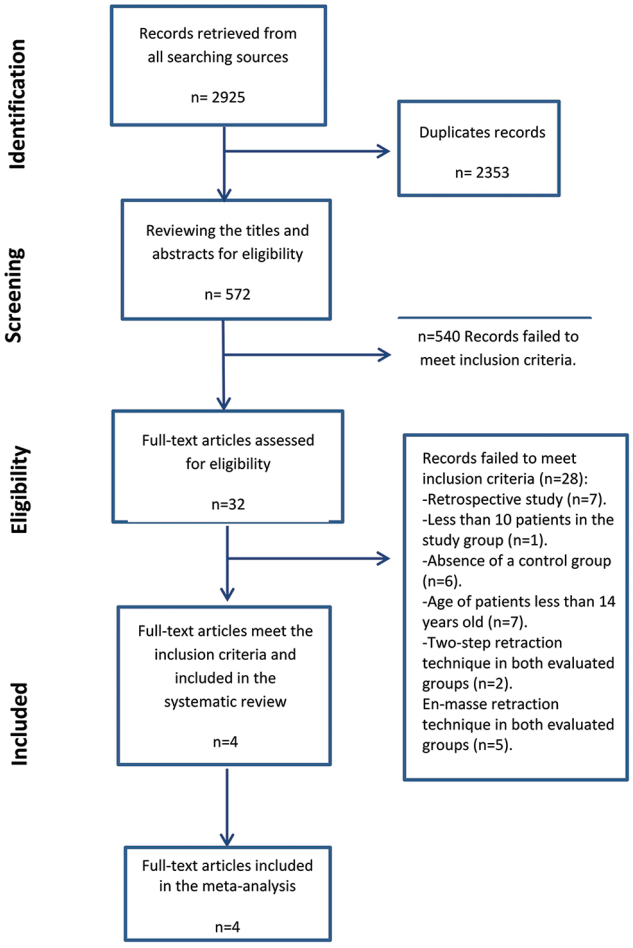

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009 flow diagram of the study selection process

$P = 0.88$ WMD = 0.47°, $P = 0.58$; WMD=−0.29°, $P = 0.46$; WMD=–0.16°, $P = 0.89$, respectively).

Table 5: Methodological quality of the selected nonrandomized studies according to the methodological index for nonrandomized studies assessment tool

Item	Upadhyay *et al.*, 2008[17]	Solem *et al.*, 2013[18]
1. A stated aim of the study	1	2
2. Inclusion of consecutive patients	2	1
3. Prospective collection of data	2	2
4. Endpoint appropriate to the study aim	2	2
5. Unbiased evaluation of endpoints	0	0
6. Follow-up period appropriate to the major endpoint	2	2
7. Loss to follow-up not exceeding 5%	0	0
8. A control group having the gold standard intervention	2	2
9. Contemporary groups	2	2
10. Baseline equivalence of groups	2	2
11. Prospective calculation of the sample size	0	0
12. Statistical analyses adapted to the study design	2	2
Total	17	17

The items are scored 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The global ideal score being 24 for comparative studies

Dentally, a sensitivity analysis was carried out in all the dental changes and it was decided not to include CCTs[17,18] with RCTs[1,7] for more reliable results. A distal movement of maxillary first molar (U6) was reported in G1, while a mesial movement of U6 was reported in G2 with a significant difference between the two

groups (SMD = –3.03 mm, $P < 0.0001$), [Figure 4]. A greater retraction of incisors (U1) with better inclination were detected in G1 with a significant difference between the two groups [SMD = –0.46 mm, $P = 0.03$; SMD = 0.74°, $P = 0.003$, Figures 5 and 6, respectively]. An intrusion force was applied on U1 and U6 in G1, while an extrusion force was applied on U1 and U6 in G2 with a significant difference between the two groups in the vertical movement of U1 and U6 [SMD = –2.48 mm, $P < 0.00001$; SMD = –0.61 mm, $P = 0.010$, Figures 7 and 8, respectively].

Regarding soft-tissue variables, two articles[1,7] reported a significantly greater increase in the nasolabial angle (NLA) in G1 (WMD = 4.73°, $P = 0.007$) [Supplementary Figure 2]. One study[1] measured the facial convexity angle, with significantly higher decrease in G1 ($P = 0.0435$). Sensitivity analysis was carried out in the UL-E and LL-E, and it was decided to exclude one CCT[18] in the analysis. No significant difference between the two groups was observed regarding the UL-E (SMD = –0.28 mm, $P = 0.18$), [Supplementary Figure 3], while there was a significantly greater lower lip retraction in G1 (SMD = –0.95 mm, $P = 0.01$), Supplementary Figure 4].

There was no significant difference between the two groups in the duration of retraction in two studies[1,17]. In constant, one study[7] reported a significantly shorter treatment duration in G1 with an average of 4 months.

The strength of the evidence in the collected data

Based on the GRADE recommendations, the strength of evidence for the skeletal and soft-tissue measurements ranged from low to medium, while it ranged from very low to medium for dental changes, as shown in Table 6. The decline in the strength of the evidence occurred because of the imprecision, high heterogeneity, or existence of CCTs.

Table 6: Summary of findings table according to the Grading of Recommendations Assessment, Development, and Evaluation guidelines for the included studies

Outcomes	Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
SNA angle (°)	WMD 0.03 (−0.35-0.41)	92 patients (2 studies)	⊕⊕⊕⊖[a] Medium	
SNB angle (°)	WMD 0.47 (−1.19-2.12)	92 patients (2 studies)	⊕⊕⊖⊖[b] Low	
Horizontal movement of maxillary first molars	RCTs: SMD−3.03 mm (−3.65-−2.42)	96 patients (2 studies)	RCTs: ⊕⊕⊕⊖[a] Medium	
	CCTs: SMD−3.62 mm (−5.88-1.35)	54 patients (2 studies)	CCTs: ⊕⊖⊖⊖[c] Very low	
Vertical movement of maxillary first molars	RCTs: SMD−0.61 mm (−1.08-−0.15)	96 patients (2 studies)	RCTs: ⊕⊕⊕⊖[a] Medium	
	CCTs: SMD 0.75 mm (−2.07-3.57)	54 patients (2 studies)	CCTs: ⊕⊖⊖⊖[c] Very low	
Horizontal movement of upper incisal edges	RCTs: SMD−0.46 mm (−0.87-−0.04)	96 patients (2 studies)	RCTs: ⊕⊕⊕⊖[a] Medium	
	For CCTs: SMD−1.07 mm (−2.85-0.71)	54 patients (2 studies)	CCTs: ⊕⊖⊖⊖[c] Very low	
Vertical movement of maxillary incisors	RCT: Not estimable	56 patients (1 study)	RCT: ⊕⊕⊕⊖[a] Medium	
	CCTs: SMD−0.85 mm (2.77-1.08)	54 patients (2 studies)	CCTs: ⊕⊖⊖⊖[c] Very low	
UL-E	RCTs: SMD−0.28 mm (−0.69-0.13)	96 patients (2 studies)	RCTs: ⊕⊕⊕⊖[a] Medium	
	CCT: Not estimable	24 patients (1 study)	CCT: ⊕⊕⊖⊖[d] Low	

⊕Achieving one level of quality of evidence, ⊖Decline in one level of quality of evidence, [a]Decline one level for imprecision*; [b]Decline one level for imprecision* and one level for high heterogeneity; [c]Decline one level for being nonrandomized trials Upadhyay *et al*., 2008,[17] one level for high heterogeneity and one level for imprecision*, [d]Decline one level for being nonrandomized trial Solem *et al*., 2013[18]). and one level for imprecision*, *Limited number of trials, or limited sample size. GRADE: Grading of Recommendations Assessment, Development and Evaluation; CCT: Clinical controlled trials; RCT: Randomized controlled trials; SMD: Standardized mean difference; WMD: Weighted mean difference; CI: Confidence interval

