

A Systematic review on aligning efficiency of superelastic NITI: in comparison with conventional NITI and multistranded stainless steel archwires

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Abstract

Background: The initial leveling and aligning phase of orthodontic treatment involve the use of nickel titanium wires. The nickel titanium wires exhibit unique properties like shape memory and superelasticity. In the beginning, conventional nitinol wires were used, which lacked the superelastic property. Nowadays, superelastic nickel titanium wires are being used commonly. This systematic review aims to evaluate the efficiency of Superelastic NiTi in the initial alignment of orthodontic treatment in comparison with conventional NiTi and multistranded stainless steel archwires by measuring the amount of decrowding and the time taken for decrowding.

Method: A systematic literature search was performed on Pubmed, Cochrane, Google scholar & Lilacs.

Result: Thirty four studies were identified by the search and ten studies satisfied the inclusion criteria and one study was excluded after abstract reading. Finally nine articles were included for quality assessment.

Conclusion: This systematic review concluded that there was no significant differences in the aligning efficiency of superelastic NiTi in comparison with conventional NiTi and multistranded stainless steel wires.

Keywords: Decrowding, Initial Alignment, NITI

1. Introduction

Levelling can be defined as the first active phase of orthodontic treatment involving correction of individually malpositioned teeth, bracket slot leveling, correction of tooth arch discrepancy, initial correction of the curve of Spee, and torque adjustment (Evans et al. 1998). The ideal aligning archwire should have excellent strength, excellent springiness, and light continuous force of about 50g (Proffit et al. 1995). The common and broadly used materials are stainless steel and nickel titanium. In 1970, with the efforts of Dr. George Andreasen (Andreasen et al. 1971), the first commercially available NiTi alloy, Nitinol was invented.

The first discovered nitinol was a martensitic stabilised alloy. Ironically the shape memory property was present in the composition only because this property was suppressed by cold working of the alloy during manufacturing. Hence it was a passive alloy with low force, low stiffness and good springiness but lacked formability. It was considered superior to stainless steel wires in that period. Later, Chinese and Japanese NiTi with super elastic properties were introduced by Burstone (Burstone et al. 1985) and Miura (Miura et al. 1986) respectively.

Proffit (Proffit et al. 1999) has classified NiTi archwires into two major categories: M-NiTi (stabilised martensitic alloys) and A-NiTi (austenitic alloys). M-NiTi wires are much springy, lack formability, shape memory and superelasticity. The load deflection plot for M-NiTi wire is somewhat similar to other alloys (steel, TMA). The A-NiTi wires present superelasticity. It has an activation/deactivation plateau. On loading, the A-NiTi starts with a slope (stiffness) which produces three times the activation force

of the conventional M-NiTi wires. Then the stiffness becomes comparable to M-NiTi. There is a stress-induced transformation of austenite to martensite. Upon unloading, reverse occurs, the linear region associated with martensitic phase gives way to the second plateau at a lower force. The martensite is transformed into austenite. When this transformation is complete, the initial high slope of austenite is revisited. This is called as the springback. The second plateau region in which martensite changes to austenite and changes shape is called pseudoelasticity. Pseudoelasticity occurs locally in place of large deformations due to the formation of stress induced martensite (SIM).

In simpler words, austenitic active alloys are more flexible and have good spring back at room temperature and if a certain force is applied, small areas of stress induced martensite will be formed, which makes them less stiff in those areas consequently making it easier to fit into a slot.

The force deflection of superelastic NiTi or austenitic active NiTi and the multistranded stainless steel wires are less than the conventional stainless steel wires making them favourable for correction of crowding (Quintao et al. 2009).

The degree of decrowding or tooth alignment is usually assessed using Little's irregularity index (Little et al. 1975). This index is calculated using a three-dimensional digital model or directly on the model using a vernier calliper (Setchell et al. 1984).

