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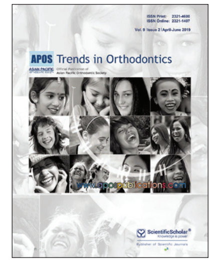

Original Article

Comparison of retraction efficacy of titanium-molybdenum and titanium-niobium alloy wires – A prospective split-mouth study

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ABSTRACT

Objectives: The study aimed to compare the efficacy of Titanium-Molybdenum (Ti-Mo) and Titanium-Niobium (Ti-Nb) alloy wires as retraction springs, by comparing: The amount and rate of canine retraction, the degree of canine rotation, the change in axial inclination of canines, and the associated anchorage loss.

Material and Methods: All 17 participants (age: 18–25 years) to be treated with the first premolar extraction approach by canine retraction were assigned Ti-Mo and Ti-Nb alloy T-loop springs to either of the upper quadrants randomly. Digital intraoral 3-D scans and panoramic radiographs orthopantomagram (OPG) were taken before (T_0) and after (T_1) the study period (4 months). 3-D superimposition was performed and using the digital models and OPG, changes in canine position, angulation, and anchorage loss were compared between the two groups.

Results: There was no significant difference between the two treatment groups for all the parameters pertaining to maxillary canine retraction, that is, canine retraction ($P = 0.72$), change in axial inclination of canines ($P = 0.71$), rotation of canines ($P = 0.74$), and anchorage loss ($P = 0.13$) as well as extraction space closure ($P = 0.74$).

Conclusion: Ti-Nb and Ti-Mo alloy wires show a similar potency for use in retraction mechanics for orthodontic space closure.

Keywords: Tooth movement, Digital models, Wire, Niobium

INTRODUCTION

Titanium-Molybdenum (Ti-Mo) alloys have excellent formability and by a preserved spring back, they deliver gentler forces with an edgewise wire. This has an added advantage of full bracket engagement and thus, torque control.[1] It has the most favorable outcome in two-stage retraction when compared with NiTi and SS.[2] However, in situations where larger deflections and lower forces than those offered by Ti-Mo are required, such as in the initial leveling and alignment phase of orthodontic therapy, Ni-Ti alloy with a lower biocompatibility quotient continues to be indispensable. It has been previously demonstrated that a newer Titanium-Niobium (Ti-Nb) alloy could serve as nickel-free titanium-based shape memory and superelastic alloy wire.[3,4] Its ultra-low Young's modulus, non-linear elastic behavior, high ductility, and superplastic deformability without work hardening at room temperature make it almost ideal for orthodontic applications.[5] If Ti-Nb alloy shows satisfactory results at the space closure stage, it would be a step in the direction of simplifying orthodontic therapy by reducing the number of wires needed for mediating the desired type of tooth movement. Hence, in this study, we aim to assess the efficacy of Ti-Nb alloy in the space closure stage in comparison to Ti-Mo alloy. The objectives of the study were to compare: The amount and rate of canine retraction, the degree of canine rotation, the change in axial inclination of canines, and the associated anchorage loss, between the two treatment groups.

MATERIAL AND METHODS

This was a single-center, split-mouth, and prospective clinical study approved by the Institutional Ethics Committee (EC/NEW/INST/2019/329). The inclusion and exclusion criteria are summarized in [Table 1]. Informed consent was obtained from all participants before the commencement of the study. For all volunteers, fixed orthodontic metal brackets (3M Unitek™ Gemini, Saint Paul, MN, USA) with a slot size of 0.018 × 0.025-inch (McLaughlin Bennett Trevisi prescription) were bonded by a single operator (NJ). Initial leveling and alignment were done to alleviate any crowding, spacing, or rotations. After addressing these confounding factors, the study was initiated.