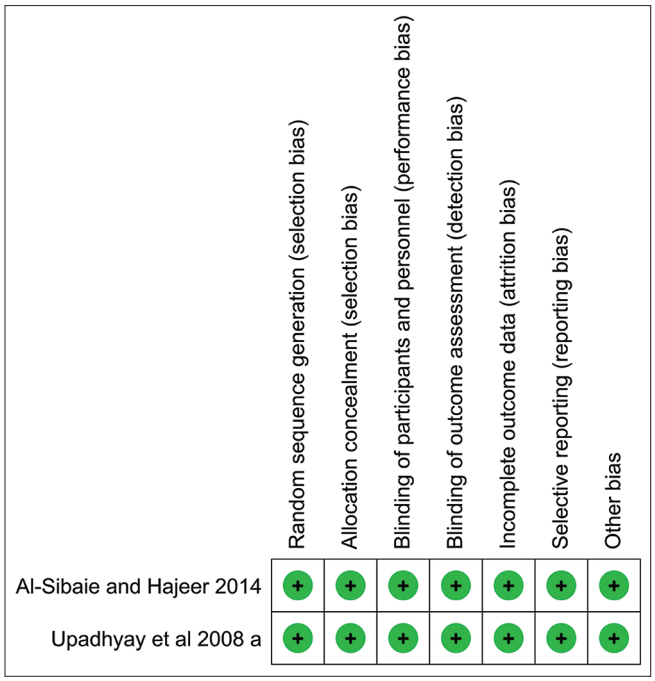

Figure 2: The risk of bias in randomized controlled trials

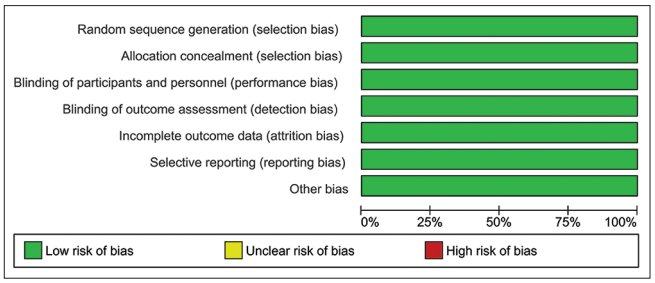

Figure 3: The overall risk of bias for each domain

Discussion

Skeletal changes

The SNA and ANB angles decreased with no significant difference between the two groups. This decrease would indicate that point A had moved back during the upper anterior teeth retraction. Al-Sibaie and Hajeer[7] reported a decrease in the SNB and MP-SN angles in both groups with no significant difference between them, while Upadhyay *et al*.[1] reported an increase in the SNB and decrease in the MP-SN in the *en masse*/TSAD group, which could be related to the molars intrusion in both arches causing counterclockwise rotation of the mandible.

Since there were no significant differences in the skeletal variables between both retraction methods, there is no preference for one method over the other in terms of the skeletal improvement. The strength of evidence in this context ranged from low to medium.

Dental changes

The horizontal movement of first molars

Using TSADs seem to supply not only less mesial movement of first molars but also a distal movement of them when interdental contact occurs between the canine and second premolar, so a retraction force would translate to the first molars, as reported in all the included studies[1,7,17,18]. Hence, using TSADs for anchorage appears to be better than CA. The strength of evidence ranged between very low to medium.

The vertical movement of first molars

Intrusion of first molars occurred when anchoring the anterior teeth retraction with TSADs; while in contrast, extrusion of first molars occurred when using the CA devices. Hence, using TSADs are expected to prevent the worsening of the profile with clockwise rotation of the mandible in cases with increased vertical dimensions. The strength of the evidence ranged between very low to medium in this aspect.

The horizontal movement of upper incisal edges

It was higher when using TSADs in comparison with CA because CA allowed posterior teeth to move mesially so that the anterior teeth were retracted a less amount. Therefore, it is preferable to use TSADs when a larger amount of retraction is needed. The strength of evidence ranged between very low to medium.

The vertical movement of incisors

The incisor edges and apices were exposed to an intrusion force when using the TSADs, due to the placement of TSADs 8–10 mm apically to the occlusion line, so the point of force application is apical to the center of resistance (CR). Furthermore, the height of the power arm influenced the amount of intrusion force. By reducing it, a higher intrusion could be achieved. In contrast, extrusion of incisal edges and apices would occur in the CA group, due to the coronal orientation of the force vector in relation to the CR. Therefore, using TSADs prevents the incidence of a postretraction increase in the overbite. The strength of the evidence in this context ranged between very low to medium.

The incisors inclination

It is one of the hardest and most important goals in the camouflage treatment. In the *en masse*/TSAD group, the upper incisors were retracted by controlled tipping and bodily movement, whereas in the two-step/CA group the retraction was primarily accomplished through controlled and uncontrolled tipping. Therefore, the upper incisor axis would show an optimal inclination when using TSADs with *en masse* retraction of the upper anterior teeth.

Soft-tissue changes

The NLA increased in both groups after retraction because of the backward movement of the upper incisors. This increase was significantly greater in the TSADs/*en masse* group in comparison with the CA/two-step group because of the larger amount of upper anterior teeth retraction in the TSADs/*en masse* group.

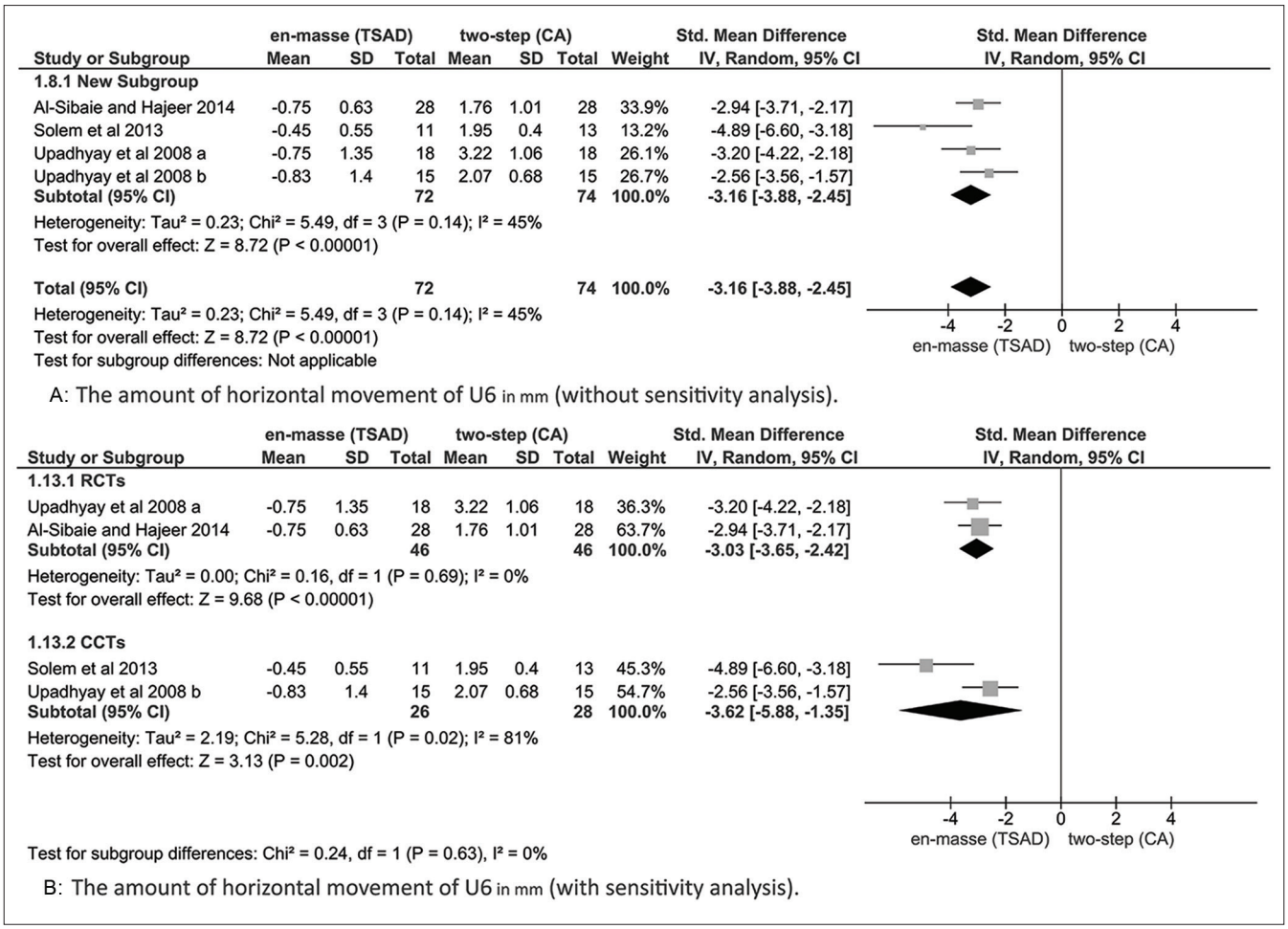

Figure 4: Forest plot showing the amount of horizontal movement of U6 in *en masse*/ temporary skeletal anchorage devices group versus two-step/ conventional anchorage group

The facial convexity angle decreased in both groups because of the retraction of the upper incisors and that improved the appearance of the facial profile. Upadhyay *et al*.[1] reported that this decrease was significantly higher in the *en masse* retraction compared to the two-step retraction. The reason for this seems to be the significant difference between the two techniques in the amount of upper anterior teeth retraction.