There are numerous in-vitro studies available to evaluate the superiority of one archwire over the other. There is a scarcity of in vivo studies assessing the efficiency of initial archwires in the literature (Evans et al. 1998). Hence this systematic review has been carried out to find out the efficiency of superelastic NiTi over conventional NiTi and multistranded stainless steel wires.

2. Method

2.1. Search strategy

Database search was performed in PUBMED, COCHRANE, GOOGLE SCHOLAR & LILACS till October 2016. PICO analysis was done. Population; Malocclusion, Intervention; Orthodontic archwire, Comparison; Superelastic NiTi and conventional NiTi, Superelastic NiTi and multistranded stainless steel, Outcome; amount of decrowding, Time taken for decrowding. (Fig-1).

2.2. Selection criteria

Randomised controlled trials (RCT), prospective controlled trials, clinical trials, Studies comparing the Superelastic NiTi archwire with conventional NiTi archwire and superelastic Niti with multistranded Stainless steel archwire, Studies which used round initial wires, Upper or lower full arch fixed appliances were included. In vitro studies, Case reports, case series, review articles, abstract papers, Trials which have studied pain perception and discomfort level with initial archwires, Lingual appliances and studies which have used rectangular NiTi wires or square NiTi wires for initial alignment were excluded.

2.3. Search terms

The search followed the PICO analysis. The search terms included. Wewere (malocclusion or "class, I" or "class II" or "class III") and (conventional NiTi or "niti" or "nitinol" or "nickel titanium" or "archwire" or "martensitic stabilised niti") and (superelasticniti or "SE niti" or "pseudo elasticity" or "superelasticity" or "austenitic active niti" or "austenitic niti" and (stainless steel or "multistranded stainless steel" or "multiflex" or "coaxial stainless steel") and (tooth alignment or "levelling and aligning" or "decrowding" or "aligning and leveling" or "dental alignmen" or "arch alignment" or "initial alignment" or "decrowding" or "mandibular decrowding" or "full arch decrowding" or "correction of crowding" or "alleviation of crowding")

2.4. Primary objectives

The variables of interest of this systematic review are: The amount of decrowding or the Tooth alignment reported as LII/ DII/ ITA/ tooth movement (LII; Little's irregularity index, DII; Dental irregularity index, ITA; Index of tooth alignment). The Time taken for decrowding.

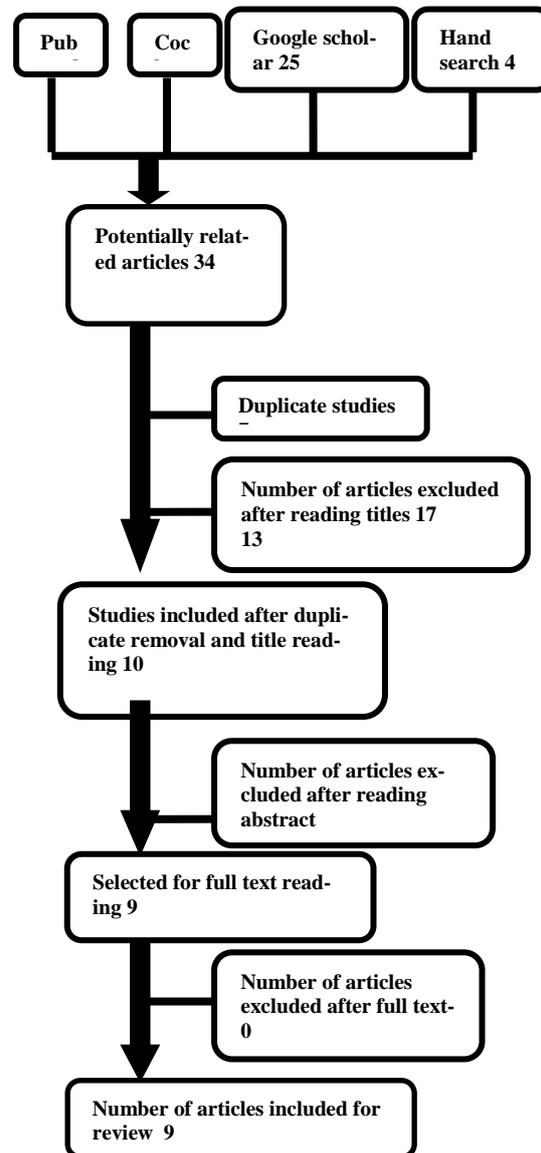


Fig. 1: Search Flowchart.

