Review Article

Orthodontic Anchorage: A Systematic Review

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Abstract: The aim of this systematic review was to examine, in an evidence-based way, what kind of orthodontic anchorage systems/applications are evaluated and their effectiveness. A literature survey from the Pub Med and Cochrane databases covering the period from January 1966 to December 2004 was performed. Randomized controlled trials (RCT), prospective and retrospective controlled studies, and clinical trials comparing at least two anchorage situations were included. Two reviewers selected and extracted the data independently and also assessed the quality of the retrieved studies. The search strategy resulted in 494 articles, of which 14 met the inclusion criteria. Two main anchorage situations were identified: anchorage of molars during space closure after premolar extractions and anchorage loss in the incisor or premolar region (or both) during molar distalization. Because of contradictory results and the vast heterogeneity in study methods, the scientific evidence was too weak to evaluate anchorage efficiency during space closure. Intraoral molar distalization leads to anchorage loss in various amounts depending on the choice of distalization unit. Most of the studies had serious problems with small sample size, confounding factors, lack of method error analysis, and no blinding in measurements. To obtain reliable scientific evidence, controlled RCT's with sufficient sample sizes are needed to determine which anchorage system is the most effective in the respective anchorage situation. Further studies should also consider patient acceptance and cost analysis as well as implants as anchorage. (*Angle Orthod* 2006;76:493–501.)

Key Words: Orthodontic anchorage; Systematic review

INTRODUCTION

During orthodontic treatment the teeth are exposed to forces and moments, and these acting forces always generate reciprocal forces of the same magnitude but opposite in direction. To avoid unwanted tooth movements and maintain treatment success, these reciprocal forces must be diverted. Orthodontic anchorage, defined as the ability to resist these unwanted reactive tooth movements, can be provided by other teeth, by the palate, head, or neck, or implants in bone.[1–10]

To date, several studies have been published concerning different anchorage systems from the aspect of application, function, or effectiveness. However, it can be difficult for the practitioner to interpret the results and evidence presented in these studies because a variety of study designs, sample sizes, and research approaches exists. In view of this, and because evidence-based medicine has grown in importance,[11] a systematic review of the present knowledge seems desirable. Systematic reviews aim to locate, appraise, and synthesize the evidence from scientific clinical studies to provide informative answers to scientific questions by including a comprehensive summary of the available evidence.[12] This systematic review was undertaken to answer the following questions.

- What kind of orthodontic anchorage systems/applications are evaluated in an evidence-based manner, and how effective is the anchorage produced?
- Furthermore, a quality analysis of the methodological soundness of the selected studies was performed in this review.

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TABLE 1. Exclusion Criteria and Number of Excluded Articles in This Systematic Review

Exclusion Criteria	Number of Excluded Articles
Animal studies	65
Review articles and letters	27
Case reports and case series	153
Do not follow the objective of this review	92
Technical presentation of an anchorage system	93
In vitro studies	25
Surgical treatment or cleft lip and palate treatment (or both)	16
Papers written in a language other than English	9
Total number	480

MATERIALS AND METHODS

Search strategy

The strategy for undertaking this systematic review was mainly influenced by the National Health Service, NHS, Center for Reviews and Dissemination.[12] To identify all the studies that examined orthodontic anchorage systems and their effectiveness, a literature survey was done by applying the Medline database (Entrez Pub Med, www.ncbi.nim.nih.gov) and the Cochrane Collaboration Oral Health Group Database of Clinical Trials (www.cochrane.org). The survey covered the period from January 1966 to December 2004 and used the Mesh term (Medical Subject Heading) ''orthodontics'' and was crossed with a combination of the following term ''anchorage.''

