AJO-DO

Anchorage reinforcement with miniscrews and molar blocks in adolescents: A randomized controlled trial

Niels Ganzer,[a] Ingalill Feldmann,[b] and Lars Bondemark[c]
Gävle and Malmö, Sweden

Introduction: Anchorage can be reinforced in many ways. Due to the variety of anchorage concepts, only a few general conclusions can be drawn. Therefore, more research is needed to investigate specific concepts with specific indications. The objective of this trial was to compare the anchorage capacities of miniscrews and molar blocks. **Methods:** This randomized controlled trial was conducted on 2 parallel arms. The trial was conducted at the Public Dental Service Orthodontic Clinic in Gävle, Sweden. Participants were adolescents who needed orthodontic treatment with a fixed appliance, extraction of the maxillary first premolars, and anchorage reinforcement. In group A, miniscrews were used as direct anchorage during space closure. In group B, molar blocks were used as anchorage reinforcement during leveling and alignment and space closure. The primary outcome was loss of anchorage assessed as maxillary first molar movement. Random allocation was maintained with a simple randomization stratified by sex. The observer was blinded to the allocations during the measurements. **Results:** Forty participants each were randomized to groups A and B. Results were analyzed on an intention-to-treat basis, meaning that all participants, successful or not, were included in the analysis. Group A showed a mean anchorage loss of 1.2 mm during leveling and alignment. During space closure with miniscrews, no significant anchorage loss was found. Group B showed mean anchorage losses of 1.4 mm during leveling and alignment and 2.4 mm during space closure. No serious harms were detected. The first molar rotation, torque, and tipping showed different characteristics during the treatment phases. **Conclusions:** Miniscrews can be recommended for anchorage reinforcement. Depending on the need for anchorage reinforcement, miniscrews can be inserted at the beginning of treatment or when space closure starts. Molar blocks cannot be recommended for anchorage reinforcement. **Registration:** This trial was registered at www.clinicaltrials.gov (NCT02644811). **Protocol:** The protocol was published after trial commencement. **Funding:** This trial received funding from the Center for Research and Development, Uppsala University/Region Gävleborg; Thuréus Foundation for the Promotion of Dental Science; and the Swedish Dental Associations Scientific Funds. (Am J Orthod Dentofacial Orthop 2018;154:758-67)

In orthodontics, teeth are moved using active elements such as tie-backs, elastomeric chains, and coil springs. Active elements always deliver the same but opposite force on the teeth being moved and on the anchor teeth. This opposite force can cause undesired movement of the anchor teeth. Anchorage, the ability to resist undesired tooth movements, needs to be reinforced in many patients. Anchorage reinforcement has traditionally been provided by adding resistant units, such as headgear or intermaxillary elastics. The basic principle of anchorage reinforcements is to distribute the reaction forces and reduce the pressure on the anchor units.[1]

These traditional methods of anchorage reinforcement have their drawbacks. Headgear can deliver outstanding anchorage reinforcement when used 10 to 12 hours every day. However, this implies that patients

[a]Public Dental Service, Region Gävleborg, Orthodontic Clinic and Center for Research and Development, Uppsala University/Region Gävleborg, Gävle, Sweden; Department of Orthodontics, Faculty of Odontology, Malmö University, Malmö, Sweden.
[b]Public Dental Service, Region Gävleborg, Orthodontic Clinic and Center for Research and Development, Uppsala University/Region Gävleborg, Gävle, Sweden.
[c]Department of Orthodontics, Faculty of Odontology, Malmö University, Malmö, Sweden.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Ganzer reports grants and nonfinancial support from the Center for Research and Development, Uppsala University/Region Gävleborg, Sweden, and grants from the Swedish Dental Associations Scientific Funds during the trial. Dr Feldmann reports grants from the Thuréus Foundation for the Promotion of Dental Science, Sweden, during the trial.
Address correspondence to: Niels Ganzer, Box 57, 80102 Gävle, Sweden; e-mail, niels.ganzer@regiongavleborg.se.
Submitted, November 2017; revised and accepted, July 2018.
0889-5406

https://doi.org/10.1016/j.ajodo.2018.07.011

must actually wear the appliance for the suggested period.[2] Clinical trials have shown that, in real life, approximately one third of patients are not accurate in reporting their headgear usage.[3] Furthermore, up to 50% of patients treated with headgear had unacceptable anchorage loss.[4]

The same applies to Class II elastics. Used full time, they are as effective as functional appliances in correcting Class II malocclusions, but even here compliance is an issue.[5]

Anchorage, however, can be reinforced in ways that do not rely on compliance. The basic assumption is that every tooth has a certain anchorage value that is correlated to its root surface.[6] The resistance of moving teeth can be overcome by uniting several teeth to an anchorage block. The more osseous tissue that needs to be remodeled, the less likely it is that these teeth will move.[7] Molars from the left and right sides can be united with a transpalatal arch. This construction produced by a dental technician can theoretically reinforce anchorage. However, a systematic review showed that this concept was not sufficient in patients who needed space closure after premolar extractions.[8]

A convenient way to reinforce anchorage is to undertie adjacent teeth with a stainless steel ligature. When the second molar is added to the appliance and tightly connected to the first molar, this so-called molar block has twice as much root surface as 1 molar. This technique is especially suitable when the first premolars are extracted because then also the second premolars can be added to the anchorage block, further increasing the anchorage value.[9] In that way, the root surface ratio between the anchor blocks and the front teeth is changed. Theoretically, this results in less mesial movement of the anchor teeth. Molar blocks do not involve a dental technician, are not based on cooperation, and can be inserted within minutes. The anchorage capacity of the molar block has not been investigated in clinical studies.

