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Comparison of Clinical Efficiency between Super Elastic Nickel Titanium (SE NiTi) and Copper Nickel Titanium (Cu NiTi) Archwires during Alignment Phase of Orthodontic Treatment

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ABSTRACT

Introduction: Transformation of the metallurgy industry over the years has led to remarkable advancement in Nickel Titanium (NiTi) alloy, producing orthodontic NiTi archwires with enhanced properties, which are routinely employed during the initial phase of orthodontic treatment. Nevertheless, the clinical superiority between the second and third generation of NiTi arch-wires; the Super Elastic NiTi (SE NiTi) and Copper NiTi (Cu NiTi) archwires respectively has not been studied in the Tanzanian population. Hence, this study aimed to compare the clinical efficiency of Super Elastic NiTi (SE NiTi) and Copper NiTi (Cu NiTi) arch-wires during the alignment phase of orthodontic treatment.

Material and Methods: A total of 86 participants were randomly assigned to either study group, Group I (0.014-in SE NiTi), n=43 or Group II (0.014-in Cu NiTi), n=43. However, three participants lost to follow up and one participant was omitted from analysis. Hence 82 participants, 41 in each of the two groups were assessed. The arch-wire types were labeled and placed in sequentially numbered opaque sealed envelopes for participant allocation. Blinding to group assignment was applied to the participant and during outcome assessment. Data were analyzed by SPSS Statistics Version 25 with a p-value set at <0.05.

Results: Little's irregularity index significantly decreased over time in both groups ($p<0.001$), however, there was no statistically significant difference between the two arch-wire types in their efficiency on teeth alignment ($p = 0.435$) and arch width expansion ($p>0.05$).

Conclusion: There was no significant difference between SE NiTi and Cu NiTi in alignment efficiency and inter-canine, inter-premolar and inter-molar arch width changes. There was no statistically significant inter-canine arch width change in the Cu NiTi group.

Keywords: Orthodontics, Alignment, Super-elastic NiTi, Copper NiTi.

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INTRODUCTION

Dental irregularity refers to the deviation of teeth relative to the arch form, clinically represented as crowding. [1] Fixed orthodontic therapy is administered in stages, and it involves the use of arch-wires which generate the biomechanical forces required for tooth movement. [2] The early stage of orthodontic treatment focuses on the alignment and levelling out the arches to rectify vertical and horizontal dental facial discrepancies. [3] Arch form alterations in transverse dimensions occur during the alignment process, and these changes are essential to relieve crowding, especially in non-extraction orthodontic cases. [4]

During alignment stage of fixed orthodontic therapy, round arch-wires are typically employed since rigid rectangular wires cause oscillation of the root apices as the teeth realign resulting in undesirable outcomes including root resorption. [5] Consequently, for proper alignment and leveling the initial arch-wires ought to exert light and steady forces. [3] During the alignment stage of orthodontic therapy, nickel-titanium arch-wires with their clinically favorable super elasticity and shape memory qualities are quite effective. [6]

Copper Nickel Titanium (Cu NiTi) is one of the modern introductions to the group of Nickel Titanium shape memory alloys whose clinical property has shown substantial dependence on temperature.[7] In the oral environment, Cu NiTi transforms to austenite phase to become stiffer and more inflexible, this alloy has less hysteresis, which enables it to distribute more force uniformly from one side to the other, resulting in a faster and more effective tooth movement.[8]

Super elastic Nickel Titanium (SE NiTi) properties are minimally affected by temperature. The super elastic property of therapeutic value is primarily dependent on the transition that takes place in the tensile strain area that produces the clinically desired light uninterrupted force during unloading, enabling effective tooth movement with a small degree of periodontium destruction. [2,8]

A previous in vitro study [9], found that thermal Copper NiTi generated light constant force, as a result, it can be used to effectively correct severe crowding as it can be readily engaged to the brackets slots with the least effort. However, several in vivo studies [10, 11] have reported no discernible difference between SE NiTi and Cu NiTi arch-wires in terms of alignment effectiveness and arch width changes.

Tanzania's clinical experience indicates that both SE NiTi arch-wire and Cu NiTi arch-wires are frequently used in orthodontic treatment. Nevertheless, a recent review [12] has claimed the insufficiency of quality randomized clinical trials to provide sufficient evidence as to which arch-wire is more effective than the other.

