Which anchorage device is the best during retraction of anterior teeth? An overview of systematic reviews

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ABSTRACT
Objectives: To evaluate the available evidence regarding clinical effectiveness of different types of anchorage devices.
Methods: A comprehensive literature search was conducted for systematic reviews investigating different anchorage methods published up to 15th April, 2021. This was accomplished using different electronic databases. Any ongoing systematic reviews were searched using Prospero and a grey literature search was undertaken using Google Scholar and OpenGrey. No language restriction was applied. Screening, quality assessment, and data extraction were performed by two authors independently. Information was categorized and narratively synthesized for the key findings from moderate and high-quality reviews.
Results: Fourteen systematic reviews were included (11 were of moderate/high-quality). Skeletal anchorage with miniscrews was found to be associated with less anchorage loss (and sometimes with anchorage gain). Similarly, skeletal anchorage is more effective in retracting anterior teeth and intruding incisors and molars resulting in minor vertical skeletal changes and improving the soft tissue profile. There was insufficient evidence for the preference of any anchorage methods in terms of duration of treatment, number of appointments, quality of treatment, patient perception, or adverse effects. The effectiveness of skeletal anchorage can be enhanced when directly-loaded, when used in the mandible, buccally rather than palatally when used in the maxilla, when using dual rather than single miniscrews, for en-masse retraction, and for adults.
Conclusions: The level of evidence regarding anchorage effectiveness is moderate. Skeletal anchorage can be used with more anchorage preservation compared to conventional anchorage. Further high-quality randomized clinical trials are required to confirm these findings.
Keywords: Orthodontic Anchorage Procedures, Anchorage loss, Orthodontic mini-implant

INTRODUCTION

Orthodontic treatment of malocclusion such as full Class II relationship, dentoalveolar protrusion or severe crowding often requires premolar extractions. Treatment outcomes in these cases depend on closure of the extraction spaces while adequately controlling the anchorage teeth.[1] Orthodontic anchorage is defined as the resistance to unwanted tooth movement.[2] Anchorage control is of great importance when there is extraction and during the space closure stage.[3,4] Conventionally, different methods and devices have been used for anchorage control, for example bonding of second molars, the use of a transpalatal arch (TPA) with or without a Nance button, lingual arches, headgear, or intermaxillary elastics.[1] Each method can be used according to the clinical situation and has its advantages and disadvantages. For instance, extra-oral appliances require greater patient compliance[5] and may be associated with facial trauma.[6,7] On the other hand, intra-oral appliances (such as TPA) have not been shown to be effective despite being widely used.[8] Recently, orthodontic temporary anchorage devices (TADs) were introduced as skeletal anchorage devices that can provide maximum to absolute anchorage[9,10] and are compliance-free. TADs can take the form of implants, plates, screws or screw-retained devices which are inserted into the bone to provide resistance to unwanted tooth movement (indirect anchorage) or a point from which orthodontic traction can be applied (direct anchorage).[11,12]

It has been suggested that two-step retraction by initially retracting the canine followed by retraction of the incisors could preserve anchorage when compared to en-masse retraction of the six anterior teeth. However,

this is still a controversial subject clinically especially when the variety of anchorage designs are considered.[13,14]

Although transpalatal arches have been found to be of very limited effectiveness in terms of anchorage control, especially the mesial movement of the anchored molars with finite element analysis[15,16], some clinical trials have suggested using them as secondary anchorage devices when maximum anchorage is not required.[9,17-19]

Several systematic reviews[8,20-32] have compared the clinical effectiveness of different types of anchorage devices in terms of amount of anchorage loss; sagittal and vertical dental, skeletal, and soft tissue changes; duration of treatment; quality of treatment; patient perception; and adverse effects. However, to date researchers have not provided a robust and clear answer for the question: which anchorage method is the best during retraction of anterior teeth according to these different treatment outcomes?

This overview was designed to evaluate the available evidence (on a systematic review level) regarding clinical effectiveness of different types of anchorage devices during retraction of anterior teeth. The reason for conducting an overview of systematic reviews is that all the available systematic reviews were variable in terms of the types of anchorage devices, method and time of assessment, types of tooth movement, and treatment outcomes. Therefore, this overview aimed to gather all the available evidence for each intervention, evaluate the level of evidence and then categorize the outcomes to translate the evidence into practice. By undertaking an overview, it will be able to identify what is known in this topic area, what remains unknown and where investigators should focus their efforts in future research projects.

MATERIALS AND METHOD

Ethical approval was not required as there was no individual participation, no intervention or personal data collection. This overview was prepared in line with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement[33], and according to the methodological guidelines in conducting overviews of systematic reviews of health care intervention, as provided by **Smith et al. (2011)**[34].

Protocol and registration

The protocol for the present review was registered with PROSPERO. Registration number: CRD42020218197.

Eligibility criteria

The eligibility criteria were determined according to the Population, Intervention, Comparison, Outcome, and Study design (PICOS) scheme:

Population: patients of any age undergoing orthodontic treatment with fixed appliances and requiring retraction of anterior teeth with anchorage control after premolar extraction.

Intervention: orthodontic treatment with fixed appliances and any type of anchorage reinforcement device.

Comparison: orthodontic treatment with fixed appliances and any other type of anchorage reinforcement device.

Outcome: comparison of the effectiveness of anchorage devices.

Study design: systematic reviews with or without meta-analysis. In case of Cochrane reviews, the most recent publication was included, and all previous versions were excluded. Studies with any other design or without orthodontic treatment were also excluded as well as any systematic review with only in-vitro or animal studies.

