Review Article

Comparison of anchorage capacity between implant and headgear during anterior segment retraction

A Systematic Review

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ABSTRACT

Objective: To compare the anchorage effects of the implants and the headgear for patients with anterior teeth retraction in terms of incisor retraction, anchorage loss, inclination of maxillary incisors, positional change of maxillary basal bone, and treatment duration.

Materials and Methods: An electronic search for relative randomized controlled trials (RCTs) prospective and retrospective controlled trials was done through the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, Embase, Medline, and CNKI, regardless of language of study. Study selection, methodological quality assessment, and data extraction were performed by two reviewers independently. Meta-analysis was performed when possible; otherwise descriptive assessment was done.

Results: The search yielded 35 articles, of which eight met the inclusion criteria and were categorized into five groups according to types of intervention. For the midpalatal implant, the anchorage loss was much less than for the headgear group, with insignificant differences in terms of anterior teeth retraction, maxillary incisor inclination, positional change of basal bone, and treatment duration. For the mini-implant, greater anterior teeth retraction and less anchorage loss were demonstrated, with inconsistent results for the other measures. For the onplant, less anchorage loss was noted, with insignificant differences for the other measures.

Conclusions: 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. There were inconsistent results from the included studies in terms of maxillary incisor inclination, positional change of maxillary basal bone, and treatment duration. More qualified RCTs are required to provide clear recommendations. (*Angle Orthod.* 2011;81:915–922.)

KEY WORDS: Systematic review; Implant; Headgear; Anchorage

INTRODUCTION

The treatment of orthodontic patients with bimaxillary dental protrusion, Class II division 1 malocclusion, or anterior segment crowding usually demands

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extraction of maxillary (or bimaxillary) first/second premolars and anterior segment retraction.^{1–4} During anterior segment retraction, the force acting on the anterior teeth would generate a reciprocal force on the posterior teeth, with the same magnitude but opposite direction.⁵ This reactive force moves the posterior teeth forwardly, taking up a considerable proportion of the extraction space and obstructing anterior teeth retraction.^{6,7} Anchorage, defined as the ability to resist unwanted tooth movement,^{8,9} is of importance to guaranteeing the effectiveness of retraction. For anterior tooth retraction, which usually demands maximum anchorage, headgear and orthodontic implants are the two main types of anchorage source.¹⁰

At present, three orthodontic implant systems are commonly used for anterior teeth retraction: the midpalatal implant, the onplant, and the mini-implant. The midpalatal implant is placed near the midline of the

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palate and is connected with a transpalatal arch (TPA) to the maxillary molar bands.¹ If there is insufficient bone mass to facilitate placement of the midpalatal implant, the onplant would be an alternative choice. Onplants are located subperiosteally and shaped like a titanium disk.¹ Both midpalatal implants and onplants are osseointegrated implants and cannot be loaded until after an integration period of 3 to 4 months. The mini-implants are immediately loadable implant devices characterized by a smaller size, a simpler surgical procedure, and better patient perceptions.^{11–15} Mini-implants are usually located on the buccal side of the alveolar bone between the maxillary or mandibular second premolars and the first molars, at the apical level.

In clinical practice, the orthodontists' concern is which anchorage type—the headgear or the implant would be more effective. Therefore, the aim of this review is to compare the anchorage effects of the implants and the headgear in terms of incisor retraction, anchorage loss, inclination of maxillary incisors, positional change of maxillary basal bone, and treatment duration.

MATERIALS AND METHODS

Search Strategy

An electronic literature search was done through the Cochrane Central Register of Controlled Trials (CEN-TRAL), PubMed, MEDLINE, EMBASE, and CNKI, regardless of the language of the study. Terms used in the search included orthodontic anchorage, implant, and headgear. Full texts of all potentially relevant articles were obtained from available sources on the Internet.

Selection Criteria

Two reviewers independently assessed the retrieved articles for eligibility, and any disagreement was resolved through discussion or through further independent assessment by a third reviewer. Studies not fulfilling the inclusion criteria were eliminated from further review.

Inclusion Criteria

The inclusion and exclusion criteria are as follows:

Type of study

-Published randomized controlled trials (RCTs), prospective and retrospective controlled trials.

Type of participant

 Patients with bimaxillary dental protrusion, Class II division 1 malocclusion, or anterior segment crowding, whose orthodontic treatment usually demands extraction of maxillary/bimaxillary premolars (mostly first premolars) and maximum anchorage during anterior segment retraction.