Selection criteria

Human studies written in English were included. Randomized controlled trials (RCT), prospective and retrospective controlled studies, and clinical trials comparing at least two anchorage applications reporting quantitative data on the effects of different anchorage devices were selected. Case series, case reports, abstract papers, review articles, animal and in vitro studies, letters, and papers describing surgical procedures and cleft lip or palate treatment (or both) were not considered. All the exclusion criteria and the number of excluded articles are listed in detail in Table 1. The reference lists of the retrieved articles were also checked for additional studies. Two reviewers (Drs Feldmann and Bondemark) independently assessed all the articles with respect to the inclusion and exclusion criteria, and the Kappa score measuring the level of agreement was 0.94 (very good).[13] Any interexaminer conflicts were resolved by discussion to reach consensus.

Data collection and analysis

Data were extracted on the following items: author, year of publication, study design, material, sex and age, treatment time, anchorage unit used, ratio between anchorage loss and active movement. In addition, to document the methodological soundness of each article, a quality evaluation modified by the methods described by Antczak et al[14] and Jadad et al[15] was performed with respect to preestablished characteristics. The following eight variables were evaluated: study design (RCT = 3 points; prospective study = 1 point; retrospective study = 0 point); adequate sample size = 1 point; adequate selection description = 1 point; valid measurement methods = 1 point; use of method error analysis = 1 point; blinding in measurement = 1 point; adequate statistics provided = 1 point; confounders included in analysis = 1 point. In sum, of the eight variables, a study could maximally score 10 points and a study was categorized as low (0–5 points), medium (6–8 points), or high (9 or 10 points).

The data extraction and quality scoring from each article were assessed independently by two evaluators (Drs Feldmann and Bondemark) and without blinding. Interexaminer conflicts were resolved by discussion of each article to reach a consensus. The Kappa scores measuring levels of agreement between the two reviewers are shown in Table 2.

TABLE 2. Kappa Scores Measuring Levels of Agreement Between the Two Reviewers in Assessing Data Extraction and Quality Scores of the Included Articles[a]

	Kappa Value	Level of Agreement
Study design	0.97	Very good
Sample size	1.0	Very good
Selection description	1.0	Very good
Valid measurement methods	1.0	Very good
Method error analysis	0.75	Good
Blinding in measurements	1.0	Very good
Adequate statistic provided	0.72	Good
Confounding factors	0.77	Good
Judged quality standard	0.94	Very good

[a] Kappa values—0.20 = poor, 0.21–0.40 = fair, 0.41–0.6 = moderate, 0.61–0.8 = good, 0.81–1.0 = very good.

RESULTS

The search strategy resulted in 494 articles. All these articles were analyzed according to the inclu-

sion/exclusion criteria, and 14 articles[16–29] were qualified for the final analysis. The reasons for exclusion and the number of excluded articles are listed in Table 1. The excluded articles also contained 149 studies concerning different types of implants used to produce skeletal anchorage. However, because the implant articles were technical presentations, or case reports (or both), or small case-series, they did not qualify for the analysis. The two main anchorage situations found were anchorage of molars during space closure after premolar extractions and anchorage in the incisor and premolar region during distal movement of molars.

The effectiveness of anchorage of molars during space closure

Summarized data of the seven studies are listed in Table 3. Two studies were RCT,[24,29] one a prospective split-mouth randomization study,[19] one a prospective split-mouth comparative study,[18] and three were retrospective comparative studies.[16,17,25] Various techniques and auxiliary holding appliances were used for either active movement or anchorage (Table 3).

Using RCT methodology, Usmani et al[24] showed no difference in anchorage loss of molars during leveling in the upper jaw with or without laceback ligatures. Irvine et al,[29] on the other hand, demonstrated a significant larger anchorage loss when laceback ligatures were used for leveling in the lower jaw.

In a split-mouth randomized study, Lotzof et al[19] compared two bracket systems (Tip-Edge and A-Company straight wire) and found no significant difference between the two systems. Baker et al[16] found significant less anchorage loss with an edgewise technique using an auxiliary holding appliance compared with the Begg technique used with the differential force concept. However, according to the ratio anchorage loss/active movement, the difference between the groups was small. Hart et al[17] demonstrated possibilities to alter anchorage control with a differential moment technique according to the type of malocclusion and degree of crowding. They found that anchorage loss was significantly lower in cases with maximum anchorage need.