Information sources, search strategy and study selection

A comprehensive literature search was conducted for systematic reviews published up to 15 April, 2021 using the following key terms: “anchorage”, “conventional”, “transpalatal”, “screw”, “implant”, “retraction”, “systematic review”, and “meta-analysis”. This was accomplished using electronic databases: MEDLINE via OVID (1946 to 15 April, 2021), EMBASE (1974 to 15 April, 2021), AMED (Allied and Complementary

Medicine Database) (1985 to 15 April, 2021), PubMed (inception to 15 April, 2021) and, Web of Science (1900 to 2021). Any ongoing systematic reviews were searched using Prospero and a grey literature search was undertaken using Google Scholar and OpenGrey (www.opengrey.eu/). No restrictions were applied in terms of language, date, and status of publication, and age of treated patients. All relevant articles were identified, retrieved and assessed for eligibility of inclusion by two authors (Y.A.Y. and S.A.N.). Any disagreement was resolved by discussion to reach consensus or alternatively by consulting a third author (D.R.B.).

Data items and collection

After screening the eligible systematic reviews, the following data were extracted independently and in duplicate by two authors (Y.A.Y. and S.A.N.): (1) authors; (2) year of publication; (3) study design; (4) number of studies included; (5) type of studies; (6) number of participants; (7) period of search; (8) name of journal; and (9) objectives of the study (Table 1).

Quality assessment in individual studies

Two authors (Y.A.Y. and S.A.N.) assessed the included reviews independently using the AMSTAR 2 quality assessment tool (A Measurement Tool to Assess Systematic Reviews)[35] (Table 2). Any disagreement was initially resolved by discussion or in conjunction with a third author (D.R.B.), if necessary. The level of evidence according to the AMSTAR 2 is presented in Table 3.

Summary measures and approach to synthesis

Data pooling was planned to qualitatively assess the effectiveness of CAT as systematic reviews per se do not have primary data.

RESULTS

Study selection and characteristics

A total of 332 potentially eligible studies were identified. After exclusion of the duplicates, 274 studies were left. Then, initial screening for the titles and abstracts reduced the number to 34 studies. After full-text assessment, 20 reviews were excluded (four reviews were not systematically designed or were older versions of Cochrane reviews and 16 reviews were not relevant to the aim) leaving 14 systematic reviews for inclusion (Figure 1).

A summary of the characteristics of the included systematic reviews is presented in Table 1. The included studies were published from 2006 to 2021. Meta-analyses were carried out in 85.7% of the systematic reviews (12/14 systematic reviews).

Data synthesis

Due to the lack of primary data, differences in types of anchorage devices used, method and time of anchorage loss measurement, further meta-analysis was not possible. The data were, therefore, synthesized qualitatively using thematic synthesis by identifying the most prominent and important themes with the findings summarized accordingly.

Quality of the evidence

According to the AMSTAR 2 checklist, the quality of the included reviews was variable: 2 (14.3%) critically low, 1 (7.1%) low, 9 (64.3%) moderate, and 2 (14.3%) high (Table 1). Most of the AMSTAR 2 items were covered to a varying degree. Only one review[22] reported the source of funding of the included studies (Table 2). There was complete consensus between the reviewers regarding the quality assessment.

In this overview review, the main findings from the moderate and high-quality systematic reviews were considered in the thematic synthesis. Therefore, the results of **Feldmann and Bondemark (2006)**[8], **Li et al. (2011)**[20] (critically low-quality) and **Jayaratne et al. (2017)**[25] (low-quality) were not considered further.

Method and time of measuring anchorage loss

Anchorage loss was measured using different methods, for example study model analysis (including three-dimensional methods), cephalometric analyses, or using reference points clinically. Regarding the time of measurement, this was also variable, i.e. from the start of treatment until achieving Class I canine relationship or to the end of space closure, from the start to the end of anchorage phase, during space closure, at the start and end of active orthodontic treatment.[22,30]

Amount of anchorage loss

The mean anchorage loss as represented by the mesial movement of the maxillary first molar was shown to be significantly greater with conventional anchorage devices (transpalatal arches, headgear, Nance appliances, banding of second molars, and differential anchorage methods) when compared to miniscrews.

The results of the included systematic reviews in terms of *amount of anchorage loss* and the influence of anchorage method on: *vertical change of maxillary first molar, anterior teeth retraction, vertical change of maxillary incisors, skeletal changes, soft tissue changes, duration of space closure, overall duration of treatment, number of appointments, quality of treatment, patient perception, and adverse effects* are described in detail in Table 4.

DISCUSSION

Since the effectiveness of anchorage devices had been investigated by various heterogenous systematic reviews, the logical next step was to perform an overview of these reviews. This could allow the findings of these separate reviews to be appraised, compared, and contrasted in order to highlight and summarize the best available evidence from more than one systematic review in a single document. This consequently aids in evidence-based clinical decision-making.[34,36]

Amount of anchorage loss

All the included systematic reviews showed a consensus in terms of greater anchorage preservation with skeletal anchorage than conventional anchorage. The amount of anchorage loss between the two methods was roughly 2 mm and this can be considered of clinical importance since it represents about 25% of the extraction space. This consistent finding can be attributed to the fact that miniscrews are solely anchored by bone, so they usually provide maximum anchorage with zero effect on the first molars. Alternatively, they either fail or migrate, however there is no evidence in the current systematic reviews regarding the side-effects of migration. **Becker et al. (2018)**[27] and **Khlef et al. (2018)**[28] reported that skeletal anchorage not only preserves the anchorage but can produce distalisation of the molars. This might be explained by the friction between the archwire and molar tube during sliding of the wire during incisor retraction. This friction is the result of the direction of retraction (distal and intrusive) which could cause binding of the archwire in the molar tube and hence the force will be transmitted through the archwire to the dentition.[27] The greater distal tipping of molars with miniscrews, albeit non-statistically significant, could be the result of the lack of a reactive force on the molars during retraction of the anterior teeth.[23] Additionally, this distal tipping could also be attributed to the friction between the archwire and molar tube when the distal force transmitted through the archwire and resulting in distal tipping of molars.