Due to the limited anchorage capacity of dental noncooperation-based techniques, skeletal anchorage with miniscrews has been claimed to be the ideal anchorage reinforcement.[10] However, the literature includes only moderate evidence that miniscrews can provide good anchorage.[11] General conclusions must be drawn with caution due to the heterogeneity of the published data.[12] To fill these knowledge gaps about miniscrews, more research is needed about their use for specific indications in specific insertion sites.

Specific objectives

Anchorage capacity has traditionally been discussed mainly in the sagittal and vertical dimensions.[11,13] Changes in the transverse dimension are rarely reported.

The main objectives of this trial were to evaluate anchorage capacity in its three dimensions at different timepoints: during leveling and alignment anchorage loss with and without molar blocks was evaluated (T1-T2); when molar blocks and buccal miniscrews were used during space closure for en masse retraction (T2-T3). It was hypothesized that miniscrews deliver better anchorage capacity than molar blocks and that the molar block is capable of certain anchorage reinforcement.

MATERIAL AND METHODS

This trial was designed as a randomized controlled trial with 1 intervention arm and 1 active comparator and a 1:1 allocation ratio.

PARTICIPANTS

The sample was collected at the Public Dental Service Orthodontic Clinic in Gävle, Region Gävleborg, Sweden. The sample consisted of adolescents, 11 to 19 years of age, who needed orthodontic treatment with a fixed appliance, extraction of the maxillary first premolars, and anchorage reinforcement. Anchorage need was assessed according to the dental visual treatment objective.[14] Moderate anchorage need corresponded to approximately 75% retraction of anterior teeth during space closure.[15] All subjects had permanent dentition, including erupted maxillary second molars, and had received regular dental care since the age of 3 years. Adolescents who previously had orthodontic treatment or needed maximum anchorage or orthognathic surgery were excluded from the trial.

Interventions

All patients were treated with extraction of the maxillary or maxillary and mandibular first premolars and fixed appliances in both jaws. Treatment with fixed appliance (Victory Series stainless steel brackets, 0.022-in slot size, MBT prescription; 3M Unitek, Monrovia, Calif) followed a straight-wire concept.[16] The recommended archwire sequence was 0.016-in heat-activated nickel-titanium alloy, 0.019 × 0.025-in heat-activated nickel-titanium alloy, and 0.019 × 0.025-in stainless steel with posted hooks (3M Unitek). Space closure was accomplished as en-masse retraction of the 6 anterior teeth. The treatment was conducted by the first 2 authors, and the staff had several years of experience in various systems for skeletal anchorage.

The 2 treatment groups were different in their anchorage strategy depending on the treatment phase. During leveling and alignment (T1-T2), the molars in group A had no anchorage reinforcement. In group B, anchorage was reinforced with molar blocks. During space closure (T2-T3), anchorage reinforcement was provided by miniscrews in group A, whereas group B continued with molar blocks.

Leveling and alignment phase (T1-T2)

In the maxilla, the appliances were bonded on all teeth from the right first to the left first molars. Lacebacks were used in both groups to control canine proclination with the 0.016-in heat-activated nickel-titanium alloy archwire. In contrast to group A (Fig 1, A), anchorage in group B was reinforced by bonding the maxillary second molars. The second molars were then united with the first molars and second premolars using a stainless steel ligature (Fig 1, B).[9] Leveling and alignment were considered completed when the 0.019 × 0.025-in stainless steel archwire was in place and space closure was started.

Space closure (T2-T3)

In group A, all patients received 1 miniscrew on each side in the maxilla (Spider Screw K1 SCR-1510 or SCR-1508, diameter 1.5 mm, length 8-10 mm; Health Development, Sarcedo, Italy). The miniscrews were placed from the buccal side between the maxillary second premolar and first molar under local anesthesia according to the protocol published in the clinical trials register. The miniscrews were immediately loaded with 150-g closed-coil springs (Ortho Technology, Tampa, Fla) (Fig 2, A) In group B, the molar block was loaded with 150-g active tie-backs (Fig 2, B). To reduce friction, all archwires were cut distal of the first molars during space closure.

Space closure was considered completed when the canines reached a Class I relationship or all spaces were closed.

Alginate impressions for plaster casts were taken at the start of treatment (T1), after leveling and alignment (T2), and after space closure (T3). The plaster casts were produced at the clinic's laboratory within 24 hours, and then the casts were digitized with a desktop scanner (R700; 3Shape, Copenhagen, Denmark).

