Original Article

Evaluation of the rate of anterior segment retraction in orthodontic patients with bimaxillary protrusion using friction vs frictionless mechanics: a single-center, single-blind randomized clinical trial

Monica Guirguis Youssif Tawfik[a]; Dorra M. H. D. Izzat Bakhit[a]; Fouad A. El Sharaby[b]; Yehya A. Moustafa[c]; Heba Mohamed Dehis[d]

ABSTRACT

Objectives: To evaluate the effect of friction vs frictionless mechanics on the rate of anterior segment retraction (ASR) in patients with bimaxillary protrusion.

Materials and Methods: Thirty females (18.3 ± 3.7 years) with bimaxillary protrusion were randomly allocated into the friction group, using elastomeric power chains, and the frictionless group, using T-loop springs for ASR. Eligibility criteria included absence of skeletal discrepancies and any systemic diseases or medications, among others. Randomization in a 1:1 ratio was generated by Microsoft Excel. Opaque sealed envelopes were sequentially numbered for allocation concealment. Only blinding of the outcome assessor was applicable. Activations were done every 4 weeks until completion of ASR. The primary outcome was the rate of ASR measured on digital models. Anchorage loss, molar rotation, and pain experienced were also assessed.

Results: Two patients were lost to follow-up. The rate of ASR was 0.68 ± 0.18 mm/mo in the friction group vs 0.88 ± 0.27 mm/mo in the frictionless group, with no significant difference. A significant difference in anchorage loss of 1.63 mm and molar rotation of 7.06° was observed, being higher in the frictionless group. A comparable pain experience associated with both mechanics was reported.

Conclusions: No difference in the rate of ASR or pain experience was observed between friction and frictionless mechanics. However, extra anchorage measures should be considered when using frictionless mechanics as greater anchorage loss and molar rotations are anticipated. (*Angle Orthod.* 2022;92:738–745.)

KEY WORDS: Friction; Frictionless; Anterior retraction; Bimaxillary protrusion; Orthodontic tooth movement; Mechanics

INTRODUCTION

Extraction space closure is a major phase during orthodontic treatment that dramatically affects the total treatment duration.[1] Retraction of the incisors in two-step retraction techniques could be achieved using one of two methods. The first is friction (sliding) mechanics, which involves the use of elastomeric chains or closed titanium coil springs as force-delivery systems.[2] This method is more convenient and more frequently used because of its simplicity for patients and clinicians. However, unaccounted loss of force associated with friction, binding, and notching could compromise the efficiency of this technique.[3] The second method is frictionless "loop" mechanics with no guiding wire, in which tooth movement is thus not restricted by the disadvantages of sliding mechanics. However, the complicated design, elaborate wire bending, and

[a] Resident, Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, Future University in Egypt, Cairo, Egypt.

[b] Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, Cairo University, Cairo, Egypt.

[c] Professor and Chairman, Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, Future University in Egypt, Cairo, Egypt.

[d] Lecturer, Orthodontic Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.

Corresponding author: Fouad A. El Sharaby, 11 El Sarayat St., El Manial, Cairo, Egypt
(e-mail: fsharaby@dentistry.cu.edu.eg)

Accepted: May 2022. Submitted: January 2022.
Published Online: August 15, 2022

Table 1. Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Females	Systemic diseases or syndromes
Age 18.3 $\pm$ 3.7 y	Anti-inflammatory medication
Skeletal and Angle Class I malocclusion with bimaxillary dentoalveolar protrusion.	Extracted or missing permanent teeth
Fully erupted permanent dentition (not necessarily including third molars)	History of previous orthodontic treatment
Requiring extraction of four first premolars and maximum anchorage	Parafunctional habits
Good oral and general health	Badly decayed teeth

patient discomfort could be considered drawbacks of this technique.

Using a typodont simulation system, Rhee et al.[4] did not find superiority of either mechanics over the other for canine retraction. Despite reporting comparable anchorage loss in the two techniques, they addressed better mesiodistal and vertical control with frictionless mechanics compared with rotational control and arch dimensional maintenance by friction mechanics.[4] Likewise, Hayashi et al.[5] demonstrated better rotational control with sliding mechanics compared with loop mechanics. On the other hand, Dinçer et al.[6] reported a marginally faster, yet not significantly different, rate of incisor retraction when frictionless mechanics were implemented vs friction mechanics.[6]

Specific Objectives and Hypotheses

The primary aim of this study was to compare the rate of anterior segment retraction between friction and frictionless mechanics. The secondary outcomes were to evaluate the associated anchorage loss, molar rotation, and pain experience during retraction. The null hypothesis was that there would be no difference in the rate of ASR between the two methods of retraction mechanics.

