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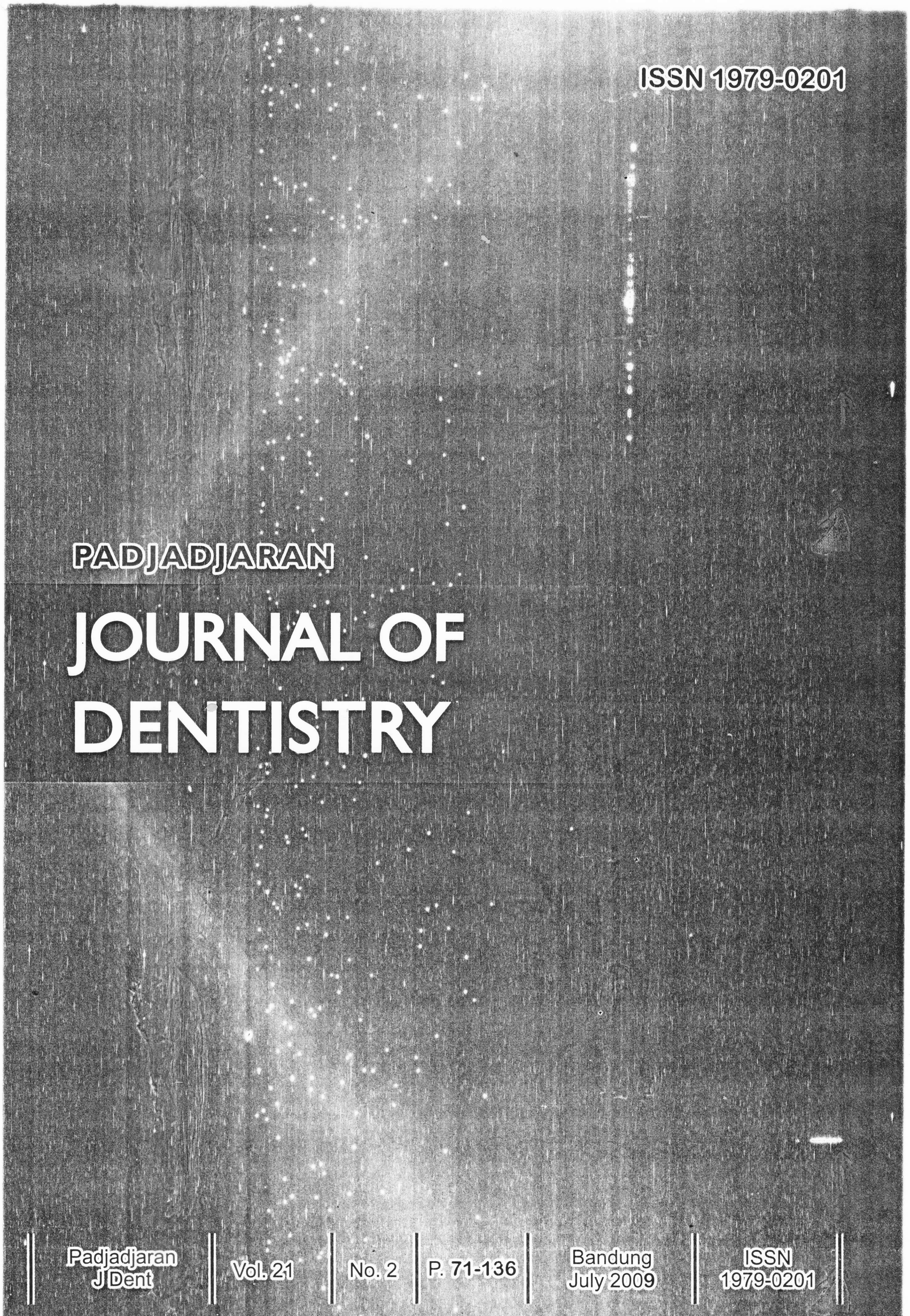

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Content of this issue

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The effect of Gable angle size and spring activation distance of 0.016x0.022 NiTi and TMA sectional T-loop towards force, moment$_y$ and moment$_z$ values