The finding of less anchorage loss with dual miniscrews than single miniscrew[21,22] is logical and related to the greater stability and hence lower failure with dual miniscrews. On the other hand, the reduced anchorage loss in the mandible than in the maxilla whether between miniscrews and conventional anchorage or between miniscrews themselves[21] may be a matter of higher density with less resiliency of the mandibular bone, providing more stability for the skeletal anchorage, as miniscrews rely on mechanical retention not

osseointegration. The finding that anchorage loss was greater for younger patients could also be due to quality of bone which is denser with higher cortical thickness at specific sites in the maxilla and mandible for older patients than for younger patients and hence provides greater stability for mesial molar movement.[21,31] Nevertheless, further investigations are needed to confirm this information.

Anchorage loss was greater when the miniscrew/implant was placed palatally rather than buccally.[21,22] This can be correlated with another finding where direct anchorage gave greater preservation than indirect anchorage.[21,27] In general, with indirect anchorage the force of retraction is applied to the tooth which is ligated by the miniscrew. So, any resilience/deformation of the connecting wire, or loose ligation can lead to loss of anchorage. Since miniscrews that are placed palatally are mostly used for indirect anchorage, this can explain these findings.

According to the results by **Papadopoulos et al. (2011)**[21], one should be aware that any pre-treatment mesial drifting of molars can be a risk factor for anchorage loss and hence, implementing skeletal anchorage may be necessary during treatment.

A transpalatal arch alone does not prevent molar mesial movement and is comparable to "no anchorage". Using headgear can enhance anchorage when compared to transpalatal arches. This is due to the use of the extra-oral skeletal component of the headgear. However, headgear is only used part-time and, generally, it is less acceptable when compared to miniscrews. Furthermore, both transpalatal arch and headgear showed greater anchorage loss than miniscrews.[24]

When en-masse retraction with miniscrews was compared with two-step or en-masse retraction with conventional anchorage, the result is in line with the above findings and leads to the conclusion that even with increasing the number of retracted teeth, the skeletal anchorage did not have any adverse effect on the anchored teeth.[28,29] Miniscrews were also more effective in preserving the anchorage than conventional anchorage methods in two-step retraction technique.[32]

Anchorage method and vertical change of maxillary first molar

The vertical force vector associated with retraction using miniscrews explains the finding of intrusion of molars[27-29,31] as the incisors will be subject to distal and intrusive force vectors due to the position of the miniscrew and hence, the intrusive force will be transferred to the molars via the archwire. Therefore, the intrusive force on molars while retracting incisors with miniscrews could be beneficial for patients with clockwise rotation of the mandible, anterior openbite, and Class II malocclusion.[28,31] It has been reported that even minor intrusion of posterior teeth of about 1 mm can produce a significant upward and forward movement of the chin of about 3-4 mm.[37]

Anchorage method and anterior teeth retraction

Although incisor retraction was greater with miniscrews and was statistically significant[23,26,28,29,31], this was of less clinical significance (0.46 mm-1.5 mm) when compared to the amount of anchorage loss. The greater incisor retraction may be related to the greater stability of bone than teeth as anchor unit as well as to the greater space available for incisor retraction with miniscrews (due to less anchorage loss).[23,28,31] The same is true for canine retraction.[32]

Incisor inclination and tipping depends on factors such as size of archwire, point of force application, and presence or absence of third order bends, which do not have a direct relation with the anchorage method.[23] **Khlef et al. (2018)**[28] reported that when using temporary skeletal anchorage devices, the incisors would be retracted by controlled tipping and bodily movement, whereas with conventional anchorage the incisors would be retracted by controlled and uncontrolled tipping. Therefore, optimal incisor inclination can be achieved with skeletal anchorage devices.

Anchorage method and vertical change of maxillary incisors

As with molar vertical changes, the incisors will be subject to an intrusive force when retracted with miniscrews.[28,29,31] This is the effect of the line of force application which is higher with miniscrews than with

conventional anchorage methods where the point of force application is on the molars which may result in downward vector and extrusion. The length of the power arm can also play a role in the amount of vertical change as decreasing the height of the power arm results in increasing the intrusive force on incisors.[28]

Anchorage method and skeletal changes

Since the effect of incisor retraction whether with miniscrews or with conventional anchorage methods is mainly dental, its reflection on skeletal components is mainly limited to the skeletal regions that are affected indirectly by the dentition. Consequently, the difference in incisor retraction between different methods of anchorage will rarely influence sagittal jaws position and hence it is not sufficient to be shown as a difference in SNA, SNB, and ANB angles. Whereas, intruding molars with miniscrews and extruding them with conventional anchorage can influence the vertical skeletal measurements as shown with SN-MP angle.[26,29] However, this difference can be masked if the amount of vertical molar change is minimal between the two anchorage methods as detailed in the systematic review by **Khlef et al. (2018)**[28], where the molar vertical change was only 0.61 mm and hence no significant difference in the SN-MP angle was revealed. Both meta-analyses by **Xu and Xie (2017)**[26] and **Khlef et al. (2019)**[29] found similar differences in the SN-MP angle between skeletal and conventional anchorage (1.12˚), which in general is not of clinical significance.