Type of intervention

-The experimental group and control group used implants and headgear as anchorage reinforcement, respectively, with variations in treatment details.

Type of outcome

-Lateral cephalogram measurements or three-dimensional digitizer analysis, which assessed the dental and skeletal movements.

Exclusion Criteria

- · Case reports, reviews, and letters.
- Articles focusing on the application of implants.
- Trials only evaluating the effects of headgear.
- Studies exploring measurement methods.
- Studies concerning other anchorage situations, such as molar distalization.
- Studies using molar anchorage or other conventional anchorage in the control group.
- Studies concerning intrusive effects.

Methodological Quality and Risk of Bias

A methodological quality assessment was performed according to the standards described in the *Cochrane Handbook for Systematic Reviews of Interventions* (version 4.2.6). Two reviewers evaluated the selected trials independently, and disagreements were resolved through discussion or consultation with a third reviewer.

The following four main criteria are evaluated as "yes," "no," or "unclear":

- 1. Was the method of randomization adequate?
- 2. Was the treatment allocation concealed?
- 3. Were outcome assessors blinded to intervention?
- 4. Was the withdrawal/dropout rate described and clearly explained?

A study was graded to have a low risk of bias if it yielded three or more "yes" answers to the four questions, moderate risk if it yielded two "yes" answers, and high risk if it yielded one "yes" answer or less. Another four methodological criteria were also assessed, as follows:

- 5. Was the sample size calculation reported?
- 6. Were the groups comparable at the beginning of treatment?
- 7. Were the inclusion/exclusion criteria clear?
- 8. Was the method of assessment valid and reproducible?



Figure 1. Flow diagram summarizing the literature search.

Data Extraction

Data were extracted by two reviewers independently and in duplicate using a customized data collection form, on the following items: author and year of publication; study design; number, age, gender, type of malocclusion, anchorage demand, and tooth extraction plan of participants; and anchorage devices.

Data Analysis

Included studies were classified into five groups based on types of intervention. Pooling of data and meta-analysis were performed using Review Manager 5.01. Statistical heterogeneity within or between groups was assessed by the Cochrane's test. For potentially combinable data from studies of different groups, subgroup analysis was performed. If subgroup analysis failed, meta-analysis was carried out within each group. Outcomes unable to be synthesized through meta-analysis were descriptively assessed.

In this systematic review, evaluation of anchorage effects mainly includes four aspects, as follows: (1) Incisor retraction and anchorage loss; (2) Inclination of maxillary incisors; (3) Positional change of maxillary basal bone; and (4) Treatment duration. Not all of these aspects were reported in all included studies.

RESULTS

Description and Classification of Included Studies

The search strategy yielded 35 articles, of which eight articles qualified based on the inclusion criteria. The flow of the selection process is demonstrated in Figure 1. Summary details of included studies are given in Table 1. According to types of intervention, the included eight articles were categorized into five groups, as shown in Table 2. One article¹ offered a comparison of four anchorage types—the onplant, the midpalatal implant, the headgear, and the TPA—and therefore was included into both group 1 and group 5.

Methodological Quality of Included Studies

Of the eight included studies, the risk of bias was low in two studies,^{1,16} medium in two studies,^{12,17} and high in four studies.^{3,4,11,18} The methodological quality assessment is detailed in Table 3.

Effects of Interventions

Group 1: Midpalatal implant vs headgear. Two articles were categorized into this group.

Incisor retraction and anchorage loss. Both studies^{1,16} reported the anteroposterior movement of maxillary incisors (IsSu-OLP, the distance of the incisal edge of the maxillary central incisor perpendicular to the occlusal line perpendiculare [OLP]) and molars (Sm-OLP, the distance of the mesial contact point of the maxillary first permanent molar perpendicular to OLP) on cephalograms from pretreatment to the end of space closure. Meta-analysis was done, the Forest plot is shown in Figures 2-3. For IsSu-OLP, the weighted mean difference (WMD) 95% confidence interval (95% CI) between the midpalatal implant group and the headgear group was -0.33 mm (-1.47, 0.81), implying a trend of larger retraction for maxillary incisors, with no statistical significance (P = .57). For Sm-OLP, the WMD (95% CI) was -1.34 mm (-2.02, -0.67) (P < .0001), indicating significantly less mesial movement of the maxillary permanent molars in the midpalatal implant group. Therefore, the much stronger anchorage capacity of midpalatal implants is indicated.

