A comparison of the effectiveness of three types of orthodontic aligning archwire materials: A randomized clinical trial

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ABSTRACT-

Objectives: To compare the heat-activated nickel titanium (HANT), conventional NiTi and Copper NiTi archwires in terms of their effectiveness of aligning the teeth, possibility of inducing root resorption and pain perception

Subjects and methods: Thirtyparticipants aged 15-30 years with mandibular anterior crowding of 4–6 mm, who required fixed orthodontic treatment were randomly allocated into the three archwires groups with each group having 10 patients. The archwire sequence in both groups was 0.014-inch followed by 0.016-inch. Each archwires were placed for a period of 4 weeks. The outcome measures included the amount of crowding assessed by using Little's irregularity index (LII), apical root resorption, and pain perception by Visual Analogue Scale(VAS). The intra group comparison of alignment was done by using repeated measures of ANOVA whereas inter group comparison of alignment was done by ANOVA test, root resorption was tested by Paired t-test and Kruskal-Wallis test and pain perception were tested by Kruskal-Wallis test ($P < 0.05$).

Results: The patients were selected and randomized into the three groups and analyzed.Theintergroup and intra group comparison of alignment for the three archwire groups at different time events was not found statistical significant with $p>0.05$.Root resorption and pain perception also showed non-significant difference between the three groups.

Limitations: Risk of bias during allocation as it was performed by a single examiner in a single centre anda long-term evaluation of root resorption is required.

Conclusions: All the three archwires were almost similar in terms of alignment, inducing root resorption and pain perception with a slight favor in case of Heat Activated NiTi (HANT) in terms of crowding relief.

INTRODUCTION

Fixed orthodontic appliances use brackets and different types of archwires to deliver forces on teeth. Light and continuous forces are required to achieve tooth movement with minimum patient discomfort and pathological effects on the teeth and their surrounding structures. In the early stages of treatment, lighter and more flexible aligning archwires are used to correct teeth crowding and rotations. Due to variation in archwires, it is important for the orthodontist to understand the optimal properties for all of the available archwires in order to choose the most appropriate and effective type.[1]

Orthodontic archwires have undergone remarkable progression concurrent with the introduction of different alloy systems, archwire configurations and appliance systems. Gold archwires were the only available orthodontic wires in 1930s.[2] In 1933, gold alloy was replaced by stainless steel and solid steel wire marketed in different sizes, which became widely accepted by orthodontic practice. The use of NiTi archwires in orthodontics was first described by Andreasen and Hilleman in 1971; these wires were manufactured as Nitinol wires. Later on came the introduction of the superelastic NiTi archwires, which were first adopted in 1985 by Burstone et al. and Miura et al. in Japan. Since their development, improvements in their manufacturing and composition designed to enhance their properties have been introduced. It has been suggested that because superelastic alloy archwires provide a more continuous light force to the teeth than do other alloy archwires, rapid tooth movement will result.[1]Nickel Titanium alloy can be manufactured in a stable form, so that there is no possibility of phase transition. It can also exist in an active form with two different crystalline or lattice structures namely the martensitic (M) form and the austenitic (A) form. Transition between the two phases can be induced by stress application or a change in temperature and this alters the properties of the wire without affecting the integrity of the wire. Active form wires have both phases existing simultaneously in variable proportions. It is the ability of the two phases to coexist which gives rise to the superelastic properties of active NiTi alloys. The temperature at which the alloy change from one phase to another is known as the transition temperature and this can be present during manufacturing.[3]

Root resorption is undesirable because it can affect the long-term viability of the dentition, and reports in the literature indicate that patients undergoing orthodontic treatment are more likely to have severe apical root shortening. Histologic studies reported greater than a 90% occurrence of orthodontically induced inflammatory RR (OIIRR) in orthodontically treated teeth. Lupi and Linge reported the incidence of external apical RR (EARR) at 15% before treatment and 73% after treatment. In most cases, the loss of root structure was minimal and clinically insignificant.[4] Root resorption associated with orthodontic treatment has been recognized since the report of Ketcham (1927). Later, Massler and Malone (1954) found root resorption in 86.4 per cent of orthodontic patients. Risks for root resorption such as systemic factors (Linge and Linge, 1983; Goldie and King, 1984), treatment mechanics (Malmgren et al., 1982; Linge and Linge, 1983), treatment period (Linge and Linge, 1983; Levander and Malmgren, 1988; Mirabella and Årtun, 1995), age (Oppenheim, 1942; Newman, 1975; Linge and Linge, 1983), root shape (Goldie and King, 1984; Levander and Malmgren, 1988; Mirabella and Årtun, 1995), density of alveolar bone (Oppenheim, 1942; Goldin, 1989; Kaley and Phillips, 1991), and oral habits (Odenrick and Brattström, 1985) have been investigated.[5]

Pain is a common experience for patients undergoing any form of dental treatment. It may be that patients even decide to avoid dental treatment because of the pain they anticipate or the fear of pain. The situation is not different for the patients seeking orthodontic treatment. Patients often experience some degree of discomfort after placement of orthodontic appliances, which is expressed as feelings of pressure, tension, soreness of teeth, and pain. Patel and Lew have reported that about 8% and 30% of patients, respectively, discontinue treatment because of the pain experienced at the early stages of orthodontic treatment.[6] During active orthodontic treatment, 70% to 95% of patients have been found to report pain, with some seeming to have a higher tendency to suffer acute and prolonged pain than others. The magnitude of pain depends on several objective and subjective factors such as sex, individual pain thresholds, the magnitude of force applied, emotional state and stress, cultural factors, previous pain experiences and age.[7]

Light and continuous forces are desirable to achieve physiologic tooth movement with minimum pathological effect on the teeth and their surrounding structures. The theoretical advantage of superelastic NiTi wires over other archwires is based solely on in vitro testing, and in order to be validated, this should be assessed clinically.[8]

In this study, we aim to compare the effectiveness of using heat-activatedNiTi(HANT), conventional NiTi and CuNiTi archwires during the initial phase of orthodontic treatment in terms of alleviation of crowding, possibility of inducing root resorption and pain perception.