2.5. Quality assessment

Risk of Bias in included studies

The quality assessments of the studies were screened by using (Higgins and Green. Cochrane reviewer's hand book 2009). The study was assessed to have a "High risk" of bias if it did not record a "Yes" in three or more of the four main category, "Moderate Risk" if two out of four categories did not record a "Yes," and "Low Risk" if all the four categories recorded: randomization assessor, Blinding and Completeness of follow-up were considered adequate. In case of non randomized and clinical trials without control group, it is recorded as not applicable.(TABLE- 1&2), (GRAPHS- 1&2).

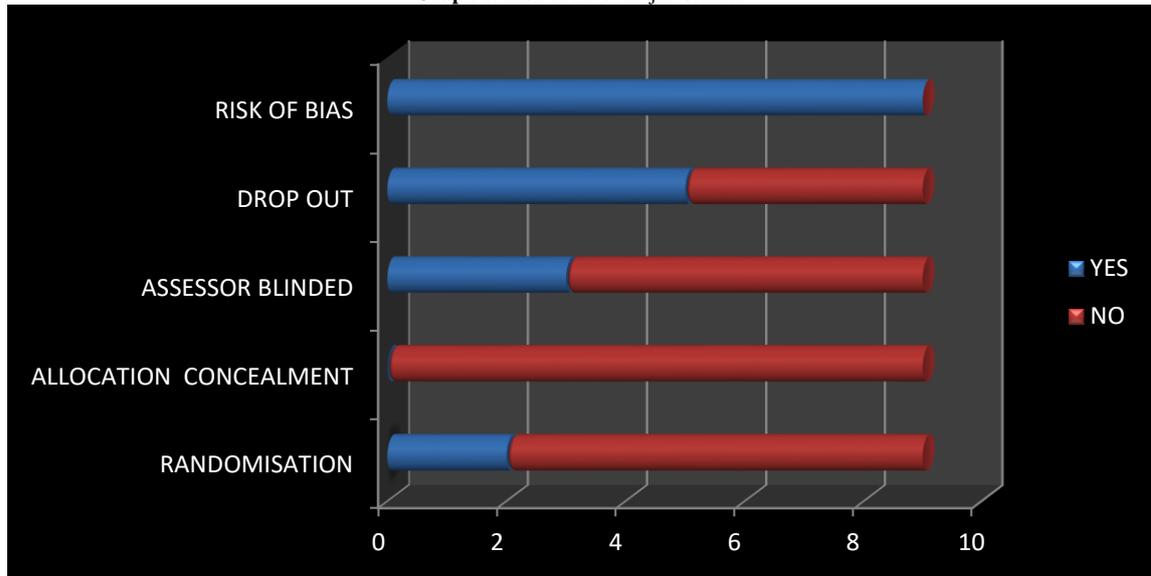
Table 1: Risk of Bias: Major Criteria

S.No	Study	Randomization	Allocation concealment	Assessor Blinded	Drop outs described	RISK OF BIAS
1	Kevin et al 1990	NO	NO	YES	NO	HIGH
2	Marco et al 2013	NO	NO	NO	NO	HIGH
3	Rheem et al 2015	NO	NO	YES	NO	HIGH
4	Catia et al 2005	YES	NO	NO	YES	HIGH
5	Cobb et al 1998	NO	NO	NO	YES	HIGH
6	West et al 1995	YES	NO	NO	NO	HIGH
7	Jones et al 1992	NO	NO	NO	YES	HIGH
8	Ramya et al 2013	NO	NO	NO	YES	HIGH
9	Sandhu et al 2012	NO	NO	YES	YES	HIGH