The primary objective of this study was to clinically compare the efficiency of SE NiTi arch-wires and thermally activated Cu NiTi arch wires by measuring the amount of tooth movement over a period of 6 weeks using little's irregularity index reduction while the secondary outcome measure of the study was transverse arch dimension changes.

The null hypothesis of the study was that there is no significant difference in the performance of the two arch-wires (SE NiTi and Cu NiTi) in regard to Little's Irregularity index reduction and transverse arch expansion.

MATERIAL AND METHODS

This single-center randomized prospective comparative study was conducted at the School of Dentistry of Muhimbili University of Health and Allied Science (MUHAS). The study was approved by the MUHAS Research and Ethics Committee with a registration number of MUHAS-REC-07-2022-1294.

Study Design

This randomized prospective comparative study with a 1:1 allocation ratio, compared the efficiency of two orthodontic arch-wires amongst participants in two groups of SE NiTi and Cu NiTi archwires.

Participants

The study was conducted in the pediatric/orthodontic clinic of the School of Dentistry at Muhimbili University of Health and Allied Sciences located in Dar es Salaam, Tanzania. It is a public dental clinic; the clinic offers specialized treatment in the spectrum of clinical dentistry and attends to patients from most parts of the country. This study was carried out on patients attending orthodontic treatment at the MUHAS dental clinic. Informed consent and/or assent forms were voluntarily signed by all participants, together with their parents or guardians. The following criteria had to be met in order for a patient to be considered for inclusion; (1) aged between 9 to 25 years with permanent dentition; (2) Non-extraction fixed orthodontic treatment; (3) Little irregularity Index score > 2mm; (4) patients with no pathological lesion, both clinically and radiologically; (5) treatment approach which did not involve lingual arch appliance; (6) no congenitally missing or impacted lower anterior teeth; (7) no previous history of active fixed orthodontic treatment.

Study intervention

Group I

After obtaining an OPG x-ray, alginate impression of the mandibular arch, clinical photographs and bonding of teeth with 0.022 * 0.028 slot MBT stainless steel metal bracket (Guber dental manufacturer, Hangzhou, PR. China) and fine-tuning the bracket's location

, 0.014 SE NiTi arch-wires (Guber dental manufacturer, Hangzhou, PR. China) was fully inserted into the bracket slot and ligated using 0.2mm stainless steel ligatures (Guber Dental Manufacturer, Hangzhou, PR. China).

Group II

After obtaining an OPG x-ray, alginate impression of the mandibular arch, clinical photographs and bonding of teeth with 0.022 * 0.028 slot MBT stainless steel metal bracket (Guber dental manufacturer, Hangzhou, PR. China) and fine-tuning the bracket's location 0.014 Cu NiTi arch-wires (Guber dental manufacturer, Hangzhou, PR. China) was fully inserted into the bracket slot and ligated using 0.2mm stainless steel ligatures (Guber Dental Manufacturer, Hangzhou, PR. China).

The arch-wires were cut distal to the molar tube without cinching back. The arch-wire was not changed for the entire follow-up period of six weeks.

Outcomes

The primary goal of this study was to evaluate the amount of tooth movement using the Little's irregularity index, the secondary outcomes were to evaluate the arch width expansion. The Little's irregularity index measurements were taken from contact point displacement between the left canine to the right canine by holding the digital Vernier caliper parallel to the occlusal plane. These measurements were performed on the study cast fabricated at T0 (Before initiation of treatment) and at T6 (Six weeks after initiation of treatment). The same examiner (P.M), and the same instruments were applied at T0 and T6. The transverse length between the canine cusp tips was taken as the inter-canine width, inter-first premolar width was taken as the distance between facial cusp tips of first bicuspids and inter-molar width was taken between Mesiobuccal cusp tips of first molars. There were no changes in the outcomes after the trial commenced as all outcome measurement was preplanned.

A sample size of 86 patients (43 in each group) was estimated based on a preceding study by Sebastian et al. [13] Randomization was accomplished by random number generation, which was produced via Microsoft Excel, employing the Excel formula (=CHOOSE (ROUNDUP (RANK (B87, B2:B172)/43, 0), "CU", "SE")

Blinding

The study followed a double-blind design where the participants were blinded to the type of arch-wire they received. The operator was not blinded throughout the treatment period as he could distinguish the NiTi arch-wire varieties. The examiner evaluating the irregularity index and arch width expansion was unaware of the group allocation of participants. The participants name and the type of arch-wire were concealed before the measurements by assigning an identification number to the study casts, which allowed the examiner to be blinded throughout the procedure.