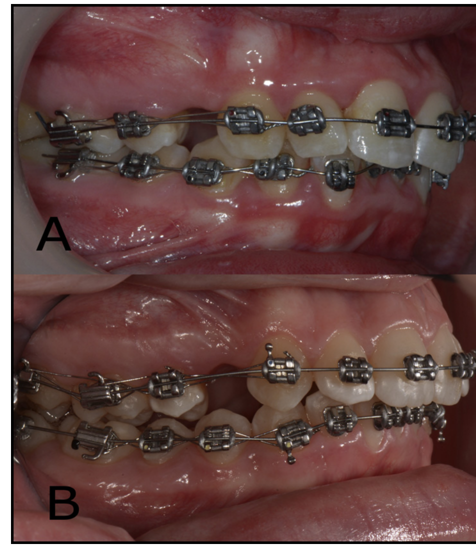

Fig 1. Leveling and alignment: **A,** without anchorage reinforcement; **B,** with molar block as anchorage reinforcement.

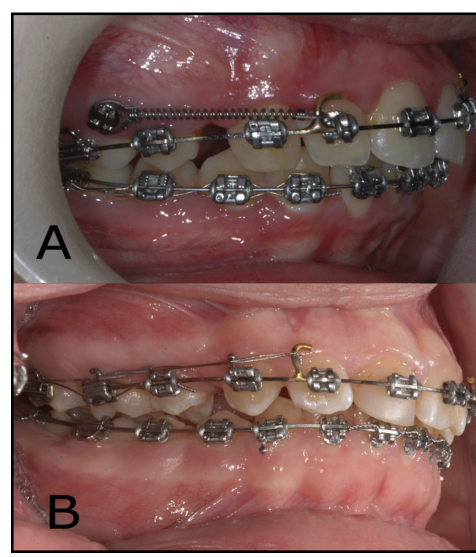

Fig 2. Space closure: **A,** with miniscrew and closed-coil spring; **B,** with molar block and active tie-back.

Outcomes

The primary outcome measures were loss of anchorage during leveling and alignment (T1-T2), defined as changes in tooth position of the maxillary right and left first molars, and loss of anchorage during space closure (T2-T3), defined as changes in tooth position of the maxillary right and left first molars.

Superimposition was performed on digital 3-dimensional models with a computer program (Final Surface; GFaI, Berlin, Germany) and according to the raw, fine matching, and deformation superimposition technique.[17] This technique calculates individual reference points for every subject. Reference points were detected with an algorithm-based deformation analysis that identified unchanged areas in the palate. Tooth movement was assessed in millimeters. Rotations, tipping, and torque were assessed in degrees.

Sample size calculation

The sample size calculation was based on values for anchorage loss and standard deviation in previous studies in our research group (headgear, anchorage loss 1.2 mm, SD 1.96 mm).[4] Additionally, we assumed that the loss of anchorage would be half as much when miniscrews were used. The smallest clinical difference for the margin of superiority was set at 1 mm. The significance level was set at 5%.

Thus, under these circumstances, a sample of 26 subjects in each group would give 90% power. In addition, dropouts due to discontinued treatment or patients moving from the area and a 15% to 20% failure rate for the miniscrews were expected.[12,18] Consequently, a sample size of 40 patients was established for both groups A and B.

Randomization

This trial was conducted as a randomized controlled trial with 2 parallel arms. The protocol was approved by the regional ethical review board of Uppsala University, Uppsala, Sweden (number 2009/188).

All participants were randomly allocated to either group A or group B. The allocation was conducted by an independent person not involved in the trial. Each participant was given a sealed opaque envelope that contained a note with either "Group A" or "Group B," and all envelopes were assigned using simple randomization, stratified on sex, with SPSS statistical software (version 18; IBM, Chicago, Ill). After informed consent, the allocation was revealed when the participant opened the envelope.

Blinding

All measurements were performed by 1 examiner (N.G.), who was blinded during the assessments of the outcomes. All details revealing the groups, such as the maxillary buccal part of the second molar and the buccal portion of the attached gingiva from the maxillary first premolar to the second molar, were removed from the plaster casts before the scanning.

Statistical analysis

Statistical analysis was performed using the programming language R (version 3.42).[19] Arithmetic means and standard deviations were calculated for numeric variables. For every patient, the maxillary right and left first molars were included in the analysis, giving 2 dependent observations for every treatment phase. The maxillary first molar movements were analyzed with adjustments for the left and right sides using linear mixed effect models.[20] Linear mixed effect models are statistical models containing fixed and random factors, which are particularly suitable for analysis of repeated measurements and dependent data. The statistical model was built with the following fixed factors: treatment group and maxillary molar position on the left and right sides. Each subject was assigned as a random factor. Data were analyzed separately for the treatment phases (T1-T2 and T2-T3) and for the total observation period (T1-T3). Differences with probabilities of less than 5% ($P < 0.05$) were considered statistically significant.

Data on all patients who were randomly assigned to the 2 groups were analyzed on an intention-to-treat basis.[21,22] This implies that all subjects irrespective of success were included in the final analysis. In addition, if there were any dropouts during the trial, they were considered unsuccessful. Unsuccessful anchorage was defined as reciprocal space closure: ie, mesial movement corresponding to 50% of a premolar width (3.75 mm). All other variables such as transverse and vertical movements, rotation, tipping, and torque were set to the mean value of the variables calculated from the per-protocol subsample.

Method error analysis

Repeated superimpositions and measurements were performed on 15 randomly selected subjects after at least 2 weeks. No significant mean differences between the 2 series of records were found with the linear mixed effect models.[20] The arithmetic mean error was −0.01 mm and the absolute mean error was 0.14 mm (95% confidence interval [CI], 0.10-0.18), for distance measurements and 0.02°,with an absolute mean error of 0.34° (95 % CI, −0.14-0.12), for rotational measurements.