Dincer and Iscan[18] focused on space closure using a Gjessing retractor vs a reverse closing loop and found that the Gjessing retractor produced significantly less anchorage loss and also a shorter treatment time.

Geron et al[25] examined the relative contribution of five different factors to anchorage loss: extraction site (first vs second premolar), mechanics (labial vs lingual), age (growing vs nongrowing), crowding, and overjet. The authors concluded that anchorage loss is a multifactorial response where mechanics and crowding are considered to be primary factors. Significant less anchorage loss was found with the lingual appliance compared with labial appliances, and the initial crowding was inversely correlated to anchorage loss. Because active movement was not declared, the ratio anchorage loss/active movement was not possible to calculate.

The effectiveness of anchorage during distal movement of molars

The summarized data of the seven studies are listed in Table 4. The primary concern in all these studies was to demonstrate distal molar movement and secondarily to show anchorage loss. One study was an RCT,[23] two studies were prospective comparative studies,[22,26] one was a retrospective controlled study,[20] and three were retrospective comparative studies.[21,27,28]

In one study,[27] molar distalization was performed in the mandible, whereas in all other studies it was in the maxilla.

Mostly a Nance or a modified Nance appliance served as an anchorage unit during the intraoral distalization procedure, and different active units were used for molar movements (Table 4). The anchorage loss measured at the incisors or premolars varied from 0.2 to 2.2 mm, and the ratio anchorage loss/distal molar movement ranged from 0.2 to 0.8 mm.

Quality of the studies

A quality analysis of the 14 studies involved is summarized in Table 5. The research quality and methodological soundness were high in two studies,[24,29] medium in three studies,[20,21,23] and low in nine studies.[16–19,22,25–28] The most obvious shortcomings were retrospective study design with inadequate selection description and small sample sizes implying low power.

In all studies, the methods used to detect and analyze the anchorage loss and active tooth movements were valid and generally well known. However, nine studies[16,19,22–28] did not include a method error analysis, and only three[21,23,24] studies used blinding in measurements. Moreover, three studies[16,17,25] did not consider the risk for confounding factors (Table 5).

A majority of the studies used adequate statistical methods, but in one study,[21] nonparametric tests were used on interval level data. The choice of statistical methods was generally not explained.

DISCUSSION

Initially, three main anchorage situations were identified (1) anchorage of molars during space closure after premolar extractions, (2) anchorage loss in

TABLE 3. Summarized Data of Seven Studies Concerning Anchorage Loss During Space Closure After Premolar Extraction