MATERIALS AND METHODS

Trial Design

This study was a two-arm, parallel, single-center, single-blind randomized clinical trial with a 1:1 allocation ratio following the CONSORT statement reporting guidelines. The study methodology was approved by the Faculty of Dentistry Ethical Committee, Future University in Egypt ([9]/10-2018). There were no changes in methods after trial commencement.

Participants, Eligibility Criteria, and Settings

Screening of 42 patients was performed in the Orthodontic Clinic at Future University in Egypt. Thirty participants were recruited according to the eligibility criteria presented in Table 1. Patients or their guardians were asked to sign an informed consent after careful explanation of the study design, interventions, and possible drawbacks.

Interventions

Standard pretreatment records were taken for each patient including photographs, panoramic and lateral cephalometric radiographs, and study models. Bonding of 0.022-inch Roth brackets (American Orthodontics, Sheboygan, Wis) was done in both arches. Leveling and alignment proceeded until 0.017 $\times$ 0.025-inch stainless steel (SS) wire was reached. One miniscrew (temporary anchorage device; TAD) per quadrant (1.6 $\times$ 8 mm, bracket head design; Dual Top Anchor System, Jeil Medical Corporation, Seoul, Korea) was inserted between the upper first molar and second premolar roots at the mucogingival junction at a 45° angle. After checking the primary stability of the miniscrews, the second premolar was anchored to the miniscrews using a twisted ligature wire until completion of canine retraction. Canine retraction was achieved using elastomeric power chains, which is the common method. Prior to the commencement of anterior segment retraction, canines were anchored to the TADs for indirect anchorage. Preintervention alginate impressions were taken, and the obtained study models were scanned (T_0). Each patient was given a visual analog scale (VAS) sheet following each activation to report their pain experience for 1 week. Patients were instructed to avoid analgesics during the course of treatment.

In patients randomized to the friction group (F), anterior segment retraction was done using an elastomeric power chain, extending between 8-mm hooks (variable crimpable hook; Dentos, Daegu, South Korea) crimped distal to the lateral incisors on a 00.017 $\times$ 0.025-inch SS wire at one end and the miniscrew at the other end, delivering 160 g of force per side, measured using a force gauge (Orthodontics Tensiometer 5gm-500gm, MORELLI Orthodontics, Sorocaba, Brazil). Reactivation was achieved by replacing the power chains, which were also calibrated (Figure 1).

In patients randomized to the frictionless group, T-loops were fabricated using 0.017 $\times$ 0.025-inch TMA wire according to Burstone's design.[7] Alpha and Beta gable bends of 45° were added to the T-loop. A step was created between the alpha and beta legs of the T-loop to accommodate for the difference in level between the auxiliary tube of the first permanent molar

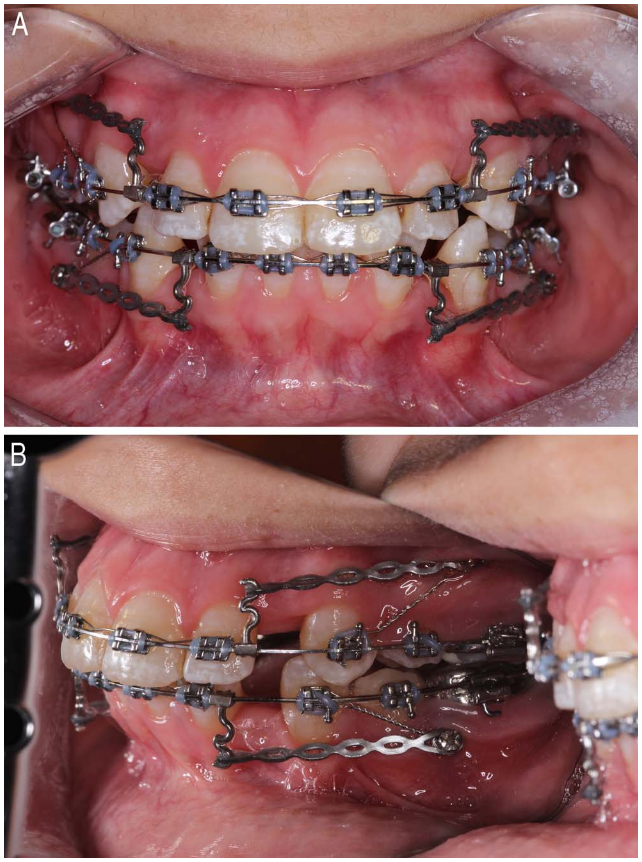

Figure 1. Friction mechanics appliance setup. (a) Frontal view. (b) Lateral view.