The upper lip retraction was higher in the *en masse* retraction with TSADs in comparison with two-step retraction with CA, but it was not significantly difference between the two groups. This could be explained by the differences in thickness and lip strain between the patients. In addition, the mobile and flexible lip texture could cause large variations of lip position on the lateral cephalogram. The strength of evidence ranged from low to medium.

The lower lip retracted in the *en masse*/TSADs group and two-step/CA groups because it contacts the upper and lower incisors, so it is influenced by both incisors retraction. This could explain the reason for lower lip retraction in class II division 1 cases where the extraction was performed only in the upper dental arch, as reported in Al-Sibaie and Hajeer.[7] However, the lower lip retracted due to the retraction of the upper anterior teeth.

Retraction or overall treatment duration

Regarding the overall treatment duration, Al-Sibaie and Hajeer[7] reported a significantly shorter treatment duration in the *en masse*/TSAD group and that because performing a two-step retraction technique prolonged the duration of space closure as it took 6–8 months just to retract the canine into the extraction site.[19] Surprisingly, Upadhyay *et al*.[1,17] reported no significant difference between the two groups in the retraction duration with indicating that the incorporation of skeletal anchorage devices may enhance the treatment outcomes without affecting the retraction duration, but the explanation given in their paper was not convincing.

Limitations of the current review

Being confined to the papers written in English is one limitation. Despite the separation between RCTs and CCTs, heterogeneity remained high in some comparisons. Only two prospective RCTs and two CCTs were found in the medical literature comparing between *en masse*

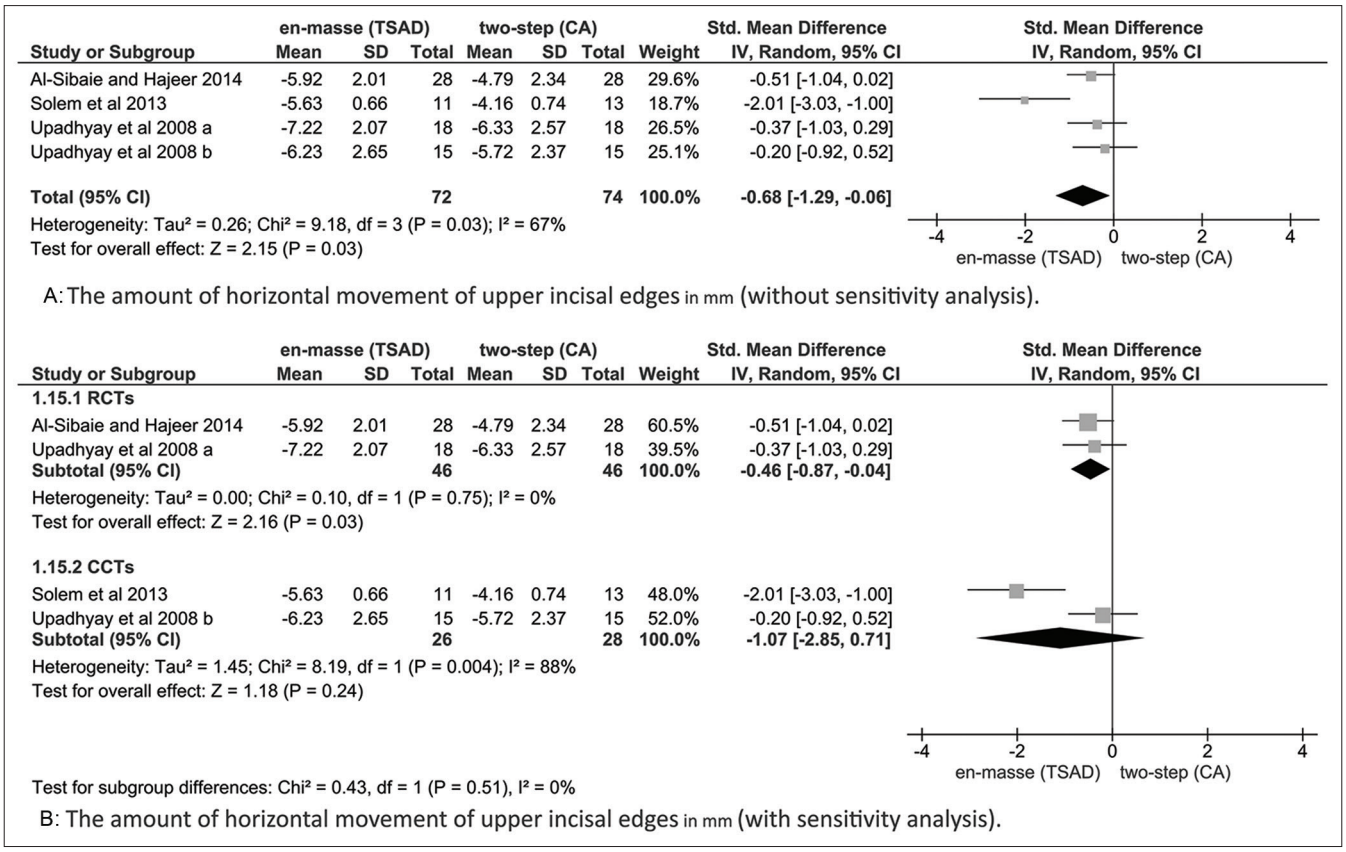

Figure 5: Forest plot showing the amount of horizontal movement of upper incisal edges in *en massel* temporary skeletal anchorage devices group versus two-step/conventional anchorage group

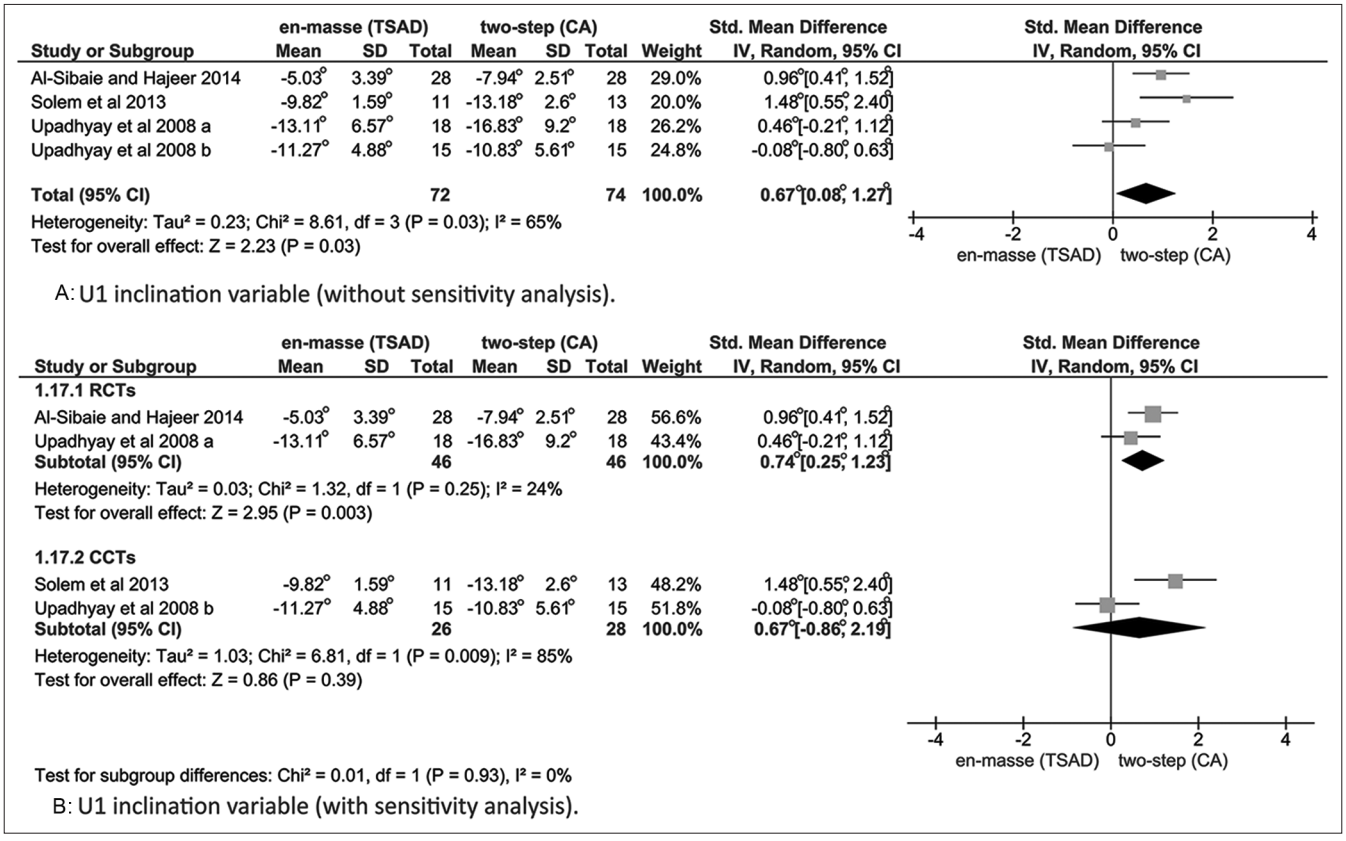

Figure 6: Forest plot showing the incisors' inclination variable in *en massel* temporary skeletal anchorage devices group versus two-step/conventional anchorage group

