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Article

Research to Improve Fixed Orthodontic Treatment of Angle Class II Severe Malocclusion with Premolar Extractions

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Abstract

The aim of the study was to evaluate the new orthodontic TiNb wires, in direct comparison to the golden standard in orthodontics, NiTi wires, when treating. There is limited information, in the literature, about patients with severe malocclusions being treated from start to end with TiNb, and the TiNb wires were mostly use in the final stages of treatment. Our protocol consisted of three orthodontic wires 0.016, 0.016x0.025, 0.019x0.025 for levelling and aligning stage and 0.019x0.025 stainless steel for finishing stage, in order to treat the same case reproduced on a modified scientific simulator. The bracket system used was made by GC slot 0.22, TiNb wires made by Morita and the NiTi wires produced by GC. We ligated all bracket using SS wire ligatures 0.008, for anchorage we used transpalatal arch. The temperature of the scientific simulator was set between 20-25 degrees Celsius. We've used upper arches and we studied the repositioning of upper ectopic canines and space closure in order to obtain an equilibrated maxillary arch. After each changing of orthodontic wires we scanned the upper arch using Medit I600. After concluding all stages on all upper arches we assessed the results using LITTLE's Irregularity index and stereo microscopy to explain metal stress on NiTi and TiNb, we propose an optimized process of using TiNb and NiTi wires when treating class II severe malocclusions with premolar extractions. Thus, we observed permanent deformation for all 0,016 TiNb wires used in first stage, so TiNb underperformed in comparison with NiTi. Also, the Little's Irregularity Index was superior in the NiTi wires group on 0.016 wires verifying the change of state in TiNb wires group.

Keywords: Angle class II malocclusion; electrodont; fixed orthodontic treatment; orthodontic scientific simulator; TiNb wires

1. Introduction

The aim of the study was to evaluate the new orthodontic TiNb wires, in direct comparison to the golden standard in orthodontics, NiTi wires, when treating a Class II severe malocclusion with premolars extraction using Strait Wire method and trans palatal arch [1]. This type of treatment not

only addresses the cases with transversal or sagittal discrepancies but also addresses to vertical dimension (ectopic and high positioned canines) and closing the spaces after extractions [2]. During space closing stage we produce bodily movements of dental units and we need special characteristic of wires (rigid and with low frictional profile) to finish the case due to frictional forces [3].

After researching the available literature regarding the new TiNb proprieties and also finding the right moment to use it, when treating an severe malocclusion with extractions; the information was intriguing because there was little to no information about patients with severe malocclusion being treated with TiNb, and the TiNb wires were mostly used in the final stages of treatment [4,5]. Nitinol was developed in the early 1960s and introduced to orthodontics in the late 1970s [6]. Orthodontic nickel-titanium (NiTi) wires are widely used. They have simplified the initial phase of orthodontic treatment due to their low forces over a wide range of activation and superelastic properties [7]. However, the low deformability of NiTi archwires limits their use in the final phases of orthodontic therapy.

Gummetal is a new multifunctional β -Ti alloy. It consists of titanium, niobium, tantalum, zirconium, and oxygen (TiNbTaZrO), making it bioinert [8–10]. Gummetal was invented in 2001 by the Metallurgy Research Section of Toyota Central R&D, Inc. in Japan [11]. The chemical composition of Gummetal (Ti-23Nb-0.7Ta-2Zr-1.2O) was based on atomic valence theory. To achieve its rare characteristics, the alloy is intensively cold- worked. According to Hasegawa, Gummetal wire can reduce friction between the archwire and metal brackets by up to 50% compared with other titanium wires [12]. It exhibits a very low Young’s Modulus constant with the temperature and high tensile strength (which is extremely rare) and provides lower force than NiTi and β -Ti archwires. Manufacturers state that the dislocation motion of the crystal (plastic deformation) is controlled completely, which makes Gummetal unique [13].

The new approach of modern oral medicine and in particular orthodontics, is to limit usage materials such as nickel in daily practice due to his allergenic profile most common immunological reaction is contact hyper sensibility, when placed in patient mouth, and as orthodontists we appreciate the versatility of a wire to be used from initial stages to the final stage [14,15].

This study aims to offer insight of orthodontic fixed treatment focused on time in treatment when adresssing class II malocclusion patients with severe crowding and premolar extractions, using TiNb as a new solution to golden standard of NiTi wires.