Anchorage method and soft tissue changes

The greater amount of incisor retraction with miniscrews can explain the increase in the nasolabial angle, greater reduction of upper lip to E-line, and the tendency of decreasing the facial convexity.[26,28,29] However, it is difficult to explain that when mean differences of incisor retraction between the two anchorage methods are 1.5 mm[26] and 0.46 mm[28] that this can result in mean differences of nasolabial angle increase of 3.52˚ and 4.73˚, respectively, unless if there is a growth factor that can play a role in this.

Anchorage method and duration of space closure/treatment

According to the decision algorithm by **Jadad et al., (1997)**[38], the evidence about the non-significantly shorter duration of treatment with miniscrews when compared to conventional anchorage[22,28-30] outweighs that of the significantly shorter duration with miniscrews[23]. This together with the non-significant difference between skeletal anchorage and conventional anchorage in duration of extraction space closure[22,30] could be explained by the same reason. If miniscrew failures occur, this will take greater time to allow bone healing before re-insertion and resuming treatment. Moreover, in spite of the more effective retraction with miniscrews as anchorage, the greater loss of anchorage with conventional anchorage devices results in smaller extraction space and hence time required to close that space with conventional anchorage will be shortened.[30]

The difference in the duration of space closure between single and dual miniscrews (2.19 months in favour of single miniscrew) was not statistically significant, and was derived from one study and so no meta-analysis was performed.[22] Therefore, this may be due to chance.

Anchorage method and number of appointments

The number of appointments to complete treatment is correlated with the technique used with space closure. Since skeletal anchorage is usually used with en-masse retraction and conventional anchorage with two-step retraction, this may indicate less appointments with skeletal anchorage than the conventional methods. However, the number of appointments was reported with contradicting results in two reviews[22,30] each took its information from one study, and factors such as miniscrew failure rate, surgical healing of mid-palatal implant were not taken into consideration.

Anchorage method and quality of treatment

There is not enough evidence to determine which anchorage methods is associated with better outcomes, because the available information was derived from one meta-analysis[30] which was in turn obtained from one study.

Anchorage method and patient perception

Both miniscrews and conventional anchorage methods showed a comparable level of discomfort as each has its disadvantages; miniscrews are associated with pain during insertion and removal, while conventional methods are characterized by their bulkiness which is unpleasant for patients. However, generally the feedback with miniscrews is positive especially if they are the pre-drilling type. It is worth mentioning that some of the discomfort reported by **Jambi et al. (2014)**[22] was due to a surgical procedure which is not relevant to the majority of skeletal anchorage.

Anchorage method and adverse effects

One meta-analysis[22] found that the failure rate of the anchorage method with conventional anchorage methods was greater than with miniscrews, however miniscrew success depends on biological factors, while that of conventional methods is mainly dependent on the durability of the cementing material. It seems that re-using conventional methods is easier and quicker than miniscrews, but there is insufficient evidence on this aspect. Miniscrew failure rate was about 10%-12%[21,27] and it does not differ between early and delayed loading.[22]

CONCLUSIONS

1. The level of evidence regarding the effectiveness of anchorage methods is moderate. High-quality RCTs are still required. According to the available evidence, skeletal anchorage with miniscrews is clinically more effective than conventional anchorage methods especially in preventing horizontal mesial molar movement.
2. During space closure, skeletal anchorage is also more effective than conventional anchorage for the following:
   - Retraction of anterior teeth.
   - Intrusion of incisors and molars.
   - Minor decrease in vertical skeletal relationship.
   - Improving the soft tissue profile.
3. There was insufficient evidence to determine the benefit of specific anchorage methods for the following:
   - Duration of space closure and overall duration of treatment.
   - Number of appointments.
   - Quality of treatment.
   - Patient perception and adverse effects.
4. The effectiveness of skeletal anchorage can be enhanced for the following:
   - When directly-loaded.
   - When placed in the mandible than maxilla.
   - When placed buccally rather than palatally.
   - When using dual rather than single miniscrews.
   - For en-masse retraction.
   - For adult patients.

CONFLICT OF INTEREST

None of the authors have any conflict of interest to declare.

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None

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Figure 1: PRISMA flow diagram of the literature selection process