Intra-oral photographs of the maxillary arch were taken as records [Figure 1A-H]. 3-D laser intraoral digital scans [Figures 2 and 3] and panoramic radiographs (OPG) [Figure 4] were taken for measurements, at the start of the study period, (T_0). Activations were done at every 4 weeks interval for 4 months, following which, the T-loops were retrieved. This marked the end of study period (T_1) and another set of records was taken. The remainder spaces were closed bilaterally with a closing loop archwire after correction of canine rotations experienced in the course of retraction was performed on a flexible wire.

The second molars were banded and the posterior segments were consolidated with a sectional 0.016 × 0.022-inch SS wire in the main archwire slot extending from the second premolar to the second molar bilaterally. The anterior segment was stabilized with a 0.016 Australian SS wire and secured with the figure of eight ligations. The T loops constructed from Ti-Mo (TMA, Ormco Corp, Orange, Calif) and Ti-Nb (Gummetal, Rocky Mountain-Morita Corp, Japan) were assigned randomly to the left and right maxillary canines using a block randomization method, and retraction was commenced. The T-loop springs were designed as described by Burstone and Kuhlberg for the

Table 1: Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Male and Female Age range: 18–25 year	Poor oral hygiene for ≥2 visits Occlusal interferences from crossbite or deviations during jaw closure
Class I Bimaxillary dentoalveolar protrusion or Class I malocclusion (with dental crowding), with bilateral extraction of maxillary and mandibular first premolars	Long term use of antibiotics, phenytoin, cyclosporine, anti-inflammatory drugs, systemic corticosteroids, and calcium channel blockers
Critical anchorage and two-stage retraction Good gingival and periodontal health	Dental caries, Gingivitis, or Periodontitis Habits such as smoking, current, or past evidence of periodontal disease or systemic illness

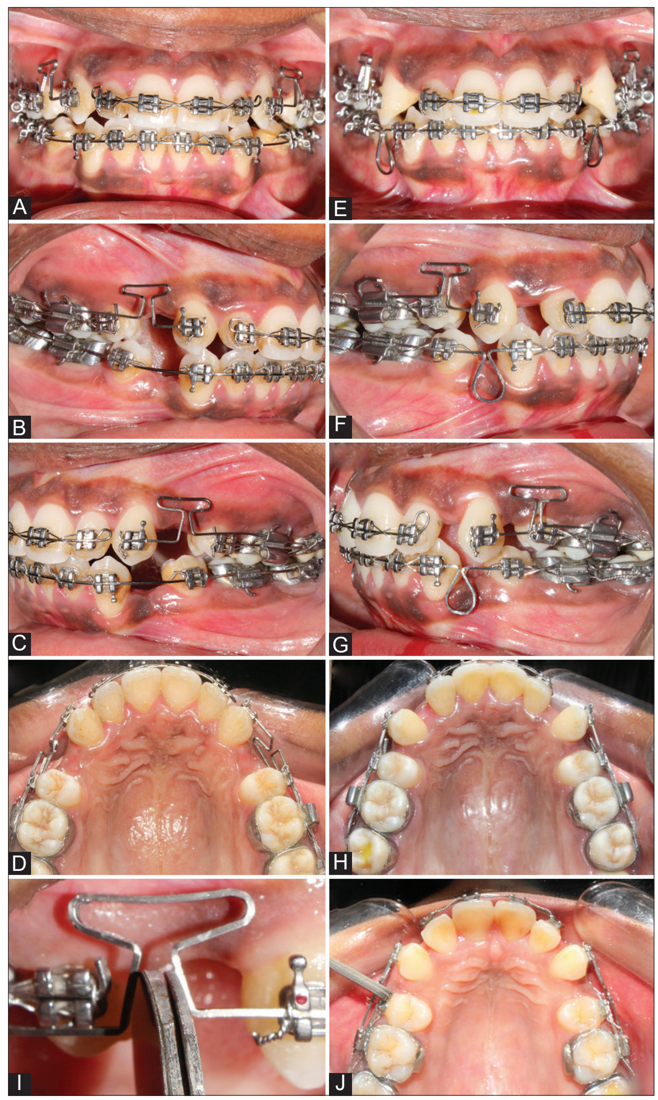

Figure 1: Intraoral photographs at T0 (A-D) and T1 (E-H). (Volunteer ID-13).