2. Materials and Methods

The present study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova, Romania (approval reference no. 56/29.01.2024), in accordance with the ethical guidelines of the University of Medicine and Pharmacy of Craiova, Romania

We selected to treat in vitro orthodontic thirty-six cases with different degree of angulation and height of the canine in vertical and transversal planes reported to the occlusal plane, on a modified orthodontic scientific simulator that includes an electodont by made by Savaria-Dent Kft (Szombatheley, Hungary) inside an controlled environment with Peltier effect for heating or cooling, as shown in Figure 1.



Figure 1. Scientific orthodontic simulator with temperature control and thermo controlled chamber.

Also, we added for each dental arch amperage controller and embed in wax, thermo sensors, to monitor the wax temperature, in order to keep the wax temperature stable between 20 to 25 degrees Celsius during active phase [16]. When the wax temperature reached 25 degrees the thermo sensor shut down the current injection into electrodont and permitted for the controlled environment, thermo chamber, to keep environment temperature to 24-25 degrees Celsius. This process was repeated without intervention until the orthodontic wires used for orthodontic treatment transfer all information to electrodont dental units and perform levelling and alignment. The cases presented severe crowding, ectopic canines and premolar extractions in order to have space for canines.

In our case, all electrodonts setup comprised full anatomic mandibular and maxillary teeth with orthodontic brackets with 0.022-inch slots (GC Axxess Roth), Two types of wax, first layer pink (Base plate wax; Regular; Kerr Corporation) and second layer sticky (Sticky wax; Kerr Corporation). The electrodonts are created by setting the teethes with clinical roots in a silicone mould filled with dual consistency wax following the user protocol. Every root of tooth is wrapped in coper coil and continuous electric current is injected, heating the wax generating orthodontic movement under the action of orthodontic wires.

The bracket system used was made by GC slot 0.22, all TiNb wires (Morita, Japan) and the NiTi and SS wires (GC Orthodontics, Japan). We ligated all bracket using SS wire ligatures 0.008 for more precise position of wire in the bracket slot and for posterior anchorage we used transpalatal arch. We’ve started the orthodontic treatment on all electrodonts arches and as a measure of success we followed the repositioning of upper ectopic canines and space closure in order to obtain an equilibrated maxillary arch.

Every upper arch bracket was ligated, and injection of heat in the resistive material that wraps the roots programmed for 60 minutes for each wire size. After assessing the results, the orthodontist decides to proceed to ligate the next wire in the bracket slots, if the levelling and aligning could permit, in safe limits of force delivered to dental units. After each changing of orthodontic wires we scanned the upper arch using Medit I600. On the scan models obtained after each stage we start measuring Little irregularity index using Medit measuring tool. All scan and measurements were performed by a single orthodontist. In the end we studied five TiNb C, ten TiNb R1, ten TiNb R2, fifteen NiTi C wires, five NiTi R1, five NiTi R2 and five SS R1 wires using stereo microscope to find indentation and metal deformation during repositioning the ectopic canines and closing of spaces.

Table 1. Codification of used arch wires, by geometrical section and dimension.

Wire	Geometrical section	Dimension [inch]	Code
NiTi	Circular	0,016	NiTi c
	Rectangular	0.016x0.022	NiTi r1
	Rectangular	0.019 x 0.025	NiTi r2
SS	Rectangular	0.019 x 0.025	SS r1
TiNb	Circular	0,016	TiNb c
	Rectangular	0.016x0.022	TiNb r1
	Rectangular	0.019 x 0.025	TiNb r2

Our initial protocol contained two study groups:

- NiTi group – I.
- TiNb group – II.

For NiTi group the protocol selected for this study contain three sizes of orthodontic wires NiTi C1, R1, R2 for levelling and aligning stage and SS R1 stainless steel wire in finishing stage.

For TiNb group the protocol selected for this study contain the same three sizes of orthodontic wires TiNb C, R1, R2 for levelling and aligning stage, eliminating SS R1 stainless steel needed for finishing stage. Deformation of TiNb C orthodontic wires made us change the initial protocol, and use after them for additional 40 minutes a NiTi wire in order to perform initial alignment and levelling.

The obtained results, made us create a third study group were we eliminated the TiNb C.

Table 2. Experiment design related to arch wire structure.