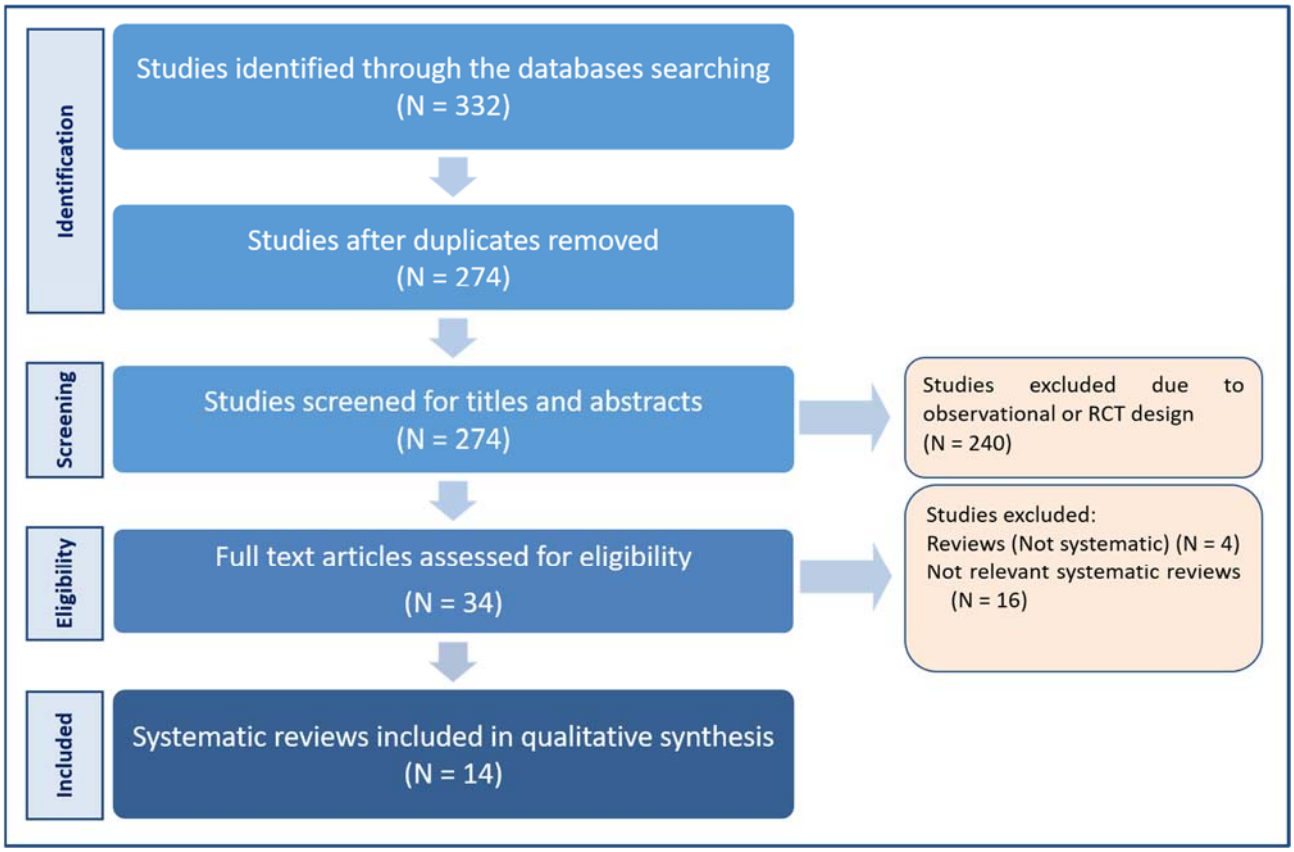

Table 1: Systematic reviews that have assessed anchorage reinforcement devices during orthodontic treatment

Author	Year	Study Design	No. of Studies	No. of Participants	Intervention anchorage	Comparison anchorage	Type of Studies	Period of Search	Journal	Main Outcomes	Quality of Evidence
Feldmann and Bondemark[8]	2006	Systematic review	14 (7 of these are related to the aim of the current study)	388	Space closure with different techniques	Different anchorage devices/methods	2 RCTs 3 Retrospective studies 2 Prospective studies	January, 1966 to December, 2004	Angle Orthodontist	Due to contradictory results and the vast heterogeneity in study methods, the scientific evidence was too weak to evaluate anchorage efficiency during space closure	**Critically Low** Score: 4
Li et al.[20]	2011	Systematic review and meta-analysis	8	392	Midpalatal implant, mini-implant, and onplant	Headgear	4 RCTs 1 Prospective cohort study 3 Retrospective studies	Not reported	Angle Orthodontist	The skeletal anchorage of the midpalatal implant, mini-implant, and onplant offer better alternatives to headgear, with less anchorage loss and more anterior teeth retraction	**Critically Low** Score: 7
Papadopoulos et al.[21]	2011	Meta-analysis	8	206	Mini-implants	Different types (TPA, headgear, banding the second molar and application of differential moments Mini-implants were also compared according to location, number, and etc	3 RCTs 5 CCTs	Up to June, 2010	Journal of Dental Research	The use of MIs significantly decreased or negated loss of anchorage	**Moderate** Score: 10

Author	Year	Study Design	No. of Studies	No. of Participants	Intervention anchorage	Comparison anchorage	Type of Studies	Period of Search	Journal	Main Outcomes	Quality of Evidence
Jambi et al.[22]	2014	Systematic review and meta-analysis (Cochrane Review)	15 (11 for meta-analysis)	561	Mid-palatal implants, onplants, mini-screw implants, spider screws, titanium plates and zygomatic wires	Conventional methods (headgear, chin caps, face masks, transpalatal arches, Nance buttons, lingual arches and interarch elastics. Studies with two methods of surgically assisted anchorage were also included.	RCTs	Up to October 28, 2013	Cochrane Database of Systematic Reviews	Reinforcement of anchorage is more effective with surgical anchorage than conventional anchorage methods	**High** Score: 15
Antoszewska-Smith et al.[23]	2017	Systematic review and meta-analysis	14	616	Miniscrew and Miniplate	TPA and headgear	7 RCTs 7 CCTs	1990 to March, 2016	American Journal of Orthodontics and Dentofacial Orthopedics	Skeletal anchorage devices are more effective for en-masse retraction than conventional methods of anchorage reinforcement	**Moderate** Score:10
Diar-Bakirly et al.[24]	2017	Systematic review and meta-analysis	14 (13 for meta-analysis)	579	TPA	Other types of anchorage including skeletal anchorage (miniscrews, onplants), and headgear	9 RCTs 5 Non-RCTs	Up to April 2015	Angle Orthodontist	Transpalatal arch alone should not be recommended to provide maximum anchorage during retraction of anterior teeth in extraction cases	**Moderate** Score:11