MATERIAL AND METHODS

The participants were selected from the Out Patient Department (OPD) of Department of Orthodontics, Jaipur Dental College,Maharaj Vinayak Global University, Jaipur who were undergoing fixed orthodontic treatment.

Sample design: A total of 30 participants (10 patients in 3 groups) in the age group of 15-30 years, undergoing active fixed orthodontic treatment were included in this study.

The patients were randomly allocated into the 3 groups with each group containing 10 patients. In Group I, the participants were given Heat-activated NiTi (HANT) archwires. Group II, the participants were given conventional NiTi archwires. In Group 3, the participants were given CuNiTi archwires.

Patient records were included if they satisfied the following criterias:

a) Patients requiring fixed orthodontic treatment
b) Lower anterior crowding with Little's Irregularity Index (LII) of 4-6mm
c) All teeth erupted to the second molars in the lower arch
d) Patients with favourable overbite and overjet that allowed brackets to be placed on the lower teeth without occlusal interferences
e) Patient with good periodontal health

EXCLUSION CRITERIA

Exclusion criteria for participants selection included the following:

(a) Patients who had undergone previous active orthodontic treatment.
(b) Patients who had spacing in the lower anterior region or a missing lower incisor.
(c) Patients whose treatment plans included extraction of a lower incisor.
(d) Patients with blocked-out tooth that did not allow for placement of the bracket at the initial bonding appointment.
(e) Participants with a positive history of dental pain or on any medication that could influence pain perception.
(f) Patients with parafunctional habits or history of dental trauma or pre-existing root resorption.

The study and the examinations throughout its course was performed by a single examiner. The data collected by the examiner was reported to a supervising authority at each interval. All the materials used during the study remained the same and no alteration in the materials and method of recording the data was made sure.

The participants were informed about the study verbally in order to take the initial approval of participation and written informed consent was obtained from the patients or their parents (in case of minor) before entering the study.

After approval from the supervising authorities, the study design and protocols were presented to the institutional ethical clearance committee and approval was made by the research approval committee of Jaipur Dental College, Maharaja Vinayak Global University, Jaipur.

METHODS

The patients were bonded with MBT prescription brackets(0.022×0.028inch slot). **Archwire sequence for each group are as follows:**

1) Heat activated NiTi (HANT): 0.014 inch 0.16 inch
2) Conventional NiTi: 0.014 inch 0.016 inch
3) Copper NiTi: 0.014 inch 0.016 inch

On the day of bonding, the 0.014inch archwire was placed. The archwires were fully tied to the brackets by ligature ties. The date that each of the patient received a wire was recorded, and all patients were followed for a duration of 4 weeks. After 4 weeks, it was replaced by the 0.016inch archwire.

A good quality alginate impression for the lower arch was taken at the pre-treatment phase. The arch is then bonded with the brackets and bands and the initial wire was placed. At the routine follow-up appointment after 4 weeks(T1), the 0.014inch wire was removed and another alginate impression was taken. At the subsequent appointment after 4 weeks(T2), the whole procedure was repeated. Patients were called to remind them of upcoming appointments 1 to 2 days ahead of time. Stone study models, using Type 3 Dental Stone was obtained at each stage without any inconsistencies (such as bubbles) to be used to measure the changes of alignment.

The changes in the alignment of the lower incisors was measured in millimeters from the study models using Little's irregularity index (LII) at the designated serial stages of alignment (T0,T1,T2) using a digital Vernier caliper to measure the extent of mesial and distal contact displacement from the mesial contact point of lower canine to that on the other side (to the nearest 0.01 mm).

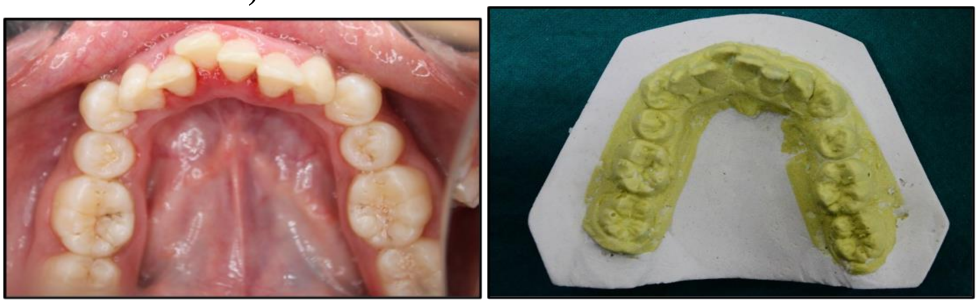

Figure 1(a)Figure1(b)

Figure 1-Pre-treatment photographs of a patient treated with Copper Nickel Titanium archwires (a) Clinical photographs (b) On cast

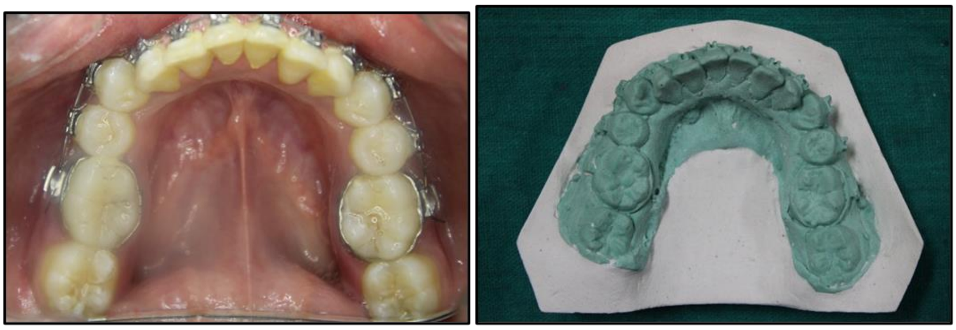

Figure 1(c) Figure 1(d)

Alignment after placement of 0.014 inch CuNiTi archwire(c)Clinical photographs (d) On cast