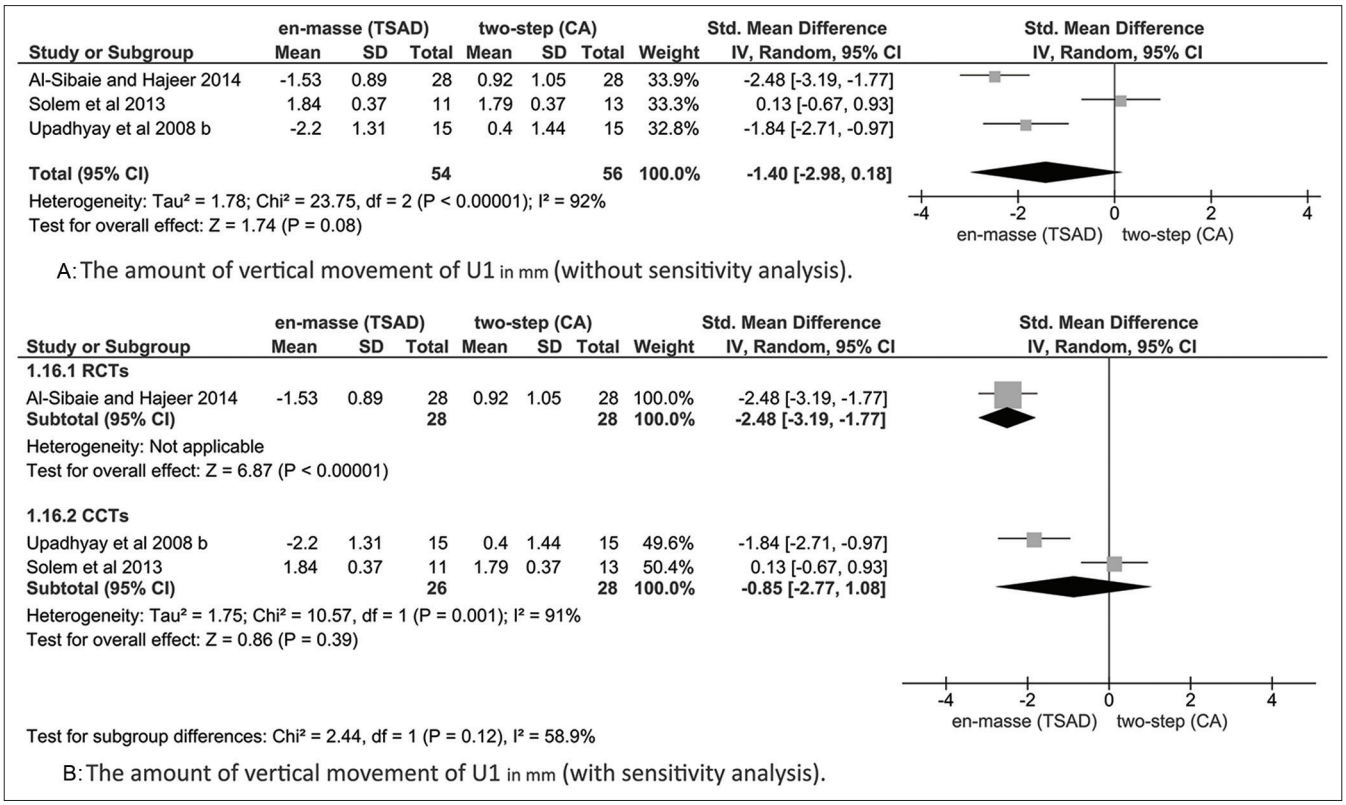

Figure 7: Forest plot showing the amount of vertical movement of incisors in *en massel* temporary skeletal anchorage devices group versus two-step/ conventional anchorage group

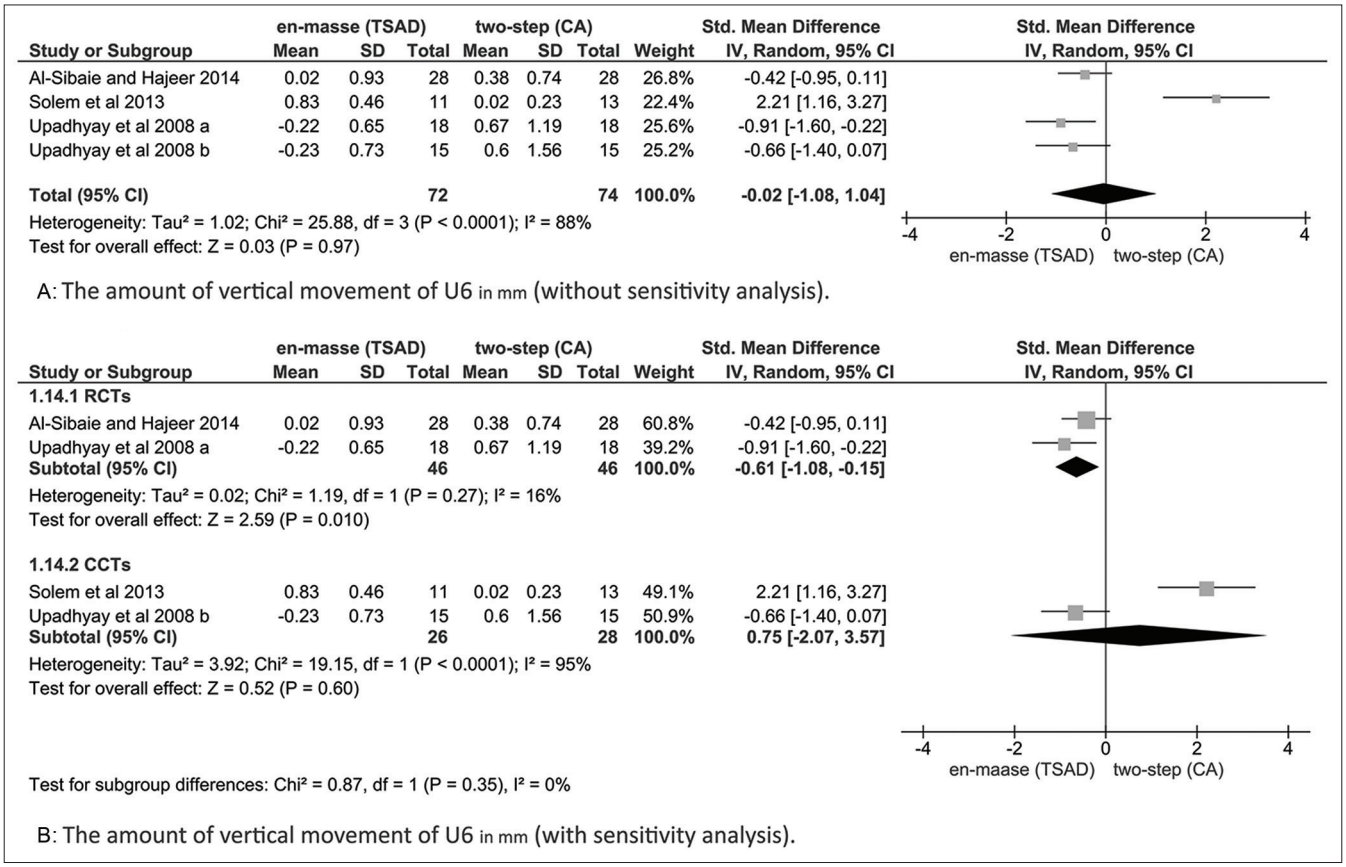

Figure 8: Forest plot showing the amount of vertical movement of U6 in *en massel* temporary skeletal anchorage devices group versus two-step/ conventional anchorage group

retraction and two-step retraction in adult patients with a strength of evidence ranged between weak/very weak to moderate. Therefore, the results of this systematic review should be taken cautiously. The methodologic quality of the included studies was assessed rigorously, and none of the selected CCTs were of high quality. The cephalometric analyses were conducted by different reference points and planes, but the ability to arrive at conclusions was possible since the accomplished comparisons were based on the treatment-induced changes and not the actual values *per se*.