Author	Year	Study Design	No. of Studies	No. of Participants	Intervention anchorage	Comparison anchorage	Type of Studies	Period of Search	Journal	Main Outcomes	Quality of Evidence
Jayaratne et al.[25]	2017	Systematic review	6	327	Mini-implants	Different types (TPA, headgear, banding the second molar and application of differential moments	RCTs	Up to May, 2015	Journal of Istanbul University Faculty of Dentistry	The amount of incisor retraction and intrusion was greater with buccally placed mini-implants when compared to conventional anchorage techniques	**Low** Score: 8
Xu and Xie[26]	2017	Systematic review and meta-analysis	14	450	Mini-implants	Conventional anchorage	8 RCTs 6 CCTs	December, 1966 to March, 2016	Angle Orthodontist	Mini-implant anchorage was more effective in retracting the anterior teeth, produced less anchorage loss, and had a greater effect on SN-MP for the high-angle patients than did conventional anchorage	**Moderate** Score: 9
Alharbi et al.[30]	2018	Systematic review and meta-analysis	7 (6 for meta-analysis)	271	Miniscrews	Different types (TPA, headgear, banding the second molar and application of differential moments	RCTs	Up to March 16, 2018	Acta Odontologica Scandinavica	Miniscrews are more effective in preserving orthodontic anchorage than conventional appliances	**Moderate** Score: 14
Becker et al.[27]	2018	Systematic review and meta-analysis	12 (7 for meta-analysis)	393	Mini-implants	Different types (TPA, headgear, Nance button, lingual arch, mushroom loops, intrusion arch, banding the second molar,	9 RCTs 1 CCT 1 Cohort study	1992 to December 31, 2017	International Journal of Implant Dentistry	maximum anchorage en-masse retraction can be achieved by orthodontic mini-implants and direct anchorage	**Moderate** Score: 12

Author	Year	Study Design	No. of Studies	No. of Participants	Intervention anchorage	Comparison anchorage	Type of Studies	Period of Search	Journal	Main Outcomes	Quality of Evidence
						application of different moments,					
Khlef et al.[28]	2018	Systematic review and meta-analysis	4	150	En-masse retraction of the upper anterior teeth associated skeletal anchorage (mini-implant, miniplates, and C-tube)	Two-step retraction of the upper anterior associated with conventional anchorage	2 RCTs 2 CCTs	January, 1990 to April, 2018	Contemporary Clinical Dentistry	There is a very weak-to-moderate evidence that using skeletal anchorage devices with en-masse retraction would cause better posterior anchorage and incisors inclination, and greater anterior teeth retraction than using conventional anchorage with two-step retraction	**Moderate** Score: 14
Khlef et al.[29]	2019	Systematic review and meta-analysis	8 (5 for meta-analysis)	255	En-masse retraction of maxillary anterior teeth with skeletal anchorage	En-masse retraction of maxillary anterior teeth with conventional or no anchorage system and without any approach for tooth movement acceleration	6 RCTs 2 CCTs	January, 1990 to April, 2018	The Journal of Contemporary Dental Practice	There is weak to moderate evidence that using skeletal anchorage devices would lead to better posterior anchorage than using conventional anchorage	**Moderate** Score: 13
Liu et al.[31]	2020	Systematic review and meta-analysis	12	Not reported	Mini-implants	Different types (TPA, headgear, Nance button, lingual arch)	4 RCTs 3 Prospective controlled trials 5 Retrospective studies	Up to July, 2018	The Journal of Evidence-Based Dental Practice	Mini-implants seem to be more effective than the conventional anchorage devices in terms of minimizing	**High** Score: 13

Author	Year	Study Design	No. of Studies	No. of Participants	Intervention anchorage	Comparison anchorage	Type of Studies	Period of Search	Journal	Main Outcomes	Quality of Evidence
										unintended mesial movement of molars with maximum retraction of anterior teeth	
Tian et al.[32]	2020	Systematic review and meta-analysis	8	146	Miniscrew (during the first phase of the two-step retraction technique)	Different types (TPA, lingual arch, and dental anchorage)	3 RCTs 5 CCTs	Up to June 30, 2019	BMC Oral Health	Anchorage with miniscrew is more efficient than conventional anchorage during canine retraction	**Moderate** Score: 12

RCT: Randomized controlled trial, CCT: Controlled clinical trial, TPA: Transpalatal arch
Score of each review represents the number of "YES" answer in the AMSTAR2 checklist. However, this may not always reflect the quality as not all the items have the same weight.

Table 2: A Measurement Tool to Assess Systematic Reviews (AMSTAR 2) items

AMSTAR 2 Items	Meeting the criteria		
	Yes	**Partial Yes**	**No**
1. Did the research questions and inclusion criteria for the review include the components of PICO?	13		1
2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	8		6
3. Did the review authors explain their selection of the study designs for inclusion in the review?	14		
4. Did the review authors use a comprehensive literature search strategy?	6	7	1
5. Did the review authors perform study selection in duplicate?	14		
6. Did the review authors perform data extraction in duplicate?	14		
7. Did the review authors provide a list of excluded studies and justify the exclusions?	7	4	3
8. Did the review authors describe the included studies in adequate detail?	5	7	2
9. Did the review authors use a satisfactory technique for assessing the risk of bias in individual studies that were included in the review?	12	1	1
10. Did the review authors report on the sources of funding for the studies included in the review?	1		13
11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?	12		
12. If meta-analysis was performed, did the review authors assess the potential impact of risk of bias in individual studies on the results of the meta-analysis or other evidence synthesis?	11		1
13. Did the review authors account for risk of bias in individual studies when interpreting/ discussing the results of the review?	11		3

14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	12		2
15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	5		7
16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	8		6

Table 3: Level of evidence according to the AMSTAR 2 assessment tool

Level	Description
High	No or one non-critical weakness: the systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest.
Moderate	More than one non-critical weakness*: the systematic review has more than one weakness but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review.
Low	One critical flaw with or without non-critical weaknesses: the review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest.
Critically low	More than one critical flaw with or without non-critical weaknesses: the review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies.