Statistical methods

The normal distribution of the data was analyzed using the Kolmogorov-Smirnov method

Independent samples t-test and paired t-test were used for comparison via the IBM SPSS Statistics version 25. At $p < 0.05$, the limit for statistical significance was established.

RESULTS

A total of 86 patients were randomly assigned to either study group, group I (SE NiTi), n=43 or group II (Cu NiTi), n=43. In group I, one participant lost to follow up and another one was omitted from analysis while in group II, two participants lost to follow up. Consequently, at the completion of the study 82 participants were assessed in the two groups each n=41. As portrayed in Table 1. There were no significant differences between the two groups in sex ($p=0.182$), age ($p=0.230$), arch width dimensions ($p>0.05$), and the initial Little's irregularity index ($p=0.133$). The demographic and the pretreatment data are portrayed in Table 1.

Table 1: Pretreatment characteristics of the arch-wires groups.

Variable	Category	Groups		*p*-values
		SE NiTi	Cu NiTi	
Sex of Participants	Female	20 (48.8%)	26 (63.4%)	0.182*
	Male	21 (51.2%)	15 (36.6%)	
Age of Participants (yrs)	09-14	27 (65.9%)	22 (53.7%)	0.230*
	15-25	14 (34.1%)	19 (46.3%)	
Arch width Dimension at T0	Intercanine	27.96 ± 2.22	27.81± 2.15	0.761**
	Interpremolar	35.25 ± 2.29	34.99 ± 2.41	0.617**
	Intermolar	45.80 ± 2.97	45.48 ± 2.78	0.617**
Initial Little's Irregularity Index at T0		8.35 ± 2.73	7.35 ± 3.33	0.133**

**Independent t Test, *Chi-Square test

As shown in Table 1, at baseline, the mandibular anterior mean irregularity index in the two groups was nearly the same (p=0.133). After intervention the mandibular anterior irregularity index reduction between T0 and T1 (6 weeks period) was assessed (Table 2). Over the course of six weeks, the mean Little's irregularity index significantly decreased in each of the SE NiTi and Cu NiTi groups (p<0.001). Moreover, the difference in Little's irregularity index reduction was not statistically significant in the groups during the study period. (Table 2).

Table 2: Comparison of Little's irregularity index (mm) before and after intervention between and within the two groups.

Time	Study Group Irregularity Index		P value*	Test Statistics
	SE-NiTi mean (SD)	CU-NiTi mean (SD)		
T0	8.35 (2.73)	7.35 (3.33)	0.133	1.518
T1	4.56 (2.12)	4.04 (2.46)	0.310	1.021
P value**	<0.001	<0.001		
Test Statistics	8.261	7.344		
TO-T1	3.79 (2.93)	3.28 (2.86)	0.435	0.784

SD, indicates standard deviation, *Independent t Test, **Paired t Test.

Table 3 compares the mean increase in transverse arch width dimension in a period of six weeks within the two groups; In SE NiTi the mean inter-canine width increased substantially in a period of 6 weeks (p=0.001) Conversely the increase in the mean inter-canine width in the Cu NiTi group was not significant (p=0.1). For a period of 6 weeks, the inter-premolar width increased significantly in both the groups however substantial increase was scored in the SE NiTi group (p=0.002) as compared to the Cu NiTi group (p=0.01). The inter-molar width also increased significantly in both groups, whereas SE NiTi exhibited a more substantial increase (p=0.001) than the Cu NiTi group (p=0.021).

Table 3: Comparison of arch width dimension before and after intervention within groups

Arch Dimension	Study Group	Time		P value*	Test Statistic
		T0 mean (SD)	T1 mean (SD)		
Intercanine width	SE NiTi	27.96 (2.22)	28.47 (1.94)	0.001	3.633
	Cu NiTi	27.81 (2.15))	28.17 (2.07)	0.1	1.684
Interpremolar width	SE NiTi	35.25 (2.29)	35.91 (2.09)	0.002	3.349
	Cu NiTi	34.99 (2.41)	35.59 (2.03)	0.011	2.655
Intermolar width	SE NiTi	45.80 (2.97)	46.29 (2.94)	0.001	3.447
	Cu NiTi	45.48 (2.78)	45.87 (2.59)	0.021	2.406

SD, indicates standard deviation, *Paired t Test.