Author (Year)	Study Design	Material Size, Sex, Age	Treatment Time	Active Unit/ Anchorage Unit	Outcome Measurements	Ratio (Anchorage Loss/Active Movement) Authors Conclusions
Baker (1972)	Retrospective comparative	Sex and age unknown I: 50 individuals, Edgewise technique II: 50 individuals, Begg technique	Unknown	Active unit: Not specified in detail Anchorage: I: Auxiliary holding appliance II: Differential force concept	Cephalometric analysis of upper molar and incisor position before and after treatment	I: 0.33 (1.5/4.5 mm) II: 0.38 (2.7/7.1 mm) Significantly less anchorage loss with edgewise technique using auxiliary holding appliances
Hart et al (1992)	Retrospective comparative	17 females (10.5–41.4 y) and 13 male (8.4–15.0 y) IA: 10 individuals Angle Class I, maximum anchorage need IB: 7 individuals Angle Class I, moderate/minimum anchorage need IIA: 8 individuals Angle Class II maximum anchorage need IIB: 5 individuals, Angle Class II, moderate/minimum anchorage need	1.6–7.7 y	Active unit: Space-closure with power chain Anchorage: Differential moment technique	Cephalometric analysis of upper molar and incisor position before and after treatment	IA: 0.11 (0.6/5.4 mm) IB: 1.71 (3.25/1.9 mm) IIA: 0.04 (0.28/6.8 mm) IIB: 0.41 (2.3/5.6 mm) Differential moment concept as anchorage can achieve different control according to type of malocclusion and degree of crowding.
Dincer and Iscan (1994)	Prospective comparative ''split mouth''	Sex unknown I, II: 12 individuals with upper canine retraction (11.8–19.8 y) III, IV: 8 individuals with lower canine retraction (13.6–16.8 y)	I: 7.8 mo II: 6.3 mo III: 7.8 mo IV: 6.0 mo	Active unit: I, III: Reverse closing loop II, IV: Gjessing retraction arch Anchorage: No auxiliary anchorage unit present	Cephalometric analysis of molar and canine position before and after canine retraction	I: 0.63 (2.5/4.0 mm) II: 0.34 (1.6/4.7 mm) III: 0.48 (1.3/2.7 mm) IV: 0.32 (1.3/4.1 mm) Significantly less anchorage loss and treatment time with the Gjessing retractor
Lotzof et al (1996)	Prospective ''Split mouth randomization''	Seven females 13 y Five males 14 y I: 12 individuals Tip-Edge brackets II: 12 individuals A-company straight wire brackets	I: 10.7 wk II: 11.7 wk	Active unit: Canine retraction with elastic chains Anchorage: No auxiliary anchorage unit present	Analysis of upper molar and canine position measured on study casts before and after canine retraction	I: 0.30 (1.7/5.7 mm) II: 0.41 (2.3/5.6 mm) No significant difference in anchorage loss between the two types of bracket systems
Usmani et al (2002)	Randomized controlled clinical trial	13 males and 22 females (13.7 y $\pm$ 1.8) I: 16 individuals II: 19 individuals	Unknown	Active unit: I: Levelling with laceback ligatures II: Levelling without laceback ligatures	Analysis of upper molar and incisor position measured on study casts before and after levelling	I: 0.98 (0.49/0.5 mm) II: -1.38 (0.5/-0.36 mm) No significant difference in anchorage loss with or without lacebacks

TABLE 3. Continued

Author (Year)	Study Design	Material Size, Sex, Age	Treatment Time	Active Unit/ Anchorage Unit	Outcome Measurements	Ratio (Anchorage Loss/Active Movement) Authors Conclusions
Geron et al (2003)	Retrospective comparative	I: 12 individuals (24.8 y ± 5.6) Nongrowing subjects, maxillary first premolar extraction, lingual appliance II: 13 individuals (24.4 y ± 6) Nongrowing subjects, maxillary second premolar extraction, lingual appliance III: 20 individuals (20.1 y ± 5.4) Nongrowing subjects, maxillary first premolar extraction, labial appliance IV: 42 individuals (12.6 y ± 2) Growing subjects, maxillary first premolar extraction, labial appliance	Unknown	Active unit: I, II: Space closure with elastic chains III, IV: Space closure with sliding mechanics and Bull-loops Anchorage: I, II: Class II elastics and bonding of second molars III, IV: Headgear and Class II elastics	Analysis of upper molar position from measurements on cephalograms before and after treatment	Active movement not declared Anchorage loss: I = 1.8 mm II = 2.4 mm III = 3.0 mm IV = 3.5 mm Significantly less anchorage loss with the lingual appliance. Initial crowding was indirect correlated to anchorage loss
Irvine et al (2004)	Randomized controlled clinical trial	62 individuals 13.7 y randomized into two groups I: 18 females, 12 males II: 18 females, 14 males	I, II: 6 mo	Active unit: I: Levelling with laceback ligature II: Levelling without laceback ligature Anchorage: I, II: No auxillary anchorage unit present	Cephalometric analysis of molar and incisor position before and after levelling	I: 1.41 (0.75/0.53 mm) II: −0.18 (−0.08/ 0.44 mm) Significantly larger anchorage loss with lacebacks