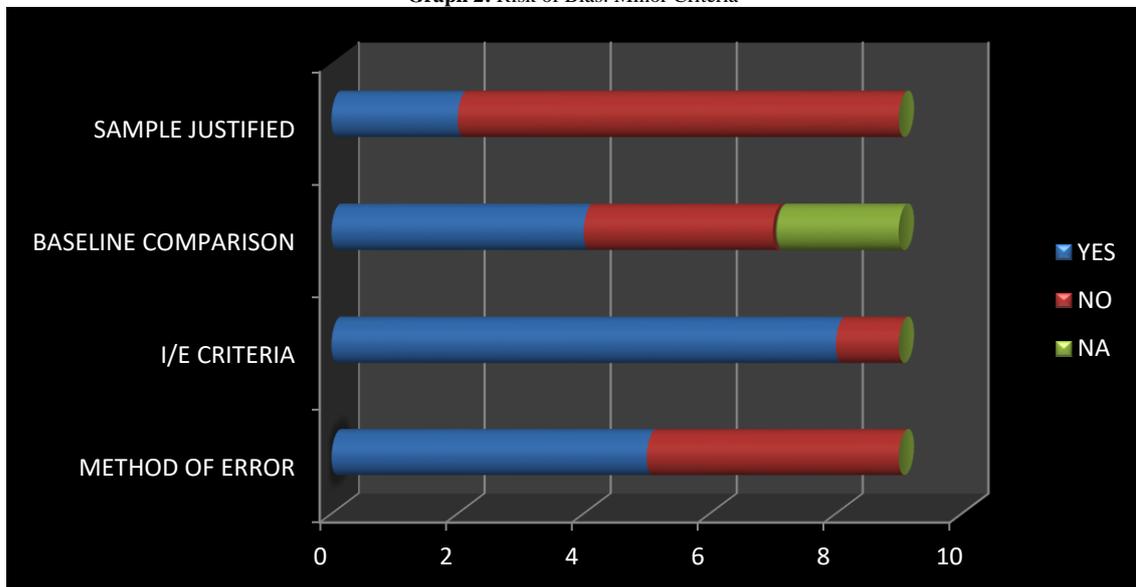
Table-2: Risk of Bias: Minor Criteria

S.NO	STUDY	SAMPLE JUSTIFIED	BASELINE COMPARISON	I/ E CRITERIA	METHOD OF ERROR
1	Kevin et al 1990	NO	YES	YES	YES
2	Marco et al 2013	NO	YES	YES	YES
3	Rheem et al 2015	YES	YES	YES	YES
4	Catia et al 2005	NO	NA	YES	NO
5	Cobb et al 1998	NO	YES	YES	YES
6	West et al 1995	YES	NA	YES	YES
7	Ramya et al 2013	NO	NO	YES	NO
8	Jones et al 1992	NO	NO	NO	NO
9	Sandhu et al, 2012	NO	NO	YES	NO

Graph 1: Risk of Bias: Major Criteria



Graph 2: Risk of Bias: Minor Criteria



2.6 Data Extraction

Data extraction for general characteristics of studies and variables of outcome was done. For each trial, the following was recorded: Author and Journal, Study Design, Sample Size, Participants and

Group, Methodology, Parameters studied, Statistical Analysis, Results (Table 3)

