Comparison of Pain Experience among Patients using Super Elastic Nickel-Titanium Vs Copper Nickel-Titanium Archwires during Alignment Stage

Ferdinand Mabula Machibya[1], Protas John Msungu[2], Matilda Mtaya Mlangwa[3], Eladius Laswai Daniel[4]

Author(s) Affiliation
[1,2,3,4]Orthodontic Unit, Department of Orthodontics, Pedodontics and Community Dentistry, School of Dentistry, Muhimbili University of Health, and Allied Sciences (MUHAS), Tanzania

Corresponding Author
Ferdinand Mabula Machibya,
Email: frmachibya@yahoo.com

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ABSTRACT

Introduction: Pain and discomfort associated with teeth movement during the early phase of orthodontic treatment are major concerns for many orthodontic patients. The aim of this study was to compare the pain experience among patients undergoing orthodontic treatment using Super Elastic NiTi (SE NiTi) and Copper NiTi (Cu NiTi) arch-wires during the alignment phase.

Materials and Methods: A prospective randomized study was carried out among patients who were in the alignment stage of fixed orthodontic treatment, using two different types of archwires, SE NiTi or Cu NiTi. Eight-six participants were recruited conveniently in the study, and randomly allocated to either of the study groups. Fixed orthodontic treatment was then initiated with 0.014-inch archwire in both groups. Participants were followed for pain assessment using a modified McGill Pain Questionnaire with Visual Analogue Scale (VAS) for the duration of 7 days. Data were analyzed by SPSS Statistics version 25.0 with a *P*-value set at <0.05. Pain comparison between two groups was done using Wilcoxon Signed Rank test and Mann Whitney U test.

Results: Three participants were lost to follow up and one participant was omitted from the analysis. Therefore, total of 82 participants were analyzed, 41 participants from each of the study group. Participants from both groups reported pain experience during the initial phase of fixed orthodontic treatment. The pain experience was highest 6 to 12 hours after insertion of the initial archwires in both groups. The majority of the participants reported a gradual decrease in pain intensity over time, with the rate of decline been relatively faster in SE NiTi group.

Conclusion: There was no significant difference between SE NiTi and Cu NiTi in pain experience.

Keywords: Copper NiTi, Orthodontic, Pain, Super-elastic NiTi

INTRODUCTION

The early phase of contemporary fixed orthodontic therapy involves the use of round and flexible archwires that generate biomechanical forces through brackets for tooth movement.[1] The initial forces associated with the placement of archwires and activation of fixed orthodontic appliances are accompanied by pain and discomfort that adversely affect adaptation and

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acceptance of appliances, motivation, compliance and the overall treatment outcomes.[2,3] Most orthodontic patients experience considerable pain and discomfort following insertion of orthodontic archwire.[4-6] The degree of pain during orthodontic therapy can be influenced by a variety of factors, including age, gender, cultural variations, prior experiences, and most importantly the force produced by the archwire, particularly in the early stages of treatment.[3,4,7] It is well established that the force applied by an archwire for orthodontic tooth movement triggers inflammatory responses in the dental pulp and periodontium, which in turn trigger the production of several biochemical mediators, mainly Interleukin 1β, Prostaglandin E2, and Substance P, that independently contribute to pain perception.[8,9]

Thermal Copper Nickel Titanium (Cu NiTi) archwire is found to deliver light continuous force more efficiently than other orthodontic Nickel Titanium Archwires,[10,11] thus, they are believed to cause less initial orthodontic pain as compared to super elastic Nickel Titanium (SE NiTi).[12,13] However, the claimed benefit of the thermo elastic archwire by manufacturers need be verified in clinical setting to cater for impact of possible geographical, genetic and environmental variation of population studied.

Both SE NiTi and Cu NiTi archwires are commonly utilized in orthodontic therapy. However, there is hardly any quality randomized comparative study to provide sufficient clinical evidence to guide clinicians in managing pain during early phase of orthodontic treatment. Thus, this study was designed to compare the pain experience among patient undergoing orthodontic treatment using Super Elastic NiTi (SE NiTi) and Copper NiTi (Cu NiTi) archwires during the alignment phase.

MATERIALS AND METHODS

This was a single-center randomized prospective comparative study with a 1:1 allocation ratio that compared the pain experience among orthodontic patients using SE NiTi and Cu NiTi archwires.

