Comparative evaluation of the efficiency of canine retraction using modified Marcotte and T-loop retraction springs – A split-mouth, randomized clinical trial

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Abstract:

OBJECTIVE: The aim of this study was to compare the efficiency of canine retraction using modified Marcotte and T-loop retraction springs.

MATERIALS AND METHODS: Twenty-four subjects with a treatment plan involving bilateral extractions of upper first premolars were included in the study. A split-mouth design was used to randomly allocate opposite quadrants to either modified Marcotte spring (MS) or T-loop spring (TLS) for canine retraction. Cephalometric radiographs and models were used to measure the rate of canine retraction (primary outcome) and compare the angular/rotational changes in the canines and anchorage loss in molars (secondary outcomes) following retraction. Subjective assessment of pain and discomfort was compared using visual analog scale (VAS). Paired and independent t-tests were used to evaluate changes.

RESULTS: The mean amount and rate of retraction of the canine were found to be significantly higher for MS (3.56 ± 0.696 mm and 1.188 ± 0.232 mm, respectively) when compared with TLS (2.125 ± 0.472 mm and 0.71 ± 0.157 mm, respectively). Distopalatal rotation of the canine was also significantly lesser for MS (2.42° ± 1.868°) than TLS (5.65° ± 2.84°, P < 0.001). However, the amount of anchorage loss and canine tipping were significantly higher for MS. Statistically significant higher values in the VAS score for TLS indicated greater discomfort.

CONCLUSION: MS exhibited increased rate of retraction and rotation control when compared with TLS during sectional canine retraction. Patient comfort was better for MS as evidenced by the VAS scores. However, the amount of tipping and anchorage loss obtained with MS were significantly higher than TLS.

Keywords: Canine retraction, Marcotte spring, T-loop spring

Introduction

Closure of extraction spaces is an integral part of many orthodontic treatment plans. In goal-oriented orthodontics, the closure of these spaces requires an understanding of the mechanical systems used. Space closure can be achieved by either friction (sliding) mechanics or frictionless (loop) mechanics. Retraction of teeth for closing spaces can be made possible in two ways, either en masse or segmental. The two-step retraction (segmental retraction) approach allows retraction of canine teeth independently, followed by the incisors in a second step. Springs of various designs for canine retraction...
[Gjessings, Ricketts retraction, NiTi coil, and T-loop springs (TLSs)] have been described and their suitability and efficacy tested. These studies have contributed to a better understanding of the biomechanics of canine retraction.

The T-loop design for orthodontic space closure has been comprehensively studied, particularly loops made from titanium–molybdenum alloy (TMA). The T-loop design generally provides a constant moment:force (M:F) ratio, a light and constant force throughout the entire activation range of a closing loop, and a constant low load–deflection rate. Another canine retraction spring with a single closing loop design using 0.016” SS wire has been described by Michael Marcotte. He has recommended its use for minor cuspid retraction. The design of this spring is very simple and may be fabricated at the chairside. However, no literature exists to date regarding the use of Marcotte springs (MSs).

Pain and discomfort associated with orthodontic treatment is a matter of great concern for most patients. It is a critical deterrent to orthodontic treatment and a common cause for treatment discontinuation. Evaluating pain and discomfort caused by the two springs is therefore necessary and would be of substantial clinical value.

Specific Objectives and Hypothesis

This study was carried out to compare the efficiency of canine retraction using modified MSs and TLSs. The primary objective was to compare the rate of canine retraction. The secondary objectives were to compare the tendency for canine rotation and change in first molar position for the two springs as well as make a subjective assessment of pain and discomfort. The null hypothesis generated was that there may be no difference between the two springs regarding the above factors.

Materials and Methods

Trial design and any changes after trial commencement

This was a single-center, split-mouth, simple randomized trial, with an allocation ratio of 1:1 between the two quadrants. The two springs were randomly assigned to the right and left quadrants of the upper arch. This study was approved by the Institutional Research Board, Institutional Ethics Committee and registered under the Clinical Trials Registry (CTRI no. CTRI/2013/11/004129). There were no changes after trial commencement.

Study sample, participants, eligibility criteria, and setting

The sample size was calculated using the below formula:

\[ n = f(\alpha, \beta) \frac{\sigma^2}{(\mu_1 - \mu_2)^2} \]

Where \( \sigma \) is the standard deviation of the within-person differences (\( \mu_1 - \mu_2 \)), and \( f(\alpha, \beta) \) is a function of power and significance level. According to the data from a previous study for the parameter of rate of retraction, a sample size of 22 was found to be required to be able to reject the null hypothesis with a probability of 0.90. To increase the power of the study and compensate for possible dropouts during the study period, it was decided to include more patients.