Norman Wachyudi, Tono S. Hambali, Jono Salim, Endah Mardiati

Department of Orthodontic Faculty of Dentistry Universitas Padjadjaran

ABSTRACT

This study was carried out to find the effects of angle of Gable bends and amount of activations of 0.016x0.022 inch NiTi and TMA sectional T-loop springs to the force moment$_y$ and moment$_z$ delivered. The design of the research is true in-vitro laboratory experimental design, to measure the force, moment$_y$. and moment$_z$, an axial moment devices was designed purposely. The samples were 30 springs comprised of 15 NiTi and 15 TMA with variations of Gable bends 0°-0°, 10°-10°, and 20°-20° Force, moment$_y$ and moment$_z$ was measured at 1, 2, and 3 mm amount of activations. Data was tested statistically using the ANAVA with 3x2x3 factorial designs and 5 replications for each all. The results showed that angle of Gable bends, amount of activations and type of wires significantly affect the force and moment$_z$ delivered, but angle of Gable bends unsignificantly affect moment$_y$. It could be concluded that the greater angle of Gable bends will produce the greater force and moment$_z$. The greater amount of activations will produce the greater force and moment$_z$.

Key words: Gable, force, moment$_y$, moment$_z$

INTRODUCTION

In orthodontic practice, the orthodontists are demanded to understand the principles of biomechanics very well. The use of these principles is necessary to get optimum dental movement quality to reach good and stable treatment result.[1-3]

The optimum dental movement, especially in closing post extraction space through maxillary canine and four incisive retractions, is a very important and basic movement in orthodontic treatment. The accurate position of maxilarry canines and four incisives at the end of the treatment affect function, stability and esthetic of the patient.[4] Therefore, in this stage, it is necessary to apply a real consistent biomechanical principle through the application of specific orthodontic force system.[2]

Clinically, the dental movement can happen through the orthodontic force system resulted from orthodontic appliance application.[5] The force from orthodontic appliance is often applied inaccurately at the tooth resistant core leading to moment creation. The moment that works on the Y axis is referred as moment$_y$ (M_y), while the moment that works on Z axis is called moment$_z$ (M_z). If the amount of moments that work on the teeth is uncontrolled, unwanted side effects will be created. The side from moment$_z$ is uncontrolled

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tipping effect while the side effect from moment$_y$ is uncontrolled rotation of the teeth. To produce translation movement on the teeth, the moments that work on anterior and posterior units should have appropriate size.[2] Therefore, an orthodontic appliance that can produce moment/force ratio that is appropriate for the expected dental movement through accurate combination between appliance design and force system application is necessary.[1,2-6]

Relationship between appliance design and orthodontic force system is very important to understand. In sliding mechanic system, the teeth move along the archwire. Frictions between bracket and archwire is difficult to estimate because it is affected by the form, bracket slot size and archwire used.[3,7] Another method is segmented approach by using sectional closing loop. With this method, the forces and moments resulted during activation only works in the bracket at both ends of the wire so that the forces and moments resulted are easier to determine.[3,5,8,9]

Various designs of loop have been used in orthodontic treatment. An ideal loop design is needed to reach treatment efficiency and controlled dental movement. Loop design includes vertical dimension, horizontal dimension, Gable angle size, inter-bracket distance and type of wire. An ideal loop should meet several criteria, i.e. able to control force, moment$_y$, and moment$_z$ in a well manner. Several experts recommend T-loop as one of the ideal loop forms.[3,5,6,10-12]

Differences in height, width and size of Gable angle in T-loop affect the force, moment and moment/force ratio resulted. The higher and the wider the T-loop, the resulted force and moments will be smaller.[5,6] The recommended size of the T-loop is 10 mm wide and 6 to 7 mm high.[3,9,11] The size of Gable angle in T-loop may affect resulted force, moment$_z$ and moment$_z$/force ratio. Gable size can be made with a variation of 10°, 20°, 30°, 40°.[6,12,13] The bigger the Gable size, the bigger the force and moment$_z$ resulted.[6,12] Inter-bracket space really affects the force system produced. The