Conclusion

Implications for practice

There is weak-to-moderate evidence that performing either *en masse* retraction with TSADs or two-step retraction with CA can lead to similar skeletal improvements. There is very weak-to-moderate evidence that using TSADs would lead to better posterior anchorage and incisors inclination and a greater amount of upper anterior teeth retraction in comparison with the CA . An intrusion force was found to be applied on incisors and molars when using TSADs, whereas an extrusion force was found to act on them when using CA , however, the strength of evidence in this regard is very weak to moderate. There is a weak-to-moderate evidence that using *en masse*/TSAD combination would lead to better improvement in the facial profile by causing a decrease in the facial convexity angle and increase the NLA and retracting the upper and lower lips.

Implications for research

As the quality of evidence ranged between low to moderate in terms of the skeletal and soft-tissue variables and very low to moderate in term of the dental variables, therefore, we confirm the need for more well-conducted RCTsin the *en masse* retraction field.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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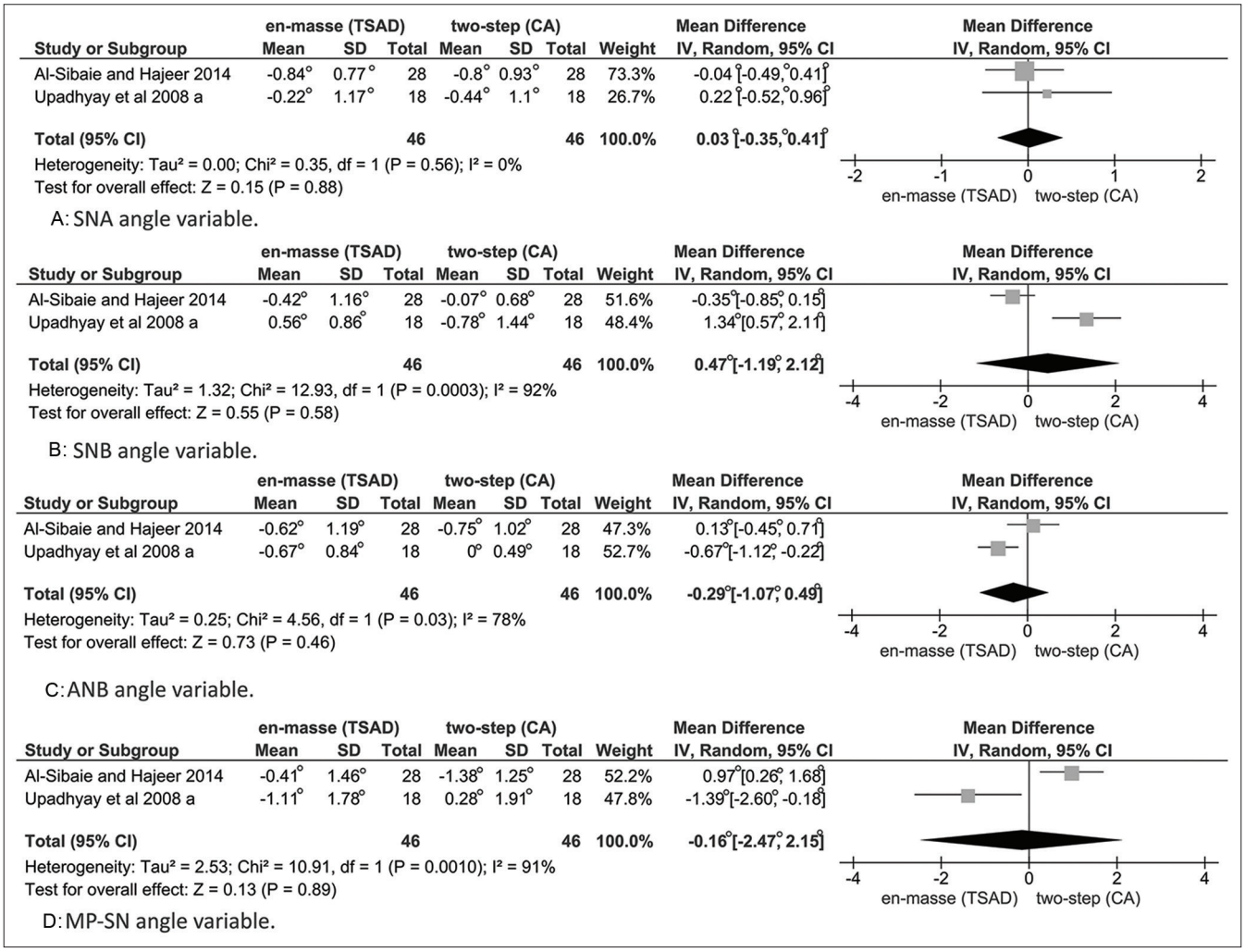
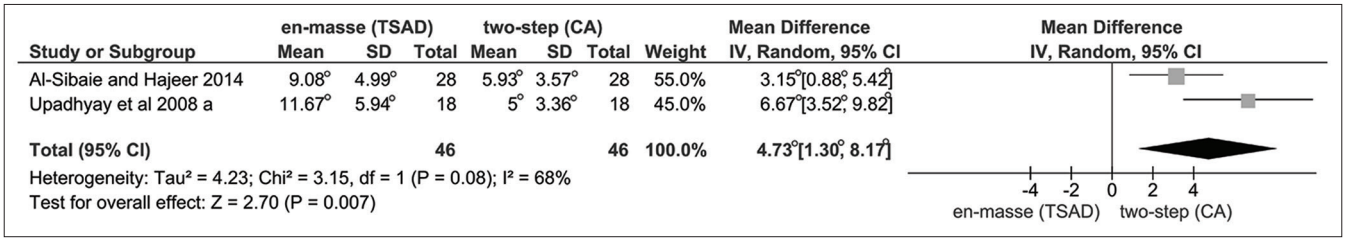
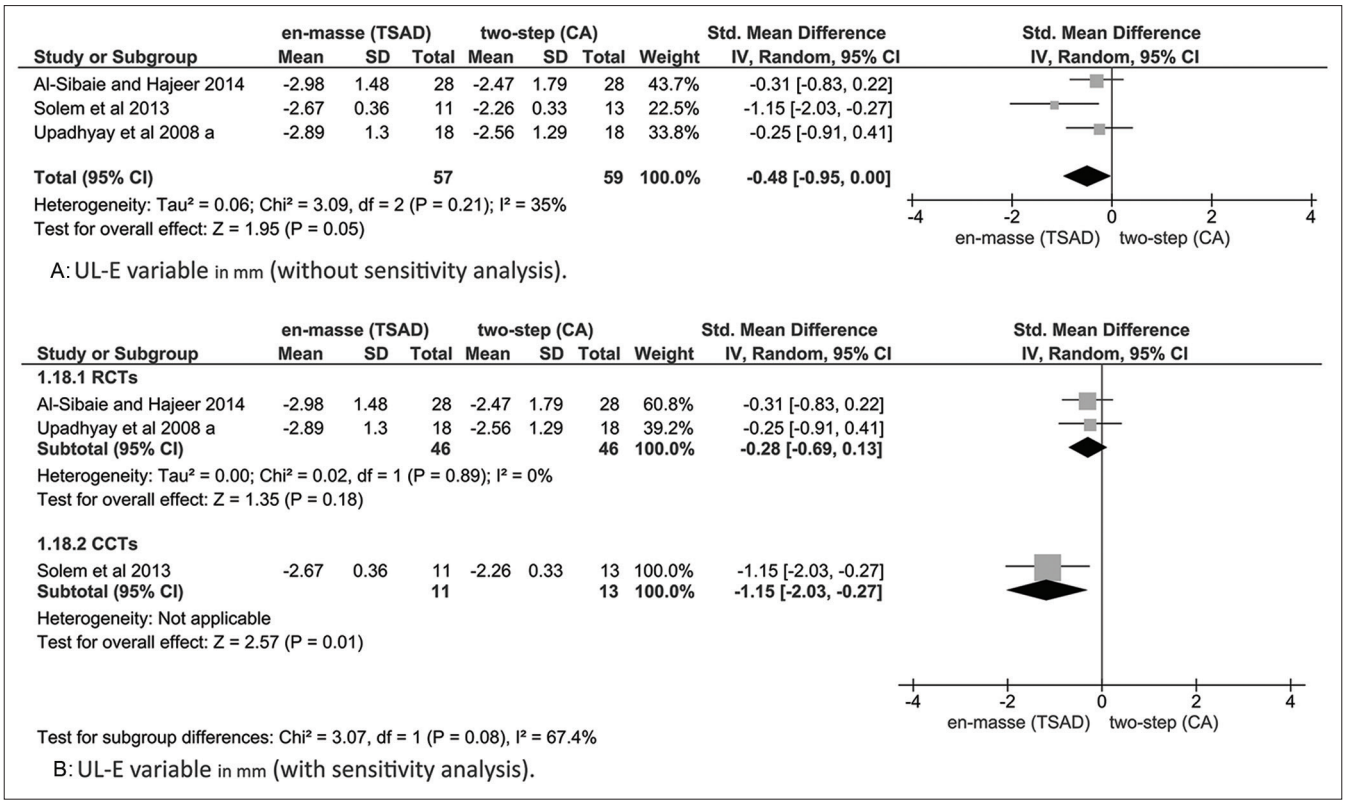
Supplementary Figures