Nr Crt	Exp	Stages / wires			
	Type	Levelling	Aligning		Finishing
I	NiTi	NiTi C	NiTi R1	NiTi R2	SS
II	TiNb	TiNb C	TiNb R1		TiNb R2
III	Experiment Solution for Severe Malocclusion with Ectopic canines	NiTi C	TiNb R1		TiNb R2

Study group I consisted of 36 maxillary arches in which the NiTi C1 orthodontic wires were ligated with 0.008 steel metal ligatures. These were introduced into the orthodontic simulator, setting the working temperature at 24 degrees Celsius in the calorimetric chamber, the monitoring temperature of the arch at 24 degrees Celsius and the exposure time to the current injection of 60 minutes dividend in ten minutes pulses, with the possibility to evaluating the leveling degree. In the literature the estimated time to treat an orthodontic case with ectopic canines and premolar extractions varies between 18 to 30 months [17].

The OSS can simulate in ten minutes in vitro exposure equivalent of 1 month of treatment in vivo and as movement we corelate 1 mm for 10 minutes, so the exposure of 60 minutes can emulate 6 months treatment. The OSS experiments where under direct observation by the operator, the alignment of the ectopic canine bracket slot, in the plane made by the central and lateral incisors, the premolar II and the molar I bilaterally is monitored, so that the transition to the next NiTi R1 arch in the treatment sequence can be achieved. After bringing the ectopic canine slot into plane, we could move on to the NiTi R1 arch wire, which is ligated with 0.008 steel wire and reinserted into the simulator.

To complete the alignment phase, the NiTiR2 arch wire will be used, also using metal ligature for brackets. Space closure, after leveling and aligning the dental units, will be performed on SS arch wire using an elastic chain.

Study group II was composed of 36 maxillary arches with the same variables in vertical and transversal planes reported to the occlusal plane in which the TiNb C1 orthodontic wires were ligated with 0.008 steel metal ligatures. These were introduced into the orthodontic simulator, the working temperature set to 24 degrees Celsius at the enclosure level, the arch monitoring temperature to 24 degrees Celsius and the exposure time to current injection to 60 minutes in 10-minute pulses in which the degree of leveling is evaluated.

3. Results

At the beginning of the treatment, the canine ectopic positions selected for treatment according to the vertical and transversal planes, for all 36 cases, led to variations of treatment time. The following table shows the times required to perform the simulated orthodontic treatment and as can be seen, there were cases that could not be aligned due to the change in shape of the titanium niobium orthodontic wires.

In cases with a vertical deviation of 1 or 2 mm, we observed that we can perform orthodontic treatment through any of the three proposed protocols, if the transversal deviation is less than 3 mm. The treatment period is with 60 minutes shorter for groups two and three.

If the transverse deviation is 4 mm or greater, an irreversible change occurs in the TiNb wire, which no longer allows the orthodontic treatment to continue.

In cases with a vertical deviation of 3 mm, he irreversible modification of the wire used in the second batch already occurs from a transverse deviation of 3 mm.

In cases where the vertical deviation IS at least 4 mm, the wires in the second group suffer this irreversible change no matter how small the transverse deviation is.

Based on this information, we considered it useful to quantify the deviation as a sum between the vertical and transverse deviation. We were thus able to observe the existence of a borderline at a sum of 5 mm and below for which cases can be finalized with any of the three groups, except in the case where the vertical deviation is 4 mm, when even if we have a transverse deviation of 1 mm, the blockage occurs anyway. Thus, after differences greater than 4 mm in the transverse, vertical or combined planes, the wire suffers a permanent deformation, the ectopic canine begins to descend in the early stages of treatment and stop in high position and the treatment cannot be continued.

Table 3. Total time diagram for all study groups regarding the severity of canine ectopic position in vertical and transversal planes.