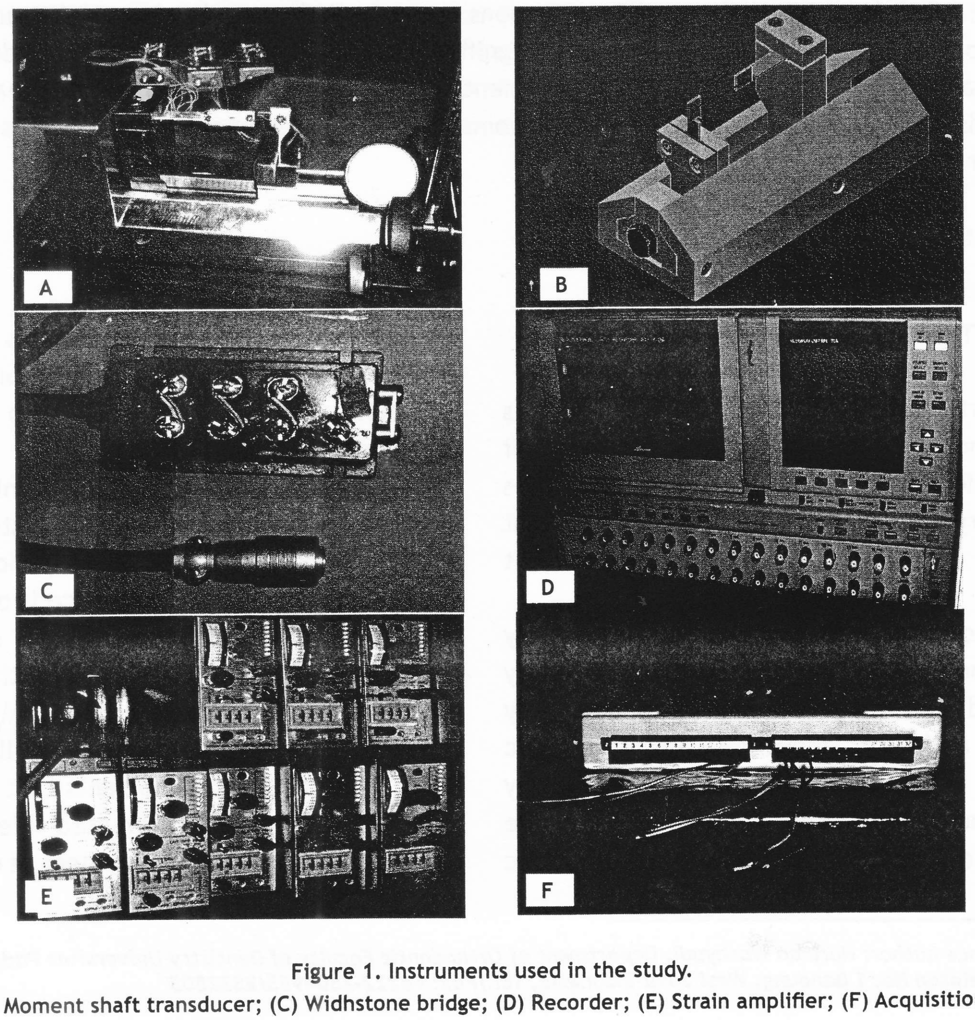

Figure 1. Instruments used in the study.
(A&B) Moment shaft transducer; (C) Widhstone bridge; (D) Recorder; (E) Strain amplifier; (F) Acquisition data.

addition of inter-bracket space causes decrease in deflection rate due to load deflection so that the force produced will be more constant, force direction changes during dental movement will be minimum and the activation range of T-loop spring will be bigger.[10] The types of wire that is usually used to produce optimum force and moments are 0.016x0.022 inch NiTi[14] and 0.016x0.022 inch TMA.[15]

The activation distance affects produced force, moment$_y$, and moment$_z$, the bigger the activation force, the bigger the force, moment$_y$, and moment$_z$ produced.[5,6,12] The objective of this study is to reveal whether there is a difference between the sizes of the force, moment$_y$, and moment$_z$ produced by sectional T-loop spring from NiTi and TMA with a size of 0.016x0.022 inch with different Gable angle size and activation distance.