*Multiple non-critical weaknesses may diminish confidence in the review and it may be appropriate to move the overall appraisal down from moderate to low confidence

Table 4: The results of the included systematic reviews in terms of anchorage methods and their influence on different factors

Amount of anchorage loss	
Buccal miniscrews vs conventional anchorage	▪ The mean difference of anchorage loss between miniscrews and conventional anchorage was -2.4 mm (95% CI: -2.9 to -1.8 mm)[21], -1.68 mm (95% CI: -2.27 to -1.09 mm)[22], -1.87 mm (95% CI: -2.21 to -1.53 mm)[23], -2.01 mm (95% CI: -2.45 to -1.58 mm)[26], -1.94 mm (95% CI: -3.46 to -0.42 mm)[30] ▪ Miniscrews were more effective for anchorage reinforcement than conventional anchorage methods in the mandible (mean difference -3.1 mm) than in the maxilla (mean difference -2.2 mm) and in adults than in young patients.[21] ▪ There was greater but non-statistically significant distal molar tipping with miniscrews when compared to conventional anchorage methods.[23] On the other hand, another meta-analysis[32] reported (from one study) that mesial tipping of maxillary and mandibular molars was significantly greater with the conventional anchorage methods than with miniscrews by 2.15˚ and 2.5˚, respectively. ▪ Anchorage loss was significantly lower in the miniscrew group when compared to TPA alone (mean difference -2.09 mm, 95% CI: -2.38 to -1.8 mm), TPA and headgear (mean difference -1.71 mm, 95% CI: -2.6 to -0.81 mm), and TPA and utility arch (mean difference -0.63 mm, 95% CI: -1.15 to -0.12 mm).[24] ▪ Miniscrews are either associated with no anchorage loss or with "anchorage gain" in contrast to the conventional anchorage methods (mainly TPA) and the significant mean difference was -2.79 mm (95% CI: -3.56 to -2.03 mm).[27] ▪ Miniscrews achieved maximum anchorage with significantly lesser mesial movement of first molar by -1.48 mm (95% CI: -2.25 to -0.72 mm) than conventional anchorage. This difference between the two methods was greater for patients aged less than 18 years (-2.36 mm, 95% CI: -4.18 to -0.53 mm) than those older than 18 years (-1.2 mm, 95% CI: -2.01 to -0.39 mm).[31]
Mid-palatal implant vs conventional anchorage	▪ Anchorage loss was greater with conventional anchorage compared to mid-palatal implants (mean difference -1.02 mm, 95% CI: -2.31 to 0.26 mm) and alveolar miniscrews (mean difference -2.17 mm, 95% CI: -2.58 to -1.77 mm).[22]
miniscrews vs miniscrews	▪ Anchorage loss with miniscrews was significantly lower in the following situations: when the miniscrews were placed in the mandible than in the maxilla (-0.6 mm vs. 0.2 mm), when the miniscrews were placed between the second premolar and first molar than palatally (-0.2 mm vs. 1.3 mm), when two miniscrews were placed rather than one (-0.2 mm vs. 1.3 mm), when miniscrews were loaded directly rather than indirectly (-0.2 mm vs. 0.8 mm), and when there was absence of pre-treatment space loss rather than existing loss (-0.4 mm vs. 0.9 mm).[21] ▪ Anchorage loss was in favor of dual miniscrews than single miniscrews (mean difference -1.62 mm, 95% CI: -2.26 to -0.98 mm).[22] ▪ Indirect anchorage with miniscrews was associated with greater anchorage loss than that of direct anchorage with miniscrews but still lower than that of the conventional anchorage methods.[27]
En-masse vs two-step retraction	▪ *En-masse retraction" with miniscrews and "two-step retraction" with conventional anchorage methods:* the maxillary first molar was moved distally with miniscrews and moved mesially with conventional anchorage with a significant mean difference of -3.03 mm (95% CI: -3.65 to -2.42 mm).[28] ▪ *En-masse retraction with miniscrews and conventional anchorage:* There was significantly greater anchorage loss with conventional anchorage (mean difference -1.17 mm, 95% CI: -1.81 to -0.53 mm).[29] ▪ *Two-step retraction technique:* anchorage preservation was greater with miniscrews than with the conventional anchorage methods both in the maxilla (mean difference -1.56 mm, 95% CI: -1.98 to -1.14 mm) and the mandible (mean difference -1.62 mm, 95% CI: -2.01 to -1.24 mm) with an overall greater effect of the direct anchorage method.[32]