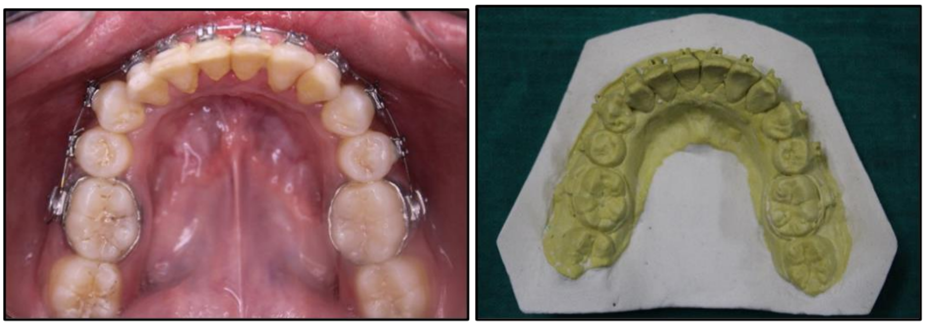

Figure 1(e) Figure 1(f)

Alignment after placement of 0.016inch CuNiTi archwire (e)Clinical photographs (f) On cast

Root resorption was assessed by digital periapical radiographs obtained by long cone paralleling technique for the lower incisors for each patient using intraoral sensors. Two radiographs were taken for each of the patients, the initial radiographs were taken before bond-up and the final radiographs were taken after 8 weeks after the alignment of 0.016inch archwire. Root resorption was evaluated for the mandibular central incisors and the worst score was taken using the scoring index by Malmgren et al (1982).

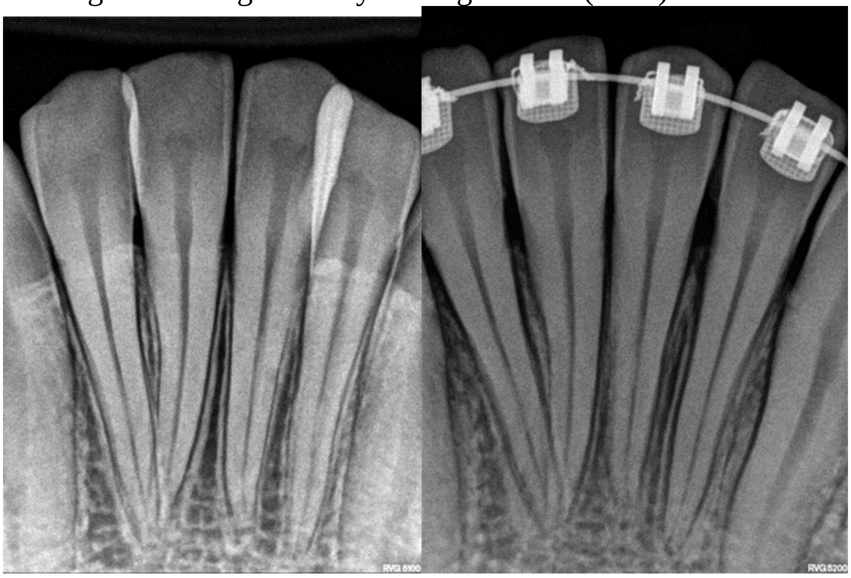

Figure 2(a) Figure 2(b)

Figure 2: Digital periapical radiograph of a patient treated with Copper Nickel Titanium archwires (a) Pre-treatment radiograph(T0) (b)Radiograph after 8 weeks (T2)

Pain perception of the patients was recorded after the placement of the archwires on a Visual Analog Scale (VAS).On the day of placement of the initial archwire, a seven-page booklet that contained 100-mm horizontal visual analogue scale (VAS) was provided to each of the patients to mark their pain intensity. Subjects were asked to mark the point on the line which they believed to best represent the maximum pain they experienced per day, at the indicated time periods. Verbal instructions and guidance during the baseline assessment were provided to familiarize the participants with the pain assessment procedure. The patients were instructed to mark on the scale at each time interval to represent the perceived severity of pain during each of four activities: chewing, biting, fitting the back teeth, and fitting the front teeth. Patients were reminded daily by a phone call or a text message to fill in the recording sheet. Incidence and severity of pain were recorded by the patient for seven days after bonding. For all participants, assessments of pain/discomfort were made at night on a daily basis to ensure that the follow-up time points for pain assessment were the same. Patients were asked to return the questionnaire at the next appointment. This was repeated after T1 and T2 routine follow-up adjustment appointments.

Patients were instructed not to take any additional analgesics. If additional ‘‘rescue’’ medication was needed, they were instructed to indicate the date and the dosage of the medication taken. The trial would be stopped if there is severe pain which cannot be tolerated by the patient.

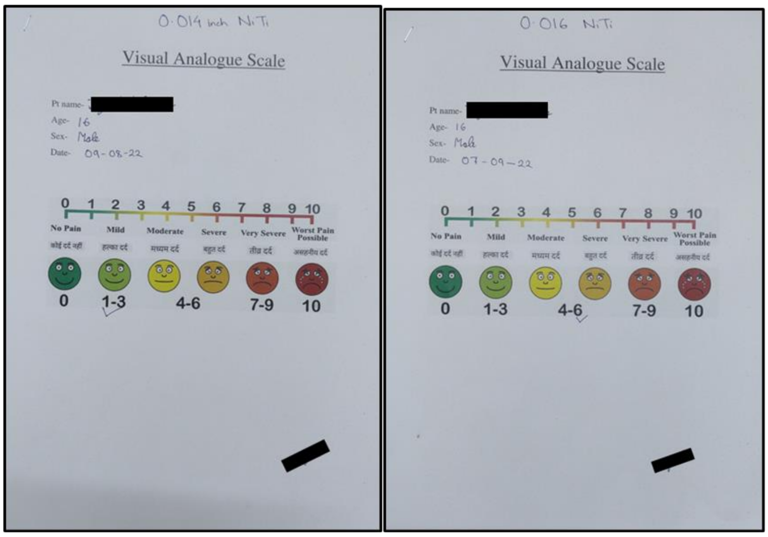

Figure 3 (a　　　　**Figure 3 (b)**

Figure 3: The front page of the seven page booklet of Visual Analogue Scale of a patient treated with conventional Nickel Titanium wires (a) After 0.014 inch wire placement (b)After 0.016 wire placement at an interval of 4 weeks