	LOTUL I					LOTUL II				LOTUL III				
	NiTiC	TiNbR1	TiNbR2	SS	TTL I	TiNbC	TiNbR1	TiNbR2	TTL II	NiTiC	TiNbR1	TiNbR2	TTL III	
Cazul 1.1														
V:1mm	10	40	40	60	150	10	40	40	90	10	40	40	90	
T:1mm														
Cazul 1.2														
V:1mm	20	40	40	60	160	20	40	40	100	20	40	40	100	
T:2mm														
Cazul 1.3														
V:1mm	30	40	40	60	170	30	40	40	110	30	40	40	110	
T:3mm														
Cazul 1.4														
V:1mm	40	40	40	60	180	40	-	-	NA	40	40	40	120	
T:4mm														
Cazul 1.5														
V:1mm	50	40	40	60	190	40	-	-	NA	50	40	40	130	
T:5mm														
Cazul 1.6														
V:1mm	60	40	40	60	200	40	-	-	NA	60	40	40	140	
T:6mm														
Cazul 2.1														
V:2mm	20	40	40	60	160	20	40	40	100	20	40	40	100	
T:1mm														
Cazul 2.2														
V:2mm	30	40	40	60	170	30	40	40	110	30	40	40	110	
T:2mm														
Cazul 2.3														
V:2mm	40	40	40	60	180	40	40	40	120	40	40	40	120	
T:3mm														
Cazul 2.4														
V:2mm	50	40	40	60	190	40	-	-	NA	50	40	40	130	
T:4mm														
Cazul 2.5														
V:2mm	60	40	40	60	200	40	-	-	NA	60	40	40	140	
T:5mm														
Cazul 2.6														
V:2mm	70	40	40	60	210	40	-	-		70	40	40	150	
T:6mm														
Cazul 3.1														
V:3mm	30	40	40	60	170	40	40	40	120	30	40	40	110	
T:1mm														
Cazul 3.2														
V:3mm	40	40	40	60	180	40	40	40	120	40	40	40	120	
T:2mm														
Cazul 3.3														
V:3mm	50	40	40	60	190	40	-	-	NA	50	40	40	130	
T:3mm														
Cazul 3.4														
V:3mm	60	40	40	60	200	40	-	-	NA	60	40	40	140	
T:4mm														
Cazul 3.5														
V:3mm	70	40	40	60	210	40	-	-	NA	70	40	40	150	
T:5mm														
Cazul 3.6														
V:3mm	80	40	40	60	220	40	-	-	NA	80	40	40	160	
T:6mm														

	LOTUL I				LOTUL II				LOTUL III				
	NITIC	NITIR1	NITIR2	SS	TTL I	TINbC	TINbR1	TINbR2	TTL II	NITIC	TINbR1	TINbR2	TTL III
Cazul 4.1													
V:4mm	40	40	40	60	180	40	-	-	NA	40	40	40	120
T:1mm													
Cazul 4.2													
V:4mm	50	40	40	60	190	40	-	-	NA	50	40	40	130
T:2mm													
Cazul 4.3													
V:4mm	60	40	40	60	200	40	-	-	NA	60	40	40	140
T:3mm													
Cazul 4.4													
V:1mm	70	40	40	60	210	40	-	-	NA	70	40	40	150
T:4mm													
Cazul 4.5													
V:1mm	80	40	40	60	220	40	-	-	NA	80	40	40	160
T:5mm													
Cazul 4.6													
V:1mm	90	40	40	60	230	40	-	-	NA	90	40	40	170
T:6mm													
Cazul 5.1													
V:5mm	50	40	40	60	190	40	-	-	NA	50	40	40	130
T:1mm													
Cazul 5.2													
V:5mm	60	40	40	60	200	40	-	-	NA	60	40	40	140
T:2mm													
Cazul 5.3													
V:5mm	70	40	40	60	210	40	-	-	NA	70	40	40	150
T:3mm													
Cazul 5.4													
V:1mm	80	40	40	60	220	40	-	-	NA	80	40	40	160
T:4mm													
Cazul 5.5													
V:1mm	90	40	40	60	230	40	-	-	NA	90	40	40	170
T:5mm													
Cazul 5.6													
V:1mm	100	40	40	60	240	40	-	-	NA	100	40	40	180
T:6mm													
Cazul 6.1													
V:6mm	60	40	40	60	200	40	-	-	NA	60	40	40	140
T:1mm													
Cazul 6.2													
V:6mm	70	40	40	60	210	40	-	-	NA	70	40	40	150
T:2mm													
Cazul 6.3													
V:6mm	80	40	40	60	220	40	-	-	NA	80	40	40	160
T:3mm													
Cazul 6.4													
V:1mm	90	40	40	60	230	40	-	-	NA	90	40	40	170
T:4mm													
Cazul 6.5													
V:1mm	100	40	40	60	240	40	-	-	NA	100	40	40	180
T:5mm													
Cazul 6.6													
V:1mm	110	40	40	60	250	40	-	-	NA	110	40	40	190
T:6mm													

We therefore considered the sum of the transverse deviation with the vertical deviation as a severity factor of the orthodontic anomaly and depending on its value we divided the cases into cases with reduced severity with severity value below 5, medium severity with a value between 5 and 8 or high severity with a value over 8. For situations in groups two and three we have a reduction in orthodontic treatment time by 60 minutes.