RESULTS

Participant flow and baseline data

Ninety-eight patients matched the inclusion criteria and were invited to participate in this trial; 18 patients declined to participate. Thus, 80 patients were enrolled in the trial. Informed consent was collected from all patients and their parents. There were 7 dropouts in group A and 2 in group B. The details are given in the CONSORT flow diagram (Fig 3). The baseline demographic characteristics are presented in Table I.

Outcome analysis

Details about maxillary first molar movements—means, standard errors, and comparisons within and between groups—are given in Table II.

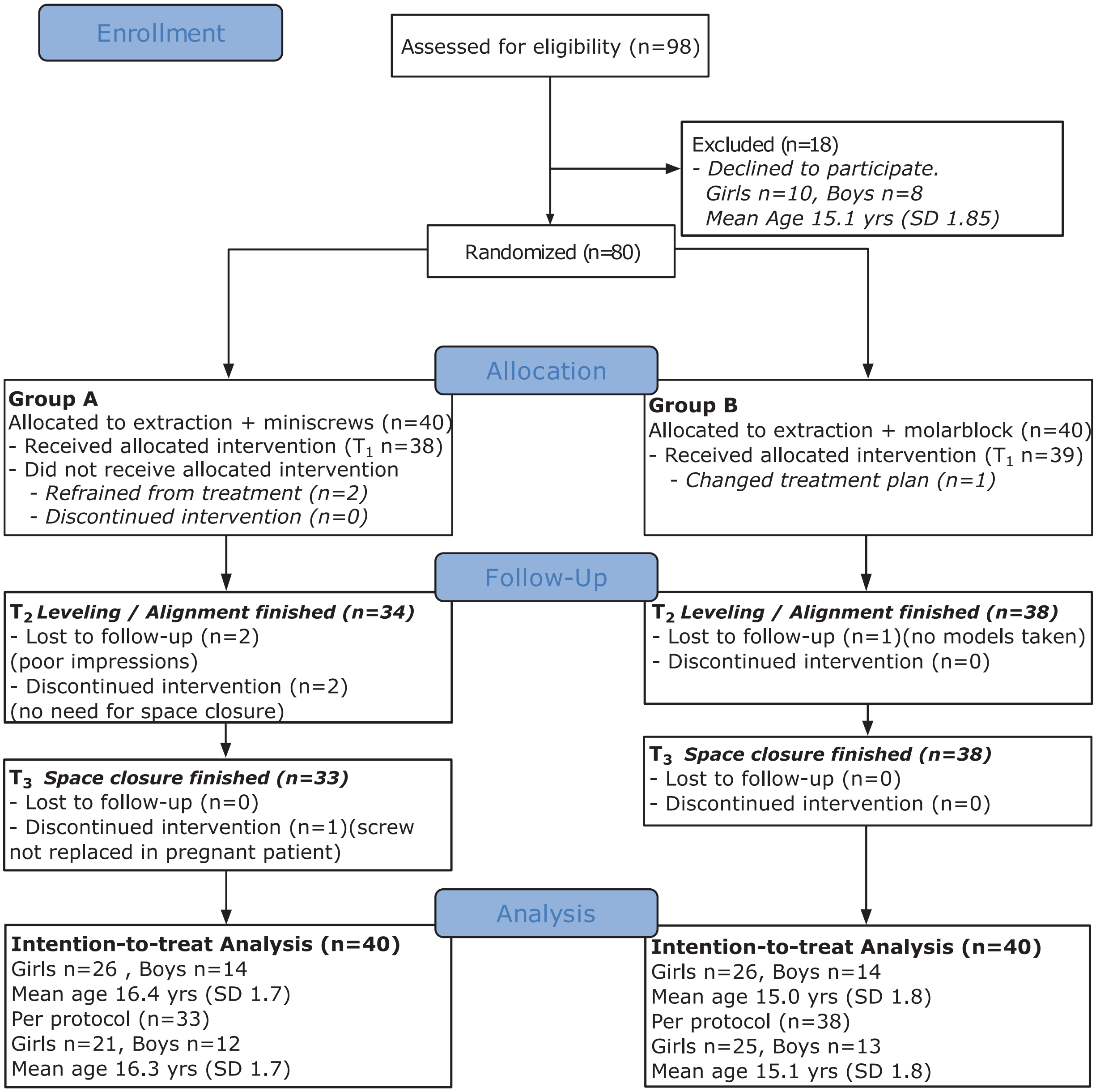

Fig 3. CONSORT flow chart.

Sagittal movement

In the sagittal plane, changes in group A were characterized by the maxillary first molars moving 1.5 mm mesially during the total observation period. This mesial movement (1.2 mm) occurred mainly during the leveling and alignment phase. During the space closure, no significant mesial movement was found. Thus, loss of anchorage in the anteroposterior dimension occurred before miniscrew insertion.

In group B, the maxillary first molars had mesial movement of 3.8 mm during the total observation period, and 1.4 mm of mesial movement occurred during leveling and alignment and 2.4 mm during space closure.