RESULT

STATISTICAL ANALYSIS

All the collected data was tabulated in MS-Excel. Data was analysed using the Statistical Package for Social Sciences (SPSS) for Windows, version 28.0 (SPSS Inc., Chicago, Illinois, USA). The descriptive statistics was done by using frequencies, percentages, mean, and standard deviation. Normality of variance between groups was checked by Shapiro–Wilk test. Homogeneity (Equality of Error Variances) was tested by Levene's test. Inter group comparison of pain at different time events was compared by Kruskal-Wallis Test. Paired t-test was used to compare the root resorption between study groups. Kruskal-Wallis Test was used to compare the root resorption at T2 within study group. The intra-group comparison of alignment was done by using repeated measures of ANOVA whereas inter group comparison of alignment was done by ANOVA test.

The significance level was set as $p < 0.05$ except where a Bonferroni correction was applied to control type I error at 95% confidence interval.

Group 1- Conventional NiTi

Group 2- Heat Activated NiTi(HANT)

Group 3- Copper NiTi

Table 1: Intergroup comparison of alignment at different time events

Alignment	NiTi		HANT		CuNiTi		ANOVA F-value	p-value
	Mean	SD	Mean	SD	Mean	SD		
Pre-Treatment	4.8	1.033	5.1	1.1	4.6	1.17	0.52	0.6
0.014 (T1)	2.1	0.74	1.8	1.62	2.4	1.43	0.52	0.6
0.016 (T2)	0.8	0.63	1.3	1.34	1.2	1.32	0.53	0.59

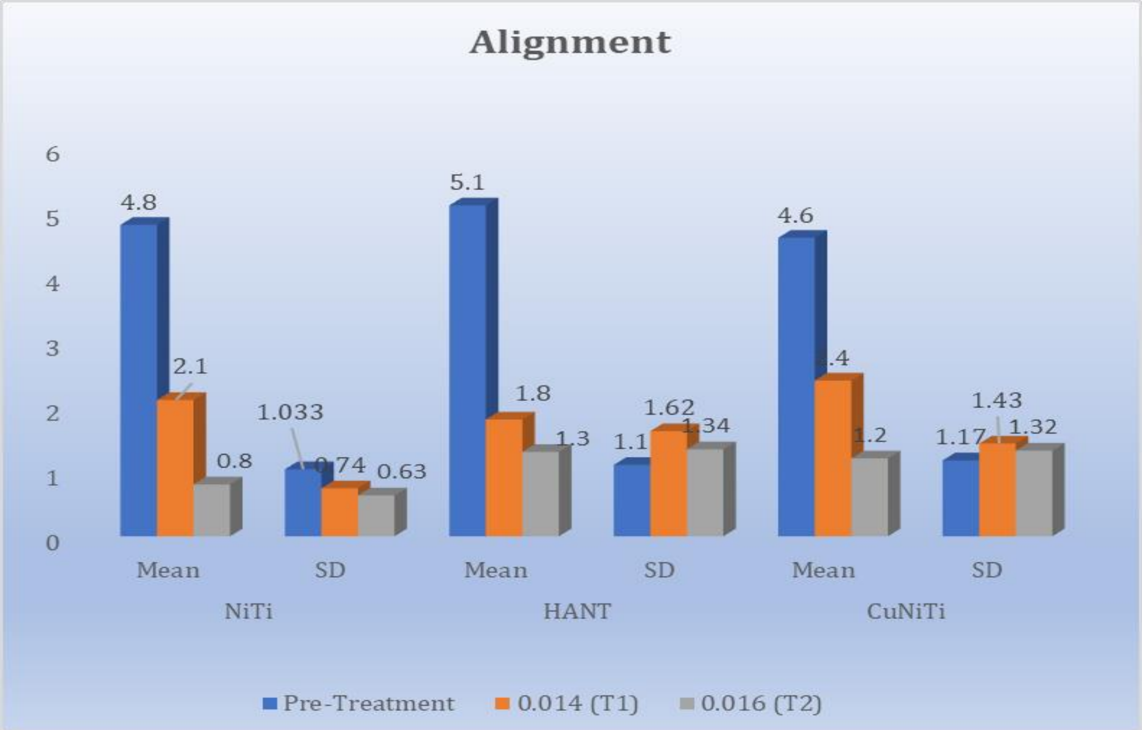

Figure 4: Intergroup comparison of alignment at different time events.

The above Table 1 and Figure 4 shows that inter group comparison of alignment at different time events such as pre-treatment, T1 & T2 where alignment score for pre-treatment was 4.8±1.033 of NiTi followed by 5.1±1.1 of HANT and 4.6±1.17 of CuNiTi respectively. For T1 alignment score was 2.1±0.74 of NiTi followed by 1.8±1.62 of HANT and 2.4±1.43 of CuNiTi respectively. For T2 alignment score was 0.8±0.63 of NiTi followed by 1.3±1.34 of HANT and 1.2±1.32 of CuNiTi respectively.Almost all the study groups alignment for pre-treatment, T1 and T2 was not found statistical significant with p>0.05.

Table 2: Intra group comparison of alignment at different time events.

	NiTi		HANT		CuNiTi	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Pre-Treatment	4.8	1.033	5.1	1.1	4.6	1.17
0.014 (T1)	2.1	0.74	1.8	1.62	2.4	1.43
0.016 (T2)	0.8	0.63	1.3	1.34	1.2	1.32
ANOVA F-value	92.9		54.55		68.034	
p-value	<0.0001*		<0.0001*		<0.0001*	

Table 2 shows that intra group comparison of alignment at different time events where for all the study group we could found that significant change from pre-treatment to T2 by using repeated measures of ANOVA with p<0.05.