the incisor or premolar region (or both) during distal movement of molars, and (3) appliances that used implants, miniscrews, or similar techniques to produce skeletal anchorage. However, only case reports and small case series, albeit with promising results, were found regarding skeletal anchorage. It is well known that case series and case reports give very low scientific evidence, and this is the reason why these studies were excluded in this systematic review. Moreover, a considerable number of in vitro and animal studies were found. Also, these studies were excluded because it is difficult and often not possible to extrapolate the result of animal and in vitro studies to humans.

The kappa scores measuring levels of agreement between the two reviewers in assessing data extraction and quality scores of the included articles were in the range of good to very good, and thus indicated that the results were reliable.

The effectiveness of anchorage of molars during space closure

The seven studies[16–19,24,25,29] showed a vast heterogeneity, which means that it was difficult to combine data and draw any consistent conclusions from these studies. For example, two RCT studies[24,29] examined anchorage loss with or without laceback ligatures but the results were contradictory, ie, no significant difference in anchorage loss with or without laceback ligatures[24] vs less anchorage loss without ligatures.[29] Conceivable explanations for the difference in results were forces on different anchorage teeth (maxillary vs mandibular molars), sample size discrepancy, and different

TABLE 4. Summarized Data of Seven Studies Concerning Anchorage Loss During Molar Distalization

Author (Year)	Study Design	Material Size, Sex, Age	Treatment Time/ Observation Time	Distalizing Unit/ Anchorage	Outcome Measurements	Ratio Authors Conclusions
Ferro et al (2000)	Retrospective controlled clinical trial	I: 43 females, 67 males 10 y II: 52 females, 48 males 10 y	I: 12 mo (6–18) II: 13 mo	I: Cetlin plate and cervical headgear/Cetlin plate II: Untreated control group	Cephalometric analysis of upper incisor and first molar position	I: 1.02 (2.3/2.2 mm) II: −1.09 (1.5/−1.4 mm) The Cetlin method is reliable for molar distalization but 81% of the cases show anchorage loss
Bondemark (2000)	Retrospective comparative	I: 21 females 14.4 y II: 21 females 13.9 y	I: 6.5 mo II: 5.8 mo	I: NiTi-coils/Nance appliance II: Magnets/Nance appliance	Cephalometric analysis of upper incisor and first molar position	I: 0.6 (1.5/2.5 mm) II: 0.69 (1.9/2.6 mm) No significant difference in anchorage loss between the two groups
Kinzinger et al (2000)	Prospective comparative	29 females and 21 males 11.2 y: I: 24 individuals with deciduous molars as anchorage II: 26 individuals with premolars as anchorage	I: 23 wk II: 21.9 wk	I, II: Modified pendulum/Nance appliance	Cephalometric analysis of upper incisor and first molar position	I: 0.83 (1.0/2.9 mm) II: 0.40 (1.1/2.8 mm) No significant difference in anchorage loss when dediduous or permanent premolars served as anchorage for the modified Pendulum
Paul et al (2002)	Randomized controlled clinical trial	16 females and seven males I: 12 individuals 13.5 y II: 11 individuals 14.8 y	I, II: 6 mo	I: Upper removable appliance II: Jones jig/Nance appliance	Analysis of upper premolar and first molar position measured on study casts	I: 0.14 (0.18/1.3 mm) II: 0.15 (0.18/1.17 mm) No significant difference in anchorage loss between the two groups
Kinzinger et al (2003)	Prospective comparative	I: Four females, six males 9.5 y (mixed dentition) II: seven females, three males 12.3 y (permanent dentition)	I, II: 20 wk	I, II: Pendulum in the maxilla and and lingual arch in the mandible/ Nance appliance and lingual arch appliance	Cephalometric analysis of incisor and first molar position	I: 0.28 (1.1/4.0 mm) II: 0.55 (1.6/2.9 mm) No significant difference in anchorage loss between the two groups
Kinzinger et al (2004)	Retrospective comparative	25 females, 11 males 12.4 y Were divided into three groups I: 18 individuals Second molar not erupted II: 15 individuals Second molar erupted III: 3 individuals Third molar germectomy completed	I: 18.4 wk II: 25.5 wk III: 24 wk	Pendulum/Modified Nance appliance	Cephalometric analysis of upper incisor and first molar position	I: 0.30 (1.0/3.1 mm) II: 0.31 (1.0/3.2 mm) III: 0.83 (2.2/2.7 mm) The best time to start therapy with a pendulum appliance is before the eruption of second molars. No significant differences are shown
Kinzinger et al (2004)	Retrospective comparative	I: seven individuals 14.3 y II: seven individuals 12.3 y III: six individuals 12.2 y	I: 12.5 wk II: 14.5 wk III: 22.6 wk	Lingual arch appliance/ I: Lingual arch appliance II: Lingual arch with sectional archwire III: Lingual arch with sectional archwire and lip bumper	Analysis of lower incisor and first molar position measured on study casts	I: 0.79 (2.6/3.3 mm) II: 0.21 (0.7/3.3 mm) III: 0.21 (0.7/3.3 mm) Significantly less anchorage loss in group II and III

