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REVIEW ARTICLE

En-masse Retraction of Upper Anterior Teeth in Adult Patients with Maxillary or Bimaxillary Dentoalveolar Protrusion: A Systematic Review and Meta-analysis

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ABSTRACT

Aim: To evaluate the efficacy of accelerated and non-accelerated methods of en-masse retraction of the upper anterior teeth in terms of 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 randomized controlled trials (RCTs) and clinical controlled trials (CCTs) was performed between January 1990 and April 2018. The bibliography in each identified article was reviewed. In addition, manual searching was performed in the same time frame in five major orthodontic journals.The participants were patients over 14 years old undergoing fixed orthodontic treatment with extraction of maxillary or bimaxillary premolars followed by en-masse retraction of maxillary anterior teeth in both groups. Cochrane's risk of bias tool for RCTs and methodological index for non-randomized studies (MINORS) for CCTs were used.

Results: Eight articles (six RCTs and two CCTs) were included in this review, and only five articles were suitable for quantitative synthesis. The en-masse retraction caused a decrease in the SNA and ANB angles with no significant differences between the different en-masse retraction methods. Using temporary skeletal anchorage devices (TSADs) gave significantly better results in terms of posterior anchorage in comparison with conventional anchorage(standardized mean difference (SMD) = –3.03 mm, $p < 0.001$). No significant difference was found between en-masse/flapless corticotomy and en-masse/control groups in terms of anterior teeth retraction ($p = 0.661$); while there was a significantly greater anterior teeth retraction in corticotomy with flap elevation group compared to control group ($p < 0.001$).

Conclusion: There is a weak to moderate evidence that using accelerated and non-accelerated methods would improve the facial profile and lead to similar skeletal corrections. There is weak to moderate evidence that using TSADs would lead to better posterior anchorage than using conventional anchorage.Moderate evidence was found regarding the benefit of using piezosurgery in achieving good incisors' inclination. Contradictory results were found regarding the amount of achieved anterior retraction and the retraction time in the studies that evaluated acceleration methods versus the traditional methods of retraction. According to the quality of evidence, there is a need for more well-conducted RCTs, and more work to be oriented towards en-masse retraction with the use of other acceleration methods.

Clinical significance: The correction of the maxillary or bimaxillary dentoalveolar protrusion by en-masse retraction of the upper anterior teeth with/without acceleration is accompanied by aesthetic results in the facial soft tissues as well as in the underlying skeletal and dental structures. The traditional corticotomy-assisted retraction is expected to reduce the retraction time significantly. However, the strength of evidence is not strong and requires additional research work.

Keywords: Acceleration, Anchorage, Anterior teeth, Corticotomy, En-masse, Extraction, Meta-analysis, Piezosurgery, Protrusion, Retraction, Systematic review.

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INTRODUCTION

Maxillary dentoalveolar protrusion is one of the most common cases seen in orthodontic clinics.[1] In addition, the bimaxillary protrusion is widespread across the world.[2] Treatment of these malocclusion types often requires

extraction of maxillary (or bimaxillary) first or second premolars with using maximum anchorage.[3,4] Anchorage control is necessary to achieve good results when treating patients with the severe maxillary dentoalveolar protrusion.[3,5] To promote anchorage, various auxiliary methods can be used such as the Nance button, headgear, transpalatal arch, intermaxillary elastics, and bonding of second molars.[3,6] Recently, Tanta Scientific Association of Dental Students (TSADS) have been suggested as an alternative method for anchorage control.[4]

The en-masse retraction of the anterior teeth after first premolar extraction has been practiced in the Begg and Tip-Edge edgewise techniques for many years.[7] In the straight wire appliances, the en-masse retraction of maxillary anterior teeth was first presented by Andrews, and then it has been used routinely by Bennett and McLaughlin in their preadjusted appliance system.[7] It might be expected to lose posterior anchorage, so the use of anchorage devices has been emphasized.[7]

Because adult patients typically want to improve their dental aesthetics in a short time with satisfactory results, many techniques to accelerate orthodontic tooth movement have been explored in the literature,[8] such as surgical (e.g., corticotomy),[6,9] mechanical (e.g., reducing friction when moving teeth using special brackets),[10] pharmacological (e.g. prostaglandin E1),[11] and physical methods (e.g. low-intensity laser irradiation).[12] One of the most common modes of surgical intervention is corticotomy-assisted orthodontics.[12] Corticotomy is defined as osteotomy of the cortical bone only,[13] leaving the medullary vessels and periosteum intact.[12] The rapid tooth movement in corticotomy happens because of increased bone turnover in response to the surgical intervention, which in turn presents less resistance to tooth movement, so it offers an advantage to adult patients by way of reduction in the orthodontic treatment time.[6,9] Also, piezoelectric surgery is a new minimally invasive version of corticotomy, which uses a piezotome to cause bone injury in order to stimulate rapid tooth movement.[10] Piezoelectric surgery can be done with or without elevation of flaps.[8,14]

There are some 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.[15] did not focus on studying the articles that usedone retraction technique in both experimental and control groups.The systematic reviews carried out by Antoszewska-Smith et al.,[15] and Rizk et al.[16] did not analyze the skeletal and soft-tissue variables and focused on dental variables. It should be noted that Xu and Xie[3] and Antoszewska-Smith et al.[15] systematic reviews have included retrospective studies, which suffer from a high risk of bias. In addition, none of the previously published systematic reviews considered the accelerated mode of en-masse retraction of upper anterior teeth with its resultant efficacy and compared it with non-accelerated methods of en-masse retraction.

Given the shortfalls listed above, a new systematic review seemed desirable to answer the following explicit focused review question:'What is the overall efficacy of accelerated and non-accelerated methods of en-masse retractionof the upper anterior teeth in patients with maxillary or bimaxillary dentoalveolar protrusion?'

MATERIALS AND METHODS

A PubMed scoping search was performed to verify the presence of similar systematic reviews and to explore potentially eligible articles before writing upthe 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)[17] checklist and the Cochrane Handbook for Systematic reviews of interventions version 5.1.0[18] were used for performing and presenting this systematic review and meta-analysis.

Eligibility Criteria

The PICOS framework was as follows:

- *Participants*: Healthy patients, both males and females, over 14 years old to minimizethe effects of growth, with class I or II dentoalveolar protrusion,undergoing fixed orthodontic treatment with maxillary or bimaxillary premolar extraction and retraction of maxillary six anteriorteeth.
- *Intervention*: En-masse retraction of maxillary anterior teeth with TSADs or any approach for tooth movement acceleration used.
- *Comparison*: En-masse retraction of maxillary anterior teeth with conventional or no anchorage system and without any approach for tooth movement acceleration.
- *Outcome measures*: Skeletal, dental, and soft-tissue variables and overall treatment or retraction duration.
- *Study design:* Prospective RCTs and CCTs that were published between January 1990 and April 2018, in the English language only.

