SCIENTIFIC SECTION

A randomized clinical trial to compare three methods of orthodontic space closure

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Abstract

Aim To compare the rates of orthodontic space closure for: Active ligatures, polyurethane powerchain (Rocky Mountain Orthodontics, RMO Europe, Parc d'Innovation, Rue Geiler de Kaysersberg, 67400 Illkirch-Graffenstaden, Strasbourg, France) and nickel titanium springs.

Sample Patients entering the space closure phase of fixed orthodontic treatment attending six orthodontic providers. Twelve patients received active ligatures (48 quadrants), 10 patients received powerchain (40 quadrants) and 11 patients, nickel-titanium springs (44 quadrants).

Method Patients were randomly allocated for treatment with active ligatures, powerchain or nickel titanium springs. Upper and lower study models were collected at the start of space closure (T_o) and 4 months later (T_1). We recorded whether the patient wore Class II or Class III elastics. Space present in all four quadrants was measured, by a calibrated examiner, using Vernier callipers at T_o and T_1. The rate of space closure, in millimetres per month (4 weeks) and a 4-monthly rate, was then calculated. Examiner reliability was assessed at least 2 weeks later.

Results Mean rates of space closure were 0.35 mm/month for active ligatures, 0.58 mm/month for powerchain, and 0.81 mm/month for NiTi springs. No statistically significant differences were found between any methods with the exception of NiTi springs showing more rapid space closure than active ligatures ($P < 0.05$). There was no effect of inter-arch elastics on rate of space closure.

Conclusions NiTi springs gave the most rapid rate of space closure and may be considered the treatment of choice. However, powerchain provides a cheaper treatment option that is as effective. The use of inter-arch elastics does not appear to influence rate of space closure.

Index words: Active ligatures, orthodontic space closure, nickel titanium springs, powerchain, rate of tooth movement, randomized clinical trial.

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Introduction

In this study, we set out to evaluate the effectiveness of three space closure methods: polyurethane powerchain, active ligatures, and nickel titanium (NiTi) springs for orthodontic space closure.

During orthodontic treatment involving extraction of teeth, there is often a need to close residual space. When space-closing sliding mechanics are used with the straight wire appliance, a force of between 100–200 g has been recommended by using elastic or wire springs.[1]

Currently, there are several commonly used methods of applying this force: these are elastic modules,[2] elastic chain and NiTi springs. However, the potential disadvantage of elastic chain or active modules is the significant force decay over time.[3–6] As a result, NiTi springs are an alternative in widespread use. NiTi springs have the reported advantage of giving significantly quicker and more consistent rates of space closure,[2,7,8] but are relatively expensive to use. In contrast, active ligatures are cheap and arguably easier for the patient to keep clean.

Since the comparative clinical performance of powerchain, active ligatures and NiTi springs has not previously been reported, the aim of the study was to compare the effectiveness of these three methods of orthodontic space closure.

Sample

We calculated the sample size for each group as 11 patients, based on an alpha significance level of 0.05 and

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a beta of 0.1. This gave a 90 per cent power to detect a difference of 3 mm ($\pm$2 mm) of space closure, per 4-month time period, in each quadrant. A 4-monthly rate was used as this was judged to be an approximate average of the time taken for space closure with straight-wire mechanics. A difference of 3 mm space closure in this time was considered clinically significant.

The sample was obtained from patients attending for orthodontic treatment at the University Dental Hospital of Manchester, Royal Bolton Hospital, Booth Hall Childrens' Hospital, and three specialist orthodontic practices. We applied the following inclusion criteria:

- Patient 10–18 years old at start of treatment
- A premolar extraction in each quadrant (no other extractions).
- Upper and lower pre-adjusted edgewise appliance (Roth prescription)
- Upper and lower 0.019 $\times$ 0.025-inch stainless steel working archwire in place for at least 4 weeks.
- Informed written consent was obtained from the patient and, where appropriate, the parent.