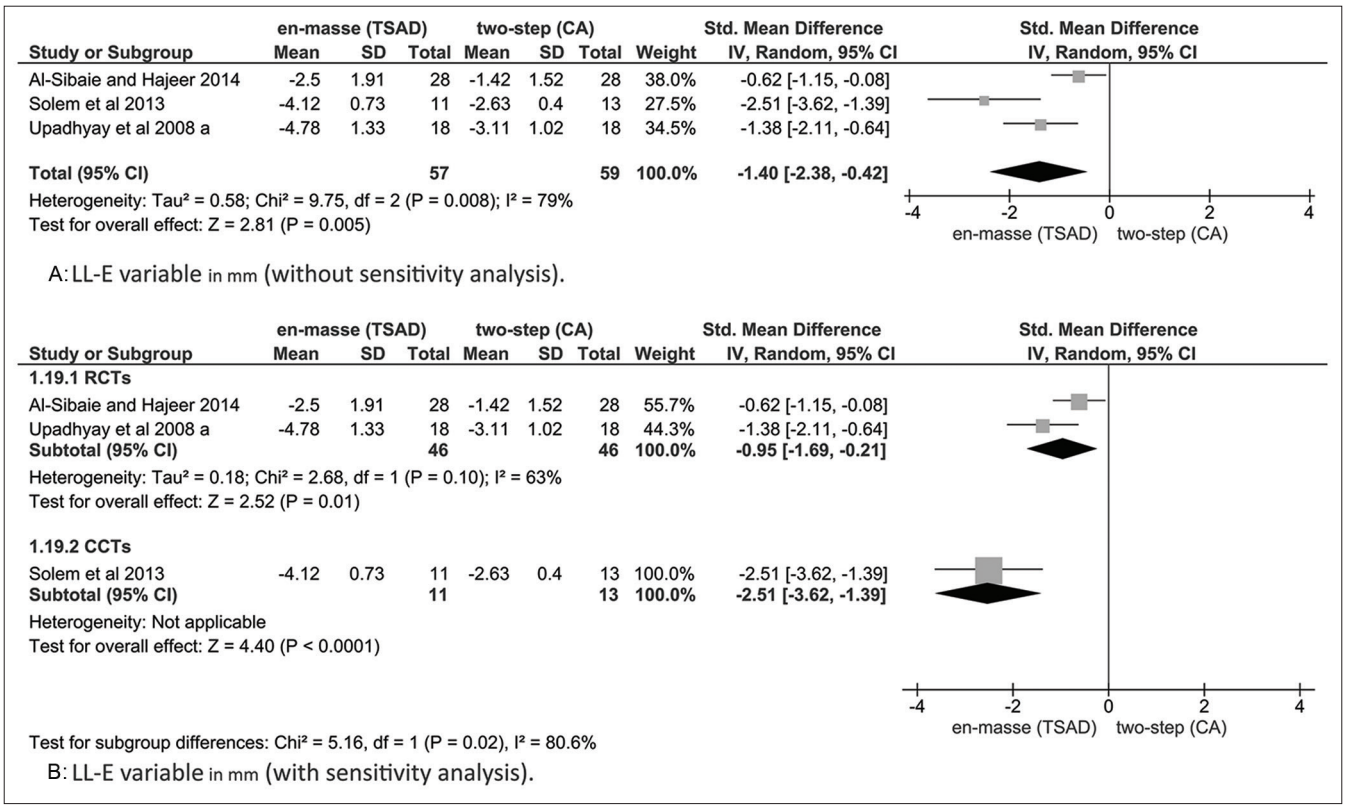
Supplementary Figure 1: Forest plots of some skeletal variables



Supplementary Figure 2: Forest plots showing the changes in the nasolabial angle variable



Supplementary Figure 3: Forest plot showing the changes in the UL-E variable



Supplementary Figure 4: Forest plot showing the changes in the LL-E variable

Supplementary Tables

Supplementary Table 1: Keywords used in the search

Orthodontics	Malocclusion	Retraction	Anchorage
Orthodontic	Tooth displacement	*En masse*	Anchorage
Orthodontic treatment	Skeletal Class II	*En masse*	Skeletal anchorage
Orthodontic therapy	Class II Div 1	*En masse*	Maximum anchorage
	Maxillary protrusion	Retraction	Absolute anchorage
	Dentoalveolar protrusion	One-step retraction	Traditional anchorage
	Maxillary dentoalveolar protrusion	Anterior teeth	TPA
	Bimaxillary protrusion	Six anterior teeth	Transpalatal arch
	Premolar extraction	Maxillary anterior teeth	Transpalatal bar
		Two-step retraction	Nance button
		Two-step retraction	Headgear
			Mini-plate
			Mini-plate
			Mini-plate
			Mini-screw
			Mini-screw
			Mini-screw
			Micro-screw
			Mini-implant
			Mini-implant
			Micro-implant
			Micro-implant
			Mini-screw implant
			TADs
			TSADs
			TISADs
			TADs
			Titanium micro-screw
			Titanium mini-implant
			Orthoimplant

TSAD: Temporary skeletal anchorage devices; TADs: Temporary anchorage devices; TPA: Transpalatal arch; TISADs: Temporary intraoral skeletal anchorage devices

Supplementary Table 2: The lateral cephalometric measurements performed

Measurement	Abbreviation
The inferior posterior angle formed by the intersection of lines SN and NA	SNA
The inferior posterior angle formed by the intersection of lines SN and NB	SNB
Difference between the SNA and SNB angles	ANB
Inclination of the mandibular plane to the cranial base	MP-SN
The linear distance between upper lip and the esthetic line	UL-E
The linear distance between lower lip and the esthetic line	LL-E
Nasolabial angle	NLA
Facial convexity angle	G-Sn-Pog
The amount of vertical movement of upper first molar (U6)	-
The amount of horizontal movement of upper first molar (U6)	-
The amount of vertical movement of upper incisors (U1)	-
The amount of horizontal movement of upper incisal edges	-
The upper incisor's inclination	-

SNA: The inferior posterior angle formed by the intersection of lines SN and NA; SNB: The inferior posterior angle formed by the intersection of lines SN and NB; SN: Line from sella to nasion; NA: Line from nasion to A point

Supplementary Table 3: Articles excluded after full-text evaluation according to the inclusion criteria

Authors	Year	Publication journal	Study title	Reason for exclusion
Ahn HW, Chang YJ, Kim KA, Joo SH, Park YG, Park KH	2014	Angle Orthod	Measurement of three-dimensional perioral soft tissue changes in dentoalveolar protrusion patients after orthodontic treatment using a structured light scanner	Retrospective study
Barros SE, Janson G, Chiqueto K, Baldo VO, Baldo TO	2017	Am J Orthod Dentofacial Orthop	Root resorption of maxillary incisors retracted with and without skeletal anchorage	Retrospective study
Benson PE, Tinsley D, O'Dwyer JJ, Majumdar A, Doyle P, Sandler PJ	2007	Am J Orthod Dentofacial Orthop	Midpalatal implants versus headgear for orthodontic anchorage — A randomized clinical trial: Cephalometric results	1. Age range was greater than 15 years 2. Included patients younger than 14 years old
Bhattacharya P, Bhattacharya H, Anjum A, Bhandari R, Agarwal DK, Gupta A, Ansar J	2014	Journal of clinical and diagnostic research: JCDR	Assessment of corticotomy facilitated tooth movement and changes in alveolar bone thickness - A CT scan study	*En-masse* retraction technique in both groups
Borsos G, Vokó Z, Gredes T, Kunert-Keil C, Vegh A	2012	Ann anat	Tooth movement using palatal implant supported anchorage compared to conventional dental anchorage	Two-step retraction technique in both groups
Chandra P, Kulshrestha RS, Tandon R, Singh A, Kakadiya A, Wajid M	2016	APOS trends orthod	Horizontal and vertical changes in anchor molars after extractions in bimaxillary protrusion cases	1. Absence of a control group 2. No information about the age of recruited patients
Chen M, Li ZM, Liu X, Cai B, Wang DW, Feng ZC	2015	Am J orthod dentofacial orthop	Differences of treatment outcomes between self-ligating brackets with microimplant and headgear anchorages in adults with bimaxillary protrusion	*En masse* retraction technique in both groups
Choo H, Heo HA, Yoon HJ, Chung KR, Kim SH	2011	Am J orthod dentofacial orthop	Treatment outcome analysis of speedy surgical Orthodontics for adults with maxillary protrusion	Absence of a control group
Chopra SS, Mukherjee M, Mitra R, Kochar GD, Kadu A	2017	Medical journal armed forces India	Comparative evaluation of anchorage reinforcement between orthodontic implants and conventional anchorage in orthodontic management of bimaxillary dentoalveolar protrusion	*En masse* retraction technique in both groups
Davoody AR, Posada L, Utreja A, Janakiraman N, Neace WP, Uribe F, Nanda R	2013	Eur J orthod	A prospective comparative study between differential Moments and miniscrews in anchorage control	1. Age range was greater than 15 years 2. Included patients younger than 14 years old
Feldmann I, Bondemark L	2008	Am J orthod dentofacial orthop	Anchorage capacity of osseointegrated and conventional Anchorage systems: A randomized controlled trial	Adolescence patients
Heo W, Nahm DS, Baek SH	2007	Angle orthod	*En masse* retraction and two-step retraction of maxillary anterior teeth in adult Class I women. A comparison of anchorage loss	Retrospective study
Huang Y, Wang XX, Zhang J, Liu C	2010	Angle orthod	Root shortening in patients treated with two-step and *en masse* space closure procedures with sliding mechanics	Included patients younger than 14 years old
Ibrahim G	2015	J Dent health oral disord ther	Comparison of the amount of anchorage loss of the molars with and without the use of implant anchorage during anterior segment retraction combined with alveolar corticotomies	<10 patients in the experimental group *En masse* retraction technique in both groups