Exclusion Criteria

Retrospective studies, studies using two-step retraction in at least one of the evaluated groups, studies using lingual or self-ligating brackets in comparison with labial or conventional-ligating brackets, *in vitro* studies, animal studies, finite element analysis studies, split-

mouth-design studies, case reports or case series reports, editorials, personal opinions, reviews and technique description articles, articles without a reported sample, non-English language trials, absence of acontrol group or the presence of a control group of non-treated subjects, fewer than 10 patients in the experimental group, a control group of patients being treated on a non-extraction basis, and oran age range between the youngest and the oldest patient in any studied group being greater than 14 years.

Information Sources

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

Search Strategy and Study Selection

The search strategy for PubMed is presented in Table 1. Two reviewers (HNK and MYH) evaluated the articles for eligibility independently, and in the event of any discrepancy, the reviewers resolved it by discussion until consensus was reached. In the first step, the two reviewers checked the titles and abstracts of studies during the search by using the eligibility criteria. In the second phase, the same two reviewers assessed the full-text of all articles that might be included in the review. Articles were eliminated from the review when they did not fulfill one or more of the eligibility criteria.

Data Collection Process

Data extraction tables were initially developed, then the first reviewer (HNK) retrieved the data from the included studies 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 re-examination of the original article. If no consensus could be attained, a third reviewer (OH) was asked to decide and resolve it. In the event of a lack of data, the authors of the included studies were e-mailed for additional information.

In this systematic review, the following data were extracted from the included studies:Author's name, year of publication, country of publication, study design, sample size, age of the patients at the beginning of the treatment, gender of the patients, types of appliances used for anchorage reinforcement, diameter and length of TSAD, type of malocclusion, overall treatment or retraction duration, and magnitude of force during retraction.

Lateral cephalometric measurements (if available) were also extracted from the included studies to assess the skeletal, dental, and soft-tissue variables.

Assessment of risk of bias in individual studies and strength of pieces of evidence

The Cochrane Collaboration tool[19] was applied to assess the risk of bias for RCTs.Bias was evaluated as a judgment (high, low, or unclear) for individual elements from seven domains. The MINORS Index[20] was applied to assess the risk of bias for CCTs. 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)

Table 1: Search strategy of PubMed

Publication Date: from January 1990 until April 2018. Language: English. Species: Human. Article types: Clinical trial. Ages: Adolescent: 13–18 years. Young adult: 19–24 years. Adult: 19–44 years.	#1 orthodontic treatment OR orthodontic therapy. #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". #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". #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 tivads OR "temporary anchorage devices" OR "titanium microscrew" OR "titanium mini-implant" OR "ortho implant" #5 corticotomy OR "corticotomy-assisted orthodontic" OR "tooth movement acceleration" OR piezo* #6 #1 AND #2 AND #3 AND #4 AND #5

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

	Experimental group (G1)				Control group (G2)			
Study ID: Author and year	Female	Male	n	Age at start of treatment (years)	Female	Male	n	Age at start of treatment (years)
Ma et al.[23]	NR	NR	15	20.50 ± 3.14	NR	NR	15	20.33 ± 3.67
Liu et al.[24]	14	3	17	21.65 ± 4.49	14	3	17	19.71 ± 3.06
Victor et al.[25]	NR	NR	10	14–25	NR	NR	10	14–25
Bhattacharya et al.[11]	9	1	10	(16–25) 18.8 ± 3.48	9	1	10	(15–25) 19.8 ± 3.22
Sakthi et al.[6]	11	11	22	18–25	9	9	18	18–25
Chen et al.[26]	9	6	15	26.53 ± 3.54	9	7	16	25.25 ± 3.19
Chopra et al.[27]	13	12	25	15.12 ± 1.42	13	12	25	15.08 ± 1.53
Tuncer et al.[10]	13	2	15	17.7 ± 3.4	13	2	15	17.7 ± 1.4

NR: Not reported

approach.[21] The strength of evidence was assessed as high, moderate, low, or very low for seven measurements.

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

Meta-analysis was performed using Review Manager, version 5.3. Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration. For the continuous outcomes, the random-effects model was used,[18] in which studies were weighted with the inverse of their variance and the heterogeneity parameter. The mean, standard deviation (SD), and sample size were used to combine the results into a weighted mean difference (WMD) with 95% confidence intervals when the outcome measurements in all included studies 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.[18]

The p value was used to find any significant heterogeneity when $p < 0.05$. I^2 index was used to describe the percentage of heterogeneity across the studies.[18] The forest plot was used to present a graphical assessment of the analysis results. Sensitivity analysis was conducted by tracing sensitivity plots to explore the influence of the CCTs and the RCTs with high risk of bias and discarding them when appropriate. Funnel plots were not used because we did not find more than 10 studies, so the publication bias was not evaluated.

RESULTS

Study Selection

Three thousand six hundred eighty-four articles were initially found from all the searches combined. After taking off the duplicates, 635 articles remained. Five hundred and ninety-three articles were discarded because they failed to meet the inclusion criteria after reviewing the titles and abstracts. Forty-two articles remained. The full text of the remaining articles was examined in depth. Thirty-four articles did not meet the inclusion criteria as described. Eight articles (six RCTs[8,9,22-26] and two CCTs)[6,25] met the inclusion criteria and were included in the systematic review. The PRISMA flow diagram of the study selection process is shown in (Flow Chart 1).

Study Characteristics

Baseline characteristics of the patients in the included studies are shown in (Table 2). Characteristics of the included studies are shown in (Table 3). The magnitude of the force, types of miniscrews and retraction/overall treatment duration are shown in (Table 4). Type of brackets and their prescription, slot sizes, working archwires, and source of force are shown in (Table 5). All included studies were of a two-arm parallel-group design. Extraction-based treatments were provided in the two groups in all included studies. The experimental group (G1) consisted of an en-masse retraction with TSADs without any approach for tooth movement acceleration in five studies; while it consisted of an en-masse retraction with an approach for tooth movement acceleration in the remaining three studies. The control group (G2) consisted of an en-masse retraction with conventional anchorage (CA) or no anchorage system and without any approach for tooth movement acceleration in all included studies.

In total, 255 patients were included 129 patients in G1 and 126 patients in G2. Gender distribution was not mentioned in two included studies. Three papers[8,23,26] evaluated the skeletal, dental and soft-tissue variables. Two papers[22,25] studied the skeletal and dental variables only. Evaluation of only dental variables was performed in three papers.[6,9,24] Three papers[6,8,9] mentioned the retraction duration, four papers[22,23,25,26] presented the overall treatment duration and one study[24] did not give these details.