Incisor retraction/anchorage loss ratio. Benson et al.¹⁶ reported the ratio of incisor retraction to anchorage loss to be 2.3 and 1.2 for the midpalatal implant group and the headgear group, respectively, while Feldmann and Bondemark¹ claimed much higher ratios of 50 and 6.67, respectively. Both studies indicated more rigid anchorage to be associated with the midpalatal implant.

Positional change of maxillary basal bone. Cephalometric results of the anteroposterior movement of maxillary basal bone (A-OLP, the distance of the deepest point on the anterior contour of the maxilla perpendicular to OLP) were synthesized by metaanalysis, and a Forest plot is shown in Figure 4. Results from the two trials were inconsistent, and the overall effect carries no statistical significance. In the

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		Material				
Study ID		Age, Size, and Sex (male/				
Author (Year)	Study Design	female), Anchorage Unit	Malocclusion	Anchorage Demand	Tooth Extraction	
Benson et al. (2007)	Prospective randomized	12–39 y I: 7/18, midpalatal implant plus TPA II: 6/20, headgear	Class II division 1	Maximum	Premolars extracted when necessary	
Feldmann and Bondemark (2008)	Prospective randomized	I: 14.0 ± 1.53 y, $15/15$, onplant plus TPA II: 14.6 ± 1.99 y, $15/15$, midpalatal implant plus TPA III: 14.0 ± 1.72 y, $15/15$, headgear IV: 14.4 ± 1.65 y, $15/15$,	Large overjet or crowding	Moderate to maximum	2 maxillary premolars, in most cases also 2 mandibular premolars	
Ma et al. (2008)	Prospective randomized	transpalatal bar 18–22 y I: 14/16, mini-implant II: 14/16, headgear	Bimaxillary anterior teeth protrusion	Maximum	All first premolars	
Huang and Han (2007)	Prospective randomized	I: average 15.4 y, 4/6, mini-implant II: average 14.8 y, 3/7, headnear	Crowding or anterior teeth protrusion	Maximum	All first premolars	
Qin and Mao (2008)	Retrospective	11–14 y I: 16, mini-implant II: 16, headgear	Class II division 1	Maximum	Maxillary first premolars; mandibular first/sec- ond premolars	
Kuroda et al. (2009)	Prospective	13–39 y I: 0/11, mini-implant II: 0/11, headgear plus TPA	Skeletal Class II jaw-based relationships	Maximum	Maxillary and mandibu- lar first or second premolars	
Yao et al. (2008)	Retrospective	Age unknown I: 2/20, mini-implant plus TPA II: 2/23, headgear plus TPA	Class II division 1 or Class I bimaxillary dentoalveolar protrusion	Maximum	Maxillary first premolars; mandibular premolars extracted when nec- essary	
Lai et al. (2008)	Retrospective	Age unknown I: 25.1 \pm 4.7 y, 1/14, miniscrew plus TPA II: 24.1 \pm 3.2 y, 2/7, miniplate plus TPA III: 21.7 \pm 2.5 y, 0/16, headgear plus TPA	Class II division 1 or Class I bimaxillary dentoalveolar protrusion	Maximum	Maxillary first premolars	

Table 1. Characteristics of Included Studies^a

^a TPA indicates transpalatal arch.

study of Benson et al.,¹⁶ point A moved posteriorly in the midpalatal implant group, but anteriorly in the headgear group. In the study of Feldmann and Bondemark,¹ both anchorage groups showed anterior movement of point A.

Treatment duration. Both studies^{1,16} reported no significant difference in treatment duration between the two anchorage groups.

Group 2: Mini-implant vs headgear. Three articles were categorized into this group.

Incisor retraction and anchorage loss. For maxillary incisors, all three studies demonstrated significantly greater retraction with mini-implants than with headgear. For maxillary molars, two studies^{17,18} reported significantly less mesial movement in the mini-implant group, and information was absent in the other study.¹² However, the results from all three trials

demonstrated that mini-implants provided better an-chorage.

Inclination of incisors. Two studies^{12,17} in this group and one study³ in group 4 reported the inclination of maxillary incisors (<u>1</u>-SN, the axial inclination of the maxillary central incisor to the SN plane), and the outcomes were synthesized through subgroup analysis. A Forest plot is demonstrated in Figure 5. As shown in Figure 5, results from the two groups were inconsistent, and the overall effect carries no statistical significance. The outcomes of the two studies^{12,17} in group 2 indicated a trend toward less palatal inclination of the maxillary incisors in the minimplant group, while the results from the study³ in group 4 implied an opposite situation.