Table 3: General Information of the Included Articles

S.NO	AUTHOR	STUDY DESIGN	PARAMETERS EVALUATED	WIRES USED
1.	Catia et al Korean J Orthod, 2005	Prospective clinical trial	Tooth movement in whole upper and lower arch, upper and lower anterior area Number of cases in which point approximation occurred and point separation occurred	0.016 "SE NITI 0.016" Thermoactivated NITI 0.0155"Multistranded SS 0.014"stainless steel
2	Reem et al Angle Orthodontist, 2015	Prospective clinical trial	Overall tooth movement and time taken for decrowding in the lower anterior region	0.014" SE NITI 0.014" Thermoelastic NITI" 0.014" Conventional NITI
3.	Kevin O' Brien European Journal of orthodontics 1990	Clinical trial	Overall tooth movement in the upper anterior region in 35 days	0.016" Titanol(SE NITI) 0.016" Nitinol(conventional NITI)
4	Marco AbdoGravina Dental Press J Orthod 2013	Clinical study	Overall tooth movement of lower arch Axial inclination (labial proclination)of lower incisors Curve of spee of lower arch period of two months	0.014" SS 0.015" Multistranded SS 0.014" SE NITI
5	West, AJODO, 1995	RCT	Degree of tooth alignment	0.0155 multiple-stranded stainless steel 0.014 Niti 0.014 SE Niti
6	Jones, JCO, 1990	Clinical study	Time taken for decrowding Degree of tooth mvement	0.015 multistranded stainless steel 0.016 ion implanted Niti 0.016 Niti
7	Cobb, ClinOrthod Res, 1998	Clinical study	Degree of tooth movement	0.0175 multistranded stainless steel
8	Ramya , IOSR JDMS, 2013	Clinical study	Time taken for decrowding	0.016 Niti 0.0155 multistranded stainless steel wire 0.016 SE niti PAE
9	Satpal S Sandu, Angle Orthodontist , 2012	Prospective clinical trial	Degree of tooth movement	0.0175 multistranded SS PAE 0.016 SE nitibegg 0.0175 multistranded SS begg

Table 3: Continued

METHODS USED FOR EVALUATION	SAMPLE SIZE	STATISTICS	RESULTS
DII (Dental irregularity Index) reflex microscope contact points measurement after 8 weeks mesial surfaces of molar to the mesial surfaces of opposite molar	90 dental arches(26 SE NITI, 22 SS, 22 multistranded SS, 20 thermoactivated NITI)	ANOVA	No statistical differences between 4 groups Data distribution showed superior aligning capacity of thermoactivated NITI Whole lower arch- Multistranded SS was superior Upper anterior area- Superelastic NITI was superior Lower anterior area- multistranded wire was superior
Little crowding index every two weeks till 16 weeks Lower anterior crowding Vernier calliper Contact point measurement Upper anterior crowding Reflex metrograph	24- SE NITI 25- Thermoelastic NITI 24- Nitinol(conventional NITI)	ANOVA	No statistically significant differences in amount of decrowding and the time taken for decrowding
Lateral cephalogram- axial inclination of lower incisors Irregularity index Reflex microscope	20- Titanol 20-Nitinol	t-test	No statistically significant differences between SE NITI(Titanol) and Conventional NITI (Nitinol) in the amount of decrowding No statistical differences in the axial inclination of incisors- all 3 wires caused labial tipping of incisors Statistical significance in the irregularity index between SE NITI and multistranded SS at significance level (P=0.003) No statistical differences between curve of spee correction caused by 3 wires
Contact point distances Index of tooth alignment full arch and anterior segment Reflex microscope Contact point distances Full arch 3D measurement Anterior contact point distance Digital callipers Contact point distance Digital calliper Lower anterior crowding	74 dental arches 0.0155 multiple stranded stainless steel- 36 0.014 Niti- 38	Covariance analysis	Niti wire improved alignment when compared to multiple stranded stainless steel wire in lower labial segment with statistical significance
LII- Vernier calliper Lower anterior crowding	43 patients 43 archwires	Linear plotting of values Students t test	No statistically significant difference between Niti and multistranded stainless steel wires
	158		No significant differences between the wires
	30	Student t test	Time taken by nickel titanium wires less compared to multistranded stainless steel wires and is statistically significant No significant differences between reduction in crowding in PAE brackets between SE niti and MULTistranded SS in severe and moderate crowding SE niti in begg appliance reduced crowding significantly than the muktistranded stainless steel wires
	0.016 SE niti PAE-25 0.0175 multistranded SS PAE-25 0.016 SE nitibegg-25 0.0175 multistranded SS begg-25	ANOVA Linear regression	