Random allocation method

Randomization was completed by throwing an unweighted di, where 1,2 = active ligatures, 3,4 = powerchain, and 5,6 = NiTi springs. A restricted randomization method was used in blocks of 12 to ensure that equal numbers of patients were allocated to each of the three treatment groups. The author then concealed the random allocation in envelopes labelled with the study identification number and held them in a central place.

When the patient was registered, the operator telephoned the study centre and a research assistant revealed the space closure method to which the patient (the unit of randomization) was allocated. In this way, the clinician and the patient were blind to the treatment allocation until the patient was registered and the treatment was due to start. During the trial, the operator could not be blind to the method of space closure, however, the examiner carrying out the model outcome measurements was blind until all the data were recorded and the code then broken.

Interventions and their timing

The planned interventions were rate of space closure over a 1- and 4- month time period using active ligatures, powerchain, or NiTi springs. All patients were treated identically apart from the named interventions. If the clinician wished to use Class II or Class III elastics, they did so and this was recorded and taken into account in the statistical analysis.

Outcome measures

The outcome measure we assessed in the trial was rate of space closure in millimetres per month (4 weeks) in all four quadrants. A 4-monthly rate of space closure was additionally calculated since this was the unit of time used in the sample size calculation.

Appliance design and data collection

At the end of levelling and aligning, upper and lower 0.019 $\times$ 0.025-inch stainless steel posted working archwires were placed. The patient was recalled after at least 4 weeks to ensure that the archwires were passive, by sliding the archwire through the bracket slots.

Active ligatures

Active ligatures were constructed from one grey elastic module and a long ligature. The elastic module was placed round the hook on the first molar band and the metal ligature tied to the hook on the posted archwire, stretching the elastic module twice its resting length. The active ligatures were replaced at each visit.

Powerchain

Narrow spaced polyurethane powerchain was placed from the first molar hook to the hook on the posted archwire. The powerchain was stretched to approximately twice its resting length and changed at each subsequent visit.

NiTi springs

NiTi springs (GAC Sentalloy), with 200 g force level, were used in this study and attached in the way described for active ligatures. It would have also been possible to use 150 g springs as these have been shown to be equally effective.[8] The springs were not stretched to more than 9 mm as suggested by Manhartsburger and Seidenbusch,[9] and if they were too small, a short ligature wire was used to attach the spring to the archwire hook. The NiTi springs were not replaced during treatment but were activated as necessary.

Patient records and stopping rules

When the working archwires had been in place at least 4 weeks, the operator removed them, and took upper and lower alginate impressions (T_o), then replaced and tied in with steel ligatures. They then started space closing mechanics. After 4 months (T_1) or earlier if space closure was complete, upper and lower alginate impressions were repeated. The patients' age at start of space closure and whether they had inter-arch elastics was also recorded. There were no stopping rules identified for this trial as all methods of space closure are in routine use and no special problems with any method were foreseen.

Measurement method

Vernier callipers were used to measure the maximum distance between the cusp tip of the canine to the buccal groove of the first permanent molar all four quadrants at T_o and T_1. Space between premolar and canine contact points was not measured because in many cases, the space at the end of 4 months was too small to be able to fit the Vernier callipers between the contact points. A rate of space closure in millimetres per month and per 4 months for each quadrant, and overall for each patient, was then calculated.

Method error

Systematic error was reduced by ensuring that the examiner was blind to the treatment group when the model measurements were made. The examiner was also blind (as much as was possible) to whether the model was from the start or after 4 months of space closure. All models were measured in a random order so that the same patient's start and finish models were not measured consecutively.

Random error was addressed by taking each space measurement three times and calculating an average. The error associated with the alginate impression technique and model preparation has been investigated by O'Brien *et al.*[10] and this technique has been shown to have a 97 per cent coefficient of reliability.

Examiner calibration and reliability

Examiner calibration with Vernier callipers was completed using four metal calibration cubes with different known heights, widths, and lengths. Reliability of the measurements was assessed by re-measuring all the study models at least 1 week later.

Statistics

We checked the data for normality and produced simple summary statistics. Mean monthly and 4-monthly rates of space closure were compared across the three treatment groups using a two-way ANOVA to take into account the effects of inter-arch elastic wear. Examiner calibration and reliability were assessed using *t*-tests.