The differences between groups were statistically significant for space closure and the total observation period. However, there was no statistically significant difference between the groups during the leveling and

Table I. Baseline demographic characteristics

Group	Per protocol						Intention to treat					
				Age (y)						Age (y)		
	Total	Girls	Boys	Mean	Range	SD	Total	Girls	Boys	Mean	Range	SD
A	33	21	12	16.3	12.3-19.3	1.7	40	26	14	16.4	12.3-19.3	1.7
B	38	25	13	15.1	11.1–18.7	1.8	40	26	14	15.0	11.1-18.7	1.8

Table II. Intention-to-treat analysis of maxillary first molar movements during different treatment phases

		Within groups				Between groups		
		Group A Miniscrew		Group B Molar block		Difference	95% CI	
Tooth movement	Treatment phase	Mean (SE)	P	Mean (SE)	P	Mean	Upper- lower	P
Sagittal (+mesial/−distal)	T1-T2 leveling and alignment	1.2 mm (0.1)	<0.001	1.4 mm (0.1)	<0.001	0.1 mm	−0.2-0.5	0.492
	T2-T3 space closure	0.2 mm (0.2)	0.381	2.4 mm (0.2)	<0.001	2.2 mm	1.7-2.8	<0.001
	T1-T3 total observation period	1.5 mm (0.2)	<0.001	3.8 mm (0.2)	<0.001	2.3 mm	1.7-2.8	<0.001
Transversal (+increased/− decreased width)	T1-T2 leveling and alignment	0.2 mm (0.1)	0.103	0.1 mm (0.1)	0.203	0.0 mm	−0.3-0.2	0.743
	T2-T3 space closure	0.0 mm (0.1)	0.950	0.1 mm (0.1)	0.381	0.1 mm	−0.2-0.4	0.565
	T1-T3 total observation period	0.2 mm (0.1)	0.248	0.2 mm (0.1)	0.126	0.1 mm	−0.3- 0.4	0.769
Vertical (+eruption/− intrusion)	T1-T2 leveling and alignment	0.0 mm (0.1)	0.526	0.0 mm (0.1)	0.610	0.0 mm	−0.2-0.2	0.930
	T2-T3 space closure	−0.1 mm (0.1)	0.127	0.6 mm (0.1)	<0.001	0.7 mm	0.5-0.9	<0.001
	T1-T3 total observation period	−0.1 mm (0.1)	0.559	0.6 mm (0.1)	<0.001	0.7 mm	0.3-1.0	<0.001
Rotation (+mesiopalatal/− distopalatal)	T1-T2 leveling and alignment	−2.1° (0.6)	0.002	−3.9° (0.6)	<0.001	−1.8°	−3.6-0.0	0.051
	T2-T3 space closure	−0.2° (0.5)	0.763	6.4° (0.5)	<0.001	6.6°	5.2-8.0	<0.001
	T1-T3 total observation period	−2.3° (0.8)	0.005	2.6° (0.8)	0.002	4.9°	2.6-7.1	<0.001
Tipping (+mesial/− distal)	T1-T2 leveling and alignment	3.2° (0.5)	<0.001	2.8° (0.5)	<0.001	−0.5°	−1.8-0.8	0.462
	T2-T3 space closure	−3.1° (0.5)	<0.001	1.1° (0.5)	0.028	4.2°	2.8-5.5	<0.001
	T1-T3 total observation period	0.6° (0.7)	0.393	3.9° (0.7)	<0.001	3.3°	1.4-5.2	<0.001
Crown torque (+palatal/− buccal)	T1-T2 leveling and alignment	1.3° (0.4)	0.003	0.6° (0.4)	0.168	−0.7°	−1.9-0.5	0.229
	T2-T3 space closure	−3.4° (0.4)	<0.001	−0.8° (0.4)	0.045	2.6°	1.5-3.8	<0.001
	T1-T3 total observation period	−2.2° (0.6)	<0.001	−0.2° (0.6)	0.664	2.0°	0.4-3.6	0.016

Millimeters and degrees were rounded to 1 decimal, n = 80 (40 in each group) (2 observations per participant).

alignment phase. More details about the movement in the anteroposterior direction are presented in Figure 4.

Transverse movement

There were no statistically significant differences within or between groups in the transverse plane.

Vertical movement

During the total observation period, the maxillary first molars showed no significant vertical change in group A. In group B, a significant eruption of 0.6 mm was found. This eruption occurred during the space closure phase. The difference between the groups was statistically significant.

Rotation

In group A, the maxillary first molars showed distopalatal rotation of 2.3° during the total observation period. This rotation was mainly established during leveling and alignment. The changes in rotation during space closure were not significant. In contrast, the maxillary first molars in group B showed a mesiopalatal rotation of 2.6° during the total observation period. There was a statistically significant difference between the groups of 4.9° in rotation. An interesting finding was that rotation characteristics were similar during the leveling and alignment phase but significantly different during space closure: group B had a 6.4° mesiopalatal rotation.