Table 4: Group ISE NITI VS Conventional NITI

AUTHOR	PARAMETERS EVALUATED	COMPARISON GROUPS	METHODS USED FOR EVALUATION	SAMPLE SIZE	RESULTS
1. Kevin et al, EJO, 1990	Overall tooth movement in the upper anterior region in 35 days	0.016" Titanol(SE NITI) 0.016" Nitinol(conventional NITI)	Contact point measurement	20- Titanol 20- Nitinol	Mean tooth movement Titanol- 1.7mm Nitinol- 1.42 mm
2. Reem et al, AO, 2015	Overall tooth movement and time taken for decrowding in the lower anterior region	0.014" SE NITI 0.014" Thermoelastic NITI" 0.014" Conventional NITI	Little crowding index every two weeks till 16 weeks	24- SE NITI 25- Thermoelastic NITI 24- Nitinol	Mean irregularity score at the end SE NITI- 0.276 Nitinol- 0.354 Mean number of days for alignment SE niti- 73 days Nitinol- 63 Days

Table 5: Group IISE NITI VS Multistranded NITI

AUTHOR	PARAMETERS EVALUATED	COMPARISON GROUPS	METHODS USED FOR EVALUATION	SAMPLE SIZE	RESULTS
1. Catia et al, KJO, 2005	Tooth movement in whole upper and lower arch, upper and lower anterior area Number of cases in which point approximation occurred and point separation occurred	0.016 "SE NITI 0.0155" Multistranded SS	DII (Dental irregularity Index) reflex microscope contact points measurement after 8 weeks mesial surfaces of molar to the mesial surfaces of opposite molar	26 SE NITI 22 multistranded SS	Mean irregularity score Upper whole arch SE NITI- 48.60 Multistranded SS- 21.37 Lower whole arch SE NITI- 34.75 Multistranded SS- 46.38 Upper anterior area SE NITI- 30.29 Multistranded SS- 14.61 Lower anterior area SE NITI- 16.71 Multistranded SS-22.11
2. Marco et al, DPJO, 2013	Overall tooth movement of lower arch Axial inclination (labial proclination)of lower incisors Curve of spee of lower arch period of two months	0.015" Multistranded SS 0.014" SE NITI	Lateral cephalogram-axial inclination of lower incisors Irregularity index Reflex microscope	12- multistranded SS 13- SE NITI	Mean irregularity scores at the end Multistranded SS- 180.9 SE NITI- 178.1
3. West et al, AJODO, 1995	Degree of tooth alignment	0.0155 multiple-stranded stainless steel 0.014 SE Niti	Contact point distances Index of tooth alignment full arch and anterior segment Reflex microscope	0.0155 multiple stranded stainless steel- 36 0.014 SE Niti- 38	No numerical data available
4. Jones et al, JCO, 1990	Time taken for decrowding Degree of tooth movement	0.014 SE Niti 0.015 multistranded stainless steel	Contact point distances Full arch 3D measurement	43 patients 43 archwires	SE NITI- 1.82 mm Multistranded SS- 1.53
5. Cobb et al, COR, 1998	Degree of tooth movement	0.016 Niti 0.0175 multistranded stainless steel	Anterior contact point distance Digital callipers	158	No numerical data available
6. Ramya et al, IOSR JDMS, 2013	Time taken for decrowding	0.016 Niti 0.0155 multistranded stainless steel wire	Contact point distance Digital calliper	30	Mean number of days taken for decrowding NITI- 89.67 Multistranded SS- 113.2
7. Satpal et al, AO, 2012	Degree of tooth movement	0.016 SE niti 0.0175 multistranded SS PAE	LII- Vernier calliper	0.016 SE niti -25 0.0175 multistranded SS -25	Mean difference in severe crowding SE Niti- 6.2 mm Multistranded SS- 5.8 mm Mean difference in moderate crowding SE Niti- 4.4 mm Multistranded SS- 4.1mm

3. Results

Thirty four studies were identified by the search and ten studies satisfied the inclusion criteria and one study was excluded after abstract reading. Finally, nine studies were included for quality assessment based on the inclusion criteria (Fig-1) The amount of decrowding and the time taken for decrowding of superelastic NiTi, conventional NiTi and multistranded stainless steels were recorded as the variable of interest

Comparisons of two groups (Table 4&5) were made in this review.