Table 3: Inter group comparison of root resorption at T2.

Root resorption 0.016(T2)	NiTi(n=10)	HANT(n=10)	CuNiTi(n=10)	Kruskal-Wallis F-value	p-value
Mean	0.3	0.2	0.2	0.36	0.84
SD	0.48	0.42	0.42		

*significant when p<0.05

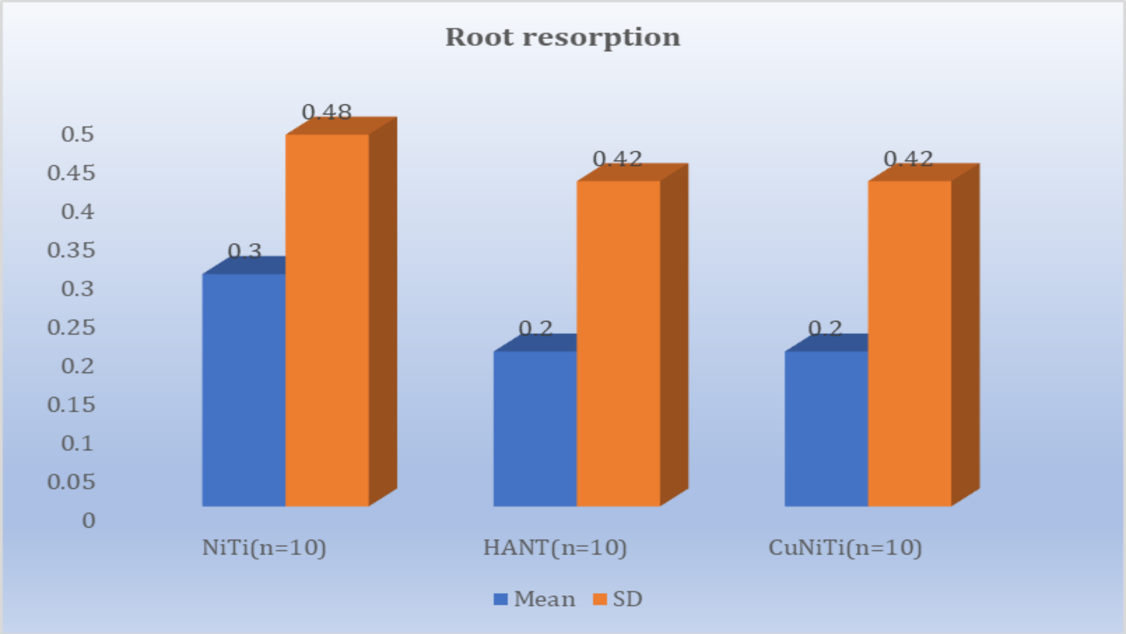

Figure 5: Inter group comparison of root resorption at T2.

The above Table 3 and Figure 5 shows that inter group comparison of root resorption at different time events. T2 for NiTi was 0.3±0.48 followed by 0.2±0.42 of HANT and 0.2±0.42 of CuNiTi respectively. The difference of root resorption for T2 was found not statistical significant with p>0.05.

Table 4: Intergroup comparison of average pain at different time events.

Time		NiTi		HANT		CuNiTi		ANOVA F-value	p-value
		Mean	SD	Mean	SD	Mean	SD		
Mean	0.014 (T1)	2.44	0.95	2.33	1.06	2.4	0.97	0.02	0.98
	0.016 (T2)	2.54	1.083	2.23	1.04	2.29	1.2	0.16	0.85

*significant when p<0.05

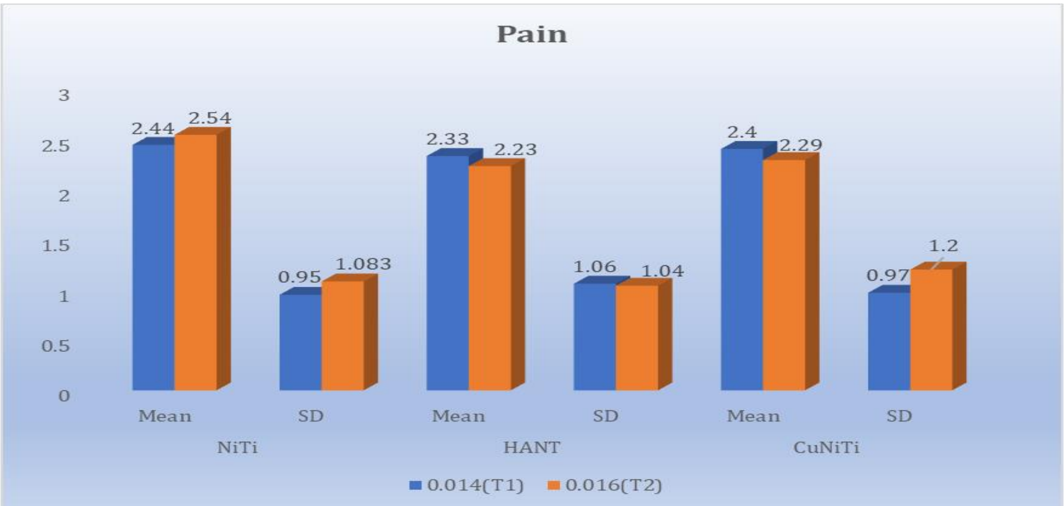

Figure 6: Intergroup comparison of average pain at different time events.

The above Table 4 and Figure 6 shows that inter group comparison of average pain at different time events T1 and T2. At T1 average pain for NiTi was 2.44±0.95 followed by 2.33±1.06 of HANT and 2.4±0.97 of CuNiTi respectively. The difference of pain for T1 was found not statistical significant with p>0.05. Similarly, for T2 average pain for NiTi was

2.54±1.083 followed by 2.33±1.04 of HANT and 2.29±1.2 of CuNiTi respectively. The difference of pain for T2 was found not statistical significant with p>0.05.