posteriorly and the incisor brackets anteriorly. The posterior segment was consolidated using a 0.017 × 0.025 SS wire. The posterior leg of the T-loops was inserted in the auxiliary tube of the first molar, and the anterior leg engaged the incisor brackets (Figure 2). Distal activation of 4 mm to deliver 160 g of force per side was achieved.[7] Reactivation was accomplished when there was 2–3 mm approximation of the loop legs during the monthly follow-up visits.

In both groups, upper alginate impressions were taken at 4-week intervals, and pain scores were recorded using a VAS with a scale from 0 to 10, with 10 being the maximum pain score and 0 no pain.[8] Scores were recorded for 7 days following each activation. Closure of the extraction space and establishment of normal overjet signaled the end of anterior segment retraction.

Measurements

Study models were scanned using a 3Shape R500 scanner (3shape, Copenhagen, Denmark) and analyzed using 3Shape analyzer software (3Shape, Copenhagen, Denmark). To ensure accuracy of the superimposed models, color-coded superimposition

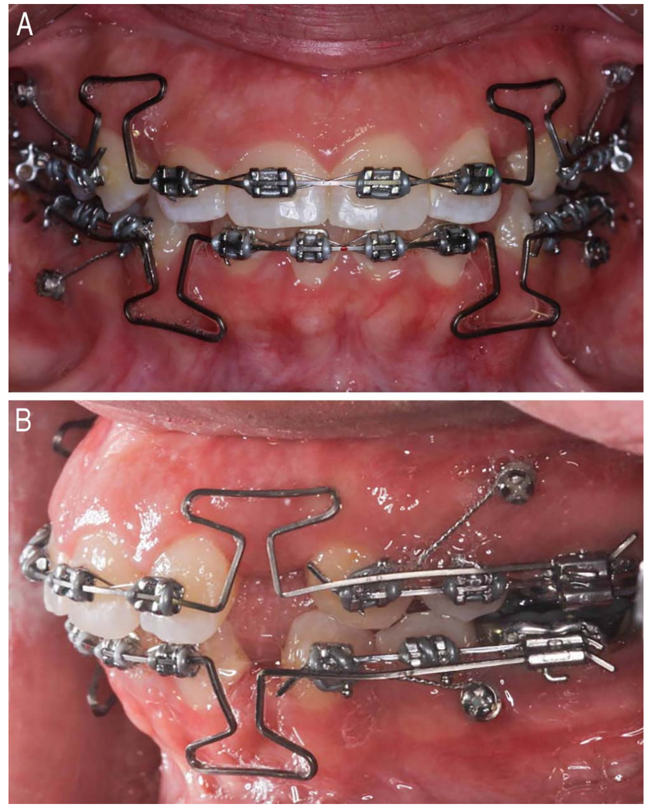

Figure 2. Frictionless mechanics appliance setup. (a) Frontal view. (b) Lateral view.

was done (Figure 3A).[9] An anteroposterior (A-P) plane was constructed using the most distal points of the third right and left rugae and the median palatine raphe (Figure 3B).[10] The distance between the contact point of the central incisors and the A-P plane was measured for assessing the rate of ASR. The distance between the mesiobuccal cusp tip[11,12] and the A-P plane was measured for assessing anchorage loss. To measure upper first molar rotation, the angle between a line extrapolated from the mesiobuccal and distobuccal cusp tips to the A-P plane was measured. Two blinded external assessors carried out the measurements.

Sample Size Calculation

Sample size was calculated using Minitab Software. Twenty subjects were required, with an alpha value of .05 and power of 80%, based on the results of Dinçer et al.,[6] who demonstrated a retraction rate of 1.07 ± 0.32 mm/3 weeks during incisor retraction. Ten additional patients were included (five in each group) to accommodate for possible sample attrition.