- 1) First group consisting of superelastic NiTi and conventional NiTi with two studies.
- 2) Second group consisting of superelastic NiTi and multistranded stainless steel with seven studies

In Group I (Table 4) there was no statistically significant difference in the tooth alignment and the time taken for alignment between the wires.

In Group II (Table 5) Ramya et al and West et al have reported statistically significant differences in the time taken for alignment between superelastic NiTi and multistranded stainless steel wires. West et al has reported statistically significant differences between superelastic NiTi and multistranded stainless steel wire.

The superelastic NiTi exhibits superelasticity and has better mechanical properties like good springback, low stiffness, high resilience, which is also present in multistranded stainless steel wires (Kapila et al.1989). The load deflection rate of superelasticNiTi is also less than conventional NiTi and multistranded stainless steel wires (Quintao et al. 2009).Although superelastic NiTi was found to be superior to multistranded stainless steel andconventional NiTi in bench studies (Tonner 1994, Kusy 1997), it has to be noted that multi-stranded wires be it braided, twisted or coaxial have similar properties and great potential for use in the early stages of orthodontic treatment (Quintao et al. 2009). However, their low elastic limit makes them susceptible to plastic deformation because of external forces, such as chewing (Kapila et al. 1989). Superelastic NiTi is the only one archwire which produces the same level of force at any range of deflection and hence biologically more acceptable (Tonner et al. 1994).

No clinically significant evidence therefore could be drawn from this systematic review which can be attributed to the following variables which could have been a probable source of bias.

3.1. Sample size

Reem et al & West et al are the only two studies with sample size calculation

3.2. Baseline homogeneity

Reported in all studies except Catia et al, West et al, Ramya et al, Jones et al, Sandhu et al.

3.3. Intervention

Although all studies used round initial wires, dimensions varied. Catia et al & Ramya et al has used 0.016 SE NiTi and 0.0155 multistranded stainless steel, Marco et al, West et al & Jones et al have used 0.014 SE NiTi and 0.0155 multistranded stainless steel. Cobb et al & Satpal et al have used 0.016 SE NiTi and 0.0175 multistranded stainless steel. The two studies which compared the superelastic NiTi with conventional NiTi used different wire dimensions. Kevin et al has used 0.016 SE NiTi and conventional NiTi. Reem et al has used 0.014 SE NiTi and conventional NiTi.

3.4. Degree of baseline crowding

Marco et al has included patients with a degree of crowding, which allowed deflection of archwire to 2mm and has checked for the homogeneity within the sample. Cobb et al has mentioned the inclusion criteria of LII>5mm. Ramya et al has mentioned the inclusion criteria of LII – 7to 9 mm. Satpal et al has reported the inclusion criteria as moderate crowding 4 to 6mm and severe crowding 6 to 9 mm. Reem et al has reported the homogeneity of baseline data but has not mentioned about the degree of crowding before treatment. Jones et al has not reported the degree of crowding before treatment.

3.5. Period of follow up

Ranged from 5 to 8 weeks. No standardization for period of observation

3.6. Method of evaluation

Both 3D measurements and manual measurements using vernier callipers were used in these studies. The studies also used various different software for measuring digitally. Kevin et al used contact

point movement differences from pre & post casts by superimposing on the palate. Reem et al, Marco et al, Cobb et al, Ramya et al, Satpal et al used LII to measure the tooth alignment. Jones et al, West et al, Catia et al used modifications of LII (ITA, DII)

3.7. Samples examined

Marco et al, Ramya et al, Satpal et al are the three studies which evaluated the lower arch alignment. Catia et al and West et al evaluated tooth alignment in upper and lower full arch and in anterior regions. Jones et al evaluated full arch upper and lower alignment. Cobb evaluated anterior region of upper and lower arch. A posterior contact point is prone to errors and hence was not evaluated in some studies (Richmond et al. 1984).