Table 4 compares the mean increase in transverse arch width dimension in a period of six weeks between the two groups. Though somewhat greater in the SE NiTi group compared to the Cu NiTi group, the overall mean increase in the inter-canine, inter-premolar, and inter-molar width was not statistically significant.

Table 4: Comparison of arch width dimension before and after intervention between the two groups

Arch Dimension	Time	Study Group		P value*	Test Statistics
		SE NiTi Mean (SD) mm	Cu NiTi Mean (SD) mm		
Intercanine width	T0	27.96 (2.22)	27.81 (2.15)	0.761	0.305
	T1	28.47 (1.94)	28.17 (2.07)	0.509	0.663
	T1-T0	0.51 (0.90)	0.36 (1.38)	0.569	0.571
Interpremolar width	T0	35.25 (2.29)	34.99 (2.41)	0.617	0.502
	T1	35.91 (2.09)	35.59 (2.03)	0.481	0.708
	T1-T0	0.66 (1.26)	0.60 (1.44)	0.836	0.208
Intermolar width	T0	45.80 (2.97)	45.48 (2.78)	0.617	0.503
	T1	46.29 (2.94)	45.87 (2.59)	0.495	0.686
	T1-T0	0.49 (0.92)	0.39 (1.04)	0.644	0.463

SD, indicates standard deviation, *Independent t Test

DISCUSSION

The purpose of this study was to compare the efficiency of Super Elastic Nickel Titanium and Copper Nickel Titanium arch-wires in terms of Little's irregularity index reduction and arch width expansion. It's the first study of its kind to be conducted in Tanzania, which involved a total of 82 orthodontic patients attending the MUHAS dental clinic divided into two groups (n=41). In line with a previous study [14], the mean age was around 14.68±3.62 years, it's during this time that most people get orthodontic treatment as their permanent teeth have erupted. Similar to a previous study [10], female participants were more than males. The current study revealed no statistically significant difference between the two initial arch-wires in terms of effectiveness in tooth alignment and arch width expansion.

The present study compared the efficiency of 0.014' SE NiTi and 0.014' Cu NiTi arch-wires regarding Little's irregularity index reduction and arch width expansion. In this study there was no statistically significant difference between the two groups in age, gender, the initial Little's irregularity index, and the initial arch-width dimensions suggesting that demographic and clinical characteristics should not be used as an explanation for any differences between the research groups. Moreover, blinding was carried out to reduce bias, which increased the accuracy of the findings.

The total amount of alleviation of crowding within 6 weeks evaluated using mean change in the Little's irregularity index was 3.79 ± 2.93 mm in the SE NiTi group and 3.28 ± 2.86 mm in the Cu NiTi group which deciphers to 45% of the total mean reduction of the Little's Irregularity index in both the two groups. This translates to the rate of alignment by 0.09 ± 0.067mm and 0.078 ± 0.068mm per day in SE NiTi and Cu NiTi, respectively. The alignment rate for SE NiTi in the present study is in agreement with that of a previous study [15] which showed that the rate for SE NiTi and Cu NiTi archwires was 0.08 mm and 0.135 mm per day, respectively. For the Cu NiTi group, however, the alignment rate is nearly half of the previously reported rate.

Precise comparison is difficult because some studies used different measurement systems, different intervals of measurement, and longer or less than a 6-week follow-up period which was employed in the current study. The results of this investigation are consistent with a prior study [16] which found that there was no statistically significant difference in the reduction of irregularity index between the two types of arch-wires. On the contrary, previous studies have reported that Cu NiTi arch-wires were substantially faster in irregularity index reduction than the traditional NiTi arch-wires [17], additionally, it has been shown that coaxial SE NiTi arch-wires were significantly more effective than single-stranded SE-NiTi arch-wires [13]. The observed variation can be accounted for by the different types of arch-wires investigated in the previous studies. Similar to this study, Atik et al. [11] found no difference in alignment efficiency between 0.014-in, thermally activated Cu NiTi arch-wires and SE NiTi arch-wires when determining the effectiveness of alignment of the upper anterior teeth whereby in a period of eight weeks, the irregularity index decreased by 6.80 ± 0.55 mm for Cu NiTi and 7.40 ± 0.50 mm for SE NiTi, respectively.