Random Sequence Generation and Blinding

Computer-generated random sequencing was performed using Microsoft Office Excel 2013. Opaque

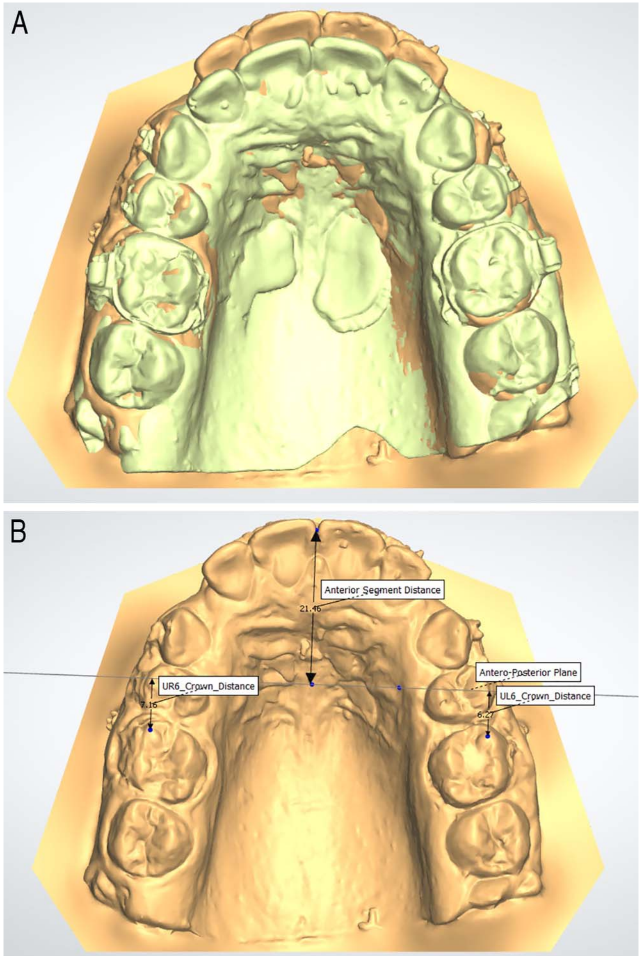

Figure 3. Superimposition of pre- and postretraction models.

sealed envelopes were used for allocation concealment. Blinding of the patients and operator was not possible because of the nature of the study. Blinding of the outcome assessor was done through data concealment during assessment.

Interim Analyses and Discontinuation Guidelines

Interim analyses were not applicable. Participants who missed at least two consecutive appointments or who presented with incisor malalignment due to appliance dislodgement were excluded from the sample. Treatment was continued as normal for such patients.

Statistical Analysis and Data Presentation

All statistical calculations were performed using IBM SPSS software (Statistical Package for the Social Sciences; IBM Corp, Armonk, NY) version 22 for Microsoft Windows. Numerical data were tested for the normality assumption using Kolmogorov-Smirnov and Shapiro-Wilk tests. Within-group comparisons were done using a paired *t*-test. Comparisons between the study groups were conducted using Student's *t*-test for independent samples. Data were statistically described in terms of mean ± standard deviation (SD). The significance level was set at $P \leq .05$. Interobserver and intraobserver reliability was assessed using interclass correlation coefficients (ICCs). The confidence level was set at 95%.

RESULTS

Participant Flow and Baseline Characteristics

Forty-two females with a mean age of 18.3 ± 3.7 years were assessed for eligibility, among whom 12 were excluded. Thirty patients were randomized in a 1:1 ratio to either the friction group or frictionless group. Two patients were lost to follow-up, as explained in Figure 4. The baseline characteristics for the subjects are displayed in Table 2. Inter- and intraobserver reliability showed excellent correlation (ICC > .98).

Numbers Analyzed for Each Outcome

The rate of retraction for the friction group was 0.68 ± 0.18 mm/mo, with a total retraction of 3.3 ± 0.9 mm. The rate of retraction for the frictionless group was 0.88 ± 0.27 mm/mo, with a total retraction of 3.8 ± 1.2 mm, with no statistically significant difference between the groups. The overall average duration in the friction group was 4.8 ± 0.74 months compared with 4.3 ± 0.78 months for the frictionless group, with a mean time difference of 0.5 months between the groups, which was not significant (Table 3).

There was significantly greater anchorage loss in the frictionless group of 2.1 mm, which was 1.63 mm more anchorage loss than in the friction group ($P < .001$; Table 4). Similarly, there was a significantly greater molar rotation observed in the frictionless group of 8.20° (95% CI = 4.43–11.97), which was 7.06° (95% CI = 3.2–10.9) more than in the friction group (Table 4).

There were no significant differences in any aspects of the pain experience reported between the groups. Pain was found to be the worst on day 1 and 2 following activation for both groups and then decreased gradually throughout the activation week (Table 5). The first activation was the most painful in both groups. As ASR progressed, overall pain decreased gradually. None of the patients reported the use of analgesics, and all were compliant with filling out the questionnaires as instructed.