Table 5: Intra group comparison of average pain at different time events.

Time		NiTi		HANT		CuNiTi	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Mean	0.014	2.44	0.95	2.33	1.06	2.4	0.97
	0.016	2.54	1.083	2.23	1.04	2.29	1.2
Mean Difference		-0.1		0.1		0.11	
Paired t-value		0.78		0.56		0.76	
p-value		0.46		0.59		0.47	
Correlation Coefficient ®		0.95		0.89		0.96	

*significant when p<0.05

The Table 5 shows that intra group comparison of average pain score at different time event where for all the study groups shows that there was no statistical significance observed for intra group comparison of pain and it was found p>0.05.

Table 6: Intergroup comparison of interquartile pain at different time events.

Time		NiTi		HANT		CuNiTi		Kruskal-Wallis F-value	p-value
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**		
Interquartile	0.014 (T1)	2	1	1.29	0.49	1.57	0.79	4.118	0.13
	0.016 (T2)	1.14	0.38	1.14	0.38	1.43	0.53	2	0.36

*significant when p<0.05

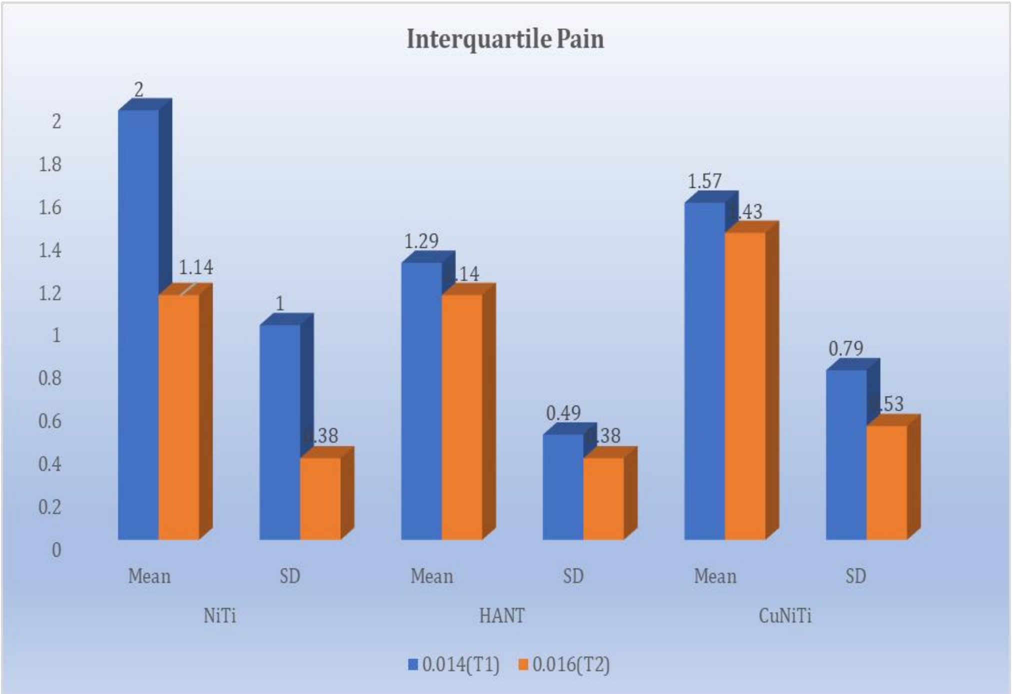

Figure 7: Intergroup comparison of interquartile pain at different time events.

The above Table 6 and Figure 7 shows that inter group comparison of average pain at different time events T1 and T2 at T1 average pain for NiTi was 2±1 followed by 1.29±0.49 of HANT and 1.57±0.79 of CuNiTi respectively. The difference of pain for T1 was found not statistical significant with p>0.05. Similarly, for T2 average pain for NiTi was 1.14±0.38

followed by 1.14±0.38 of HANT and 1.43±0.53 of CuNiTi respectively. The difference of pain for T2 was found not statistical significant with p>0.05.

Table 7: Intra group comparison of interquartile pain at different time events.

Time		NiTi		HANT		CuNiTi	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Interquartile	0.014	2	1	1.29	0.49	1.57	0.79
	0.016	1.14	0.38	1.14	0.38	1.43	0.53
Mean Difference		0		-0.28		0.36	
Paired t-value		0.99		1.55		1	
p-value		>0.99		0.17		0.35	
Correlation Coefficient ®		-0.16		0.47		-0.35	

*significant when p<0.05

The Table 7 shows that intra group comparison of interquartile pain score at different time event where for all the study groups shows that there was no statistical significance observed for intra group comparison of pain and it was found p>0.05.

DISCUSSION

The first phase of fixed orthodontic treatment is leveling and alignment of the arches[10]. The introduction of Nickel-Titanium archwires has revolutionized the field of orthodontics because of the ability of these archwires to deliver light continuous forces, thus increasing the intervals between appointments.[8]Since its introduction, different elements have been added in order to provide clinical advantages. Copper is one of these elements that have been added to nickel-titanium, resulting in lowering the loading stress while providing relatively high unloading stress,resulting in more effective orthodontic tooth movement.Heat-activated NiTi archwires have been introduced with clinically useful shape-memory, low stiffness, high spring back, and superelasticity of the first and second generation NiTi archwires.[11] Austenitic nickel-titanium alloys (superelastic and thermoelastic) were introduced later, and these were widely accepted for initial alignment of malocclusions mainly because of their unique properties of superelasticity and shape memory.