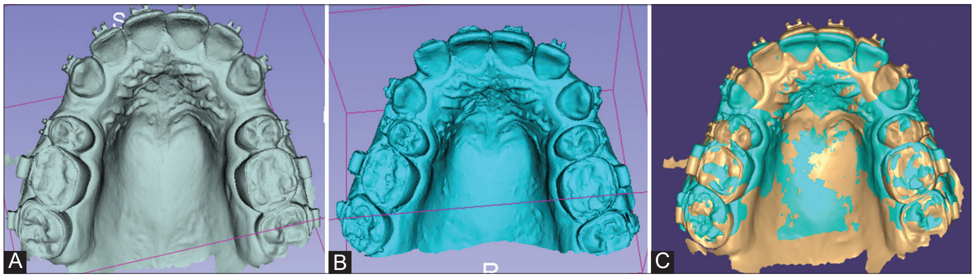

Figure 2: (From left to right) post-retraction, pre-retraction, and superimposed digital models (Volunteer ID: 13).

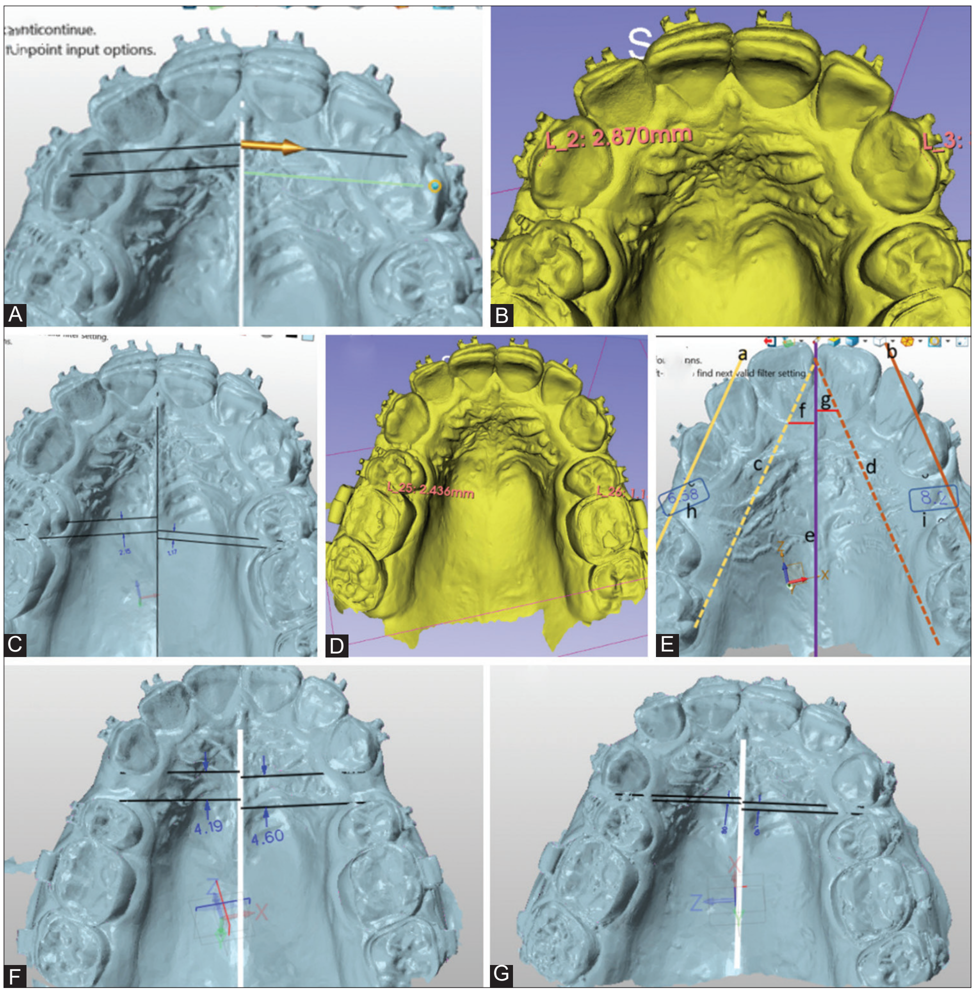

Figure 3: (A-E) Digital and superimposed models on which measurements were made. (A) Canine retraction along the sagittal plane, (B) 3D canine cusp tip displacement, (C) canine rotation in the occlusal plane, (D) anchorage loss in the sagittal plane, (E) 3D displacement of anchor units, and (F) change in axial inclination of canine with respect to the floor of orbit on orthopantomagram. (Volunteer ID: 13).

segmented arch mechanics. The 5 mm long vertical leg was engaged in the canine bracket and the 4 mm long vertical leg went into the auxiliary slot of the first molar tube and was bent back. The T-loop springs were centered in the extraction space. Preactivation bends of 30° in six places of the T loop giving a total preactivation of 180°. Anti-rotation bends of 35° to reduce the amount of distopalatal canine rotation and control the inter-canine width during the retraction were placed in the anterior legs.[6] The first activation of 1 mm was done bilaterally, immediately at insertion taking into account the 2 mm preactivation. Subsequently, both the loops were activated to a 3 mm separation between vertical legs of the T-loop springs in the following monthly visits for the subsequent 3 months. Feeler's leaf gauge (Strauss, Ra'anana, Israel) was used to measure the separation between the vertical arms of the T-loop springs [Figure 5].