Positional change of maxillary basal bone. Two articles^{12,18} reported a remarkable decrease in the SNA

	Ancho	rage Unit	Articles			
Group	Implant Group	Headgear Group	Author (Year)	Title		
1	Midpalatal implant plus TPA	Headgear	Benson et al. (2007)	Midpalatal implants vs headgear for orthodontic anchorage—a randomized clinical trial: cepha- lometric results		
			Feldmann and Bondemark (2008)	Anchorage capacity of osseointegrated and con- ventional anchorage systems: a randomized controlled trial		
2	Mini-implant	Headgear	Ma et al. (2008)	Comparative evaluation of micro-implant and headgear anchorage used with a pre-adjusted appliance system		
			Huang and Han (2007)	Comparison of clinical effects between screw- implant and extra-force as anchorage		
			Qin and Mao (2008)	Micro implant versus extraoral J hook for Angle Class II division 1 malocclusion		
3	Mini-implant	Headgear plus TPA	Kuroda et al. (2009)	Class II malocclusion treated with miniscrew anchorage: comparison with traditional ortho- dontic mechanics		
4	Mini-implant plus TPA	Headgear plus TPA	Yao et al. (2008)	Comparison of treatment outcomes between skeletal anchorage and extraoral anchorage in adults with maxillary dentoalveolar protrusion		
			Lai et al. (2008)	Three-dimensional dental model analysis of treat- ment outcomes for protrusive maxillary denti- tion: comparison of headgear, miniscrew, and miniplate skeletal anchorage		
5	Onplant plus TPA	Headgear	Feldmann and Bondemark (2008)	Anchorage capacity of osseointegrated and con- ventional anchorage systems: a randomized controlled trial		

Table 2. Groups of Included Articles^a

^a TPA indicates transpalatal arch.

angle, with no intergroup discrepancy, indicating that maxillary basal bone moved posteriorly with both anchorage devices. Meta-analysis was impossible because of an absence of data in one study.¹⁸

Treatment duration. One study¹⁷ mentioned a significantly shorter treatment duration in the miniimplant group (P < .01).

Group 3: Mini-implant + TPA vs headgear + TPA. Two trials^{3,11} were included in this group. The outcomes of the two trials were incomparable, because the results of the two studies were based on cephalometric measurement and three-dimensional digitizer analysis of study casts, respectively.^{19,20} In the study of Lai et al.,¹¹ the subjects were divided into three anchorage groups: miniplate, miniscrew, and headgear groups.

Incisor retraction and anchorage loss. The subjects in the two trials showed significantly greater retraction of the maxillary incisors and less mesial movement of the maxillary molars. Lai et al.¹¹ mentioned no significant differences between the two skeletal anchorage groups.

Inclination of maxillary incisors. For mini-implant versus headgear meta-analysis results in <u>1</u>-SN, see Figure 5.

Positional change of maxillary basal bone. Yao et al.³ reported that the maxillary basal bone of orthodontic patients showed an average of posterior

Table 3.	Methodological	Quality of	Selected	I riais"	
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	Question No.								
Study ID (Year)	1	2	3	4	5	6	7	8	Risk of Bias
Benson et al. (2007)	Yes	Yes	Yes	Yes	No	Unclear	Yes	Yes	Low
Feldmann and Bondemark (2008)	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Low
Ma et al. (2008)	Yes	No	Yes	No	No	Yes	Yes	Yes	Medium
Huang and Han (2007)	Yes	Unclear	Unclear	Yes	No	Unclear	Yes	Yes	Medium
Qin and Mao (2008)	No	No	Unclear	Yes	No	Unclear	Yes	Yes	High
Kuroda et al. (2009)	Unclear	Unclear	Unclear	Unclear	No	Yes	Yes	Yes	High
Yao et al. (2008)	No	No	Unclear	No	No	Unclear	Yes	Yes	High
Lai et al. (2008)	No	No	Unclear	No	No	Unclear	Yes	Yes	High

^a Questions are listed in Section "Methodological Quality and Risk of Bias".



Figure 2. Midpalatal implant and transpalatal arch vs headgear for meta-analysis results in IsSu-OLP.

movement in the headgear group but of anterior movement in the mini-implant group, and the difference between the two groups was statistically significant.

Treatment duration. Lai et al.¹¹ mentioned a significantly shorter treatment duration in the miniscrew group than the headgear group (P < .001), but the difference between the miniplate group and the headgear group was insignificant.

Group 4: Mini-implant vs headgear + TPA. One study ⁴ was identified in this group. Overjet reduction in the two anchorage groups was equal, but there was greater incisor retraction and less anchorage loss in the mini-implant group. As for inclination of the maxillary incisors and movement of maxillary basal bone, the difference between the two anchorage groups was insignificant.