MATERIALS AND METHODS

The study instrument was a moment shaft transducer designed and produced by the Engineering Design Centre (EDC), Machinary Engineering Department of Bandung Institute of Technology that consists of a moment shaft as a transducer that can measure force, moment$_y$, and moment$_z$, edgewise standard bracket stand for 0.018 inch slot size; Acquisition data tool, National Instruments USA; Widhstone bridge (Kyowa Elektronic Japan); Lab View Software; Template to make the T-loop; Glass lab as the auxilliary instrument in T-loop making; Faber-Castell red marker; Belzer wire cutting pliers; RMO 139 pliers (bird beak); Med Kraft Needle Holder; Furnish table for heat treatment; and Tricle Brand callipers.

Study materials was 0.016x0.022 inch NiTi wire (ORMCO) to make sectional T-loop spring using jig; 0.016x0.022 inch TMA wire (ORMCO) to make sectional T-loop spring based on template; 0.008 inch stainless steel ligature wire (ORMCO) to tie T-loop spring to the bracket.

The study was performed at the Orthodontic Specialist Department, Faculty of Dentistry, Universitas Padjadjaran Bandung; The laboratory of the Engineering Design Centre (EDC), Machinary Engineering, Bandung Institute of Technology, and the Chemistry Physic Material Department of

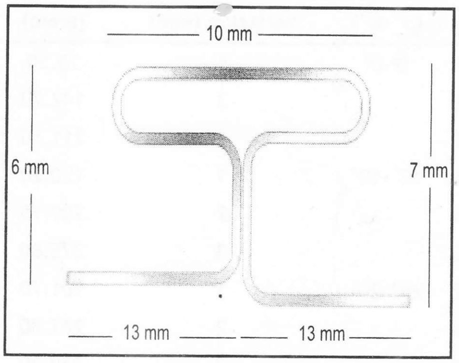

Figure 2. Height, width, and arm length of the T-loop.

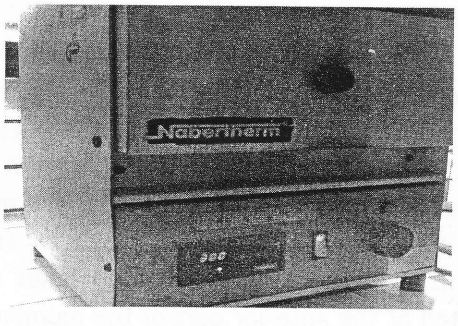

Figure 3. Furnish machine for heat treatment of NiTi T-loop spring (Material Chemistry Physic Laboratory of Bandung Institute of Technology).

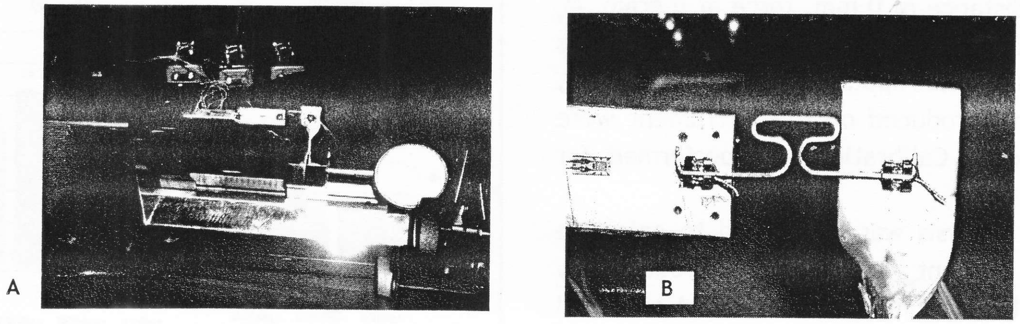

Figure 4. Force and moment testing instrument. A. Force and moment testing instrument, B. Sectional T-loop spring is attached to force and moment testing instrument. (Laboratory of Engineering Design Centre/EDC, Machinary Engineering, Bandung Institute of Technology).