A sample size of 86 patients (43 in each group) was estimated based on a previous study.[14] An adjustment for the loss to follow-up was made and it was sufficient to detect significant difference between the two archwires. Assuming $\alpha = 0.05$, $\beta = 0.2$, standard deviation 0.98, and $D = 0.6$.

Patients receiving orthodontic treatment at the Muhimbili University Dental clinic participated in this study. All participants, along with their parents or guardians, provided informed consent and/or assent forms. The Muhimbili University Research and Ethics Committee approved the study, and it was registered under the registration number MUHAS-REC-07-2022-1294.

This study involved non-extraction orthodontic cases, aged between 9 to 25 years, requiring fixed buccal arch appliances. These patients had fully erupted permanent teeth, no prior history of orthodontic treatment, and with Little Irregularity Index score of greater or equal to 2 mm. They were then randomized into two groups using random number generation via Microsoft Excel in 1:1 ratio.

The intervention was instituted immediately after baseline data collection and randomization. Teeth were bonded with 0.022 X 0.028 slot MBT stainless steel metal bracket in both groups, thereafter, 0.014 SE NiTi archwires and 0.014 Cu NiTi arch-wires were ligated using 0.2mm stainless steel ligatures in Group A and Group B respectively. Archwires from both groups were from the same manufacturer (Guber dental Hangzhou, PR. China). The archwires were cut distal to the molar tube without cinching them back. Moreover, to account for potentially confounding factors, the maxillary archwire was secured with elastic ligature seven days after the insertion of the mandibular arch wire.

The modified McGill Pain Questionnaire with Visual Analogue Scale (VAS) by Marković et al., 2015[15] was used to assess pain experience. The questionnaire consisted of 8 questions inquiring about triggers of pain, medication intake, location, description, onset, intensity, and duration of pain. Patients were further asked to score their level of pain using visual analogue scale with a scale from 0 to 10 where 0 indicates no pain and 10 indicates unbearable pain (participants were required to indicate the point on the line which they believed best represented the maximum pain they experienced per day with 0 indicating no pain, 10 indicating unbearable pain).

Two new study subjects were scheduled each day for initiation of treatment and data collection. After initiation of treatment, these patients were given a questionnaire and requested to fill it and bring it back after seven days. During this period, assessments of pain and discomfort were conducted immediately after insertion of archwire, at 4 hours, 6 hours, 12 hours, 2

days, 3 days, 4 days, 5 days, 6 days and 7 days. Patients and their guardians were reminded by phone or text message each day to complete the recording sheet.

This was a double-blind study, where participants were blinded to the type of archwire they received. The operator was not blinded during the course of the treatment. The participant's identity and the type of archwire were masked by assigning an identification number to the questionnaire paper before pain scores was evaluated. This allowed the examiner to remain blind throughout the process. The normal distribution of the data was analyzed using the Kolmogorov-Smirnov method. Comparisons were made using Wilcoxon Signed Rank test and Mann Whitney U test via IBM SPSS Statistics version 25. The level of statistical significance was set at $P < 0.05$.

RESULTS

The present study involved a total of 86 participants who were divided randomly in two study groups, Group A (SE NiTi), n = 43 and Group B (Cu NiTi), n = 43. In Group A, one participant was lost to follow-up and another was excluded from the analysis, while in Group B, two participants were lost to follow-up. As a result, 82 participants in the two groups (n = 41 in each group) were evaluated at the end of the study. There were no significant differences between the two groups in sex ($P = 0.182$), age ($P = 0.230$), and the Little's irregularity index ($P = 0.133$) (Table 1).

Table 1: Demographic details and clinical characteristics of the two groups

Variable		SE-NiTi (Group A)	CU-NiTi (Group B)
Sex of Participants	Female	20	26
	Male	21	15
Age of Participants	09-14 years	27	22
	15-25 years	14	19
Initial Little's Irregularity Index	Mild	2	7
	Moderate	12	14
	Severe	27	20

Six pain parameters were assessed in the present study as portrayed in Table 2. From this table, pain occurred spontaneously in the majority of the participants; however, it was also triggered by chewing in a quarter of the study subjects. With respect to pain location, majority of the study subjects reported pain on the anterior teeth. Furthermore, pain was perceived as pressure by 97% of participants. Regarding the timing of the commencement of pain, 44.3% of participants reported experiencing it within the first four hours of the insertion of the archwires. In terms of pain duration, three quarter of all study subject reported having pain for 4 days or less, while 24% reported having pain for more than 4 days. Across all six parameters, no significant difference noted between the two archwires ($P>0.05$).