Results

A trial profile for the registered patients is shown in Figure 1. This shows that for 36 patients initially registered, the final sample size for data analysis was 33. Three patients were not included in the data analysis since they were lost to follow-up.

Active ligatures	Power chain	NiTi springs
Received standard intervention $n = 12$	Received standard intervention $n = 12$	Received standard intervention $n = 12$
Followed up $n = 12$	Followed up $n = 10$	Followed up $n = 11$
Withdrawn $n = 0$	Withdrawn $n = 2$	Withdrawn $n = 1$
Intervention ineffective $n = 0$	Intervention ineffective $n = 0$	Intervention ineffective $n = 0$
Lost to follow-up $n = 0$	Lost to follow-up $n = 2$	Lost to follow-up $n = 1$
Other $n = 0$	Other $n = 0$	Other $n = 0$
Completed trial $n = 12$	Completed trial $n = 10$	Completed trial $n = 11$

Fig. 1 Profile of randomized clinical trial to compare active ligatures, powerchain, and NiTi springs for orthodontic space closure. Registered or eligible patients $n = 36$; not randomized $n = 0$; randomization $n = 36$.

Table 1 Mean monthly and 4-monthly rates of space closure for active ligatures, powerchain and NiTi springs

	Active ligatures (48 quadrants)	Powerchain (40 quadrants)	NiTi springs (44 quadrants)
Mean monthly rate (SD)	0.35 mm (0.23 mm)	0.58 mm (0.30 mm)	0.81 mm (0.51 mm)
Mean 4-monthly rate (SD)	1.40 mm (0.91 mm)	2.33 mm (1.18 mm)	3.23 mm (2.02 mm)
Number of quadrants (%) where space closure was complete at 4 months	18 (38%)	12 (30%)	14 (32%)

The mean patient age at the start of the trial was 15 years 6 months (SD = 2 years 5 months), and the sample consisted of 23 girls and 10 boys. The mean monthly (4-weekly) space closure rate and 4-month space closure rates are shown in Table 1.

Table 2 Examiner calibration for the use of Vernier callipers.

	Mean (SD)	SE	*P* value
Examiner	19.70 (14.47)	4.18	0.36
Gold standard	19.70 (14.51)	4.19	

Examiner calibration and reliability

The examiner (Victoria Dixon) was calibrated for the use of Vernier callipers and the results are shown in Table 2. There was no statistically significant difference between the examiner scores and the gold standard measurements for the calibration blocks ($P = 0.36$). Examiner reliability was similarly high with an intra-class correlation coefficient of 0.99.

Comparison of rates of space closure between treatment groups

Table 3 includes the comparison of data for monthly rates of space closure among active ligatures, powerchain and nickel-titanium springs. The only statistically significant difference detected was the rate of space closure between NiTi springs and active ligatures ($P < 0.05$). This was despite the number of quadrants with space completely closed being similar among all groups. There was no effect or interaction for the use of Class II or Class III elastics on the rate of space closure for any of the methods.

Discussion

This randomized clinical trial has suggested that not all orthodontic space closure methods are equally efficient. Although NiTi springs appear to offer the most rapid space closure, powerchain appears to be just as useful.

Nickel titanium springs close space more rapidly than active ligatures

The results of our study are in agreement with previously published literature, which suggests that NiTi springs give more rapid and reliable space closure than active ligatures.[2,7] However, these other studies used slightly different methodology; Samuels *et al*.[2] used a split mouth design and many of the patients had single arch fixed appliances. We did not choose this design to eliminate the possibility of one type of space closure affecting the comparison method across the arch. In another investigation, Sonis [7] used NiTi springs to retract canines rather than space close in the buccal segments.

This finding may seem surprising, at first, since Nattrass *et al*.[11] showed initial forces obtained by clinicians were 3.05 N for active ligatures and 1.5 N for NiTi springs. The increased efficiency of NiTi springs is, therefore, unlikely to be caused by the initial force exerted, but rather by the duration of the force as suggested by Proffitt's equilibrium theory.[12,13] It is also possible that the higher initial force with active ligatures is at a level that is counterproductive. It is more probable that it is the more continuous force from the super-elastic NiTi springs,[14] which explains the more rapid rates of space closure obtained by this method.