Bandung Institute of Technology. The study period was November 2007–June 2008.

The sample of this study consisted of sectional T-loop made of NiTi and TMA wires with a size of 0.016x0.022 inch with anterior arm height of 7 mm, posterior arm height 6 mm,10 mm width, anterior and posterior arm length 13 mm and three Gable angle variations of 0°-0°, 10°-10°, and 20°-20° For statistical calculation sake, each size consisted of 5 samples so that the total samples were 15 NiTi T-loop springs and 15 TMA T-loop springs. This study was a pure in vitro laboratory experimental study by using ANAVA (Variance Analysis) statistical test.

The TMA sectional T-loop was made by bending 0.016x0.022 inch TMA wire using 139 guided by the template. NiTi sectional T-loop spring was made by inserting 0.016x0.022 inch NiTi wire into the jig followed by heat treatment using a furnish machine with 300° C temperature for 3 hours. Gable bend with anterior (α) and posterior (ß) angles of 0°-0°, 10°-10°, and 20°-20° was then added to the T-loop, each contained fifteen bends. The whole spring was then calibrated using the template and the alignment was checked using the glass lab.

The measurement of force, moment$_y$, and moment$_z$ was performed using force and moment testing instrument (Fig. 5). T-loop posterior arm was tied using ligature wire to the bracket that is located at the most posterior part of the moment shaft transducer and the T-loop anterior arm was tied using ligature wire to the bracket that is situated at the anterior part of the moment shaft transducer.

Furthermore, calibration of the moment shaft transducer was performed to show an activation distance of 0 mm, force of 0 gram, M_z of 0 mm, and M_y of 0 mm. After that, retractions of 1,2 and 3 mm was applied. The force, moment$_y$, and moment$_z$ produced on the instrument were then recorded. Calibration was performed for each retraction.

Data analysis was performed to calculate the force, moment$_y$, and moment$_z$ produced by pulling 0.016x0.022 inch NiTi and TMA sectional T-loop spring for 1,2 and 3 mm. The size of force, moment$_y$, and moment$_z$ produced by 0.016x0.022 inch NiTi and TMA sectional T-loop spring was analyzed using ANAVA (Variance Analysis) statistical test by testing the data in factorial design of 3x2x3 with 5 replications for each cell. To test the force similarity produced by T-loop with optimum force, t test was performed statistically.

Table 1. Average value of force produced by 0.016x0.022 inch NiTi sectional T-loop spring based on Gable angle and activation distance variations (gram).

	Gable (α°-ß°)	Activation distance variation (mm)	Force/F (gram)	SD
NiTi1	0⁰-0⁰	1	40.10	2.02
NiTi2		2	81.30	0.77
NiTi3		3	119.20	0.17
NiTi4	10°-10°	1	70.10	1.11
NiTi5		2	110.10	2.39
NiTi6		3	148.10	0.63
NiTi7	20° - 20°	1	84.70	4.75
NiTi8		2	124.30	2.32
NiTi9		3	159.10	2.07

Table 2. Average value of force produced by 0.016x0.022 inch TMA sectional T-loop spring based on Gable angle and activation distance variations (gram).

	Gable (α°-ß°)	Activation distance variation (mm)	Force/F (gram)	SD
TMA1	0⁰-0⁰	1	75.50	5.37
TMA2		2	142.70	1.36
TMA3		3	211.30	0.52
TMA4	10°-10°	1	120.20	2.78
TMA5		2	209.10	4.74
TMA6		3	275.60	2.02
TMA7	20°-20°	1	201.70	1.39
TMA8		2	267.80	1.07
TMA9		3	339.20	0.53

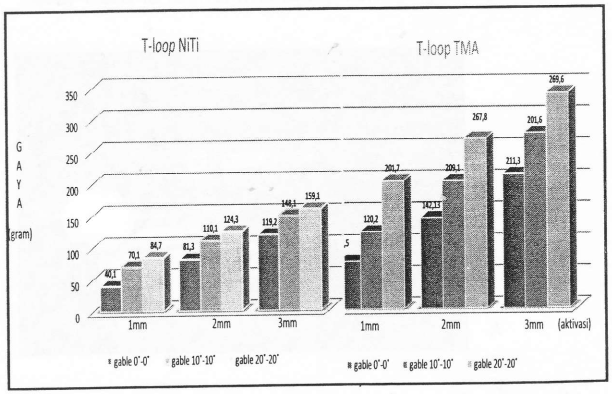

Figure 5. Average value of force produced by NiTi and TMA Sectional T-loop spring with Gable angle size variations and different activation distance (gram).