Table 2: Comparison of different pain parameters between the SE-NiTi and Cu-NiTi groups

		ARCHWIRE		
PAIN PARAMETERS	COMBINED N (%)	SE-NiTi N (%)	Cu-NiTi N (%)	*P*-Value
Pain experience				
Experienced pain	79 (96.3)	39 (49.4)	40 (50.6)	0.50
No pain	3 (3.4)	2 (66.7)	1 (33.3)	
Trigger:				
Spontaneous	58 (73.4)	30 (51.7)	28 (48.3)	0.48
Chewing	21 (26.6)	9 (42.9)	12 (57.3)	
Pain location:				
Anterior teeth only	55 (69.6)	28 (50.9)	27 (49)	0.68
All lower teeth	24 (30.4)	11 (45.8)	13 (54.2)	
Pain description				
Pressure	77 (97.5)	39 (50.5)	38 (49.4)	0.15
Dull and tingling	2 (2.5)	0	2 (100)	

Timing of pain initiation:				
Within 4 hours of archwire insertion	35 (44.3)	17 (48.6)	18 (51.4)	0.90
Beyond 4 hours of archwire insertion	44 (55.7)	22 (50)	22 (50)	
Pain duration:				
4 days or less	55 (69.6)	30 (54.5)	25 (45.5)	0.16
More than 4 days	24 (30.4)	9 (37.5)	15 (62.5)	

Regarding analgesic consumption, almost half of participants indulged on analgesics for pain relief. Analgesic use was relatively higher in SE-NiTi group compared to Cu-NiTi. Nevertheless, the difference was not statistically significant (P = 0.290) (Figure 1).

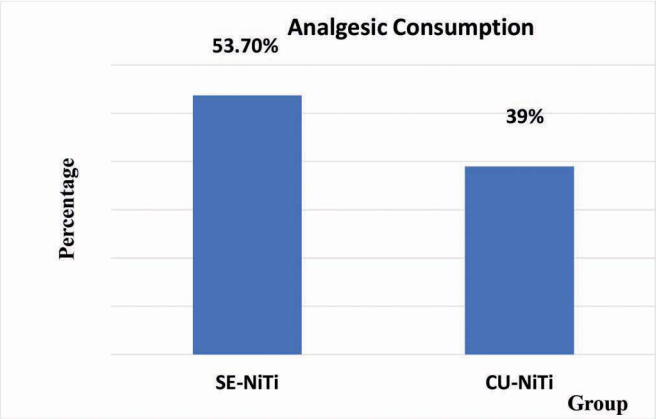

Figure 1. A bar graph to present the analgesic consumption in the two groups.

Pain was analyzed at different times according to the Visual Analogue Scale (VAS) by groups as shown in Figure 2. From the graph, VAS scores increased immediately after insertion of the archwires, peaking at 6-12 hours, and then began to decline. The rate of decline was relatively slower in the Cu-NiTi group compared to SE-NiTi group.

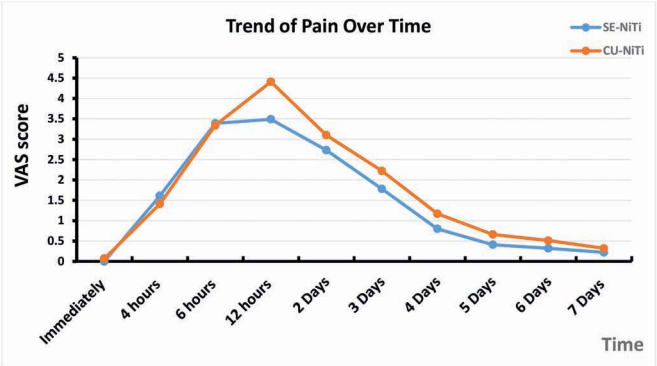

Figure 2: A line graph to show the trend of pain over time.

Table 3 shows that in each of the two groups pain increased significantly immediately after archwire insertion up to 6 hours (P < 0.05). The increase in pain was not significant from 6 to 12 hours (P > 0.05). Pain then began to decline significantly from 6 hours to day 7 (P < 0.05).

Table 3: Wilcoxon Signed Rank Test to compare Pain on the Visual Analogue Scale (VAS), between subsequent times points in each group separately.