Informed consent was obtained from all participants who were recruited from the Department of Orthodontics based on the following inclusion criteria: a treatment plan involving bilateral extractions of maxillary first premolars in the age group of 13–20 years with the canines well-aligned within the arch, mild crowding of <5 mm, and presence of all teeth up to second molars.

Interventions

Following extraction of first premolars, initial leveling was performed with the preadjusted edgewise appliance (MBT prescription, 0.022 × 0.028” slot, 3M Unitek orthodontic products, Monrovia, CA, USA). All patients were group B anchorage cases, addressed with the use of transpalatal arches and banding of second molars. Initial leveling and alignment commenced with 0.014” round NiTi wire in all cases and progressed according to common MBT treatment sequence, to 0.019 × 0.025” rectangular stainless steel wire, which was left in situ for at least 4 weeks to ensure full expression. After leveling and alignment, the molars and premolars were held as a segment by a 0.019 × 0.025” stainless steel wire and tied with stainless steel ligatures, ready for retraction of canine using either MS or TLS [Figures 1 and 2]. Study models and lateral cephalograms using radiopaque TMA wire markers to differentiate right and left sides were obtained.

Randomization

A split-mouth, cross-quadrant, paired design was used, in which each participant had TLS on one side and MS on the other. Randomization for T-loop allocation to specific upper quadrants was achieved using a block randomization method proposed by Roberts and Torgerson (1998), and the modified MS was used on the contralateral side. Ultimately, in 50% of patients, the right side was treated with MS and the left side with...
TLS, and the reverse was true for the rest of the 50%. The retraction was started at the same time on both the sides.

All the springs were constructed with 0.017 × 0.025” TMA wire (Ormco Corp, Orange, CA, USA).

**T-loop spring**
Springs were adjusted to be passive in the canine bracket and the molar auxiliary tube. The loop was placed midway between the canine and molar tube. Antirotational and 30° preactivation bend were given. A neutral position with the vertical legs of the spring in contact was achieved. A retractive force of 150 g was measured using a Dontrix gauge (American Orthodontics, Sheboygan, WI, USA) for all springs.

**Modified Marcotte**
Originally, 0.016” SS wire had been recommended by Michael Marcotte.[6] It is fundamentally a closed vertical loop spring. This spring design has been modified by us to the extent of using a 0.017 × 0.025” TMA arch wire extended from the auxiliary tube of the first molar to the cuspid. The rationale of using 0.017 × 0.025” TMA wire is that it would give a better fit in the auxiliary tube which has a 0.018 × 0.025” internal dimension. This would give better rotational and directional control. The loop design consisted of a closing loop of 3 mm width and 6–8 mm height. The height between mesial and distal arm was kept at 2 mm. Antirotation bends of 10°–15° were placed on the mesial arm along with a mesial tip of 15°–20°. Antieextrusion bends of 20°–30° were placed on the distal arm. After onset of retraction, all patients were recalled every 6 weeks to ensure the amount of activation for three visits. Both TLS and MS were activated to give a consistent 150 g deactivation force during each of the three visits. Evaluation was again done using study models and cephalometric radiographs after completion of 18 weeks.

**Blinding**
It was not possible to blind the patient or orthodontist, as the two springs on either side were different. However, blinding was possible during evaluation, as the cephalometric and model analysis was done by a third investigator who did not know which spring was used on either side.

**Outcome assessment**
Outcomes were evaluated cephalometrically and using model analysis. The primary outcome assessed was the rate of canine retraction. Rotation of the canines, changes in first molar position, and pain or discomfort experienced by the patient served as the secondary outcomes.

**Model analysis**
The movements of the teeth in the anteroposterior direction were assessed by determining their position with respect to the location of maxillary rugae and midpalatine raphe as described by Haas and Cisneros[13] and Hoggan and Sadowsky.[14] The landmarks identified and marked on the preretraction and postretraction maxillary dental casts are given in Table 1 [Figure 4a]. The casts were then scanned using Epson perfection V700 scanner (maximum resolution ~ 12,800 dpi). The midpalatine raphe, constructed by joining the anterior and posterior raphe points, was used as reference median line for measurements. The models were superimposed using the constructed midpalatal raphe as the reference.
plane and medial aspects of third rugae as reference points (RR, RL).\[^{14}\] Perpendiculars were dropped on this median line from the mesiobuccal cusp tips of the maxillary permanent first molars (ML1, ML2, MRI, MR2) and the cusp tips of the maxillary permanent canines (CL1, CL2, CR1, CR2).