The 4week appointment interval in the current study was in accordance with Cobb et al. and Ulhaq et al. Bennett and Mclaughlin reported that 4-6 weeks intervals are appropriate for the same bracket system used in the current study. The archwire sequence for this study was 0.014inch followed by 0.016-inch for all the three archwire groups which is in accordance with Gok et al who compared SENT and HANT and partially agreed with Ong et al. who used 0.014-inch archwire as the first aligning wire. The moderate crowding of 3-6mm is more common in the lower anterior teeth and it is more rational to use this archwire sequence initially at these appointment intervals in order to achieve complete ligation of teeth. All the cases were selected for treatment without indication for extraction in the lower arch to avoid the confounding influence of presence of extraction space[12]

Previous studies have found that Little's Irregularity Index(LII) is a reliable indicator and can be used to standardize research. The major drawback of LII is that it is not sensitive to rotations and axial inclinations. Two types of irregularity measurement methods exist: direct and indirect. Direct method uses Vernier calipers. Measurements can also be done indirectly for three-dimensional calculations using advanced instruments such as a reflex metrograph, reflection microscope, or CMM. [10]

There are severe trials in the literature to compare the aligning efficiency of different NiTi archwire, most of which are related to the levelling of the mandibular anterior teeth owing to the severity of crowding and reduced interbracket span.

Abdelrahman et al (2015) compared the three types of 0.014inch NiTi archwires in the mandibular arch up to the period of 16 weeks. It was found that superelastic and thermoelastic NiTi archwires did not differ from each other, and also from conventional NiTi in terms of alignment efficiency

Aydin et al(2018) compared natural arch form NiTi and Tru-Arch CuNiTi archwires in mandibular arch with a total duration of 12 weeks, and no significant difference was observed in terms of the alleviation of the crowding. The total crowding alleviation at the end of the periods was respectively 4.07 and 3.58mm for NiTi and CuNiTi groups.

Mahmoudzadeh et al(2018) compared the reduction of irregularity index in the mandibular arch from bonding to 4 weeks after, using either A-NiTi(superelastic) or heat-activated NiTi and found no significant difference.

O'Brien et al(1990)compared the speed of initial tooth alignment between 0.016inch superelastic NiTi and NiTinol archwires and found no significant difference between the two[20]

Pandis et al (2009) conducted a study was to investigate the efficiency between 0.016-inch copper-nickel-titanium (CuNiTi) and nickel-titanium(NiTi) archwires in resolving crowding of the anterior mandibular dentition and concluded that the type of wire (CuNiTi vs NiTi) had no significant effect on crowding alleviation[13]

The result of this study is in line with the clinical trial of Keerthana P, Chitra P (2021)[10] who compared HANT archwires and super elastic NiTi(SE-NiTi) in terms of alleviation of lower anterior crowding and changes in intercanine width(ICW), intermolar width (IMW) and arch depth(AD) and found that both the archwires were similar in crowding alleviation. However, the changes in ICW,IMW and AD favoured HANT wires. Phermsang ngarm(2018)[19] conducted a similar study to compare the aligning efficiency of Heat activated NiTi and customized super elastic NiTi wires and found that heat activated NiTi wires took less time for alignment than customized superelastic NiTi wires.

PAIN PERCEPTION

Pain and discomfort after the insertion of an initial archwire are common experiences among orthodontic patients.[9] The observed trend of pain reflects the underlying biological responses to orthodontic force application. Interleukin-1 beta (IL-1 beta) is the first mediator to regulate bone remodelling in response to orthodontic force, and it also plays a significant role in orthodontic pain by inducing the secretion of pain producing pro-inflammatory mediators. A recent study demonstrated that the IL-1 beta concentration in human gingival crevicular fluid increases after 1h of orthodontic force application, peaks after 24h, and subsequently declines approximately to baseline in 1 week to 1 month time period. In another study, the concentration of IL-1 beta declined to normal only towards the end of the 3-week study period. These findings could explain the pain trend observed in the present trial, where pain started after 1 h after initial arch wire placement, peaked after 24 h, then began to decline. [14]

Pain is a subjective experience and is of multifactorial origin and is influenced by many factors other than the magnitude of the applied force, such as age, gender, degree of teeth irregularity, and psychologic factors. Therefore, objective evaluation of pain is quite difficult and, at present, can only be made indirectly. Many scales can be used to measure pain. Verbal rating scales, behavioral rating scales, and numeric scales are the commonly used methods.[6]In this study, the pain perception of the patients was assessed using the Visual Analogue Scale (VAS) which was completed by the participants twice (one time after each archwire placement i.e. 0.014 inch and 0.016 inch) for all three of the NiTi groups. This method is easy to score, short, reliable and understood with ease by most patients.

Various studies have been reported in literature which have compared different archwires in terms of discomfort experienced by the patient during the initial phase of treatment.Fernandes et al evaluated pain/discomfort during the 7day period following initial placement of conventional and superelastic NiTi and did not find any significant difference between the groups. In the conventional NiTi group, significantly lower pain levels could be found at 4 hours.In another study, Abdelrahman et al assessed the pain/discomfort experience in three different types of NiTi aligning archwires(superelastic, thermoelastic and conventional) for the first 7 day period after bonding and found no statistically significant difference among the groups.[15] S.A. Nabbat et al compared Heat-activated NiTi(HANT) and superelastic NiTi(SENT) during the initial phase of treatment and found no significant difference in pain between the archwires.[12]Cioffi et al compared pain intensity using the VAS scale after placing 0.016inch superelastic NiTi and 0.016inch thermoelastic NiTi in 30 individuals. Sebastian et al compared 0.016 inch superelastic wire and coaxial wire. Both the studies found no difference in the overall discomfort level between different NiTi wires[9]

In this study, the inter group comparison of pain at different time events was compared by Kruskal-Wallis Test. At T1(0.014 inch) average pain for NiTi was 2.44±0.95 followed by 2.33±1.06 of HANT and 2.4±0.97 of CuNiTi respectively. The difference of pain for T1 was found not statistical significant with $p>0.05$. Similarly, for T2(0.016 inch) average pain for NiTi was 2.54±1.083 followed by 2.33±1.04 of HANT and 2.29±1.2 of CuNiTi respectively. The difference of pain for T2 was found not statistical significant with $p>0.05$. The intra group comparison of average pain score at different time events for each of the archwire groups also shows that there was no statistical significance difference amongst them and it was found $p>0.05$.