Time Interval	Group	Mean Ranks		*P* value
		Negative Rank	Positive rank	
Pain 4hrs. VS pain Immediately	SE-NiTi	00	9.00	<0.001
	Cu-NiTi	4.50	9.28	0.001
Pain 6 hrs. VS Pain 4 hrs.	SE-NiTi	5.50	14.02	0.001
	Cu-NiTi	3.50	11.88	<0.001
Pain 12 hrs. VS Pain 6 hrs.	SE-NiTi	12.34	17.38	0.9
	Cu-NiTi	11.73	18.35	0.19
Pain 2 days VS Pain 12 hrs.	SE-NiTi	15.42	18.42	0.006
	Cu-NiTi	14.48	10.17	<0.001
Pain 3days VS Pain 2 days	SE-NiTi	12.65	23.75	0.001
	Cu-NiTi	13.43	8.00	<0.001

Pain 4 days VS Pain 3 days	SE-NiTi	12.50	00	<0.001
	Cu-NiTi	13.00	00	<0.001
Pain 5 days VS Pain 4 days	SE-NiTi	6.50	00	0.001
	Cu-NiTi	8.50	00	0.003
Pain 6 days VS pain 5 days	SE-NiTi	2.50	00	0.046
	Cu-NiTi	3.50	00	0.014
Pain 7 days VS pain 6 days	SE-NiTi	2.50	00	0.046
	Cu-NiTi	4.50	00	0.05

Table 4 presents pain comparison between the two group in seven days the table shows that there was no statistically significant difference in pain perception between the two groups from the time of archwires insertion to seven days. (P>0.05).

Table 4: Mann-Whitney U Test to compare Pain on the Visual Analogue Scale (VAS), between groups at each time point.

Time Interval	Group	Mean Ranks	Sum of Ranks	P value
Pain Immediately after archwires Insertion	SE-NiTi	40.50	1660.50	0.155
	Cu-NiTi	42.50	1742.50	
Pain 4 hours later	SE-NiTi	41.95	1720.00	0.848
	Cu-NiTi	41.05	1683.00	
Pain 6 hours later	SE-NiTi	41.79	1713.50	0.909
	Cu-NiTi	41.21	1689.50	
Pain 12 hours later	SE-NiTi	37.50	1537.50	0.124
	Cu-NiTi	45.50	1865.50	
Pain 2 Days later	SE-NiTi	39.16	1605.50	0.336
	Cu-NiTi	43.84	1797.50	
Pain 3 Days later	SE-NiTi	38.62	1583.50	0.263
	Cu-NiTi	44.38	1819.50	
Pain 4 Days later	SE-NiTi	37.90	1554.00	0.134
	Cu-NiTi	45.10	1849.00	
Pain 5 Days later	SE-NiTi	38.65	1584.50	0.176
	Cu-NiTi	44.35	1818.50	
Pain 6 Days later	SE-NiTi	39.55	1621.50	0.337
	Cu-NiTi	43.45	1781.50	
Pain 7 Days later	SE-NiTi	41.45	1699.50	0.976
	Cu-NiTi	41.55	1703.50	

DISCUSSION

The forces applied on teeth during early orthodontic treatment result in changes in blood flow in the periodontal ligaments (PDL) and the development of an acute inflammatory process, which are responsible for the immediate painful response.[16] It is evident that all orthodontic treatments will result in tension and compression zones in the PDL region, which will cause patients to feel pain.[9]

Nickel-titanium alloys have shown innovative advancement, the introduction of nickel titanium (NiTi) alloy with superelastic (pseudoelastic) and themoelastic property has gained wide acceptance among orthodontists as these archwires are capable of producing light continuous forces that can bring out fast tooth movement with minimal tissue trauma and patient's discomfort.[1]

Studies have found a relationship between discomfort experienced by patients after archwires placement and the forces being applied to the teeth.[17] Heavy forces cause noticeably more pain than light forces within 24 hours of force application, which can be explained by the correlation between the concentration of inflammatory substances and the intensity of the pain.[18] The reported optimum force magnitude for orthodontic tooth movement of human teeth is reportedly to range from a force as light as 18g to one as heavy as 1515g.[19] Some individuals may endure greater pain with the insertion of the archwires than they would have from tooth extraction.[9,4]

In the current study pain and discomfort after placement of archwires were measured in a period of 7 days on a visual analogue scale (VAS) of 10cm. This scale was found to be effective and appropriate, easy to use, reproducible and can be understood easily by most patients.[20] In comparison to verbal rating scales and other pain/discomfort assessment techniques, VAS is more accurate and exhibits superior sensitivity to slight variations in pain intensity.[21,22]