We performed a statistical analysis of the times required for treatment depending on the severity of the anomaly and observed that the reduction in the treatment period becomes less and less significant as the severity increases.

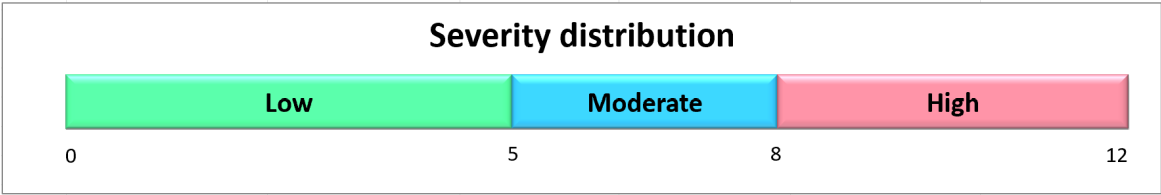


Figure 2. Severity distribution by the canine ectopy reflected in treatment time.

A Kruskal-Wallis test was conducted to determine if there were differences in the percentual variation between groups that differed in their severity level: Low (n = 10), Medium (n = 16) and High (n = 10). Distributions of variations were similar for all groups, as assessed by visual inspection of a boxplot. Median variations were statistically significantly different between the different levels of severity, $\chi^2(2) = 30.868$, $p < 0.0005$. Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons, with statistical significance accepted at the $p < 0.0166$ level. This post hoc analysis revealed statistically significant differences in median variations between the all combinations between groups.

Table 4. Severity level distribution based on Kruskal-Wallis test.

Severity level	Median percentual decrease	Overall p*	Group comparisons (p**)		
			Low	Moderate	High
Low	35.29%	< 0.0005	-	0.006 [#]	< 0.0005 [#]
Moderate	30.00%		-	-	0.006 [#]
High	26.08%		-	-	-

* Kruskal-Wallis H test. ** Post-hoc analysis, adjusted significance. [#] Significant p value.

On 28 TiNb C wires we found irreversible change in form, remaining deformed after performing the levelling and aligning. This change can be explained by the diagram of hysteresis, frictional forces and the way TiNb is absorbing and discharging the force to dental units. While the wire remained modified, the orthodontic treatment stopped, leaving the canine in higher position in vertical, transversal or combined planes, so we could not proceed to next TiNb R1 arch. The level of deflexion was different and related to case severity linked to canine position. Having high angles of the wire in the slot of the bracket and associated with the distance between canine, lateral incisor and second bicuspid will lead to higher deformation of TiNb C orthodontic archwires.