But are the results of this study clinically significant?

In interpreting the results of this research, it is necessary for the clinician to consider whether any of the results are clinically significant. In this respect, it is debatable whether the differences reported in monthly rates are clinically significant. Even the differences in mean total space closed over a 4-month period are only in the order of 1–2 mm.

However, although the difference in space closed between groups may not be large, the case of whether the patient has completed space closure by 4 months is

Table 3 Two-way ANOVA* to compare the monthly space closure rates for active ligatures, powerchain, and NiTi springs.

	Sum of squares	Df	Mean square	*F* ratio	*P* value
Space closure group	0.97	2	0.48	3.65	0.040
Inter-arch elastics	0.13	2	6.71×10^{-2}	0.51	0.61
Group × elastics	0.33	2	0.17	1.25	0.30

Comparison of groups with Bonferroni correction	Mean difference	SE	*P* value	95% confidence limits
Active ligatures vs powerchain	–0.23	0.16	0.45	–0.63–0.17
Active ligatures vs NiTi springs	–0.46	0.15	0.017	–0.85 – –0.069
Powerchain vs NiTi springs	–0.23	0.16	0.50	–0.63–0.18

*There was no interaction with inter-arch elastic wear and space closure method ($P = 0.30$), and there was no effect of the use of Class II or Class III elastics on rate of space closure ($P = 0.61$).

potentially significant. For example, compare a patient with no space left at 4 months and one with 2 mm of space left in any quadrant. The latter patient would potentially have a different amount of extra time in treatment to complete space closure depending on the method used (2 mm divided by the monthly space closure rate), i.e. 5.7 months with active ligatures, 3.4 months with powerchain, and 2.5 months with NiTi springs.

In addition, there are factors such as cost-benefit and chairside time to be considered when choosing the method of space closure. NiTi springs are the most expensive option, but have the advantage of being efficient and relatively quick to re-activate. Powerchain is cheaper, but is likely to take a little longer to replace at each visit. The chairside time with active ligatures is also likely to be increased because of their replacement at each visit and the increased number of visits required to obtain the same amount of space closure in comparison with the other methods.

The lack of effect of inter-arch elastics on the rate of space closure

It was surprising that we did not find any effect of Class II or Class III elastics on rates of space closure. Theoretically, it would seem that inter-arch elastics should speed up space closure, however, there may some explanation for their lack of effect:

- The study lacked statistical power to detect an elastic effect.
- The elastic force may not have been sufficient to influence rates of tooth movement
- Patients may not be co-operating totally with full time elastic wear
- The inter-arch elastics are moving blocks of teeth in each arch in an anterior or posterior direction without significantly adding to the space closing effect.
- For certain force levels, the addition of elastics may not increase the rate of tooth movement at the histological level.

Method issues

Internal and external bias. Consideration of internal bias is important because of the risk of biased comparisons of the interventions in the trial. Internal bias has been minimized in this trial in the following ways:

- Application of strict inclusion criteria.
- No patient refused to take part in the trial.
- Concealment of treatment allocation until the time of treatment.
- Standardization of treatment methods.
- The examiner making the measurement was blind to the treatment allocation.

One potential source of bias within this trial was 'attrition bias', since two patients were lost from the powerchain group and one from the NiTi group. Usually, a statistical comparison of the drop-outs and patients remaining in the study is carried out in an effort to ascertain that the patients lost are no different to the ones remaining in the trial. In this case, it was not considered useful to compare the start space, in each quadrant, for the patients who were lost and the study patients. Generally, it was thought that even with this potential source of bias, that external bias would be minimal and that the findings of the study were applicable to the general population of orthodontic patients.

Conclusions

Our study has shown that NiTi springs gave the most rapid rate of space closure and may be considered the treatment of choice. However, powerchain provides a cheaper treatment option that is as effective. The use of inter-arch elastics does not appear to increase rates of space closure.

Acknowledgements

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