In the current study, the majority of patients (96%) experienced pain 12 hours following the initiation of orthodontic treatment in agreement with the findings from previous studies.[23, 24] In the Cu-NiTi group pain started immediately after insertion of archwires, which can be explained by the alloy structure of the Cu-NiTi wire leads the archwires to switch to a stiffer austenitic phase when it is exposed to the oral environment, increasing strain on the teeth.[10] However, the present study revealed no significant difference in pain experience between SE NiTi and Cu NiTi groups. In agreement with earlier studies the level of pain was relatively higher in Cu NiTi than SE NiTi group.[23] In contrast, previous studies have shown that pain associated with the Cu NiTi archwires is less than that associated with the conventional NiTi archwire.[25]

The current study revealed that pain was mainly localized on teeth and according to our data, the anterior teeth experienced significantly more discomfort than all the lower teeth and posterior teeth, which is consistent with other researchers' findings.[26,27] The possible reason being the anterior teeth are frequently more involved during alignment and leveling phase coupled by the fact that the incisors have smaller root surfaces than the posterior teeth. In agreement with previous studies[3] in majority of participants pain started spontaneously at rest and on chewing.

Pain was mostly described as pressure and pain level steadily climbed, reaching an average peak of 3.51 cm and 4.4 cm on first day at 12 hours in SE-NiTi and Cu-NiTi respectively, before gradually declining each day, this general time-course of pain intensity coincides with earlier studies.[15,27] The observed pain time-course correlates well with the increase in the concentration of inflammatory mediators specifically interleukin-1b that goes to peak at 24 hours as a response to orthodontic forces and decline to normal in a period of 1 week to 1 month.[18] Furthermore, the current data revealed that Cu NiTi had higher pain at peak level as compared to SE NiTi, though the difference was not significant.

The current study revealed no significant difference on pain levels between the two groups at different points in a period of 7 days. However, it has been found that 0.014-conventional NiTi wires induced significantly higher pain levels than 0.014-Super Elastic NiTi wires at 4 hours.[28] This previous finding can possibly be explained by the fact that different archwires materials were used.

The severity of orthodontic pain was further decreased by consumption of analgesics, whereas, less than half (47.6%) of patients relied on analgesics for symptomatic relief following initiation of orthodontic treatment, on the contrary, previous studies[20,28] found that majority of participants used analgesic during the first week of orthodontic treatment. In line with a previous study,[13] the current study revealed higher consumption of analgesics (53.7%) in SE NiTi group as compared to 41.5% in Cu NiTi group, however, the difference between the two groups was not statistically significant, contrary to previous research findings[20] which found minimal intake of analgesics in SE-NiTi. Nevertheless, analgesic consumption only gives a superficial assessment of pain response because it is connected with personality variables like anxiety even if this finding is at odds with

the VAS results.[29]

Pain is a subjective perception, it can be impacted by a variety of variables in addition to the amount of force applied, such as age, gender, the degree of irregularity in the teeth, and psychological issues. The current study portrayed that younger age group of less than 15 years significantly consumed more analgesics than the older age group of 15 years and above. In line with earlier studies.[4,26] there were no statistically significant differences between male and female patients' VAS pain scores, pain duration and intake of analgesics. On the other hand, earlier research has documented that female patients experienced higher pain and consumed more analgesics.[3]

The degree of initial irregularity was not found to be statistically significant in the pain response as was previously described[20] and validated in the current study. This implies that the inter bracket span and degree of irregularity may not have a substantial impact on the forces acting on the teeth. The association between age and pain scores at different time interval after the insertion of archwires was not found. This is contrary to earlier studies, which indicated that patients under the age of 13 years had lower pain scores while those over the age of 16 years had greater pain scores.[3] This may be explained by the fact, the previous study had extensive age range of participants, and in addition the female contributed more than half the number of participants. All these factors, the interaction of the greater age and the higher percentage of female participants may account for the difference between the two studies, as previously reported.[30]

In clinical practice, managing orthodontic pain is fundamental. According to the study's preliminary findings, the majority of patients suffer their most pain during the first six to twelve hours after starting fixed orthodontic treatment. This knowledge can aid in more effective resource management, including patient motivation, education and the use of pharmaceuticals for pain relief.

CONCLUSION

Super elastic NiTi and Copper NiTi archwires have no significant difference with regard to the level of pain experienced by patients during the first week of levelling and alignment.

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