Flow Chart 1: Studies' selection process according to PRISMA 2009 guidelines

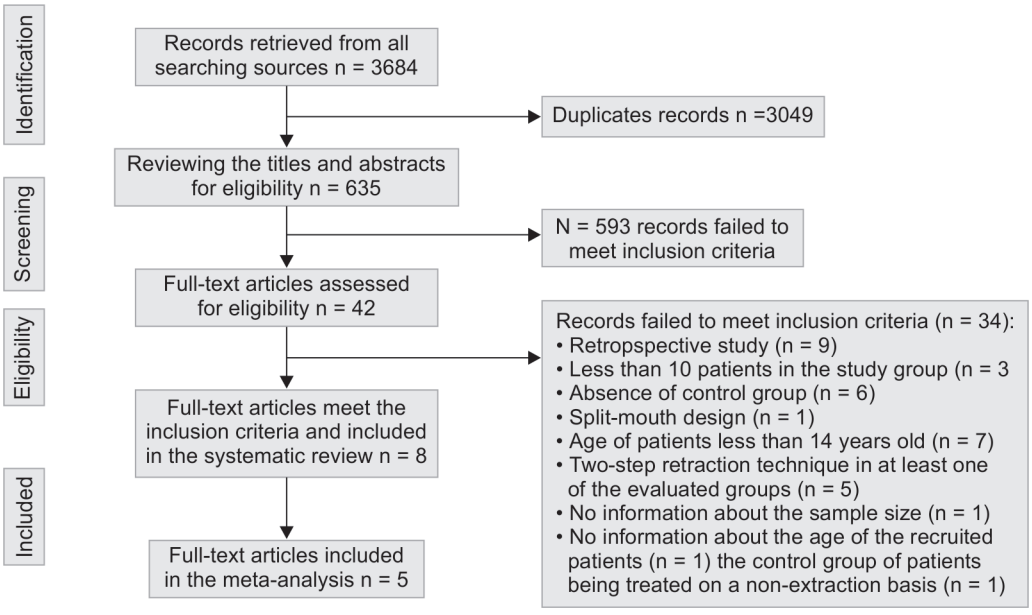


Table 3: Characteristics of the included studies

Study ID: Author and year	*Country*	*Study Design*	*Malocclusion*	*Anchorage type*	
				Experimental group	*Control group*
Ma et al.[23]	China	RCT	Bimaxillary protrusion	Micro implant	Headgear
Liu et al.[24]	China	RCT	Class I or II dentoalveolar protrusion	Miniscrew	TPA
Victor et al.[25]	India	RCT	Bimaxillary protrusion	Miniscrew	No anchorage
Bhattacharya et al.[11]	India	RCT	Class II Division 1	TPA	TPA
Sakthi et al.[6]	India	CCT	Bimaxillary protrusion	No anchorage	No anchorage
Chen et al.[26]	China	CCT	Bimaxillary protrusion	Micro implant	Headgear
Chopra et al.[27]	India	RCT	Bimaxillary dentoalveolar protrusion		
Tuncer et al.[10]	Turkey	RCT	Class II or I bimaxillary protrusion	Miniscrew	Miniscrew

RCT: Randomized clinical trial; CCT: Controlled clinical trial; TPA: Transpalatal arch.

Table 4: Magnitude of force, types of miniscrews and retraction time of the included studies.

Study ID: Author and year	*magnitude of force (g)*	*Diameter/length of TSAD (mm)*	*Retraction/Treatment duration*	
			Study group	*Control group*
Ma et al.[23]	100	1.2/6	22.0 ± 8.0 months	23.0 ± 7.0 months
Liu et al.[24]	NR	1.2/8	25.65 ± 5.06 months	26.88 ± 6.54 months
Victor et al.[25]	150	1.3/8	NR	NR
Bhattacharya et al.[11]	250	---------	(R)* 130.50 ± 7.37 days	(R)* 234.10 ± 8.91 days
Sakthi et al.[6]	250	---------	(R)* 1.8 mm/month	(R)* 1.02 mm/month
Chen et al.[26]	NR	1.6/9	21.93 ± 3.10 months	23.88 ± 2.68 months
Chopra et al.[27]	150	NR	21.16 ±1.62 months	21.76 ±1.54 months
Tuncer et al.[10]	250	(1.5–1.4)/7	(R)* 9.33 ± 4.10 months	(R)* 9.27 ± 2.55 months

NR: not reported; (R) *: retraction duration of the anterior teeth; TSAD: temporary skeletal anchorage device.

Risk of Bias of the Included Studies

The risk of bias in the RCTs is shown in (Graph 1A), and the overall risk of bias for each domain is shown in (Graph 1B). Onetrial[8] was of low risk of bias, fourtrials[9,22-24] were of unclear risk of bias, and one trial[26] was of high risk of bias. Methodological quality assessment of the CCTs[6,25] is presented in (Table 6). The global ideal score was 24 when using the MINORS scale. Studies' scores ranged

Table 5: Brackets' type and prescription, their slots' sizes, working archwires and force source of the included studies

Study ID: Author and year	*Brackets' type or prescription*	*Slots' size (in inches)*	*Working archwire (in inches)*	*Force source*
Ma et al.[23]	MBT	NR	SS 0.019 × 0.025 with hooks	Activated NiTi coil springs
Liu et al.[24]	NR	NR	SS 0.019 × 0.025 with crimpable hooks distal to the lateral incisors	Power chain and SS ligatures
Victor et al.[25]	MBT	0.022	G1: SS 0.019 × 0.025 G2: SS 0.019 × 0.025+ reverse curve.	closed NiTi coil spring.
Bhattacharya et al.[11]*	MBT	0.022	SS 0.016 × 0.022	NiTi closed coil springs from the canine to the molar hook.
Sakthi et al.[6]*	Roth	0.022	SS 0.019× 0.025	closed NiTi coil spring
Chen et al.[26]	Passive Self-Ligating	NR	SS 0.018 × 0.025	NR
Chopra et al.[27]	MBT	0.022	SS 0.019 × 0.025	Nitinol closed coil springs.
Tuncer et al.[10]*	MBT	0.018 (incisors and canine brackets) 0.022 (premolars and molars brackets)	SS 0.016 × 0.022 + 7 mm power arm distal to the lateral incisors.	NiTi closed coil Springs

SS: Stainless Steel; NiTi: Nickel Titanium; G1: group 1 (experimental group); G2: group 2 (control group); NR: not reported.
(*): in Bhattacharya et al.[14] and Sakthi et al.[7] there is a surgical intervention in group 1 (corticotomy) with no surgical intervention in group 2. In Tuncer et al.[13] there is a surgical intervention in group 1 (piezosurgery) with no surgical intervention in group 2.

Table 6: Methodological Quality of the Selected non-randomized Studies According to the Methodological Index for Nonrandomized Studies (MINORS) Assessment Tool

Item	*Sakthi et al.[6] (2014)*	*Chen et al.[26] (2015)*
1. A stated aim of the study	1	1
2. Inclusion of consecutive patients	2	0
3. Prospective collection of data	2	2
4. Endpoint appropriate to the study aim	1	2
5. Unbiased evaluation of endpoints	0	0
6. Follow-up period appropriate to the major endpoint	1	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	1
11. Prospective calculation of the sample size	0	0
12. Statistical analyses adapted to the study design	2	2
TOTAL	15	14

The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies.[20]

between 14 to 15 points, which showed that the included CCTs were of fair-quality.