Harms

No serious harms were observed. Some gingival overgrowth and inflammation occurred in the frictionless group, mainly due to irritation from the loops.

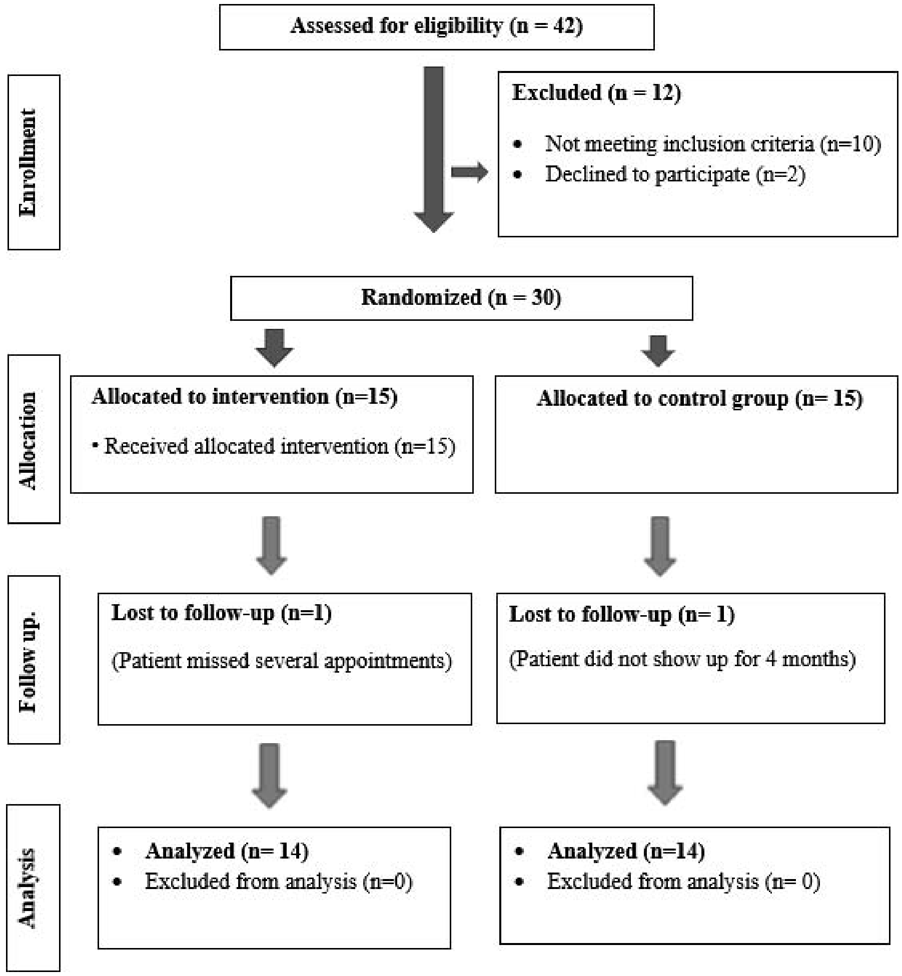

Figure 4. CONSORT flow chart of participants during the trial.

Table 2. Baseline Characteristics of Subjects in Each Group[a]

	Friction Group		Frictionless Group			
Baseline Characteristics	Mean	SD	Mean	SD	Difference (95% CI)	*P* Value
Age, y	17.6	3.1	18.0	2.9	0.40 (0.04–1.7)	.160
ANB, °	2.89	1.03	3.23	0.97	0.342 (0.6–1.3)	.140
SN/Mx plane, °	9.12	1.10	10.01	1.38	0.894 (0.3–2.0)	.174
SN/Md plane, °	34.21	3.00	34.87	2.63	0.655 (2.0–3.3)	.520
Mx/Md plane, °	28.98	2.20	30.13	1.67	1.15 (0.7–3.0)	.257
U1/Mx, °	117.51	2.29	118.16	1.94	0.644 (1.3–2.6)	.545
L1/Md, °	103.77	3.03	104.34	3.02	0.57 (2.2–3.4)	.597
U1/L1, °	110.09	4.37	109.39	3.83	0.695 (3.2–4.6)	.705

[a] Significance level, $P \leq .05$. Data are presented as mean and standard deviation.