TABLE 5. Quality Evaluation of the 14 Involved Studies

Author (Year)	Study Design	Sample Size	Selection Description	Valid Measurement Methods	Method Error Analysis	Blinding in Measurements	Adequate Statistic Provided	Confounding Factors	Judged Quality Standard
Baker (1972)	Retrospective comparative	Adequate	Inadequate	Yes	No	No	Yes	Yes, different anchorage auxiliaries used in group	Low
Hart et al (1992)	Retrospective comparative	Inadequate	Adequate	Yes	Yes	No	Yes	Yes, range between pretreatment and posttreatment cephalograms extremely long	Low
Dincer and Iscan (1994)	Prospective comparative ''split mouth''	Inadequate	Partly inadequate	Yes	Yes	No	Yes	No	Low
Lotzof et al (1996)	Prospective comparative with a split-mouth randomization	Inadequate	Adequate	Yes	No	No	Yes	No	Low
Perro et al (2000)	Retrospective controlled	Adequate	Adequate	Yes	Yes	No	Yes	No	Medium
Bondemark (2000)	Retrospective comparative	Adequate	Adequate	Yes	Yes	Yes	Yes	No	Medium
Kinzinger et al (2000)	Prospective comparative	Adequate	Adequate	Yes	No	No	Uncertain	No	Low
Paul et al (2002)	Randomized controlled clinical trial	Inadequate	Partly inadequate	Yes	No	Yes	Yes	No	Medium
Usmani et al (2002)	Randomized controlled clinical trial	Adequate	Adequate	Yes	No	Yes	Yes	No	High
Geron et al (2003)	Retrospective comparative	Partly inadequate	Adequate	Yes	No	No	Yes	Yes, different anchorage in different techniques	Low
Kinzinger et al (2003)	Prospective comparative	Inadequate	Partly inadequate	Yes	No	No	Yes	No	Low
Kinzinger et al (2004)	Retrospective comparative	Partly inadequate	Inadequate	Yes	No	No	Yes	No	Low
Kinzinger et al (2004)	Retrospective comparative	Inadequate	Inadequate	Yes	No	No	Yes	No	Low
Irvine et al (2004)	Randomized controlled clinical trial	Adequate	Adequate	Yes	Yes	No	Yes	No	High

measurement methods. Irvine et al[29] performed the measurements on lateral cephalograms, whereas Usmani et al[24] used study casts. It has been claimed that measurements on study casts and cephalograms are not comparable.[22,25]

The five other studies,[16–19,25] all had unique questions and aims and although the ratio of anchorage loss and active tooth movement was possible to calculate in four of these studies, the inconsistency in the methods made comparisons invalid. It is obvious that further studies are needed regarding the effectiveness of anchorage as well as which modality is the most effective during space closure.