Measurements were performed on scanned 3D models of the maxillary arch at T_0, T_1, and superimposed models. The T0 and T1 3D models were selected in the ExoCAD program to perform the superimpositions. Three stable reference points were selected from the T_0 model and coordinated with the reference points from the T_1 model, allowing for an overlay of the two images.[7] Structures that did not change appeared as a single image, while structures that moved appeared as a double image [Figure 2]. The double image showed the extent to which the teeth moved during the treatment.[8]

All linear and angular measurements on the digital models as well as superimposed models were performed using ZW-3D software. Constructions and measurement methodologies have been described in [Table 2, Figures 3 and 4].[9-17]

Sample size estimation: A sample size of 12 with a paired design was determined to obtain adequate power (80% at $P = 0.05$) to detect an effect size of 0.85 mm, based on the split-mouth nature of the study.[18]

Statistical analysis

All data were entered in Microsoft Office Excel 2019 (Microsoft Corporation, Redmond, WA, USA) and presented as means and standard deviation. Intraobserver variability was analyzed using the intraclass correlation coefficient (ICC). A tailed unpaired Student's *t*-test was used to compare the average canine retraction parameters between the Ti-Mo and Ti-Nb groups. All data were analyzed using SPSS 24.0 (IBM Analytics, New York, USA). $P < 0.05$ was considered significant. The null hypothesis was that there is no difference in the efficacy of canine retraction concerning the aforementioned parameters.

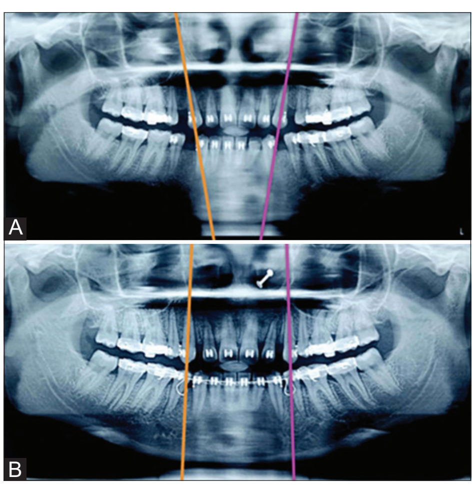

Figure 4: Change in axial inclination of canine concerning the floor of orbit on orthopantomagram at T_0 and T_1. (Volunteer ID: 13).