Group 5: Onplant vs headgear. One study¹ identified in group 1 was also classified into this group. There was no significant difference for maxillary incisor retraction and inclination, but mesial movement of the maxillary molars was much less in the onplant group than in the headgear group. The movement of maxillary basal bone and treatment duration revealed insignificant differences between groups.

A comparison between the two implant groups (onplant and midpalatal implant) was also made, and cephalometric results demonstrated no significant difference with regard to the four measures.

DISCUSSION

Effects of Interventions

Incisor retraction and anchorage loss. All of the included studies reported less anchorage loss and

more anterior teeth retraction in the implant group than in the headgear group, except for the study of Feldmann and Bondemark,¹ which showed no significant difference between the two groups in terms of incisor retraction. Since the greater anchorage capacity of implants is confirmed, the incisor retraction in the implant groups is supposed to be greater. However, the extent of anterior teeth retraction depends not only on the capability of anchorage units but also on the treatment demand based on patients' specific conditions. In the study of Feldmann and Bondemark,¹ the study sample included patients with anterior segment crowding or excessive overjet and their demands for orthodontic anchorage ranged from moderate to maximum. For patients with anterior segment crowding, a considerable amount of extraction space is needed for relief of the crowding instead of for incisor retraction. Perhaps the results of incisor retraction in the study of Feldmann and Bondemark¹ could be attributed to the imbalanced distribution of the study sample in the two anchorage groups.

Labiolingual inclination of maxillary incisors. The results of the two trials^{12,18} in group 2 and the one trial³ in group 4 were contradictory, and none of these results carried statistical significance. To investigate this effect of the two anchorage types, more RCTs are demanded. A smaller reduction of the <u>1</u>-SN angle may indicate a larger proportion of translational movement.

Positional change of maxillary basal bone. In addition to the extent of anterior teeth retraction, anterior maxillary growth was also an important factor for the positional change of maxillary basal bone. Patients recruited at different ages had different growth potentials, and this may partly explain the inconsistent results in the included trials.^{1,3,12,16,18}



Figure 3. Midpalatal implant and transpalatal arch vs headgear for meta-analysis results in Sm-OLP.



Figure 4. Midpalatal implant and transpalatal arch vs headgear for meta-analysis results in A-OLP.

Treatment duration. The duration of orthodontic treatment seems to have little correlation with anchorage effectiveness, for most trials revealed no significant difference between the implant group and the headgear group. Factors affecting the treatment duration may include mandibular premolar extraction, the severity of the initial malocclusion, the patients' compliance, the skill of the operators, and the potential of periodontal tissues for tooth movement.

Heterogeneity of Included Studies

Heterogeneity of included studies mainly existed in the types of interventions and outcomes. Differences in types of intervention could hardly be avoided because they were based on treatment demands. However, differences in outcome measurements could be eliminated. For instance, most studies reported incisor retraction, but cephalometric measurements were based on different reference planes—the FH plane and the PP plane. Another example is that most cephalometric measurements were done at the beginning of treatment and at the end of space closure (T2), except in one study,¹ for which measurements were done at the beginning of space closure (T1). Considering the minimal anteroposterior movement of teeth during leveling and alignment phase, comparison between T1 and T2 is suggested to offer a more accurate reflection of anchorage capacity.

Advantages and Disadvantages of the Two Anchorage Types

In addition to anchorage capacity, the choice between implant and headgear should also include consideration of other advantages and disadvantages. One main problem with headgear is the dependence on patients' compliance that it required; compared with the consistent action of implants, headgear may not be worn all of the time for social reasons, and therefore the intermittent force application of headgear could account for part of the anchorage loss. Samuels²¹ reported on the safety risks associated with headgear, among which the most serious complication was ocular injury and sight loss. The side effects of implant anchorage mainly consist of soft and hard tissue infection, failure of osseointegration, and risk of damage to adjacent tooth roots.

CONCLUSIONS

• The existing evidence indicates that the skeletal anchorage of midpalatal implants, mini-implants, and onplants offer better alternatives to headgear, with less anchorage loss and more anterior teeth retraction.



Figure 5. Mini-implant vs headgear for meta-analysis results in 1-SN.

- There were no consistent results from the included studies in terms of incisor inclination, positional changes of basal bone, and treatment duration.
- More qualified RCTs are required to make reliable recommendations about the anchorage capacity of implants and headgear during anterior teeth retraction.

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