The effectiveness of anchorage during distal movement of molars

When first maxillary molars are moved distally, different opinions exist concerning the influence of second molars on both the active tooth movement and the

anchorage loss. Several authors have stated that distal movement of the first maxillary molars is dependent on the stage of eruption of the second maxillary molar,[30,31] whereas other studies have shown that the second molars have limited effect.[32,33] It can be pointed out that only five of the seven retrieved articles declared the eruption status of the second molars.

Only one study[20] used an untreated control group, and, during the observation period of 13 months, maxillary growth effects with anterior displacement of molars and incisors were demonstrated. It is important to recognize that most of the retrieved articles in this review concerned growing patients, which means that the anchorage can also be influenced by growth effects. Therefore, it seems important to use matched control groups when the effectiveness of anchorage is analyzed.

Quality analysis

Several methods and scales to incorporate quality into systematic reviews have been proposed[14,15,34] and have since been extensively applied to various RCTs in medicine. However, many items were clearly not applicable, for example, placebo appearance/taste, patient blinded, or observer blind to treatment. Instead, the quality of the articles was judged as low, medium, or high according to a scoring system on the basis of the characteristics given in Table 5.

Many of the studies had serious defects, and according to the criteria used, the majority of the articles were judged to be of low quality. The most serious shortcomings were retrospective study design in combination with small sample size and inadequate selection description. Problems of confounding variables, lack of method error analysis, and the absence of blinding in measurements were other examples of shortcomings. Furthermore, the choice of statistical methods was not explained.

In all studies, the methods to detect and analyze anchorage loss were valid and well known. However, different measurement methods were used to analyze the anchorage, which caused difficulties in comparing the results of the studies.

From a methodological point of view, it was notable that only three of the 14 studies declared the use of blinding in measurements. It is known that nonrandomized trials or RCT without blinding design are more likely to show the advantage an innovation has over a standard treatment method.[35] This implies that the measurements can be affected by the researcher.

In one study,[22] the statistical methods used were judged as uncertain, which might have influenced the outcome reliability of the study.

A randomized clinical trial is our most powerful tool to evaluate therapy, and the quality of the trial significantly affects the validity of the conclusions. Three RCT studies[23,24,29] were identified in this systematic review, and two of them were judged to have high quality. These two studies[24,29] had the same objective, evaluation of anchorage loss (mesial movement of molars) with or with out laceback ligatures, but unfortunately the findings were conflicting and no conclusions could be drawn.

In the future, there is need for additional, well-controlled RCTs concerning the effectiveness of different anchorage systems including implant systems and also for assessing costs and side effects of the interventions.

CONCLUSIONS

- Two main anchorage situations were identified: (1) anchorage loss of molars during space closure after premolar extractions and (2) anchorage loss in the incisor or premolar region (or both) during distal movement of molars.
- A third anchorage category using different implants was identified, but so far only case reports and small case-series have been published, and these studies were therefore excluded in this systematic review.
- The scientific evidence was too weak to evaluate the efficiency of different anchorage systems during space closure because a vast heterogeneity of the studies existed.
- Intraoral molar distalization leads to anchorage loss in the incisor or premolar region (or both) in various amounts depending on choice of distalization unit.
- Most of the studies have serious problems with small sample size, confounding variables, lack of method error analysis, and no blinding in measurements. No evidence-based conclusions were therefore possible to draw from these studies.
- To obtain reliable scientific evidence, additional RCT's with sufficient sample size are needed to determine which anchorage system (including implants) is the most effective. Further studies should also consider patient acceptance and compliance as well as cost analysis.

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