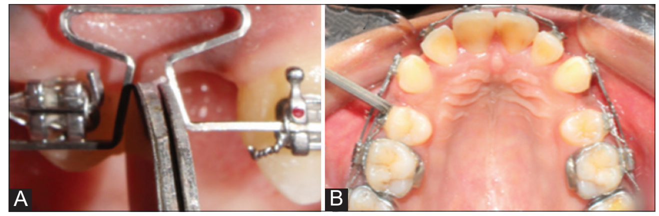

Figure 5: (A-B) Monthly 3 mm activation of the T-loop springs done with a Feeler's Leaf Gauge. (Volunteer ID: 13).

RESULTS

Seventeen healthy adult volunteers between the ages of 18 and 25 years were recruited. 15 volunteers (mean age 20.8 years) completed the research study, out of which six were male and nine were female. Two volunteers dropped out due to their inability to report for treatment. The interobserver consistency test yielded ICC value of 0.84 indicating good reliability. The results of the study are summarized in [Table 3].

- The retraction of canine along the midsagittal reference plane (MSRP) was 3.17 ± 1.02 mm in the Ti-Mo group compared to the 3.02 ± 0.97 mm in the Ti-Nb group ($P = 0.719$) (ICC = 0.78). While canine cusp tip displacement was found to be 4.26 ± 1.19 mm for the Ti-Mo group as compared to the 4.05 ± 1.04 mm for the Ti-Nb group ($P = 0.636$) (ICC = 0.81)
- Extraction space closure along MSRP was found to be 4.03 ± 0.73 mm for Ti-Mo group as compared to the 3.42 ± 1.39 mm for Ti-Nb group ($P = 0.745$) (ICC = 0.71)
- Anchorage loss along MSRP was found to be 1.69 ± 0.91 mm in TiMo group as compared to 1.26 ± 0.44 mm in Ti-Nb group ($P = 0.134$). Anchorage loss displacement (mm) was found to be 1.65 ± 0.85 mm in Ti-Mo group as compared to the1.33 ± 0.38 mm in Ti-Nb group ($P = 0.225$) (ICC = 0.83)
- Change in axial inclination of canines concerning the floor of orbit (degree) was found to be 7.30° ± 4.97° in the Ti-Mo group as compared to the 8.42° ± 4.50° in Ti-Nb group ($P = 0.277$) (ICC = 0.74)
- The rotation of canines in the occlusal plane was found to be 13.77° ± 7.87° in the Ti-Mo group as compared to the 14.69° ± 6.24° in the Ti-Nb group ($P = 0.743$) (ICC = 0.86).

DISCUSSION

The split-mouth design controlled inter-subject variability in terms of age, sex, anatomic factors, and bone metabolism, for comparison of the efficacy of the two alloys. In this

Table 2: Constructions and measurement methodologies.

Parameter	Records used	Constructions and measurements
Canine retraction along MSRP	Superimposed models	Measured as the offset (mm) between perpendiculars constricted from canine cusp tips at T_0 and T_1 to a constructed MSRP[9]
3D canine cusp tip retraction	Superimposed models	3D Euclidean distance (mm) between the T_0 and T_1 position of the canine cusp tip on the superimposed models[10,11]
3D anchorage loss	Superimposed models	3D Euclidian distance (mm) by measuring the perpendicular distance between an identifiable point on the mesial marginal ridge of 1st molar at T_0 and T_1 position on the superimposed models[12]
Anchorage loss along MSRP	Superimposed models	Measured as the offset (mm) between perpendiculars to the MSRP, constructed from an identifiable point on the mesial marginal ridge of first molar at T_0 and T_1 positions[13,14]
Extraction space closure	Scanned models at T_0 and T_1.	Lines were constructed perpendicular to MSRP to the height of distal contour of canine and height of mesial contour of second premolar at T_0 and T_1 on the same side of the arch. The offset between the two perpendiculars so constructed was measured. The T_0 and T_1 observations were subtracted to derive the magnitude of closure of extraction space (mm)[15]
Canine angulation	OPG	After tracing the orbital floor and canines on the OPG, infraorbital plane and long axis of canines were drawn. The medial angle between the long axis of the canine and the infraorbital plane was measured and compared at T_0 and T_1 (degree)[16]
Rotation of canine in occlusal plane	Scanned models at T_0 and T_1.	To determine the rotation of canine in occlusal plane, the angle between MSRP and the lines passing through the heights of contours of the mesial and distal aspects of the canine were measured and compared at T_0 and T_1 (degree)[12,17]