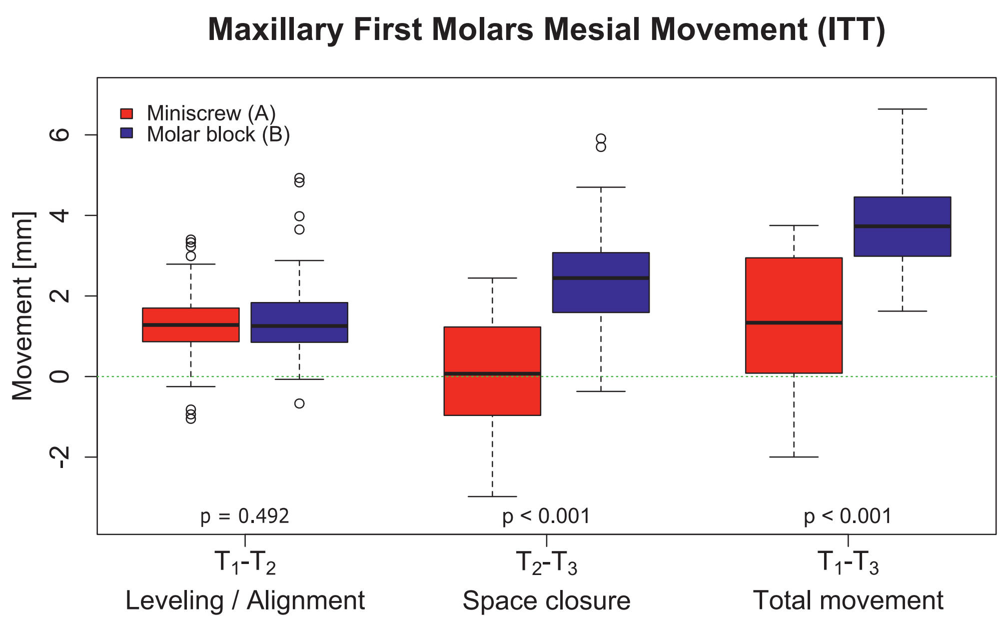

Fig 4. Box plots with Tukey hinges showing the intention-to-treat analysis of the mesial movement of the maxillary first molars.

Tipping

The maxillary first molars in both groups showed mesial tipping of about 3° during leveling and alignment. In group A, this tipping was reset during space closure. In group B, additional mesial tipping of 1° was found during space closure. For the total observation period, there was a statistically significant difference between groups of 3.3°.

Crown torque

There was no statistically significant difference in crown torque between the groups during leveling and alignment. During space closure, group A had buccal crown torque of 3.4°. During the total observation period, there was a statistically significant difference between the groups of 2.0°.

The summarized simulated mean changes in the maxillary first molar positions and rotations are depicted in Figure 5.

Treatment time

There were no statistically significant differences in treatment times between groups. Consequently, the mean times for the leveling and alignment phase were 10.5 months in group A (miniscrews) and 9.3 months in group B (molar blocks). The space-closure phase took on average 8.9 months in group A and 9.0 months in group B.

Finishing phase

When finishing started, some subjects had several millimeters of anchorage loss, and others had residual spaces. All patients were finished on an individual basis, and the finishing phase was not part of the observation time. During the finishing phase in both groups, Class II elastics were used when appropriate. If there were residual spaces, the posterior teeth were protracted. All patients reached their treatment goals.

Harms

In 36 patients, 72 miniscrews were inserted. Of these, 3 miniscrews were lost during the space-closure phase. One of these participants was pregnant. Since replacement of the miniscrew would have involved taking apical x-rays, this treatment was finished with other anchorage reinforcement. In another subject, space closure was already finished when the screw became loose, so anchorage reinforcement was not continued. Consequently, of 3 lost miniscrews, only 1 was replaced.

Furthermore, a Spider Screw, K1 SCR-1510 (10-mm length), fractured during installation. The fragment was initially left in place but was removed later. Intraoral apical radiographs of the incisors were routinely taken before and after treatment. Most patients showed no or minor root resorptions up to 2 mm.[23] There was no statistically significant difference in root resorption between groups.

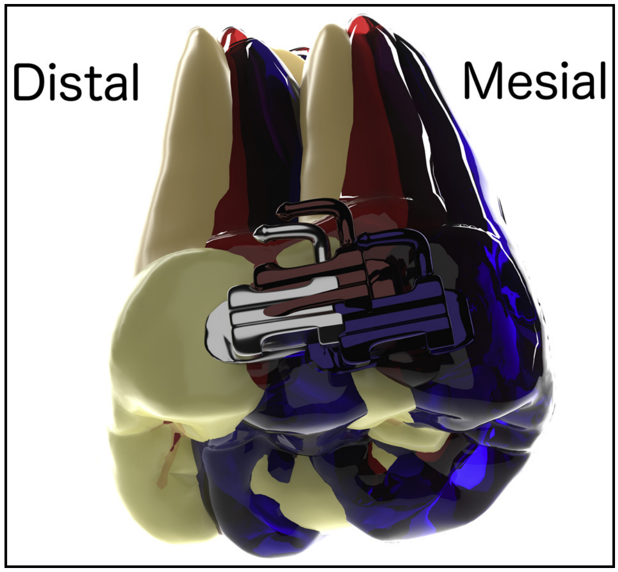

Fig 5. Maxillary first molar positions T1-T3: group A (red, miniscrew) and group B (blue, molar block).

DISCUSSION

Main findings

The main findings of this trial were that miniscrews significantly increased the anchorage capacity of the appliance. There was no statistically significant mesial movement in the miniscrew group (group A) during space closure. This finding is in line with earlier studies on different systems for bone anchorage.[4,12] Thus, the hypothesis concerning the anchorage capacity of miniscrews was confirmed.