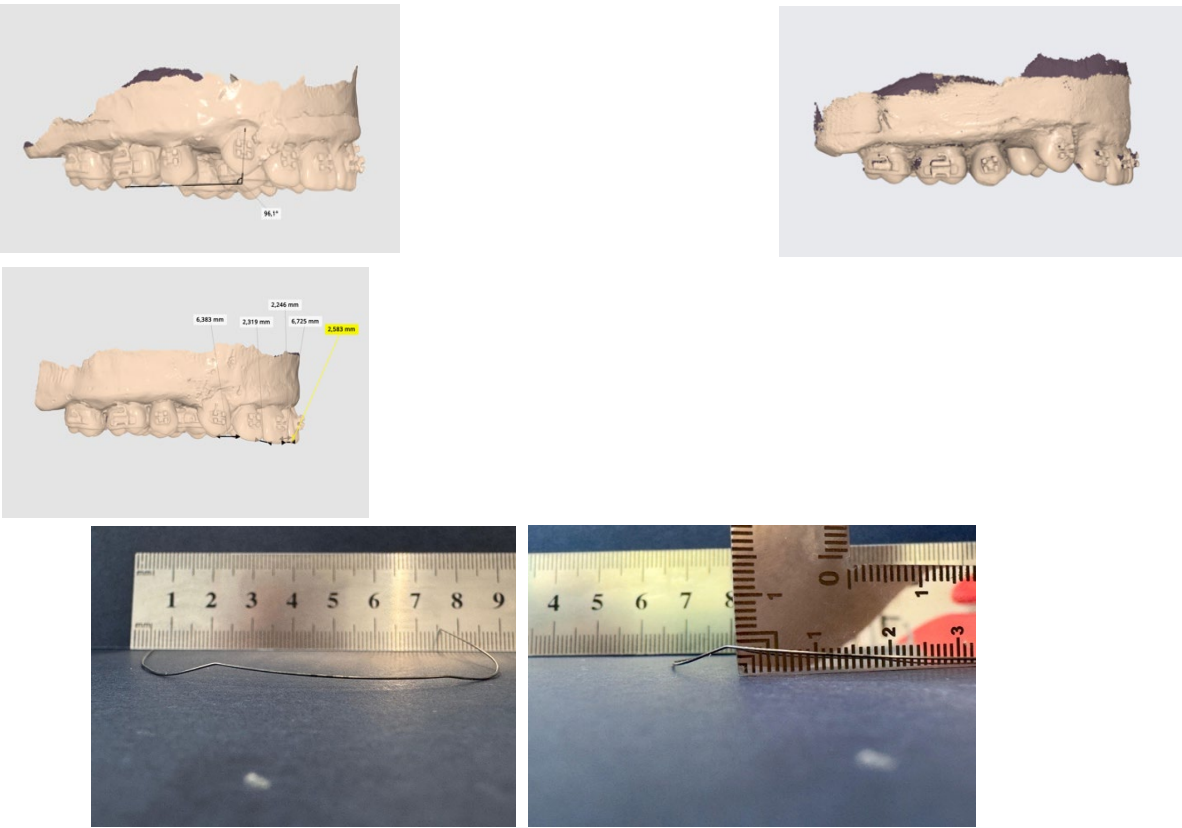


Figure 3. After scanning the cases and removing the arch wire, we’ve seen permanent dformation TiNb arch wire in vertical and transversal plane.

All rectangular archwires NiTi R1,R2; TiNb R1,R2; SS R1 did not show any permanent form modification.

Using simulated orthodontic treatment in vitro and observing how the treatment of severe class II malocclusions was concluded, made us aware of the necessity of optimizing the use of different orthodontic wires in the stages of aligning, levelling and finishing. Replacing the TiNb C with NiTi C and eliminating the SS wire made the orthodontic treatment time to be shorter.

We found a significant number on indentations on TiNb vs SS and this comes in support of the theory regarding resistance to sliding of TiNb.

Indentation pattern for NiTi was gap like in the material instead TiNb indentation pattern was more scratch like.