MSRP: Midsagittal reference plane, OPG: Orthopantomagram

Table 3: Intergroup comparison of parameters pertaining to canine retraction showing statistically insignificant differences between the Ti-Mo and Ti-Nb alloy groups.

Parameter	Ti-Mo		Ti-Nb		*P*-value by *t*-test	Significance
	Mean	SD	Mean	SD		
Retraction of canine cusp tip in sagittal plane (mm)	3.17	1.02	3.02	0.97	0.719	NS
Extraction space closure in sagittal plane (mm)	4.03	0.73	3.42	1.39	0.745	NS
Anchorage loss in sagittal plane (mm)	1.69	0.91	1.26	0.44	0.134	NS
Change in axial inclination of canine with respect to floor of orbit (degree)	7.30	4.97	8.42	4.50	0.277	NS
Rotation of caines in occlusal plane (degree)	13.77	7.87	14.69	6.24	0.743	NS
Canine retraction (3-D displacement of cusp tip) (mm)	4.26	1.19	4.05	1.04	0.636	NS
Anchorage loss (3-D displacement) (mm)	1.65	0.85	1.33	0.38	0.225	NS
Velocity of canine retraction	0.79	0.25	0.75	0.24	0.713	NS
Rate of space closure	1.007	0.22	0.85	0.25	0.745	NS

SD: Standard deviation, Ti-Mo: Titanium-molybdenum, Ti-Nb: Titanium-niobium

study, the 0.016 × 0.022-inch dimensions were chosen to keep a low load-deflection rate, a high moment-to-force ratio, and exert optimum retraction forces on the canines. It has been reported that the M/F ratio increases from 5.8 to 9.3 as the wire cross-section decreases from 0% to 50%.[19] Hence, to maximize true retraction, it was decided that the dimensions 0.016 × 0.022 be used for both the materials to make sure that the canines showed controlled tipping and forces were kept light. The activation protocol for this configuration of T-loop spring was decided as per the study conducted by Manhartsberger *et al*. (1989) wherein a T-loop spring constructed from a 0.016 × 0.022-inch Ti-Mo alloy wire generated a horizontal force of approximately 115 g, a vertical force of approximately 10 g, an α M/F ratio of 9.5 and a β M/F ratio of 10.6 giving bodily movement to canines and bodily resistance from posteriors.[20]

Digital impressions were recorded for all the volunteers at the start and end of the study period. In a study in which pre-treatment and post-treatment plaster models were digitized, Thiruvenkatachari *et al*. (2009) found that superimpositions are a valid way to visualize differences between two sets of models and that stable reference points such as palatal rugae should be used as the basis of the superimposition.[7] This methodology allowed us to make direct measurements for observing the change in canine position as well as anchorage loss on the superimposed model itself. Linear and angular measurements were made on the 3D models as well as the orthopantomograms.

The mean velocity of canine retraction along the MSRP was calculated to be 0.79 mm/month for the Ti-Mo side and 0.75 mm/month for the Ti-Nb side. The mean velocity of canine retraction for 3-dimensional (Euclidean) displacement was found to be 1.06 mm/month on the Ti-Mo side and 1.01 mm/month on the Ti-Nb side. The difference in both parameters was neither clinically, nor statistically significant. Various studies that have compared the rate of maxillary canine retraction with different methodologies have led to a conclusion that the average velocity of canine retraction is 1.42 mm/month with frictionless mechanics.[2] This ranges from 0.63 mm/month with a segmental vertical loop made out of 0.017 × 0.025-inch TMA wire to 1.97 mm/month with a Ricketts maxillary canine retractor spring.[21,22] The lesser rate of canine retraction can be attributed to the 0.016 × 0.022-inch wire dimensions which created lesser force on standard activation.