In addition, patients treated with molar blocks had reciprocal space closure during the observation time. Thus, molar blocks did not increase the anchorage capacity of the appliances. Therefore, the second part of our hypothesis was rejected. To our knowledge, the anchorage capacity of molar blocks has not been described in the literature; therefore, no comparisons with other studies could be performed.

The overall success rate was 96%, which was higher than reported in recent reviews (83.6%-86.5 %).[12,24] The high success rate in this trial can be explained by the heterogeneity of the data that the systematic reviews are based on. The systematic reviews reported results with a mixture of screw types, insertion sites, and force applications. In contrast, we used miniscrews of 1 brand. Moreover, all miniscrews in our trial were placed buccally in the attached gingiva and immediately loaded with 150 g of continuous force.

Because raw, fine matching, and deformation superimposition of digital 3-dimensional models was used, the movement of the maxillary molars could be mapped in a unique way.[17] Therefore, treatment effects are described in terms of translational movement, rotation, tipping, and torque. The analysis of tooth movement showed comprehensive information about the biomechanics of the 2 concepts used in this trial. However, it can be argued whether all statistically significant findings have clinical importance. Assuming that a difference of 1 mm or more is clinically relevant, only the anteroposterior movement has a considerable effect size. Concerning rotation, tipping, and torque, the differences between groups were less than 5°. Nevertheless, knowledge of the effects can be important in patients whose tooth positions are deviant from the beginning.

When the space-closure phase was analyzed in detail, the box plots in Figure 4 showed distalization of the maxillary first molars in about half of the subjects treated with miniscrews. Beyond distalization, there was distal tipping and buccal crown torque. This could be explained by 2 factors: the vertical component of the applied force[25] and the friction in the molar tube when the archwire is pressed distally into the tube. Compared with treatment with molar blocks, the same forces and moments occur, but in contrast to miniscrews, the active tie-back causes a contrary force. This force seems to be greater than the friction caused by the archwire, since the first molars in the molar block group rotated mesiopalatally.

At the same time that some subjects treated with miniscrews showed molar distalization, the opposite movement was found in others. One could argue that this only can happen when the miniscrew is lost; however, since only 3 miniscrews were lost during the treatment, this cannot be the main explanation. Although miniscrews show a certain displacement during treatment, the anterior component of the occlusal force is likely the explanation for this effect.[26-28] Moreover, the intention-to-treat analysis included 7 dropouts who were defined as unsuccessful. For unsuccessful treatment, mesial movement of 3.75 mm was assumed.

We used the concept of miniscrews as direct anchorage during the space-closure phase without anchorage reinforcement during the leveling and alignment phase. Since an average anchorage loss of about 1.5 mm was found during the total observation period, this should be recognized as acceptable for patients treated with this concept. Therefore, this concept should not be used for those who need maximum anchorage, where anchorage loss cannot be accepted. Instead, maximum anchorage can be provided by indirect anchorage with a rigid connection between the anchor teeth, and tooth movement can be controlled as early as the leveling and alignment phase.

Of course, both concepts described above have suitability. Indirect skeletal anchorage with rigid supraconstructions that are mounted on miniscrews are planned measures for patients where anchorage is problematic already in the planning stage. On the contrary, miniscrews as direct anchorage can be used when anchorage unexpectedly becomes a problem during treatment. Then miniscrews can be installed and loaded immediately.

Limitations and generalizability

Our sample included 65% girls and 35% boys. One could argue that an even sex distribution would have eliminated the risk for bias caused by sex differences. Yet, the sex distribution in this sample agrees with that in many orthodontic clinics. With a sex-stratified randomization, proportional sampling between groups could be maintained. However, the simple randomization could have been done in blocks and hence improved the age distribution. Although the groups had a mean difference in age of about 1 year, the differences between subjects at 15 and 16 years of age concerning growth or tooth movement were regarded negligible.

Due to the nature of the trial, blinding of the participants or care providers was not possible; this might be considered a source of bias. Nonetheless, the assessor was blinded while measuring.

The risk for bias in this trial was considered low. This sample was regarded as representative of populations in orthodontic clinics in industrialized countries.

CONCLUSIONS

Miniscrews as direct anchorage provided increased anchorage capacity with no statistically significant mesial movement during space closure. Thus, miniscrews can be recommended for anchorage reinforcement. Treatment with miniscrews resulted in movement of the maxillary first molars, characterized by distal rotation and buccal crown torque.

Molar blocks did not increase the anchorage capacity and thus cannot be recommended as anchorage reinforcement. The molar blocks caused movement of the maxillary first molars, characterized by mesial rotation and mesial tipping.

ACKNOWLEDGMENTS

We thank all participants in this trial and Per Liv and Sara Gustavsson from the Center for Research and Development at Uppsala University/Region Gävleborg, for assistance with the statistical analysis.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajodo.2018.07.011.