Table 3. Amount of Retraction per Month Between Groups[a]

	Friction Group		Frictionless Group			95% CI		
	Mean, mm	SD, mm	Mean, mm	SD, mm	Difference, mm	Lower	Upper	*P* Value
T1-T0	0.8	0.3	0.9	0.4	0.14	0.2	0.5	.381
T2-T1	1.0	0.4	1.2	0.7	0.26	0.3	0.8	.329
T3-T2	0.8	0.6	1.1	0.4	0.31	0.2	0.8	.216
T4-T3	0.9	0.5	1.5	1.3	0.62	0.6	1.9	.297
Total retraction	3.3	0.9	3.8	1.2	0.51	0.5	1.5	.288

[a] Significance level, $P \leq .05$.

Table 4. Anchorage Loss and Molar Rotation Changes Between Groups[a]

	Friction Group				Frictionless Group					
	Preretraction, mean ± SD	Postretraction, mean ± SD	Difference (95% CI)	*P* Value	Preretraction, mean ± SD	Postretraction, mean ± SD	Difference (95% CI)	*P* Value	Difference (95% CI)	*P* Value
Anchorage loss, mm	4.39 ± 1.80	3.90 ± 1.85	0.488 (0.2–0.8)	.004*	4.97 ± 1.22	2.84 ± 1.37	2.126 (1.7–2.5)	<.001*	1.6 (0.01–3.4)	< .001*
Molar rotation, °	120.0 ± 3.9	118.8 ± 2.9	1.14 (0.62–2.91)	.178	123.6 ± 3.7	115.4 ± 6.1	8.20 (4.43–11.97)	.001*	7.06 (3.2–10.9)	.001*

[a] The difference is presented as value (95% CI). Significance level, $P \leq .05$.
* Statistically significant result.

Table 5. Pain Experience (VAS) Throughout the Period of Anterior Segment Retraction Between Groups[a]

Activation, mo	Friction Group		Frictionless Group			
	Mean	SD	Mean	SD	Difference	*P* Value
1	6.21	0.88	5.79	1.10	0.43	.349
2	4.61	1.11	5.20	1.07	0.59	.245
3	5.01	0.87	5.30	1.07	0.29	.535
4	4.57	0.88	4.83	1.04	0.26	.666
5	3.86	0.40	—	—	—	—

[a] Significance level, $P \leq .05$.
* Statistically significant result.

DISCUSSION

In orthodontic practice, extraction of the four first premolars is the treatment modality of choice in cases with bimaxillary dentoalveolar protrusion. Unfortunately, there is insufficient evidence in the literature pertaining to the best possible method of incisor retraction regarding duration, quality of movement, and possible adverse effects.

The force magnitude used in the present study was 160 g/side, as used in comparable studies.[6,13,14] Intermittent force delivery was accomplished using T-loops and elastomeric power chains in the frictionless and friction groups, respectively. In a systematic review conducted by Andhare et al.,[15] a mean in vivo force decay of elastomeric chains was reported to be 55.0% after 3 weeks. Hence, they recommended changing the elastomeric chains at 3-week intervals. Closed titanium springs were avoided as they deliver constant, rather than intermittent, force that was not comparable to closing loops.[16] The force in the frictionless group was attained through 4-mm distal activation of the T-loop fabricated from 0.017×0.025-inch TMA wire, as recommended by Burstone et al.[7] However, Heo et al.[14] reported distal activations of 1 mm using open-type vertical loops made of 0.019×0.025-inch SS wire with 8-mm height to produce 150 g/side. Dinçer et al.,[6] on the other hand, used a force of 150 g by pulling the wire distal to the molar tube until the two sections of the double helix of the spring were separated by 1 mm.

Digital models were used to measure the rate of ASR and anchorage loss as they were reported to be as reliable as traditional plaster models, with high accuracy, reliability, and reproducibility.[9] The difference in the rate and total duration of ASR between the two retraction mechanics in the current study was not significant. The rate of retraction for the friction group was 0.68 ± 0.18 mm/mo, compared with 0.88 ± 0.27 mm/mo for the frictionless group. An insignificant mean difference of 0.5 months in overall retraction duration between the groups was found. A comparable rate of en masse retraction using elastomeric chains (0.415

mm/mo) was reported by Chaudhari and Tarvade,[17] with a 200-g retraction force on a 0.019 × 0.025-inch SS wire. Likewise, Dinçer et al.[6] reported a retraction rate of 1.07 mm/3 weeks in the frictionless group compared with 0.93 mm/3 weeks in the friction group, with no statistically significant difference between them. In contrast, Ziegler and Ingervall[2] found that canine retraction with frictionless mechanics was more rapid by 0.5 mm/mo, which they explained by the more constant force delivery of the closing loop as well as the absence of binding related to the use of 0.018 steel wire in a 0.018 slot used in their study. Variations in the wire size, material, loop design, bracket slot, and force applied could account for the discrepancies in the results between different studies.