3.8. Reporting of outcome measures

No numerical data could be interpreted from West et al, Cobb et al, and Jones et al as they were reported as geometric ratios or linear plots. Catia et al and Kevin et al reported the tooth movement happened during alignment. Reem et al, Marco et al, Satpal et al reported the mean irregularity index

4. Discussion

A total number of nine controlled clinical trials or randomised control trial were included in the current systematic review based on the selection criteria. These trials were aimed at testing whether there was a difference in the alignment efficiency of superelastic NiTi in comparison with conventional NiTi or multistranded stainless steel.

The nine studies were divided as two groups. Group I (Table 4) with two studies comparing superelastic niti with conventional niti. (Rheem et al. 2015, Kevin et al. 1990). While comparing superelastic NiTi with conventional NiTi (Rheem et al), the mean irregularity score for superelastic NiTi was 0.276 and for conventional. it was 0.354; the time taken for decrowding for superelastic NiTi was 70 days and for conventional NiTi, it was 63 days. In comparing the mean tooth movement between superelastic NiTi and conventional NiTi (Kevin et al), the mean tooth movement for superelastic NiTi was 1.7mm and for conventional NiTi, it was 1.42 mm.. Neither of the two studies reported statistically significant differences between the wires.

Group 2 (Table 5) which compared superelastic niti with multistranded SS Marco AbdoGravina et al. 2013 has arrived at a mean irregularity score of superelastic NiTi at 178.1and multistranded stainless steel at 180.9. He has also compared the differences in labial proclination of the lower incisors and curve of spee correction caused by superelastic NiTi & multistranded stainless steel, which, in fact, showed no difference. Both the wires invariably caused proclination of the lower incisors. There were no differences between the wires in correction of curve of spee, LII & IMPA.

Catia et al. 2005 (Table 3&5) considered the alignment in the whole upper arch, whole lower arch, upper anterior area and lower anterior area and has given the mean irregularity score for SE Niti and multistranded SS wires in all four segments. This is the only study which has included the whole upper and lower arch and also the upper anterior and lower anterior area. The explanation given by the author was that the interbracket distance affects the wire properties and therefore, in order to assess the clinical performance of wires, it is imperative that all the segments of the arches should be studied. Catia has concluded that no statistically significant differences were found between the SE NiTi and multistranded stainless steel wires under the study conditions.

Jones et al. 1990 had found that the mean tooth movement for SE Niti was 1.82 mm and multistranded stainless steel was 1.53 mm which was not statistically significant.

Sandu et al. 2012 gave the mean tooth movement as the mean difference between the pre treatment and post treatment crowding.

He has compared SE niti and multistranded stainless steel wires in PAE brackets and Begg brackets. He has concluded that there was no statistically significant difference between SE Niti and multistranded niti in their efficiency in PAE brackets.

There was no difference in the time taken for decrowding between SE Niti and conventional Niti, as reported by one study Rheem et al, which was not statistically significant. Time taken for decrowding as reported by Ramya et al was less for superelastic NiTi when compared with multistranded stainless steel, and it was statistically significant.

No data could be collected for overall tooth movement and time taken for decrowding from Cobb et al. 1998 and West et al. 1995 Cobb et al has given a distribution of the data, and West et al has used geometric mean ratios of the alignment scores.

5. Conclusion

It has to be admitted that all studies had a high risk of bias out of which one was a randomized control trial with Level 1 evidence. Two studies Ramya et al and West et al have reported significant differences between superelastic NiTi and multistranded stainless steel. Neither of the two studies which compared superelastic NiTi, and Conventional NiTi reported any significant differences between them. The lack of statistically significant evidence from this systematic review has been set out in the discussion part. This systematic review as such has to conclude that no reliable evidence could be synthesized from the studies selected.

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