**Determination of rate of canine retraction**
The linear distance from CLI to CL2 and CR1 to CR2 was measured. Measurements were made to the nearest of 0.1 mm using digital calliper (Mitutoya, Kawasaki, Japan). Each measurement was done twice and the mean of the two values was recorded. This gives the actual amount of change in canine position with reference to the tip of canine. The duration of canine retraction was recorded as time intervals, that is, each time interval was equal to 6 weeks. The rate of canine retraction was calculated as the amount of canine retraction in millimeters divided by the time interval [Figure 4b].

**Determination of change in the first molar position with reference to the mesiobuccal cusp**
The linear distance from ML1 to ML2 and MRI to MR2 was measured which gave the change in the first molar position (anchorage loss) with reference to the mesiobuccal cusp [Figure 4b].

### Table 1: Landmarks on maxillary dental cast

| Landmarks                             | Description                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------|
| Anterior raphe point (ARP)            | Most discernible anterior point on the midpalatal raphe                     |
| Posterior raphe point (PRP)           | Most discernible posterior point on the midpalatal raphe                     |
| Right/left rugae point (RR/RL)        | Most medial point of the third rugae on right/left                          |
| Right/left molar mesiobuccal cusp tip (MT) | Tip of mesiobuccal cusp of maxillary right/left first molar                  |
| Right/left canine cusp tip (CT)       | Tip of the cusp of maxillary right/left canine                               |
| Canine mesial/distal contact point (CM, CD) | The most mesial/distal contact point of canine on both sides                |
| Molar mesial/distal contact point (CM, CD) | The most mesial/distal contact point of molar on both sides                |

**Determination of canine rotation**
The rotation of upper canines was represented by the angle formed between the median palatine suture and a line passing through the mesial and distal contact points of the canines. Total rotation was considered to be the difference between the values in pre- and post models\[^{15}\] [Figure 4c].

**Cephalometric analysis**
Cephalometric analysis was done for determination of tipping of canines. Two different shaped radiopaque markers made of TMA wire (0.021 × 0.025") were ligated to canine brackets [Figure 5a]. Pre- and post-cephalograms were taken with the TMA marker wire in place. The amount of canine tipping was measured with reference to the palatal plane – ANS-PNS [Figure 5b]. All the measurements were done to the nearest 0.5° with a protractor. The amount of canine tipping was calculated by the difference in degree of tip between the marker in preretraction and postretraction cephalograms.\[^{16}\]

To assess intraexaminer reliability, 12 radiographs and models were randomly selected and all procedures repeated after 2 weeks.

**Subjective assessment of pain and discomfort**
The subjective assessment of pain and discomfort for both MS and TLS was done using visual analog scale (VAS). The patients were thoroughly instructed regarding implications of the VAS. Written instructions were also given to them. Patients were called on their mobile/landline phones after 24, 48, and 96 h following initial placement and scores obtained. Such evaluation was done after initial placement, 6, 12, and 18 weeks.

**Statistical analysis**
All the statistical analyses were performed using SPSS statistical package (version 16.0, SPSS Inc., Chicago, Illinois, USA). Intraexaminer reliability was tested using intraclass correlation coefficient [Table 2]. The analyses performed were paired t-test to quantify the changes before and after treatment within each group and independent t-test to compare the treatment changes in T-loop with modified MS. In this study, $P < 0.05$ was considered as the level of significance.
Results

Participant flow
A total of 33 patents who reported to the Department of Orthodontics between May 2014 and February 2015 were initially assessed for eligibility by two clinicians unrelated to the study. As 5 patients did not meet the inclusion criteria, 28 patients were selected (13 males and 15 females). The right/left quadrants were randomized and allocated to T-loop and modified MS groups. However, four patients opted out of the study. Patient information was stored in envelopes to ensure concealment from the researcher. Thus, a final sample of 24 patients completed the study and they were analyzed [Figure 6].