In contrast to the current study, one of the prior study [13] found that employing single-stranded and coaxial tubular SE NiTi arch-wires reduced the mean irregularity index by 4.88 ± 2.74 mm and 6.17 ± 2.38 mm, respectively, in the mandibular anterior teeth for a period of 4 weeks. This study found a statistically significant difference between the two arch-wires, nevertheless, the amount of irregularity index reduction is greater than what the present study demonstrated. In the same line, a study by Jain et al [18] reported a reduction in Little's irregularity index by 2.88 ± 0.31 mm and 2.33 ± 0.66 mm in heat-activated NiTi and SE NiTi respectively for a duration of 4 weeks. This study found no statistically difference between the archwires studied on alignment efficiency. However, the extent of irregularity index reduction is lower than the amount of reduction found in the current study. The differences in initial irregularity among the study population may be the cause of the inconsistencies in the amount or extent of de-crowding reported, additionally, individual variations in the periodontal ligament's metabolic response have been shown to have the potential to mask the differences. [18]

Besides, a previous study that used Austenite NiTi and Cu NiTi arch-wires demonstrated decrease in the irregularity index of 2.56 mm and 2.87 mm, respectively. [19] Comparably, a different earlier study [20] found that using Heat activated NiTi and SE NiTi arch-wires reduced the irregularity index by 2.69 and 2.74 mm, respectively. There were no statistically significant differences between the arch-wires evaluated in each of the two trials [19, 20] whose methodologies were substantially similar to the current study; accordingly, the trials found no statistically significant differences between the arch-wires studied. Nonetheless, the amount of irregularity index reduction is less than in the present study. This could be because the participants in the current study were, on average, younger, and it is well known that age has a substantial impact on the degree of movement of teeth in orthodontics. [21]

According to one of the aforementioned study [22] applying 0.014- and 0.016-inch archwires successively every six weeks for a total of 12 weeks reduced crowding by 4.07 mm in the Nickel Titanium and 3.58 mm in the Copper Nickel Titanium group. These results are in line with the findings of the current study, which found that for a period of six weeks, irregularity index reduced by 3.79 (2.93) mm and 3.28 (2.86) mm in SE NiTi and Cu NiTi, respectively.

The fact that the majority of alignment happens during the early phase of treatment with light arch-wires [23], may account for the observed parallels in the mean de-crowding between the two studies despite the large variations in the duration of the study period and change in the size of the arch-wires.

The current study found no statistically significant difference between the two types of arch-wires' effects on the transverse expansion of the mandibular arch (Table 4). Dimension changes in inter-canine, inter-premolar, and inter-molar width were observed in both groups. In the SE NiTi group, there was a statistically significant change in the inter-canine width, inter-premolar width, and inter-molar width; however, in the Cu NiTi group, the change in inter-canine width was not significant (Table 3), as opposed to earlier studies that portrayed greater inter-canine arch width changes in the Cu -NiTi group compared to the NiTi group. [22]

The transverse dimensions of the arch alter during alignment, and these changes are essential to relieve crowding, especially in cases where extraction is not performed. [4] In line with a previous study [24], the current study found that arch width changes are more pronounced in premolar regions as compared to molar and canine regions. In addition, no significant change in the inter-canine width were found in the Cu NiTi group in the current study. This may be because Cu NiTi, on average, exerted substantially less force for inter-canine expansion than SE NiTi. [25]

The current findings are analogous to the preceding studies [23] which reported less than 1 mm of inter-canine and inter-molar arch width expansion, along with a study by Celikoglu et al. [26] Similar to this study, a previous study [27] found no significant difference in the mandibular arch width dimensions changes between Cu NiTi and NiTi arch-wires

In the present study, treatment was administered by a single clinician, which limits how broadly our study findings may be applied. The current study's follow-up period was limited to six weeks due to time constraints. Therefore, more prospective randomized clinical studies should be carried out to ascertain the extra significant effect of different NiTi arch-wires.

CONCLUSION

The results of this study revealed no evidence that the amount of tooth movement differed between SE NiTi and Cu NiTi arch-wires and regarding arch width expansion, Cu NiTi arch-wire portrayed no significant inter-canine arch width expansion.

CONFLICT OF INTERESTS

The authors declare that they have no competing interests

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