Results of Individual Studies, Synthesis of Results and Additional Analysis

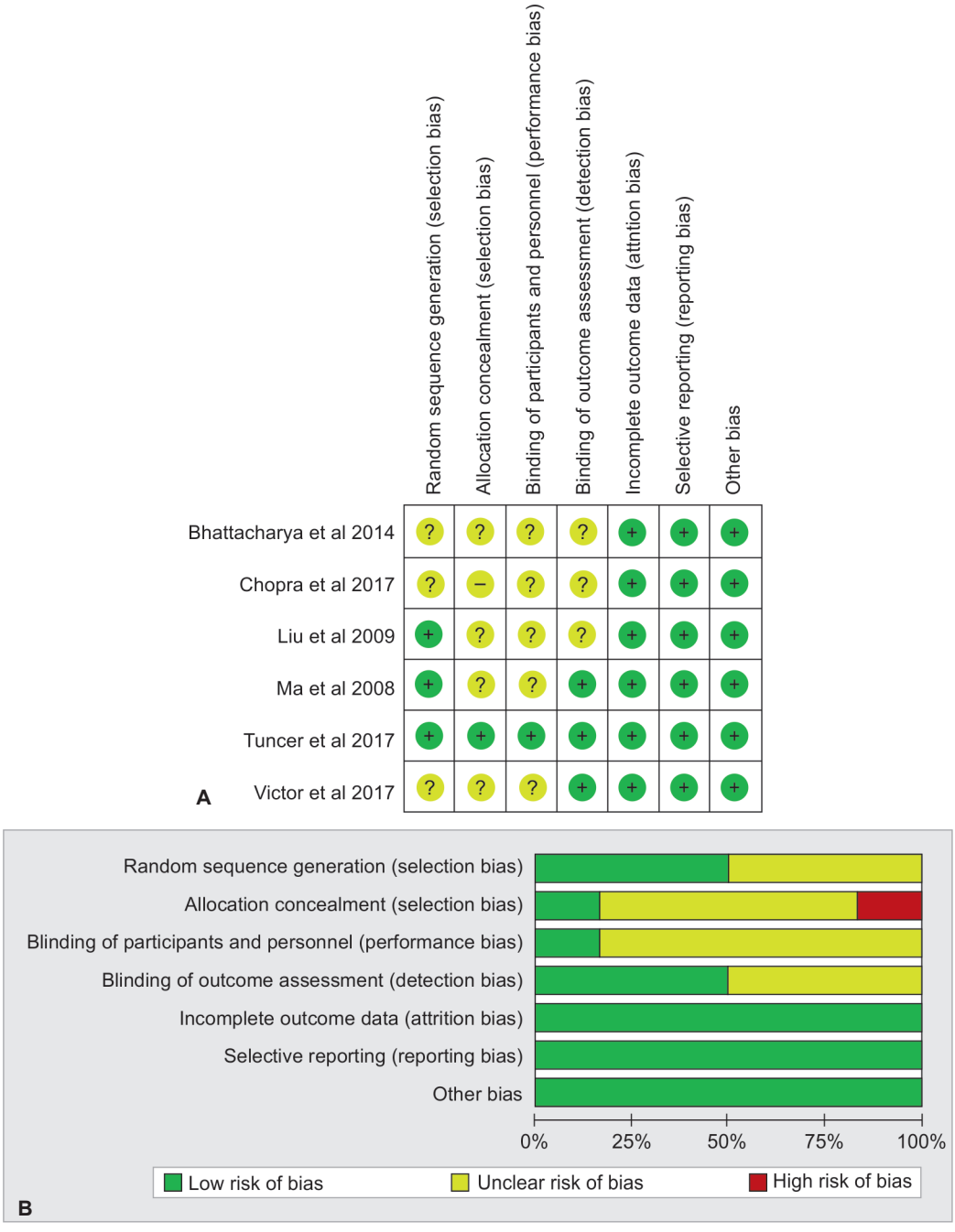
The eight included studies were divided into two comparison domains (COMPs) according to the intervention type (accelerated or non-accelerated methods) and the type of anchorage.

COMP1. TSAD (G1) *vs.* Conventional Anchorage (CA)/no Anchorage (G2)

Five articles[22-26] were included in this domain. Sensitivity analysis was carried out for all the skeletal and dental changes because of the presence of RCT with a high risk of bias[26] and a CCT study.[25]

Regarding skeletal variables,a decrease in the SNA, SNB and ANB angles was reported with no significant differences between the two groups (WMD = 0.02°, $p = 0.97$; WMD = −0.02°, $p = 0.96$;WMD = −0.98°, $p = 0.07$). A significant increase in the SN-MP angle was reported in G2 (SMD = –1.12°, $p < 0.0001$).

Dentally, there was a significantly greater mesial movement of maxillary first molar (U6) in G2 (SMD = –1.17 mm, $p = 0.002$, Graph 2). An intrusion force was applied on incisors (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 (SMD = –1.87 mm, $p = 0.04$; SMD = –1.26 mm, $p < 0.0001$, Graphs 3 and 4, respectively). U1 was reported to be retracted with no significant difference between the two groups (SMD = –0.66 mm, $p = 0.22$, Graph 5). U1 inclination decreased



Graphs 1A and B. The risk of bias: (A) in RCTs; (B) The overall risk of bias for each domain

with no significant difference between the two groups (SMD = –0.03°, p = 0.88).

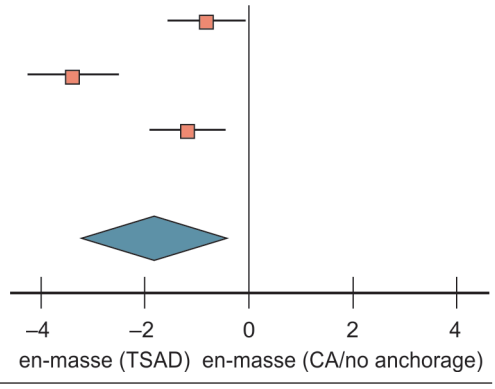
Regarding soft-tissue variables, one study[23] reported a decrease in the facial convexity angle, and one study[26] reported a retraction of lower lip with no significant difference between the two groups (p = 0.057, p = 0.79 respectively). One study[23] reported a significantly greater retraction of the upper lip in G1 (p = 0.011). For the NLA, no meta-analysis was done based on the interpretation of the sensitivity analysis. Both articles[23,26] reported an increase in the NLA in both groups with no significant difference in one article,[23]and with a significantly greater increase in G1 in the other article.[26]

For the over all treatment duration,a sensitivity analysis was carried out. It was shorter in G1 with no significant difference between the two groups (WMD = –1.15 months, p = 0.48).