Table 3 shows the amount/rate of retraction, tipping, and rotation of canines for both TLS and MS. The mean amount and rate of retraction of the canine were found to be higher for the MS (3.56 ± 0.696 mm and 1.188 ± 0.232 mm, respectively) when compared with TLS (2.125 ± 0.472 mm and 0.71 ± 0.157 mm, respectively). This difference was found to be statistically highly significant (P < 0.001). Distopalatal rotation of the canine tooth was significantly higher for TLS (5.65° ± 2.84°) when compared with MS (2.42° ± 1.868°, P < 0.001).

However, the amount of canine tipping for MS was 6.64° ± 2.74°, while that for TLS was 1.22° ± 5.12°. The mean difference was 5.42°, which was statistically highly significant (P < 0.001).

Table 2: ICC showing the level of agreement

| Parameter         | ICC  |
|-------------------|------|
| Retraction        | 0.923|
| Rotation          | 0.997|
| Anchorage loss    | 0.938|
| Tipping           | 0.891|

Table 3: Comparison of change in canine position between Marcotte and T-loop springs

| Parameters        | Marcotte spring | T-loop spring | P    |
|-------------------|-----------------|---------------|------|
|                   | Mean            | SD            | Mean | SD  |      |
| Amount of retraction | 3.562 ± 0.696   | 2.125 ± 0.472 | 0.00**|    |
| Rate of retraction  | 1.187 ± 0.232   | 0.708 ± 0.157 | 0.00**|    |
| Anchorage loss     | 0.791 ± 0.142   | 0.250 ± 0.466 | 0.00**|    |
| Tipping            | 6.645 ± 2.744   | 1.229 ± 5.124 | 0.00**|    |
| Rotation           | 2.416 ± 1.868   | 5.645 ± 2.849 | 0.00**|    |

SD—Standard deviation. **P<0.001

Figure 6: CONSORT diagram showing flow of patients through the trial
significant ($P < 0.001$). Anchorage loss was also found to be significantly higher at 0.791 for MS when compared with 0.466 for TLS ($P < 0.001$).

Table 4 showing the mean difference in the total VAS scores (28 for Marcotte and 49.45 for T-loop) found it to be statistically highly significant ($P < 0.001$).

### Discussion

Many sectional retraction springs have been designed and constructed to produce the best combination of forces and moments acting on the brackets to give an optimum rate of retraction, without undue tipping, rotation, and patient discomfort.

In this study, the mean rate of retraction for MS was found to be significantly higher than TLS. Higher rates of retraction (0.87/month) has been reported for T-loops in a previous investigation.[18] The probable reason could be due to the fact that under equal circumstances, the loops that are activated by closing rather than opening are more effective. Furthermore, Bauschinger effect points out that if wires are activated in the direction identical to their original bending direction, they will have higher maximal elastic load.[19] The rate of canine retraction using nickel–titanium closed-coil springs is reported to range between 0.81 and 0.93 mm.[18] Previous investigations on the paul gjessing (PG) spring have reported wide variations in canine retraction ranging from 1.91 ± 0.41 to 0.85 ± 0.41 mm/month.[2,16]

Canine tipping was significantly lesser for TLS in this study. The T-loop had preactivation bends, which in theory would enhance bodily movement.[19] This could account for the reduced tipping of TLS. For canine tipping, a value of 4.46 ± 6.38 for the T-loop, 3.33 ± 6.89 for the PG spring, 5.41 ± 6.38 for reverse closing loop, and 7.89 ± 2.32 for the Ricketts canine retraction spring has been reported.[5,16,19] These values are comparable to the amount of tipping shown by MS but higher than that obtained for TLS in this study.

The value of anchorage loss was significantly higher for MS (0.791 ± 0.108, $P < 0.001$) than TLS (0.250 ± 0.463). The maxillary molar crowns were protracted by controlled tipping, without significant intrusion or extrusion. Anchorage loss of TLS in this study is lesser than previously reported studies by Renato Parsekian (1.0 ± 0.6 for T-loop) and Dincer and Iscan HN (1.63 ± 1.11 for PG spring and 2.46 ± 1.5 for reverse closing loop).[16,20] The difference in anchorage control between MS and TLS may be due to the difference in design of the two retraction springs under study. In the T-loop, preactivation bends are placed equally in both the arms, while in Marcotte only antiextrusion bend is placed on the distal arm, which might have caused tipping of the molar tooth.