In the present study, anchorage was reinforced by miniscrews for both retraction mechanics. Direct vs indirect skeletal anchorage in the friction and frictionless groups, respectively, were implemented during anterior segment retraction. The posterior segments in both groups were equally restricted from mesial movement through direct ligation between the miniscrews and the retracted canines. However, a significant difference in linear anchorage loss of 1.63 mm ($P < .001$) between the groups was observed, with greater anchorage loss of 2.1 mm ($P < .001$) in the frictionless group. This could possibly have been due to direct loading of the first permanent molars by engagement of the beta arm of the T-loop. In the friction group, on the other hand, direct loading was on the miniscrews, allowing for distal sliding of the archwire through the molar tubes, which may have reduced the degree of molar mesial movement, thereby reducing the amount of linear anchorage loss. In contrast, Al-Sibaie et al.[13] and Upadhyay et al.[18] described molar distalization of 0.89 ± 0.74 mm and 0.78 ± 1.35 mm, respectively, following mini-implant–supported retraction. The results from those studies may imply that skeletal anchorage, in addition to its direct effect, could indirectly augment anchorage through the frictional effect of the archwire within the first molar tubes. Significant anchorage loss with mesial molar tipping of 2.66 ± 2.99° and linear mesial movement of 1 ± 0.85 mm was also described by Dinçer et al.,[6] without the use of skeletal anchorage.

A significant difference in molar rotation of 7.06° (95% CI = 3.2–10.9) between the groups was found, with greater molar rotation of 8.20° (95% CI = 4.43–11.97) in the frictionless group (Table 4). Again, this may be attributed to T-loop engagement in the first molar tube. Insignificant molar rotation in the friction group may be credited to the direct loading of the miniscrew rather than the first molar.

A VAS was used to record pain experienced by each patient for 7 days following each activation during the duration of retraction. Both immediate and delayed pain responses were reported in association with orthodontic treatment starting a few hours after orthodontic force application and persisting for approximately 5 days. The results corresponded with those reported by Aslıhan et al.,[19] who demonstrated that pain perception appeared approximately 2–3 hours after orthodontic appliance installment, peaking after 24 hours and decreasing after 72 hours, with a high degree of inter- and intraindividual variation. Likewise, Scheurer et al.[20] showed that 65% of the reported pain in their questionnaire study occurred after 4 hours and 95% after 24 hours. Grieve et al.[21] demonstrated that delayed orthodontic pain was mainly related to the release of peripheral inflammatory mediators in the PDL during orthodontic tooth movement.

The optimal method of retraction is primarily dependent on the skill set and judgment of the clinician. Decisions regarding the choice of retraction mechanics should be made on a case-by-case basis as well as be based on the understanding of the biomechanics involved in each method.[22,23]

Limitations and Generalizability

Despite helping in validation of the comparisons made, restriction of the gender to females and focusing on one jaw (maxilla) limit the generalizability of the results. Blinding of the operator was not applicable in this study, although assessors were blinded using anonymized digital models to minimize possible bias. Evaluation of anterior segment retraction in the lower arch was not feasible because of the absence of reliable and fixed landmarks for superimpositions of the models and extrapolation of planes. In addition, immediate pre- and postretraction lateral cephalograms were not recommended to avoid unnecessary irradiation exposure.

CONCLUSIONS

- The average rate of anterior segment retraction showed no significant differences between frictionless and friction mechanics.
- Frictionless mechanics showed greater anchorage loss and molar rotation compared with friction mechanics.
- There was no significant difference in pain experience reported between patients undergoing friction or frictionless mechanics, but pain was higher for both groups immediately following appliance activation.