REFERENCES

1. Feldmann I, Bondemark L. Orthodontic anchorage: a systematic review. Angle Orthod 2006;76:493-501.
2. Kloehn SJ. Orthodontics—force or persuasion. Angle Orthod 1953; 23:55-65.
3. Cole WA. Accuracy of patient reporting as an indication of headgear compliance. Am J Orthod Dentofacial Orthop 2002;121:419-23.
4. Feldmann I, Bondemark L. Anchorage capacity of osseointegrated and conventional anchorage systems: a randomized controlled trial. Am J Orthod Dentofacial Orthop 2008;133:339.e1-28.
5. Janson G, Sathler R, Fernandes TM, Branco NC, Freitas MR. Correction of Class II malocclusion with Class II elastics: a systematic review. Am J Orthod Dentofacial Orthop 2013;143:383-92.
6. Jepsen A. Root surface measurement and a method for xray determination of root surface area. Acta Odontol Scand 1963;21:35-46.
7. Roberts WE, Sarandeep SH. Chapter 4 - Bone Physiology, Metabolism, and Biomechanics in Orthodontic Practice. In: Graber TM, Vanarsdall RL, Vig KW, Huang GJ, editors. Orthodontics - Current Principles & Techniques. 6th ed. St. Louis, Missouri, USA: Elsevier Mosby; 2017. p. 131.
8. Diar-Bakirly S, Feres MF, Saltaji H, Flores-Mir C, El-Bialy T. Effectiveness of the transpalatal arch in controlling orthodontic anchorage in maxillary premolar extraction cases: a systematic review and meta-analysis. Angle Orthod 2017;87:147-58.
9. Proffit WR. Chapter 8 - The Biologic Basis of Orthodontic Therapy. In: Proffit WR, Fields HW, Sarver DM, editors. Contemporary Orthodontics. 5th ed. Elsevier Mosby; 2013. p. 297.
10. Maino BG, Maino G, Mura P. Spider Screw: skeletal anchorage system. Prog Orthod 2005;6:70-81.
11. Jambi S, Walsh T, Sandler J, Benson PE, Skeggs RM, O'Brien KD. Reinforcement of anchorage during orthodontic brace treatment

with implants or other surgical methods. Cochrane Database Syst Rev 2014;CD005098.
12. Schätzle M, Männchen R, Zwahlen M, Lang NP. Survival and failure rates of orthodontic temporary anchorage devices: a systematic review. Clin Oral Implants Res 2009;20:1351-9.
13. Lai EH, Yao CC, Chang JZ, Chen I, Chen YJ. Three-dimensional dental model analysis of treatment outcomes for protrusive maxillary dentition: comparison of headgear, miniscrew, and miniplate skeletal anchorage. Am J Orthod Dentofacial Orthop 2008;134:636-45.
14. McLaughlin RP, Bennett JC. The dental VTO: an analysis of orthodontic tooth movement. J Clin Orthod 1999;33:394-403.
15. Nanda R, Kuhlberg A, Uribe F. Chapter 10 - Biomechanic Basis of Extraction Space Closure. In: Nanda R, editor. Biomechanics and Esthetic Strategies in Clinical Orthodontics. 1st ed. Oxford, United Kingdom: Elsevier; 2005. p. 194–6.
16. McLaughlin RP, Bennett JC, Trevisi H. Systemized orthodontic treatment mechanics. 1st ed. St Louis: Mosby; 2001.
17. Ganzer N, Feldmann I, Liv P, Bondemark L. A novel method for superimposition and measurements on maxillary digital 3D models-studies on validity and reliability. Eur J Orthod 2018;40:45-51.
18. Rodriguez JC, Suarez F, Chan HL, Padial-Molina M, Wang HL. Implants for orthodontic anchorage: success rates and reasons of failures. Implant Dent 2014;23:155-61.
19. R Foundation for Statistical Computing; Vienna, Austria. A language and environment for statistical computing: Available at: https://www.R-project.org/. Accessed March 27, 2018.
20. Pinheiro J, Bates D, DebRoy S, Sarkar D, R Core Team. nlme: linear and nonlinear mixed effects models: Available at: http://CRAN.R-project.org/package=nlme. Accessed March 27, 2018.
21. Fisher LD, Dixon DO, Herson J, Frankowski RK, Hearron MS, Peace KE. Intention to treat in clinical trials. In: Peace KE, editor. Statistical issues in drug research and development. New York: Marcel Dekker; 1990. p. 331-50.
22. Bondemark L, Abdulraheem S. Intention to treat (ITT) analysis as reported in orthodontic randomized controlled trials—evaluations of methodology and recommendations for the accurate use of ITT analysis and handling dropouts. Eur J Orthod 2018;40:409-13.
23. Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. Eur J Orthod 1988;10:30-8.
24. Alharbi F, Almuzian M, Bearn D. Miniscrews failure rate in orthodontics: systematic review and meta-analysis. Eur J Orthod 2018; https://doi.org/10.1093/ejo/cjx093: [Epub ahead of print].
25. Lee AY, Kim YH. Comparison of movement of the upper dentition according to anchorage method: orthodontic mini-implant versus conventional anchorage reinforcement in Class I malocclusion. ISRN Dent 2011;2011:321206.
26. Stallard H. The anterior component of the force of mastication and its significance to the dental apparatus. Dent Cosmos 1923;65:457-74.
27. Southard TE, Behrents RG, Tolley EA. The anterior component of occlusal force. Part 2. Relationship with dental malalignment. Am J Orthod Dentofacial Orthop 1990;97:41-4.
28. Al Qassar SS, Mavragani M, Psarras V, Halazonetis DJ. The anterior component of occlusal force revisited: direct measurement and theoretical considerations. Eur J Orthod 2016;38:190-6.