Contd...

Supplementary Table 3: Contd...

Authors	Year	Publication journal	Study title	Reason for exclusion
Kuroda S, Yamada K, Deguchi T, Kyung HM, Takano-Yamamoto T	2009	Am J orthod dentofacial orthop	Class II malocclusion treated with miniscrew anchorage: Comparison with traditional orthodontic mechanics outcomes	1. Age range was greater than 15 years 2. Included patients younger than 14 years old
Lee AY, Kim YH	2011	ISRN dent	Comparison of movement of the upper dentition according to anchorage method: Orthodontic mini-implant versus conventional anchorage reinforcement in Class I malocclusion	Retrospective study
Lee J, Miyazawa K, Tabuchi M, Kawaguchi M, Shibata M, Goto S	2013	Am J orthod dentofacial orthop	Midpalatal miniscrews and high-pull headgear for anteroposterior and vertical anchorage control: Cephalometric comparisons of treatment changes	Retrospective study
Lee J, Miyazawa K, Tabuchi M, Sato T, Kawaguchi M, Goto S	2014	Korean J Orthod	Effectiveness of *en masse* retraction using midpalatal miniscrews and a modified transpalatal arch: Treatment duration and dentoskeletal changes	Retrospective study
Liu H, Lv T, Wang NN, Zhao F, Wang KT, Liu DX	2011	Am J orthod dentofacial orthop	Drift characteristics of miniscrews and molars for anchorage under orthodontic force: 3-dimensional computed tomography registration evaluation	Absence of a control group
Ma J, Wang L, Zhang W, Chen W, Zhao C, Smales RJ	2008	European journal of orthodontics	Comparative evaluation of micro-implant and headgear anchorage used with a preadjusted appliance system	*En-masse* retraction technique in both groups
Park HS, Yoon DY, Park CS, Jeoung SH	2008	Am J orthod dentofacial orthop	Treatment effects and anchorage potential of sliding mechanics with titanium screws compared with the Tweed-Merrifield technique	Retrospective study
Sandler J, Benson PE, Doyle P, Majumder A, O'Dwyer J, Speight P, Thiruvenkatachari B, Tinsley D	2008	Am J orthod dentofacial orthop	Palatal implants are a good alternative to headgear: A randomized trial	1. Age range was >15 years 2. Included patients younger than 14 years old
Sharma NJ	2010	Angle orthod	Skeletal and soft tissue point A and B changes following orthodontic treatment of nepalese Class I bimaxillary protrusive patients	Absence of a control group
Srinivas N, G Hanumanth Reddy, Johar Rajvinder Singh, Shridhar Munje	2012	JIOH	Evaluation of clinical efficiency of micro implant as an anchorage in comparison with conventional first molar anchorage	>10 patients in the study group
Upadhyay M, Yadav S, Nagaraj K, Nanda R	2009	Angle orthod	Dentoskeletal and soft tissue effects of mini-implants in Class II division 1 patients	Absence of a control group
Urias D, Mustafa FI	2005	Angle orthod	Anchorage control in bioprogressive vs straight-wire treatment	Adolescence patients
Wang Q, Chen W, Smales RJ, Peng H, Hu X, Yin L	2012	J Huazhong Univ Sci Technolog Med Sci	Apical root resorption in maxillary incisors when employing micro-implant and J-hook headgear anchorage: A 4-month radiographic study	Two-step retraction technique in both groups
Wehrbein H, Feifel H, Diedrich P	1999	Am J orthod dentofacial orthop	Palatal implant anchorage reinforcement of posterior teeth: A prospective study	Absence of a control group

A CT scan study: A computed tomography scan study

Supplementary Table 4: Comparison of skeletal measurements of the patients in the included studies

Study ID: Author and year	Pretreatment measurements (T1)				Posttreatment measurements (T2)				Skeletal changes (T2-T1)			
	SNA° (point A)	SNB° (point B)	ANB°	MP-SN°	SNA° (point A)	SNB° (point B)	ANB°	MP-SN°	SNA° (point A)	SNB° (point B)	ANB°	MP-SN°
Upadhyay *et al*., 2008[1]	I: 84.67±2.57	I: 80±3.82	I: 4.67±2.38	I: 30.78±6.92	I: 84.44±2.96	I: 80.56±4.29	I: 4±1.94	I: 29.67±6.6	I: −0.22±1.17	I: 0.56±0.86	I: −0.67±0.84	I: −1.11±1.78
	II: 81.33±3.6	II: 76.67±2.22	II: 4.67±1.68	II: 31.28±7.09	II: 80.89±3.74	II: 77.23±2.14	II: 4.67±1.68	II: 31.56±6.82	II: −0.44±1.1	II: −0.78±1.44	II: 0±0.49	II: 0.28±1.91
Solem *et al*., 2013[18]	I: 83.29±4.10	I:80.34±3.45	I: NR	I:36.22±5.64	I: NR	I: NR	I: NR	I: NR	I: NR	I: NR	I: NR	I: NR
	II: 83.79±3.81	II: 80.35±4.42	II: NR	II: 34.02±5.84	II: NR	II: NR	II: NR	II: NR	II: NR	II: NR	II: NR	II: NR
Al-Sibaie and Hajeer2014[7]	I: 82.91±3.24	I: 76.11±2.88	I: 6.94±1.88	I: 38.54±6.76	I: 82.07±3.35	I: 75.69±2.76	I: 6.32±1.66	I: 38.13±6.83	I: −0.84±0.77	I: −0.42±1.16	I: −0.62±1.19	I: −0.41±1.46
	II: 82.29±0.75	II: 75.81±0.72	II: 6.66±0.34	II: 42.93±1.60	II: 81.49±0.77	II: 75.74±0.75	II: 5.91±0.34	II: 41.55±1.58	II: −0.8±0.93	II: −0.07±0.68	II: −0.75±1.02	II: −1.38±1.25

NR: Not reported; SNA: The inferior posterior angle formed by the intersection of lines SN and NA; SNB: The inferior posterior angle formed by the intersection of lines SN and NB; ANB: Difference between SNA and SNB; MP-SN: Inclination of the mandibular plane to the cranial base; SN: Line from sella to nasion; NA: Line from nasion to A point

Supplementary Table 5: Comparison of pre- and post-treatment dental measurements of the patients in the included studies