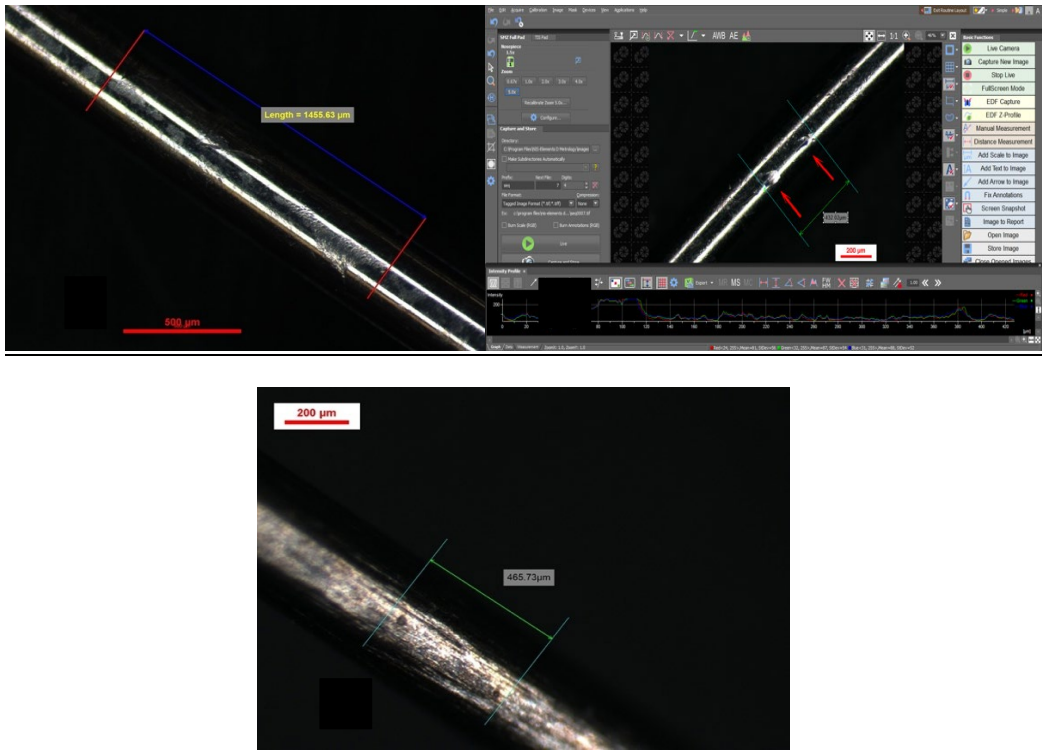


Figure 4. Indentations spectroscopy for 0.016 NiTi a,b and 0.016 TiNb c.

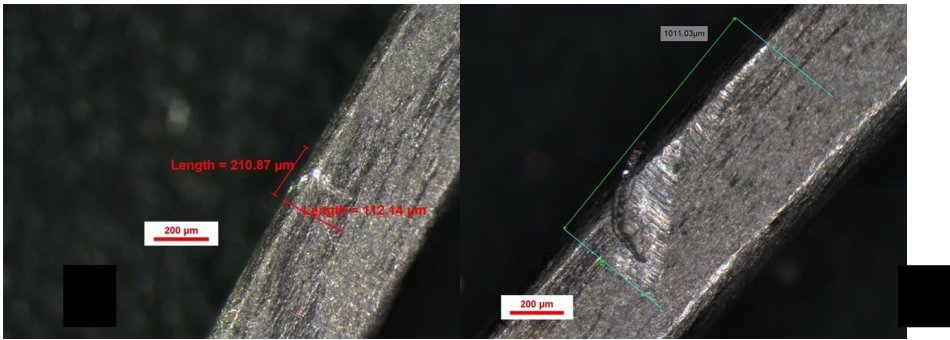


Figure 5. Indentations spectroscopy for 0.016x0.022 TiNb d,e.

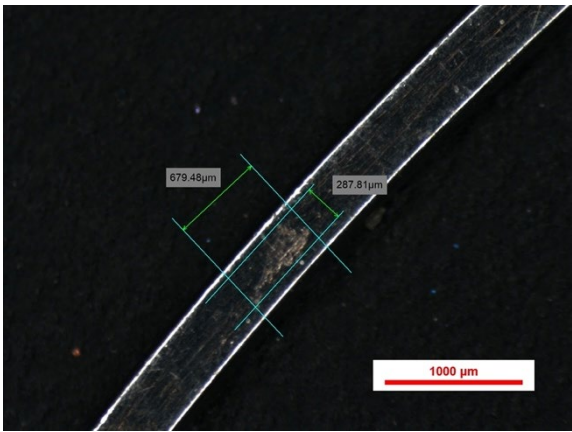


Figure 6. Indentations spectroscopy for 0.019x0.025 TiNb.

4. Discussion

Forces needed to overcome friction in vitro are higher than those in vivo, as claimed by Ho and West [18]. Lubrication plays a role in reducing frictional forces between brackets and wires during in vitro tests with different types of human and artificial saliva [19]. This fact might be a possible limitation of the present in vitro study performed in dry conditions. Fortunately, in vitro studies of archwires performed in dry conditions present rankings of frictional forces and order of frictional values similar to wet conditions and can provide orthodontists valuable and relevant clinical information [20].

On the other hand, it is difficult to be completely certain how precisely laboratory equipment could recreate the same in vivo situation with the response of periodontal ligament to orthodontic forces [21]. At the moment, tooth movement cannot be completely imitated in vitro [22,23]. Permanent deformation of TiNb wires made us to change the protocol. We did not find any reference in the literature about permanent deformation of TiNb wires related to high canine position, severe malocclusion treated with first premolar extraction.

From our simulations when treating various cases of ectopic canines, we propose to begin leveling and aligning with an ultra-elastic wire, NiTi in our case was use because of the limitations related to temperature interval, but also, we can choose a NiTi wire with thermal memory.