The tendency of the canine crown to rotate distopalatally was also found to be significantly lesser in MS than TLS. This is of great importance from a clinical standpoint. Higher amounts of canine rotation have been reported with NiTi coil springs (7.73°) and Ricketts canine retraction spring (22.06° ± 3.73°).[10,21] Thus, the modified MS showed better rotational control during distal movement of the canines when compared with TLS. The reason for improved control with MS is probably because it is more rigid than TLS, as there is less wire incorporated into it. As there are no previous studies evaluating the MS, it was not possible for us to compare our findings with any previous work.

Whatever be the design of a spring, of paramount importance is patient comfort in using the spring. The results of this study indicate that the level of discomfort was significantly higher for TLS when compared with MS. This is an important consideration while choosing the spring design.

### Conclusion

The null hypothesis stands rejected as the results of the study showed that

- Modified MS exhibited increased rate of retraction and rotation control when compared with TLS during sectional canine retraction
- TLS showed lesser canine tipping and better anchorage control
- Patient comfort appeared to be better for MS as evidenced by VAS scores.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

### References

1. Nightingale C, Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. J Orthod 2003;30:229-36.
2. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. Am J Orthod Dentofacial Orthop 1989;95:99-106.
3. Cacciafesta V, Sfondrini MF, Ricciardi A, Scribante A, Klersy C, Auricchio F. Evaluation of friction of stainless steel and esthetic self-ligating brackets in various bracket-archwire combinations. Am J Orthod Dentofacial Orthop 2003;124:395-402.
4. Bokas J, Woods M. A clinical comparison between nickel titanium springs and elastomeric chains. Aust Orthod J 2006;22:39-46.
5. Keng FY, Quick AN, Swain MV, Herbison P. A comparison of space closure rates between preactivated nickel-titanium and titanium-molybdenum alloy T-loops: A randomized controlled clinical trial. Eur J Orthod 2012;34:33-8.
6. Marcotte MR. Biomechanics in Orthodontics. Philadelphia, PA; 1990.
7. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: Comparison with fixed edgewise appliance therapy. Prog Orthod 2014;15:1-7.
8. Pandis N. Sample calculation for split-mouth designs. Am J Orthod Dentofacial Orthop 2012;141:818-9.
9. Roberts C, Torgerson D. Randomisation methods in controlled trials. BMJ 1998;317:1301.
10. Burstone CJ. The segmented arch approach to space closure. Am J Orthod 1982;82:361-78.
11. Burstone CJ, Van Steenbergen E, Hanley K. Modern Edgewise Mechanics and Segmented Arch Technique. Farmington, CT: University of Connecticut Health Center; 1995.
12. Burstone CJ, Koenig HA. Optimizing anterior and canine retraction. Am J Orthod 1976;70:1-19.
13. Haas SE, Cisneros GJ. The Goshgarian transpalatal bar: A clinical and experimental investigation. Sem Orthod 2000;6:98-105.
14. Hoggan BR, Sadowsky C. The use of palatal rugae for the assessment of anteroposterior tooth movements. Am J Orthod Dentofacial Orthop 2001;119:482-8.
15. Mezomo M, de Lima ES, de Menezes LM, Weissheimer A, Allgayer S. Maxillary canine retraction with self-ligating and conventional brackets. Angle Orthod 2011;81:292-7.
16. Dincer M, Iscan HN. The effects of different sectional arches in canine retraction. Eur J Orthod 1994;16:317-23.
17. Graber LW, Vanarsdall RL, Vig KWL. Orthodontics: Current Principles and Techniques. Elsevier Health Sciences; 2011.
18. Thiruvencatichari B, Ammayappan P, Kandaswamy R. Comparison of rate of canine retraction with conventional molar anchorage and titanium implant anchorage. Am J Orthod Dentofacial Orthop 2008;134:30-5.
19. Hayashi K, Uechi J, Murata M, Mizoguchi I. Comparison of maxillary canine retraction with sliding mechanics and a retraction spring: A three-dimensional analysis based on a midpalatal orthodontic implant. Eur J Orthod 2004;26:385-9.
20. Martins RP, Buschang PH, Martins LP, Gandini LG Jr. Optimizing the design of preactivated titanium T-loop springs with Loop software. Am J Orthod Dentofacial Orthop 2008;134:161-6.
21. Sueri MY, Turk T. Effectiveness of laceback ligatures on maxillary canine retraction. Angle Orthod 2006;76:1010-4.