Study ID: Author and year	Pretreatment measurements (T1)					Posttreatment measurements (T2)				
	Molar movement (H) mm	Molar movement (V) mm	Incisor retraction mm	Incisor movement (V) mm	Incisor inclination°	Molar movement (H) mm	Molar movement (V) mm	Incisor retraction mm	Incisor movement (V) mm	Incisor inclination°
Upadhyay *et al*., 2008[1]	I: 50.56±5.88	I: 21.78±1.06	I: 80.22±6.86	I: NR	I: 113±7.19	I: 49.78±6.11	I: 21.56±1.1	I: 73±7.01	I: NR	I: 97.89±7.22
	II: 44.44±4.42	II: 21.44±1.89	II: 76.44±3.73	II: NR	II: 115.83±4.16	II: 47.67±4.5	II: 22.11±1.97	II: 70.11±4.1	II: NR	II: 99±7.62
Upadhyay *et al*., 2008[17]	I: U6M-SV: 42.43±5.91, U6D-SV: 28.1±5.35	I: U6M-PP: 21.7±1.49, U6D-PP: 20.2±2.08	I: Ia-SV: 61±5.4, Io-SV: 69.9±6.89	I: Ia-PP: 7.13±2.83, Io-PP: 30.77±2.4	I: 109.93±4.87	I: U6M-SV: 41.93±5.72, U6D-SV: 27.63±5.63	I: U6M-PP: 21.47±1.51, U6D-PP: 19.83±2.01	I: Ia-SV: 60.5±6.11, Io-SV: 63.67±6.91	I: Ia-PP: 4.83±3.05, Io-PP: 28.69±3.25	I: 98.9±7.33
	II: U6M-SV: NR, U6D-SV: NR	II: U6M-PP: NR, U6D-PP: NR	II: Ia-SV: NR, Io-SV: NR	II: Ia-PP: NR, Io-PP: NR	II: NR	II: U6M-SV: NR, U6D-SV: NR	II: U6M-PP: NR, U6D-PP: NR	II: Ia-SV: NR, Io-SV: NR	II: Ia-PP: NR, Io-PP: NR	II: NR
Solem *et al*., 2013[18]	I: NR	I: NR	U1i-A Pg: I: 11.58±2.57	I: NR	I: 119.58±5.74	I: NR	I: NR	I: NR	I: NR	I: NR
	II: NR	II: NR	II: 10.67±2.38	II: NR	II: 122.10±6.70	II: NR	II: NR	II: NR	II: NR	II: NR
Al-Sibaie and Hajeer 2014[7]	I: NR	I: NR	I: NR	I: NR	I: 107.22±6.29	I: NR	I: NR	I: NR	I: NR	I: 102.20±2.91
	II: NR	II: NR	II: NR	II: NR	II: 105.73±1.45	II: NR	II: NR	II: NR	II: NR	II: 97.79±1.45

H: Horizontally, V: vertically, NR: Not reported, SV: Perpendicular to SN plane through S, PP: Palatal plane, U6M: The greatest mesial convexity on the upper first molar, U6D: The greatest distal convexity on the upper first molar, A Pg: Hard-tissue A-point to pogonion line, Io and U1i: Incisal tip of the upper central incisor, Ia: Root apex of the upper central incisor

Supplementary Table 6: Comparison of dental changes of the patients in the included studies

Study ID: Author and year	Dental changes (T2−T1)				
	Molar movement (H) mm	Molar movement (V) mm	Incisor retraction mm	Incisor movement (V) mm	Incisor inclination°
Upadhyay *et al*., 2008[1]	I: −0.78±1.35	I: −0.22±0.65	I: −7.22±2.07	I: NR	I: −13.11±6.57
	II: 3.22±1.06	II: 0.67±1.19	II:−6.33±2.57	II: NR	II:−16.83±9.2
Upadhyay *et al*., 2008[17]	I: U6M-SV: −0.83±1.4, U6D-SV: −0.27±0.98	I: U6M-PP: −0.23±0.73, U6D-PP: −0.3±0.65	I: Ia-SV: −0.9±1.33, Io-SV: −6.23±2.65	I: Ia-PPL: −2.13±1.58, Io-PP: −2.2±1.31	I: −11.27±4.88
	II: U6M-SV: 2.07±0.68, U6D-SV: 1.83±1.19	II: U6M-PP: 0.6±1.56, U6D-PP: 0.53±1.71	II: Ia-SV: 0.37±2.57, Io-SV: −5.72±2.37	II: Ia-PP: −0.2±1.19, Io-PP: 0.4±1.44	II:−10.83±5.61
Solem *et al*., 2013[18]	U6 crown: I: −0.45±0.55, II: 1.95±0.40	I: 0.83±0.46	U1i: I: 5.63±0.66	U1i: I: 1.84±0.37	I: 9.82±1.59
		II: 0.02±0.23	II: 4.16±0.74	II: 1.79±0.37	II: 13.18±2.60
	U6 root: I: −0.53±0.32, II: 1.81±0.33		U1 root: I: 0.89±0.47, II: −0.081±0.33		
Al-Sibaie and Hajeer 2014[7]	I: −0.75±0.63	I: 0.02±0.93	I: UIT_H: −5.92±2.01, UIA_H: −4.56±1.38	I: UIT_V: −1.53±0.89, UIA_V: −1.16±0.91	I: −5.03±3.39
	II: 1.76±1.01	II: 0.38±0.74	II: UIT_H: −4.79±2.34, UIA_H: −0.29±1.80	II: UIT_V: 0.92±1.05, UIA_V: 0.89±0.74	II: −7.94±2.51

(H): Horizontally, (V): Vertically, SV: Perpendicular to SN plane through S, PP: Palatal plane, U6M: The greatest mesial convexity on the upper first molar, U6D: The greatest distal convexity on the upper first molar. Io and U1i: Incisal tip of the upper central incisor, Ia: Root apex of the upper central incisor, UIT_H: The horizontal distance between the upper incisal tip and S_vertical (Sv) plane, UIA_H: The horizontal distance between the upper incisal apex and Sv plane, UIT_V: The vertical distance between the upper incisal tip and the rotated SN plane (SN`), UIA_V: The vertical distance between the upper incisal apex and the rotated SN plane (SN`)

Supplementary Table 7: Soft-tissue variables in the included studies

Study ID: Author and year	Pretreatment measurements (T1)				Posttreatment measurements (T2)				Soft-tissue changes (T2−T1)			
	NLA (°)	G-Sn-Pog (°)	UL-E (mm)	LL-E (mm)	NLA (°)	G-Sn-Pog (°)	UL-E (mm)	LL-E (mm)	NLA (°)	G-Sn-Pog (°)	UL-E (mm)	LL-E (mm)
Upadhyay *et al*., 2008[1]	I: 92.11±10.69 II: 103.44±16	I: 18.67±6.53 II: 19.33±3.94	I: 1.39±1.84 II: −0.11±1.57	I: 5.83±2.4 II: 4±1.46	I: 103.78±11.67 II: 108.44±14.1	I: 16.33±6.08 II: 18.17±3.29	I: −1.5±1.85 II:−2.67±0.49	I: 1.06±2.18 II: 0.89±2.08	I: 11.67±5.94 II: 5±3.36	I: −2.33±1.37 II: −1.17±1.91	I: −2.89±1.3 II: −2.56±1.29	I: −4.78±1.33 II: −3.11±1.02
Solem *et al*., 2013[18]	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	I: NR II: NR	UL retraction: I: 2.67±0.36 II: 2.26±0.33	LL retraction: I: 4.12±0.73 II: 2.63±0.40
Al-Sibaie and Hajeer 2014[7]	I: 108.18±9.72 II: 107.90±1.92	I: NR II: NR	I: 0.36±2.04 II: 1.11±0.44	I: 2.96±2.91 II: 3.86±0.48	I: 117.26±9.51 II: 113.83±2.13	I: NR II: NR	I: −2.62±1.82 II:−1.36±0.53	I: 0.46±2.42 II: 2.45±0.60	I: 9.08±4.99 II: 5.93±3.57	I: NR II: NR	I: −2.98±1.48 II:−2.47±1.79	I: −2.50±1.91 II:−1.42±1.52

NR: Not reported; NLA: Nasolabial angle; G-Sn-Pog: Facial convexity; UL-E: The linear distance between upper lip and esthetic line; LL-E: The linear distance between lower lip and esthetic line

Supplementary Table 8: Methodological quality of the selected studies according to Cochrane risk of bias tool for randomized controlled trial

Study ID	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Upadhyay *et al*., 2008[1]	Low risk: "A restricted randomization method was used in blocks of 10"	Low risk: "The principal investigator was blinded to the allocation sequence"	Low risk: No blinding, but we judge that the outcome is not likely to be influenced by lack of blinding	Low risk: "One faculty member examined all cephalograms and conducted the measurement analysis and was unaware of the objectives of the study"	Low risk: Missing outcome data balanced in numbers across control and study groups	Low risk: The protocol was not registered, but the predetermined outcomes that mentioned in the materials and methods section appear to have been reported	Low risk: The article appears to be free of other sources of bias
Al-Sibaie and Hajeer 2014[7]	Low risk: "A randomization list using Minitab® Version 15 with an allocation ratio of 1:1"	Low risk: "The allocation sequence was concealed in sequentially numbered opaque and sealed envelopes"	Low risk: No blinding, but we judge that the outcome is not likely to be influenced by lack of blinding	Low risk: "A blinding procedure of the cephalograms was performed by professional Photoshop™ designer"	Low risk: No dropouts were reported	Low risk: The protocol was not registered, but the predetermined outcomes that mentioned in the materials and methods section appear to have been reported	Low risk: The article appears to be free of other sources of bias