Anchorage method and vertical change of maxillary first molar
▪ Miniscrews were associated with less vertical anchorage loss (extrusion) compared to the conventional anchorage (mean difference -1.76 mm, 95% CI: -2.56 to -0.97 mm[27]; -0.61 mm, 95% CI: -1.08 to -0.15 mm[28]; and -1.26 mm, 95% CI: -1.86 to -0.67 mm[29]) and in the majority of the studies, molar intrusion was associated with miniscrews. These differences were statistically significant. Similar results were also found but this was not statistically significantly different.[31]
Anchorage method and anterior teeth retraction
▪ There was statistically significantly greater incisor retraction in favour of miniscrews when compared to conventional anchorage methods. The difference was 1.37 mm (95% CI: 0.83 to 1.91 mm)[23],1.5 mm (95% CI: 1.17 to 1.84 mm)[26], 0.46 mm (95% CI: 0.04 to 0.87 mm) with better incisor inclinations (mean difference 0.74˚, 95% CI: 0.25˚ to 1.23˚)[28], and 0.47 mm (95% CI: 0.07 to 0.87 mm) (however, this significance was only for patients older than 18 years)[31]. ▪ Incisor tipping was slightly greater but the difference was not statistically significant with miniscrews[23], while the reverse was found with another review[26] but again with no significant difference. ▪ When both anchorage methods were used with en-masse retraction, no significant differences in incisor retraction and incisor inclination were reported.[29] ▪ There was significantly greater canine retraction in the two-step retraction technique with the use of miniscrews than with conventional anchorage methods both in the maxilla (mean difference 0.43 mm, 95% CI: 0.16 to 0.69) and the mandible (mean difference 0.26 mm, 95% CI: 0.02 to 0.49). Distal tipping of the canines was also greater in the miniscrew group than in conventional anchorage group in both arches by about 3˚, however this difference was not statistically significant.[32]
Anchorage method and vertical change of maxillary incisors
▪ Incisors were intruded with miniscrews and extruded with conventional anchorage methods with a significant mean difference of 2.48 mm (95% CI: 1.77 to 3.19 mm)[28] and 1.87 mm (95% CI: 0.09 to 3.65 mm)[29]. Similar results were found with another review but with no significant difference.[31]
Anchorage method and skeletal changes
▪ Miniscrews as compared to conventional anchorage methods did not show a significant difference in SNA angle, but there was a significant reduction in SN-MP angle with miniscrews by 1.12˚ (95% CI: 0.03˚ to 2.21˚).[26] ▪ *En-masse retraction with miniscrews and two-step retraction with conventional anchorage:* no significant differences in terms of SNA, SNB, ANB, and SN-MP angles.[28] ▪ *En-masse retraction with miniscrews and conventional anchorage methods:* no significant differences of SNA, SNB, and ANB, while, SN-MP was significantly increased with conventional anchorage (mean difference 1.12˚).
Anchorage method and soft tissue changes
▪ The nasolabial angle increased with miniscrews significantly by 3.52˚ (95% CI: 1.17˚ to 5.87˚)[26] and 4.73˚ (95% CI: 1.30˚ to 8.17˚)[28]. ▪ Two reviews found a significant reduction of upper lip with miniscrews.[26,29] The reduction of upper lip to E-line (0.73 mm, 95% CI: 0.28 to 1.17 mm) with miniscrews rather than conventional anchorage methods.[26] Another review[28] found that there was a greater but not statistically significant reduction of upper lip to E-line in miniscrew group. ▪ There was a significantly greater lower lip to E-line reduction with miniscrews compared to conventional anchorage methods (0.95 mm, 95% CI: 0.21 to 1.69 mm).[28] While, no significant difference in lower lip was reported in different review.[29] ▪ There was a tendency to a decrease in the facial convexity angle with skeletal anchorage methods than with conventional anchorage methods.[26,28,29]
Anchorage method and duration of space closure
▪ The duration of space closure was not significantly shorter with surgical anchorage than with conventional anchorage methods (the difference was only 12 days).[22]

▪ No significant difference in the duration of space closure between miniscrews and TPA groups.[30] ▪ Although the duration of space closure was not significantly different between single and dual miniscrews, the difference was 2.19 months (95% CI: -1.97 to 6.35 months) in favour of single miniscrews.[22]
Anchorage method and overall duration of treatment
▪ A non-significant reduction in the overall duration of treatment was found with surgical anchorage (miniscrews and mid-palatal implants) by 0.15 years (95% CI: -0.07 to 0.37 years) than that with conventional anchorage methods.[22] Using miniscrews also did not show a significant difference in the duration of treatment in comparison to TPA, Nance appliances, or headgear. Overall duration of treatment was shorter by 1.1 months (95% CI: -1.79 to 3.98 months) in favor of those treated using miniscrews for anchorage.[30] ▪ A similar finding was identified of no significant shorter duration of treatment with miniscrews than conventional anchorage when both were used with en-masse retraction (mean difference 1.15 months). [28,29] ▪ One meta-analysis found significant shorter treatment duration when using miniscrews by 4 months (95% CI: 2.21 to 5.79 months) than when using conventional anchorage.[23]
Anchorage method and number of appointments
▪ A Cochrane review found (from one study) that the mean number of appointments to complete the treatment was shorter by seven appointments for conventional anchorage.[22] ▪ A meta-analysis found (from one study) that number of appointments was shorter in the miniscrews group compared to headgear and Nance appliance groups by one and three appointments, respectively.[30]
Anchorage method and quality of treatment
▪ Using Peer Assessment Rating index (PAR index), the quality of treatment was better when using miniscrews as compared to headgear (statistically significant) and Nance appliance (not significantly different). But again, this was from one study and no meta-analysis was conducted.[30]
Anchorage method and patient perception
▪ Pain was reported to last slightly longer with the conventional anchorage than with the surgical anchorage. While, discomfort was highest on the evening after onplant surgery. Placement and removal of implants was also associated with pain perception. Pain perception was reported to be lower with pre-drilling than with self-drilling miniscrews.[22] ▪ Although a mild level of discomfort was reported during the insertion and removal of miniscrews and Nance appliances, the positive feedback, comfort, and compliance were greater with miniscrews than that with headgear and Nance appliance.[30]
Anchorage method and adverse effects
▪ Although no pooled data is available, a higher failure rate was found with conventional anchorage than with surgically-placed anchorage.[22] ▪ Albeit few and with minimal complications, the failure rate was greater with miniscrews than with conventional anchorage methods.[30] ▪ It was reported that the failure rate of miniscrews was about 10% which sometimes can be replaced immediately or it may lead to peri-implant inflammation that may need discontinuation of treatment until improving the oral hygiene.[27] ▪ The failure rate of miniscrews was reported to be about 12%.[21] ▪ Early and delayed loading of surgical anchorage have similar success rates.[22]