COMP2. Acceleration (G1) *vs.* Non-acceleration (G2)

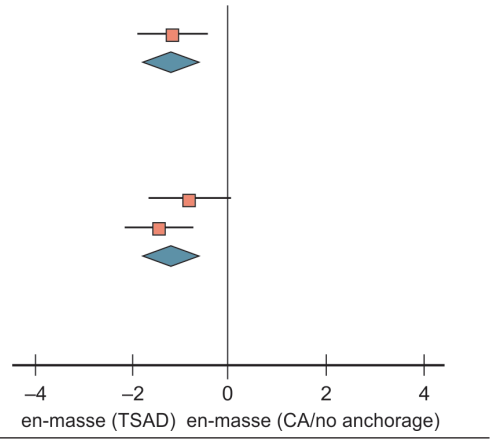
Three studies[6,8,9] were included in this domain. One study[8] measured skeletal variables .In both groups, the SNA, SNB, and ANB angles decreased; while the MP-SN angle increased with no significant difference between the two groups (p = 0.982, p = 0.648, p = 0.6730, p = 0.167

Study or Subgroup	en-masse (TSAD) Mean	SD	Total	en-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Chen et al.	0.87	1.45	15	2.19	1.69	16	33.7%	–0.81 [–1.55, –0.08]
Chopra et al.	0.2	0.35	25	2	0.65	25	32.5%	–0.81 [–1.55, –0.08]
Liu et al.	-0.06	1.4	17	1.47	1.15	17	33.8%	–1.17 [-1.90, –0.43]
Total (95% CI)			57			58	100.0%	–1. 77 [-3.25, –0.29]
Heterogeneity: Tau2 = 1.55; Chi2 = 21 .40, df = 2 (p < 0.0001); I2 = 91 %								
Test for overall effect: Z = 2.35 (P = 0.02)								



A: The amount of horizontal movement of U6 in mm (without sensitivity analysis)

Study or Subgroup	en-masse (TSAD) Mean	SD	Total	en-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.18.1 RCTs not high risk of bias								
Liu et al.	-0.06	1.4	17	1.47	1.15	17	100.0%	–1.17 [–1.90, –0.43]
Subtotal (95% CI)			17			17	100.0%	–1.17 [–1.90, –0.43]
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.11 (P = 0.002)								
3.18.2 CCTs / high risk of bias								
Chen et al.	0.87	1.46	15	2.19	1.68	16	45.6%	–0.81 [–1.55, –0.08]
Chopra et al.	0.2	0.35	25	1.47	1.15	25	54.4%	–1.47 [–2.10, –0.84]
Subtotal (95% CI)			40			41	100%	–1.17 [–1.81, –0.53]
Heterogeneity: Tau2 = 0.09; Chi2 = 1.76, df = 1 (P = 0.19); I2 = 43%								
Test for overall effect: Z = 3.59 (P = 0.0003)								
Test for subgroup differences: Chi2 = 0.00, df = 1 (P = 0.99), I2 = 0%								



B: The amount of horizontal movement of U6 in mm (with sensitivity analysis).

Graphs 2A and B: Forest plot showing the amount of horizontal movement of U6 in TSADs group vsCA or no anchorage group: (A) without sensitivity analysis; (B) with sensitivity analysis

respectively). Bhattacharya et al.[9] experimental group included an intervention of corticotomy with bone grafting. Computed tomography (CT) scans revealed that the thickness of the alveolar bone increased significantly in comparison with the control group (p <0.05).

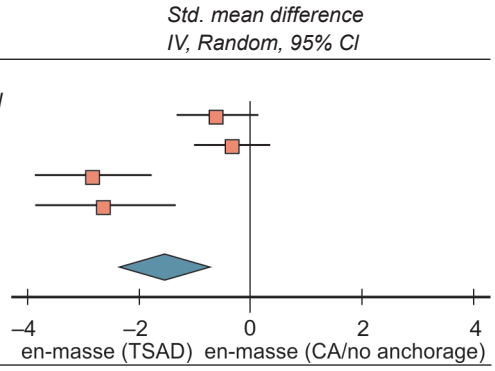
Dentally,no meta-analysis was done based on the interpretation of the sensitivity analysis. The RCT paper of Tuncer et al.[8] revealed a distal movement of U6 and retraction of U1 with no significant difference between the two groups (p = 0.954,p = 0.661 respectively); while the CCT paper of Sakthi et al.[6] reported a significantly lesser mesial movement of U6 and greater U1 retraction in G1 (p <0.001).

In terms of soft-tissue variables, Tuncer et al.[8] reported an increase in the NLA, and a decrease in the UL–VRP (Vertical reference plane) and the LL–VRP, with no significant difference between the two groups (p = 0.942, p = 0.953, p = 0.985 respectively).

For the retraction duration, Tuncer et al.[8] reported that it was 9.33 ± 4.10 months for G1 and 9.27 ± 2.55 months for G2 with no significant difference between the two groups (p = 0.958). In contrast, Sakthi et al.[6] and Bhattacharya et al.[9] reported that the retraction duration was 4.31 (4.37 ± 0.25) months for G1; 7.34 (7.8 ± 0.3) months for G2 with a significant difference between the two groups (p <0.001).

Strength of Evidences in the Collected Data

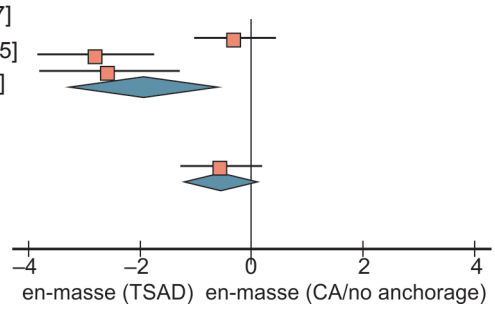
Based on the GRADE recommendations, the strength of evidences for skeletal and dental measurements ranged from very low to medium; while it ranged from low to medium for soft-tissue changes, as shown in (Table 7).



Study or Subgroup	En-masse (TSAD) Mean	SD	Total	En-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. mean difference IV, Random, 95% CI
Chen et al.	–0.13	0.52	15	0.19	0.54	16	26.6%	–0.59 [–1.31, 0.13]
Liu et al.	–1.91	2.33	17	–1 0.17	1.99	17	26.9%	–0.33 [–1.01, 0.34]
Ma et al.	–1.88	1.016	15	1.76	1.46	15	24.1%	–2.82 [–3.86, –1.77]
Victor et al.	–1.1	0.5	10	1.4	1.2	10	22.3%	–2.60 [–3.86, –1.35]
Total (95% CI)			57			58	100.0%	–1.51 [–2.72, –0.29]

Heterogeneity: Tau2 = 1.30; Chi2 = 22.66, df =3 (p < 0.0001); I2 = 87%
Test for overall effect: Z = 2.44 (P = 0.01)

A: The amount of vertical movement of U1 in mm (without sensitivity analysis).



Study or Subgroup	en-masse (TSAD) Mean	SD	Total	en-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.21.1 RCTs								
Liu et al.	–1.91	2.33	17	–1.17	1.99	17	35.4%	–0.33 [–1.01 , 0.34]
Ma et al.	–1.88	1.016	15	1.76	1.46	15	33.1%	–2.82 [–3.86, –1 .77]
Victor et al.	–1.1	0.5	10	1.4	1.2	10	31.5%	–2 .60 [–3.86, –1 .35]
Subtotal (95% CI)			42			42	100.0%	–1.87 [–3.65, –0.09]

Heterogeneity: Tau2 = 2.21; Chi2 = 20.00, df =2 (p < 0.0001); I2 = 90%
Test for overall effect: Z =2.06 (p = 0.04)

3.21.2 CCTs								
Chen et al.	-0.13	0.52	15	0.19	0.54	16	100%	-0.59 [-1.31, 0.13]
Subtotal (95% CI)			15			15	100%	-0.59 [-1.31, 0.13]

Heterogeneity: Not applicable
Test for overall effect: Z = 1.59 (p = 0.11)
Test for subgroup differences: Chi2 = 2.02, df = 1 (P = 0.15), I2 = 50.6%

B: The amount of vertical movement of U1 in mm (with sensitivity analysis)

Graphs 3A and B: Forest plot showingthe amount of vertical movement of incisorsin TSADs group vs CA or no anchorage group: (A) without sensitivity analysis; (B) with sensitivity analysis

The decline in the strength of the evidence occurred because of the imprecision, unclear or high risk of bias, high heterogeneity, or existence of CCTs.