REFERENCES

1. Mavreas D, Athanasiou AE. Factors affecting the duration of orthodontic treatment: a systematic review. *Eur J Orthod*. 2008;30:386–395.
2. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. *Am J Orthod Dentofacial Orthop*. 1989;95:99–106.
3. Burrow SJ. Friction and resistance to sliding in orthodontics: a critical review. *Am J Orthod Dentofacial Orthop*. 2009;135: 442–447.
4. Chun YS, Rhee JN, Row J. A comparison between friction and frictionless mechanics with a new typodont simulation system. *Am J Orthod Dentofacial Orthop*. 2001;119:292–299.
5. Hayashi K, Uechi J, Murata M, Mizoguchi I. Comparison of maxillary canine retraction with sliding mechanics and a retraction spring: a three-dimensional analysis based on a midpalatal orthodontic implant. *Eur J Orthod*. 2004;26:585–589.
6. Dinçer M, Gülşen A, Türk T. The retraction of upper incisors with the PG retraction system. *Eur J Orthod*. 2000;22:33–41.
7. Burstone CJ, Hanley KJ, Steenbergen EV. *Modern Edgewise Mechanics and the Segmented Arch Technique*. 1st ed. Farmington, Conn: Ormco Coporation; 1995.
8. Motyl S, Trautzel K, Stós W. Perception of pain during orthodontic treatment with fixed appliances. *Implantoprotetyka*. 2009;10:33–36.
9. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Diagnostic accuracy and measurement sensitivity of digital models for orthodontic purposes: a systematic review. *Am J Orthod Dentofacial Orthop*. 2016;149:161–170.
10. Pazera C, Gkantidis N. Palatal rugae positional changes during orthodontic treatment of growing patients. *Orthod Craniofacial Res*. 2021;24:351–359.
11. Aboalnaga AA, Salah Fayed MM, El-Ashmawi NA, Soliman SA. Effect of micro-osteoperforation on the rate of canine retraction: a split-mouth randomized controlled trial. *Prog Orthod*. 2019;20:1.
12. Jang W, Choi YJ, Hwang S, Chung CJ, Kim KH. Anchorage loss assessment of the indirect anchor tooth during adjunctive orthodontic treatment. *Am J Orthod Dentofacial Orthop*. 2019;155:347–354.
13. Al-Sibaie S, Hajeer MY. Assessment of changes following en-masse retraction with mini-implants anchorage compared to two-step retraction with conventional anchorage in patients with class II division 1 malocclusion: a randomized controlled trial. *Eur J Orthod*. 2014;36:275–283.
14. Heo W, Nahm DS, Baek SH. En masse retraction and two-step retraction of maxillary anterior teeth in adult class I women: a comparison of anchorage loss. *Angle Orthod*. 2007;77:973–978.
15. Andhare P, Datana S, Agarwal SS, Chopra SS. Comparison of in vivo and in vitro force decay of elastomeric chains/modules: a systematic review and meta analysis. *J World Fed Orthod*. 2021;10:155–162.
16. Barsoum HA, ElSayed HS, El Sharaby FA, Palomo JM, Mostafa YA. Comprehensive comparison of canine retraction using NiTi closed coil springs vs elastomeric chains: a split-mouth randomized controlled trial. *Angle Orthod*. 2021; 91:441–448.
17. Chaudhari C, Tarvade (Daokar) S. Comparison of rate of retraction and anchorage loss using nickel titanium closed coil springs and elastomeric chain during the en-masse retraction: a clinical study. *J Orthod Res*. 2015;3:129.
18. Upadhyay M, Yadav S, Patil S. Mini-implant anchorage for en-masse retraction of maxillary anterior teeth: a clinical cephalometric study. Am J Orthod Dentofacial Orthop. 2008; 134:803–810.
19. Aslıhan M. Erdinç E, Dinçer B. Perception of pain during orthodontic treatment with fixed appliances. *Eur J Orthod*. 2006;26:79–85.
20. Scheurer PA, Firestone AR, Bürgin WB. Perception of pain as a result of orthodontic treatment with fixed appliances. *Eur J Orthod*. 1996;18:349–357.
21. Grieve WG, Johnson GK, Moore RN, Reinhardt RA, DuBois LM. Prostaglandin E (PGE) and interleukin-1β(IL-1β) levels in gingival crevicular fluid during human orthodontic tooth movement. *Am J Orthod Dentofacial Orthop*. 1994;105:369–374.
22. Schneider PP, Júnior LGG, Da Costa Monini A, Dos Santos Pinto A, Kim KB. Comparison of anterior retraction and anchorage control between en masse retraction and two-step retraction: a randomized prospective clinical trial. Angle Orthod. 2019;89:190–199.
23. Tominaga J-Y, Tanaka M Koga Y, Gonzales C, Kobayashi M, Yoshida N. Optimal loading conditions for controlled movement of anterior teeth in sliding mechanics. *Angle Orthod*. 2009;79:1102–1107.