We also did not observe any changes during closing spaces stage using SS versus TiNb. Changing the protocol improved by 20 % - 40 % given the severity of the case, total time spent in simulation and this may be translated in less time when treating orthodontic patients with fixed appliances. 20 % - 40% less time for fixed orthodontic patients means less incidents related to bracket debonding, less lesions caused by brackets and overall increasing the quality of life. If we are addressing to patients with severe malocclusions and ectopic canines, who are allergic or develop allergies to Nichel, the case must be carefully evaluated before starting or when the allergic event appears. The alternative solution proposed by our team is to treat the case with aligners; the position of the canine will dictate the number of aligners, special attachments and elastics: a high position of the ectopic canine will be reflected a high cost of treatment.

Limitations of the study are that, while working in controlled environment conducting in vitro experiment, we could not simulate two important roles of saliva: lubrication and heat transfer. These two roles have much to say in increasing frictional forces for pathologic cases of ions excess in saliva created by oxides, deposits of tartar, or reducing frictional forces between brackets and wires and also reducing or accentuating heat transfer to orthodontic archwires.

Future directions include upgrading the OSS used to treat Angle class II severe malocclusions with premolars extraction and ectopic canines, so that it can perform the saliva cycle under controlled parameters. On the archwires used in this experiment will conduct further analysis related to loss of weight during the experiment in dry environment in comparing with archwires in normal condition of lubrication. Also the archwires selection for in vitro study will be enlarged, including CuNiTi, nanocoated, new bactericide orthodontic archwires and used for simulated orthodontic treatment.

5. Conclusions

This study provides an in-depth comparative analysis of TiNb and NiTi orthodontic archwires in the treatment of Class II severe malocclusions with premolar extractions, utilizing a modified orthodontic scientific simulator. Our findings revealed that while TiNb archwires present a viable alternative to conventional NiTi archwires, they exhibit significant limitations in the initial phases of treatment. The most notable drawback was the permanent deformation observed in the TiNb C archwires during the levelling and aligning stage, leading to compromised tooth movement and treatment delays. This highlights the necessity of modifying clinical protocols when incorporating

TiNb archwires, specifically by replacing TiNb C archwire with NiTi to ensure consistent and predictable orthodontic forces.

Through this optimization, we achieved a 20% - 40% reduction in overall treatment time, which has important clinical implications. Shorter treatment durations are beneficial in reducing the risk of bracket debonding, minimizing soft tissue irritation, and enhancing patient compliance. Additionally, the reduced need for stainless steel finishing wires in the TiNb group suggests that these wires could be a step toward more streamlined orthodontic mechanics, particularly for patients requiring nickel-free alternatives due to hypersensitivity or allergy concerns.

Another critical aspect of this study was the role of friction and deformation patterns. Our stereomicroscopic evaluation revealed that TiNb archwires exhibited scratch-like indentation patterns, in contrast to the gap-like indentations observed in NiTi archwires. These findings suggest differences in frictional resistance, which could influence the efficiency of space closure and overall treatment mechanics. Future research should further investigate these properties, particularly in vivo, to determine how the observed deformations and frictional characteristics translate into real-world orthodontic treatments.

Given the evolving landscape of orthodontic materials, TiNb archwires represent a promising development, but their full potential has yet to be realized. Future studies should focus on improving the mechanical properties of TiNb archwires, exploring heat-activated variants or alloy modifications to enhance their resilience in the early stages of treatment. Additionally, investigating their clinical performance in a controlled patient setting will be essential to validating the findings from this in vitro study.

For patients with severe malocclusions and ectopic canines, particularly those who are allergic or develop sensitivities to nickel, careful case selection remains crucial. In cases where TiNb archwires may not provide optimal results, alternative approaches such as clear aligners with specialized attachments and elastics could be considered. While aligners offer a potential solution, the complexity of certain malocclusions, particularly those involving high-positioned ectopic canines, may necessitate a hybrid approach that integrates different treatment modalities.

Thus, while TiNb archwires offer a promising alternative to NiTi in certain orthodontic applications, their mechanical limitations in early treatment stages must be addressed before they can fully replace traditional archwires. By refining treatment protocols and further investigating their long-term clinical performance, TiNb archwires may play a valuable role in modern orthodontics, particularly for patients requiring nickel-free solutions.

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