DISCUSSION

In this systematic review, four studies out of six were judged to be at unclear risk of bias; this could have potentially confused the results. One study out of six was judged to be at high risk of bias and two including CCTs were of fair-quality, so sensitivity analyses were performed to discard them in the quantitative synthesis of data when needed.

Skeletal Changes with En-masse Retraction

Traditional Non-accelerated Methods

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 anterior teeth retraction. The SNB angle decreased with no significant difference between the two groups; while a significant increase in the SN-MP angle was reported in the CA/no anchorage group, which could be related to the molars extrusion causing clockwise rotation of the mandible.The strength of evidences in this context ranged between very low to low.

Accelerated Methods

Only Tuncer et al.[8] reported the skeletal variables with no significant difference between the piezo surgery and the control groups. Therefore, the incorporation of an acceleration method when retracting the upper anterior teeth does not seem to affect the final skeletal outcomes. However, the strength of evidences in this aspect was medium.

Dental Changes with En-masse Retraction

Traditional Non-accelerated Methods

- *The horizontal movement of molars:* Using TSAD seems to provide not only less mesial movement of U6, but

Table 7: Summary of findings table according to the GRADE guidelines for the included studies. Patients or population: Healthy patients undergoing fixed orthodontic treatment with maxillary or bimaxillary premolars extraction. Settings: Retraction of maxillary anterior teeth. Intervention: En-masse retraction of maxillary anterior teeth with TSADs or any approach for tooth movement acceleration used. Comparison: En-masse retraction of maxillary anterior teeth with conventional or no anchorage system and without any approach for tooth movement acceleration

Outcomes	*Relative effect (95% CI)*	*Number of participants (studies)*	*Quality of the evidence (GRADE)*	*Comments*
SNA angle				
COMP 1	RCTs/not high risk of bias: WMD 0.02° (-0.78° to 0.81°)	64 patients (2 studies)	RCTs/not high risk of bias:⊕⊕⊖⊖[a] Low	
	CCTs/high risk of bias: WMD -0.16° (-5.88° to -1.35°)	81 patients (2 studies)	CCTs/high risk of bias: ⊕⊖⊖⊖[b] Very low	
COMP 2	not estimable	30 patients (1 study)	⊕⊕⊕⊖c Medium	
SNB angle				
COMP 1	RCTs/not high risk of bias: WMD -0.02° (-0.62° to 0.59°)	64 patients (2 studies)	RCTs/not high risk of bias:⊕⊕⊖⊖[a] Low	
	CCTs/high risk of bias: WMD -0.10° (-0.29° to 0.09°)	81 patients (2 studies)	CCTs/high risk of bias: ⊕⊕⊖⊖[d] Low	
COMP 2	not estimable	30 patients (1 study)	⊕⊕⊕⊖c Medium	
Horizontal movement of maxillary first molars				
COMP 1	RCT/not high risk of bias: Not estimable	34 patients (1 study)	RCT/not high risk of bias: ⊕⊕⊖⊖[e] Low	
	CCTs/high risk of bias: SMD -1.17 mm (-1.81 to -0.53)	81 patients (2 studies)	CCTs/high risk of bias: ⊕⊕⊖⊖[d] Low	
COMP 2	RCT: not estimable	30 patients (1 study)	RCT: ⊕⊕⊕⊖[c] Medium	
	CCT: not estimable	40 patients (1 study)	CCT: ⊕⊕⊖⊖[f] Low	
Vertical movement of maxillary first molars				
COMP 1	RCTs/not high risk of bias: SMD -1.26 mm (-1.86 to -0.67)	54 patients (2 studies)	RCTs/not high risk of bias: ⊕⊕⊖⊖[g] Low	
	CCT/high risk of bias: Not estimable	31 patients (1 study)	CCT/high risk of bias: ⊕⊕⊖⊖[f] Low	
COMP 2	not estimable	30 patients (1 study)	⊕⊕⊕⊖[c] Medium	
Horizontal movement of upper incisal edges				
COMP 1	RCTs/not high risk of bias: SMD -0.66 mm (-1.72 to 0.40)	64 patients (2 studies)	RCTs/not high risk of bias: ⊕⊕⊖⊖[a] Low	
	CCTs/high risk of bias: SMD -0.05 mm (-0.51 to 0.41)	81 patients (2 studies)	CCTs/high risk of bias: ⊕⊖⊖⊖[b] Very low	
COMP 2	RCT: not estimable	30 patients (1 study)	RCT: ⊕⊕⊕⊖[c] Medium	
	CCT: not estimable	40 patients (1 study)	CCT: ⊕⊕⊖⊖[f] Low	
Vertical movement of maxillary incisors				
COMP 1	RCTs: SMD -1.87 mm (-3.65 to -0.09)	84 patients (3 studies)	RCTs: ⊕⊖⊖⊖[h] Very low	
	CCT: Not estimable	31 patients (1 study)	CCT: ⊕⊕⊖⊖[f] Low	
COMP 2	not estimable	30 patients (1 study)	⊕⊕⊕⊖[c] Medium	

Contd...

Contd...

Outcomes	*Relative effect (95% CI)*	*Number of participants (studies)*	*Quality of the evidence (GRADE)*	*Comments*
				UL-E
COMP 1	not estimable	34 patients (1 study)	⊕⊕⊖⊖[i] Low	
COMP 2	not estimable	30 patients (1 study)	⊕⊕⊕⊖[c] Medium	

[a]Decline one level for risk of bias in[23,24] and one level for imprecision*

[b]Decline one level for non-randomized trial[26] and risk of bias in[27] one level for imprecision*and one level for high heterogeneity.

[c]Decline one level for imprecision*

[d]Decline one level for non-randomized trial[26] and risk of bias in[27] one level for imprecision*

[e]Decline one level for risk of bias in[24] and one level for imprecision*

[f]Decline one level for being non-randomized trial [6] and one level for imprecision*

[g]Decline one level for risk of in[24,25] and one level for imprecision*

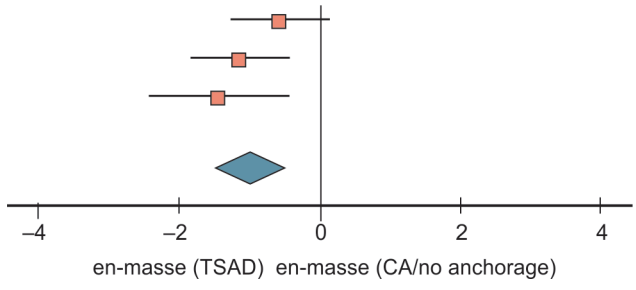
[h]Decline one level for risk of in[23-25] one level for high heterogeneityand one level for imprecision*

[i]Decline one level for risk of in[24] and one level for imprecision*

*Limited number of trials, or limited sample size.