Although, previous in vitro studies have demonstrated that super elastic NiTi are able to deliver almost continuous light forces with large activations that may generate less pain, this in vivo study found no evidence of significant difference in the pain intensity amongst the three archwire groups. The results of the present study were in line with the findings described by Ong et al, Abdelrahman et al, Arshad et al, the Cochrane review by Wang et al, and partly with the finding by Gok et al., but disagree with Cioffi et al. who found lower pain with HANT wires.[12]

ROOT RESORPTION

Root shortening as a result of apical root resorption is an undesirable consequence of orthodontic treatment. Most studies (Baumrind et al., 1996; Jiang et al., 2001) on root resorption and its relationship with orthodontic treatment have found that there are multiple factors associated with root resorption. Generally, the causes and mechanism of resorption are still unclear.[17]

Orthodontic tooth movement (OTM) is a highly coordinated process that involves effective bone remodeling (Li et al. 2018). When a sustained orthodontic force is loaded onto a tooth, a coupling of bone resorption in the compression side and deposition in tension sides of the periodontal ligament (PDL) take place to facilitate OTM (Krishnan 2017). However, if the force applied exceeds the blood pressure of the capillary bed, it occludes the vasculatures, causing hyalinization (sterile necrosis) of the PDL and surrounding alveolar bone in the compression side (Farinawati et al. 2020). In order for OTM to continue, these hyalinization sites release various biomolecules that attract macrophage like cells, multinucleated cells, osteoclasts, and cementoclasts/odontoclasts to resorb the necrotic PDL (Brudvik & Rygh 1995a). The resorption of the necrotic PDL can damage the nearby outer layer of the root, which is the cementoblast layer covering the cementoid, leaving a denuded cemental surface that is easily targeted by the odontoclast cells and triggering inflammatory events on the root surface that is similar to bone resorption (Reitan 1957). The resorption process continues until no remaining hyaline tissues and/or the orthodontic force is ceased. The cessation of the orthodontic force allows a physiological process where the reversal of the resorption and repair of the cementum can occur (Brudvik & Rygh 1995b). However, in cases where the defect at the root surface is large, the cementum or dentin eventually becomes detached from the root surface as an island. It will be resorbed, and the loss of root structure becomes irreversible, resulting in root shortening (Proffit et al. 2006).[16]

The apical third of the root is the most susceptible region to root resorption and gradually decreased toward the gingival third of the root (Sameshima & Iglesias Linares 2021). This could be explained by the apical region of the root being lined by cellular cementum, which contains active cells and supporting vasculature, while the cervical region of the root is lined by acellular cementum (Foster 2012). The cellular cementum contains active cells and supporting vasculature, trauma to this region initiates cell injury response, making this region the most vulnerable to root resorption (Henry & Weinmann 1951). This finding was further supported by Blaushild et al. (1992), who found that the PDL space in the apical region consists of 47% of blood vessels, compared with only 4% at the cervical third of the root. This shows that the apical region has higher metabolic demands and has a more rapid cell turnover than the region with acellular cementum (Abass & Hartsfield 2007). Furthermore, hardness and elastic modulus decrease gradually from the cervical region to the apical region. This makes the apical region of the root has a lower capacity to absorb the applied orthodontic force (Chutimanutskul et al. 2006).[16]

Lateral cephalograms associated with panoramic radiograph or complete periapical radiographs are routinely requested for pretreatment planning. Studies highlight better precision of periapical radiograph when compared to panoramic radiograph when determining the magnitude of root resorption, due to lower distortion and accuracy of fine details. Periapical radiographs are also much cost-benefit compared to CT scans. Therefore, an increasing number of professionals request complete periapical examination for treatment of adult orthodontic patients [18]

Paired t-test was used to compare the root resorption between the three study groups. Kruskal-Wallis Test was used to compare the root resorption at T2 within study group. The inter group comparison of root resorption at different time events. T2 for NiTi was 0.3±0.48 followed by 0.2±0.42 of HANT and 0.2±0.42 of CuNiTi respectively. The difference of root resorption for T2 was found not statistical significant with $p>0.05$. Thus, it can be concluded that the three archwires are similar in terms of root resorption.The result of this study agrees with the clinical trial of Jain S et al[9] who compared 0.016 inch superelastic NiTi and Heat activated NiTi(HANT) and found no significant difference between the two groups in terms of root resorption and also with S.A. Nabbat et al[12] who compared archwire sequence of 0.014inch followed by 0.016inch for Heat-activated NiTi(HANT) and superelastic NiTi(SENT) and found that both the archwires were similar in terms of root resorption.

LIMITATIONS OF THE STUDY

1) Root resorption was studied only over a short period of time (0 to 8 weeks). Therefore, further prospective randomized clinical trials should be carried out to reveal the long term effects of different types of NiTi archwires.
2) Since it is a single centre study performed by a single operator in a university department, blinding of the investigator was not possible during clinical intervention and only the participants were blinded to the type of archwire sequence used. So the risk of bias during allocation and randomization of the patients into the different groups increases
3) The small sample size which did not allow the evaluation of archwire performance in patients of different age groups, gender, or levels of severity of crowding.
4) In this study, certain factors were not considered during the assessment of pain that could have influenced the outcome. Although an attempt was made to control all such

factors (age, sex and initial crowding), psychological factors such as anxiety/depression and hormonal fluctuation in females during menstruation cycle were not taken into account and could have influenced the outcome of the trial. Furthermore, 'as and when required' use of analgesics could have also affected the results.

CONCLUSION

Based on the Statistical analysis it can be concluded that

(a) For the assessment of alignment, it was found that all the three archwire groups were almost equally effective in terms of crowding relief with a slight favour in case of HANT archwire group.

(b) For the root resorption, it was seen that it was almost similar in all the three archwire groups.

(c) The intergroup assessment of pain found that pain perception was similar in all the three types of NiTi archwires at different time events. Also, it was found that pain was similar in 0.014inch and 0.016inch archwires in each of the three archwire groups.

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