The magnitude of anchorage loss represented ≤25% of extraction spaces which indicated the maintenance of maximum as well as a comparable anchorage on both sides.[23] Both Ti-Nb and Ti-Mo showed an anchorage loss of 38.8% and 40.9%, respectively, of extraction space closed. Lower anchorage loss in segmented mechanics can be achieved using adjuncts like TPA.[24] The enhanced control of the force system applied to the active units and the reactive units and avoidance of the frictional element associated with the sliding mechanics can help achieve minimum anchorage loss when using segmented arch mechanics.[25] The difference in anchorage loss between the two groups was neither clinically nor statistically (P = 0.134) significant. Similar results were obtained when anchorage loss was calculated as net 3D displacement of posterior anchoring units.

The space closure along the sagittal plane occurred at the rate of 1.01 mm/month on the Ti-Mo alloy T-loop spring side and 0.85 mm/month on Ti-Nb alloy T-loop spring side. The difference, that is, 0.16 mm/month was neither clinically, nor statistically (P = 0.745) significant. In a study, the mean rate of space closure with Ti-Mo T loop spring was found to be 0.87 mm/month (±0.34).[18] Although higher mean space closure occurred in the Ti-Mo group, the associated loss of anchorage was also more.

The difference in the change in axial inclination of canines was also neither statistically (P = 0.277) nor clinically (0.88°) significant. Few other studies have shown similar results.[18,22,26] Rotational control over canines is a shortcoming of segmented mechanics and higher anti-rotation bends can provide better resistance to distal rotation as the retraction progresses. However, there seems to be no significant difference between Ti-Mo and Ti-Nb in terms of the force systems so created that caused rotations (P = 0.743).

The findings of this study point toward the versatility of the Ti-Nb alloy. The retraction efficacy of Ti-Nb alloy wire was as good as that of Ti-Mo alloy. In the case of loop mechanics, closing loop archwires can be placed earlier in patients. The true super-elasticity of the Nickel-free Ti-Nb alloy will make engagement possible even in less-than ideally-aligned teeth and the formability will aid in the fabrication of the desired loop design, giving the benefits of both Ni-Ti alloy and Ti-Mo alloy in a single wire. With superior formability, it can also be used as a finishing wire in the last phase of orthodontic treatment. As per manufacturer claims of improved surface properties, Ti-Nb alloy wire will cause lesser friction compared to Ti-Mo alloy wire when used in sliding mechanics; overcoming the only deficiency of Ti-Mo wire. Ti-Nb alloy is, hence, a significant step in the direction of one-wire orthodontics. Although higher flexibility, better surface properties, and biocompatibility make Ti-Nb alloy wire suitable for diversified use from the alignment stage to the settling of the teeth, further investigations are required to establish this omnipotency. Ti-Nb alloy, hence, can be considered a significant step in the direction of one-wire orthodontics.

There are certain limitations of the present study that should be mentioned. To measure the true rate of retraction per month supplementary intraoral measurements for extraction space closure, Canine cusp tip to molar cusp tip distance and space opening mesial to the canine should have been done at every recall visit for activation. In addition, a higher sample size would have provided more credibility to the results so obtained as well as a more homogeneous sample group in terms of age and gender would have given lesser intragroup variability.

CONCLUSION

Within the limitations of this study, both the wires retracted the canines with equivalent efficacy with no significant difference concerning the velocity, distal tipping, rotation of canines, and anchorage loss. Hence, Ti-Nb alloy wire can be used as a substitute for Ti-Mo alloy in the space closure stage.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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