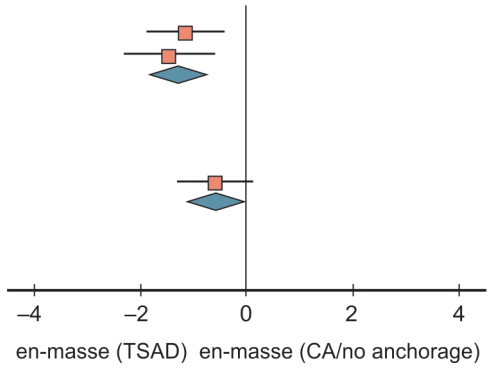
Study or Subgroup	*en-masse (TSAD)* Mean	SD	Total	*en-masse (CA/no anchorage)* Mean	SD	Total	Weight	*Std. Mean Difference IV, Random, 95% CI*
Chen et al 2015	-0.1	0.21	15	0.06	0.31	16	39.8%	-0.58 [-1.31, 0.14]
Liu et al 2009	-1.42	2.55	17	1.19	1.75	17	38.6%	-1.17 [-1.90, -0.43]
Victor et al 2014	-0.3	0.5	10	0.8	0.9	10	21.6%	-1.45 [-2.46, -0.44]
Total (95% CI)			42			43	100.0%	-1.00 [-1.48, -0.51]

Heterogeneity: Tau2 = 2.21; Chi2 = 2.22, df =2 (P < 0.0001); I2 = 10%
Test for overall effect: Z =4.02 (P < 0.0001)



A: The amount of vertical movement of U6 in mm (without sensitivity analysis).

Study or Subgroup	*en-masse (TSAD)* Mean	SD	Total	*en-masse (CA/no anchorage)* Mean	SD	Total	Weight	*Std. Mean Difference IV, Random, 95% CI*
3.19.1 RCTs								
Liu et al 2009	-1.42	2.55	17	1.19	1.75	17	65.4%	-1.17 [-1.90, -0.43]
Victor et al 2014	-0.3	0.5	10	0.8	0.9	10	34.6%	-1.45 [-2.46, -0.44]
Subtotal (95% CI)			27			27	100.0%	-1.26 [-1.86, -0.67]
Heterogeneity: Tau2 = 0.00; Chi2 = 0.20, df = 1 (P = 0.66); I2 = 0%								
Test for overall effect: Z = 4.17 (P < 0.0001)								
3.19.2 CCTs								
Chen et al 2015	-0.1	0.21	15	0.06	0.31	16	100.0%	-0.58 [-1.31, 0.14]
Subtotal (95% CI)			15			16	100.0%	-0.58 [-1.31, 0.14]
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.59 (P = 0.11)								
Test for subgroup differences: Chi2 = 2.02, df = 1 (P = 0.15), I2 = 50.6%								

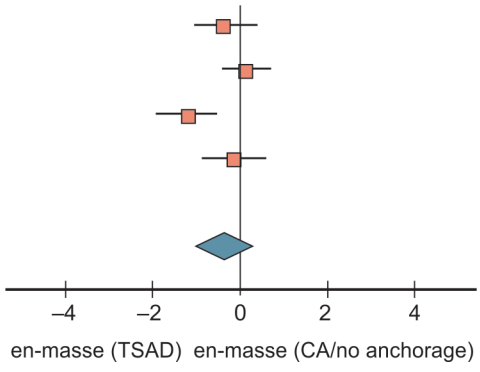


B: The amount of vertical movement of U6 in mm (with sensitivity analysis).

Graphs 4A and B: Forest plot showingthe amount of vertical movement of U6 in TSADs group vs CA or no anchorage group: (A) without sensitivity analysis; (B) with sensitivity analysis.

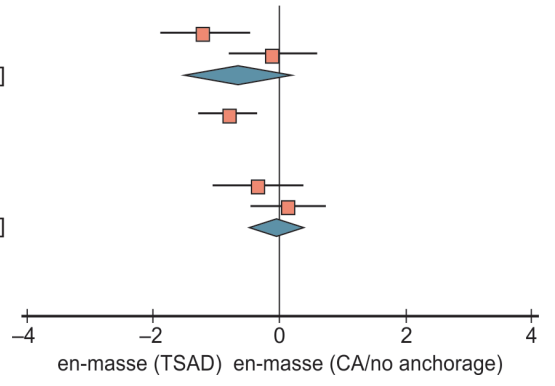
Study or Subgroup	en-masse (TSAD) Mean	SD	Total	en-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Chen et al 2015	-8.37	1.96	15	-6.63	6.63	16	24.2%	-0 .34 [-1.05, 0.37]
Chopra et al 2017	2.3	0.92	25	2.16	1.03	25	28.4%	0.14 [-0.41 , 0.70]
Liu et al 2009	-7.03	1.99	17	-4.76	1.67	17	23.5%	-1.21 [-1.94, -0.47]
Ma et al 2008	-6.65	7.815	15	-5.59	9.13	15	24.0%	-0 .12 [-0.84, 0.60]
Total (95% CI)			72			73	100.0%	-0.35 [-0.92, 0.21]

Heterogeneity: Tau2 = 0.22; Chi2 = 8.47, df = 3 (P = 0.04); I2 = 65%
Test for overall effect: Z = 1.23 (P = 0.22)



A: The amount of horizontal movement of upper incisal edges in mm (without sensitivity analysis).

Study or Subgroup	en-masse (TSAD) Mean	SD	Total	en-masse (CA/no anchorage) Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.20.1 RCTs not high risk of bias								
Liu et al 2009	-7.03	1.99	17	-4 .76	1.67	17	49.6%	-1 .21 [-1 .94, -0.47]
Ma et al 2008	-6.65	7.815	15	-5 .59	9.13	15	50.4%	-0 .12 [-0 .84, 0.60]
Subtotal (95% CI)			32			32	100.0%	-0.66 [-1.72, 0.40]
Heterogeneity: Tau2 = 0.45; Chi2 = 4.27, df = 1 (P = 0.04); I2 = 77%								
Test for overall effect: Z = 1.22 (P = 0.22)								
3.20.2 CCTs/ high risk of bias								
Chen et al 2015	-8.37	1.96	15	-6 .63	6.63	16	39.0%	-0 .34 [-1 .05, 0.37]
Chopra et al 2017	2.3	0.92	25	2.16	1.03	25	61 .0%	0.14 [-0.41 , 0.70]
Subtotal (95% CI)			40			41	100.0%	-0.05 [-0.51, 0.41]
Heterogeneity: Tau2 = 0.01; Chi2 = 1.10, df = 1 (P = 0.29); I2 = 9%								
Test for overall effect: Z = 0.20 (P = 0.84)								
Test for subgroup differences: Chi2 = 1.07, df = 1 (P = 0.30), I2 = 6.8%								



B: The amount of horizontal movement of upper incisal edges in mm (with sensitivity analysis)

Graphs 5A and B: Forest plot showingthe amount of horizontal movement of upper incisal edges in TSADs group vs CA or no anchorage group: (A) without sensitivity analysis; (B) with sensitivity analysis.

also the distal movement of U6 when interdental contact occurs between the canine and second premolar, so a retraction force would translate to U6, as reported in one study.[23] On the other hand, two studies[25,26] reported mesial movement of U6 despite the use of TSAD. This might have occurred because of the mesial movement of TSAD according to orthodontic loading, and the subsequent movement of U6 with it because they were ligated with TSAD. Also, it might have happened due to the physiological mesial movement after premolar extraction in the leveling and alignment phase. However, using TSAD for anchorage appears to be better than CA or no anchorage. The strength of evidences was low.

Vertical Movement of Molars

When anchoring the anterior teeth retraction with TSAD, the intrusion of molars occurred; while in contrast, extrusion of molars occurred in the CA or no anchorage group. So, using TSAD is expected to prevent the worsening of the profile with clockwise rotation of the mandible in cases with increased vertical dimensions. The strength of the evidences in this aspect was low.

- *The horizontal movement of upper incisal edges*: Higher when using TSAD than those with conventional anchorage, as conventional anchorage allowed posterior teeth to move mesially so that the anterior teeth were retracted a less amount. Therefore, when a larger amount of retraction is needed, it is preferable to

use TSADs. The strength of evidences ranged between very low to low.

Vertical Movement of Incisors

With the use of temporary skeletal anchorage devices, the incisor edges and apices were found to move superiorly due to the positioning of TSAD 8–10 mm apically to the occlusion line, so the point of force application was apical to the center of resistance (CR). In addition, the height of the power arm influenced the force of intrusion. In contrast, extrusion of incisal edges and apices would occur in the conventional or no anchorage group, due to the coronal orientation of the force vector in relation to the CR. Therefore, using TSADs prevents the occurrence of a post-retraction increase in the overbite. The strength of the evidences ranged between very low to low in this context.

The incisors inclination is one of the most important goals in camouflage treatment. In both TSAD and conventional anchorage group, the maxillary incisors were retracted by controlled tipping and bodily movement with no significant difference between the two groups. Victor et al.[24] reported similar results in the TSAD and no anchorage groups regarding U1 inclination, and this was explained by their use of full-sized archwires during en-masse retraction with the possible complete expression of the remaining tip and torque, and their 4-weeks activation intervals.

Accelerated Methods

The same trends in dental movements mentioned above in the non-accelerated methods of retraction were also seen in the piezosurgery-based retraction techniques with no significant differences between the accelerated and non-accelerated groups. Tuncer et al.[8] found that using piezosurgery did not significantly increase the amount of anterior teeth retraction and at the same time it did not increase the posterior anchorage loss.Final incisors' inclination following retraction was similar to that obtained with non-accelerated methods. The strength of evidences in this context was medium.

Sakthi et al.[6] reported a significantly less mesial movement of U6 when using corticotomy with en-masse retraction compared to the traditional method. Surprisingly, they did not apply any anchorage tools in both groups. This finding may be attributed to the increase in the anchorage value of the posterior teeth due to the cortication that took place close to the anterior segment. The strength of evidences regarding this point is low.

Soft-tissue Changes with En-masse Retraction

Traditional Non-accelerated Methods

The nasolabial angle increased and the facial convexity angle decreased after retraction in both TSAD and conventional anchorage groups because of the backward movement of the upper incisors. The upper lip responds proportionately to the incisors retraction, so it was retracted in both groups. The lower lip was also retracted because it contacts the upper and lower incisors, so it is influenced by both incisors retraction. These soft-tissue changes improved the appearance of the facial profile. The strength of evidences was low.

Accelerated Methods

Some authors have hypothesized that the acceleration of en-masse retraction would not lead to a proper movement of the facial soft-tissues following retraction, but the only existing study of Tuncer et al.[8] rejected this assumption. Therefore, en-masse retraction with or without using the piezosurgery seems to lead to the same soft-tissue changes. The strength of evidences was medium.

Retraction Speed and Duration

Traditional Non-accelerated Methods

Regarding treatment duration,no significant difference between the TSAD and conventional anchorage groups was observed because the extraction spaces were closed completely by anterior teeth retraction in the TSAD group, while in the conventional anchorage group an anchorage loss occurred allowing a simultaneous movement of both anterior and posterior teeth into the extraction space. Therefore, using TSAD seems not to reduce the treatment duration significantly, but it leads to better treatment results.

Accelerated Methods

Sakthi et al.[6] and Bhattacharya et al.[9] found that corticotomy-assisted retraction significantly shortened the retraction duration by accelerating tooth movement, especially during the first two months. This could be explained by the regional accelerated phenomena (RAP) taking place in the involved area with increased bone turnover in response to the surgical intervention, which in turn presented less resistance to tooth movement.[6,9]

In constant, Tuncer et al.[8] did not find significant difference between the two groups when using piezosurgery, and this could be explained by the minimal amount of bony injury that was performed labially and not palatally. In addition, the flap reflection and premolar extractions at the same time of performing corticotomy in the other two studies[6,9] could have intensified the inflammatory response.

The piezosurgery was used in many orthodontic tooth movement strategies such as canines' retraction[27,28]

and leveling and alignment treatments,[29] and these studies found a significant increase in the rate of tooth movement as did the current review regarding en-masse retraction.

Limitations of the Current Review

Being confined to the papers written in English is one limitation. The methodologic quality of the included studies was assessed rigorously, and many deficiencies were found. Only one RCT out of six was of low risk of bias, and none of the selected CCTs were of high-quality. The strength of evidences ranged between low/very low to medium. The cephalometric analyses were conducted by different reference points and planes to calculate changes,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 very weak to moderate evidence that the use of accelerated and non-accelerated methods with TSADs or CA can lead to similar skeletal improvements. There is very weak to moderate evidence that using TSADswould lead to a better anchorage when retracting upper anterior teeth than in CA or no anchorage.An intrusion force was found to be applied on incisors and molars when using TSAD; 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. Contradictory results were found regarding the amount of achieved anterior retraction and the overall retraction time in the studies that evaluated acceleration methods versus the traditional methods of retraction.There is weak to moderate evidence that en-masse retraction of upper anterior teeth in accelerated and non-accelerated methods would decrease the facial convexity, retract the upper and lower lips, and increase the nasolabial angle.

Implications for Research

As the quality of evideces ranged between very low to moderate in terms of skeletal and dental variables, and low to moderate in term of soft-tissue variables, we, therefore, emphasize the need for more well-conducted randomized controlled trials. We also recommend more work to be oriented towards en-masse retraction with the use of acceleration methods (such as traditional and flapless corticotomy, and low-level laser therapy).

Clinical Significance

The correction of the maxillary or bimaxillary dentoalveolar protrusion by en-masse retraction of the upper anterior teeth with/without acceleration is accompanied by aesthetic results in the facial soft tissues as well as in the underlying skeletal and dental structures. The traditional corticotomy-assisted retraction is expected to significantly reduce the retraction time. However, the strength of evidence is not strong and requires additional research work.

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