RESULTS

This study was performed to see the size of the force, moment$_y$, and moment$_z$ produced from activating 0.016x0.022 inch NiTi and TMA sectional T-loop spring for 1,2 and 3 mm, with anterior Gable angle (α) and posterior Gable angle (β) of 0°-0°, 10°-10°, and 20°-20°. Each contains 5 samples with the total number of samples of 30. A statistical analysis was performed to see the differences in the force, moment$_y$, and moment$_z$ produced from Gable angle and activation distance variations.

Table 3. Variance analysis for difference of average value of the force produced by T-loop spring based on the type of wire, Gable angle size and different activation distance.

SV	dk	JK	RJK	F_{count}	F_{tab}	
Average	1	2146859.33	-	-	-	-
A	2	181722.37	90861.18	4265.25	3.10	*)
B	1	228019.66	228019.66	10703.80	3.98	*)
C	2	107034.70	53517.35	2512.24	3.10	*)
AB	2	16195.53	8097.76	380.13	3.10	*)
AC	4	493.78	123.44	5.79	2.50	*)
BC	2	27210.72	13605.36	638.67	3.10	*)
ABC	4	500.61	125.15	5.87	2.50	*)
Error	72	1533.79	21.30	-	-	
Total	90	2709570.50	-	-	-	

Note: F table is gained with a significance level of 95% with dof (2;72)=3.10 and dof(1:72)=3.98 and dof (4;72)=2.50; (SV) Variation source; (B) Type of wire; (dk) Degree of Freedom; (C) Gable angle; (JK) Square sum; (AB) Activation distance and type of wire; (RJK) Average square sum; (AC) Activation distance and Gable angle; (F_{count}) F calculation; (ABC) Activation distance, type of wire and Gable angle; (F_{tab}) F table; (*) Significant; (A) Activation distance; (°) Not Significant.

Table 4. Testing similarity of force strength with optimum force for NiTi and TMA T-loop spring with different Gable angle and activation distance.

	Gable (α°-β°)	Activation distance variation	Force F (Gram)		t_{count}	t_{tab} 5 %
NiTi1	0⁰-0⁰	1	40.10	2.02	-49.66 *)	2.78
NiTi2		2	81.30	0.77	-10.79 *)	2.78
NiTi3		3	119.20	0.17	457.55 *)	2.78
NiTi4	10°-10°	1	70.10	1.11	-30.07 *)	2.78
NiTi5		2	110.10	2.39	23.5 *)	2.78
NiTi6		3	148.10	0.63	224.15 *)	2.78
NiTi7	20°-20°	1	84.70	4.75	-0.13 *)	2.78
NiTi8		2	124.30	2.32	37.91 *)	2.78
NiTi9		3	159.10	2.07	80.02 *)	2.78
TMA1	0⁰-0⁰	1	75.50	5.37	-63.41 *)	2.78
TMA2		2	142.70	1.36	94.59 *)	2.78
TMA3		3	211.30	0.52	546.25 *)	2.78
TMA4	10°-10°	1	120.20	2.78	28.28 *)	2.78
TMA5		2	209.10	4.74	58.47 *)	2.78
TMA6		3	275.60	2.02	262.38 *)	2.78
TMA7	20°-20°	1	201.70	1.39	15.00 *)	2.78
TMA8		2	267.80	1.07	381.12 *)	2.78
TMA9		3	339.20	0.53	1065.05 *)	2.78

Note: (Std) Standard of deviation (*) Significant; (°) Non significant.

Analysis of force produced

To determine the presence of different average value of force produced by retraction of sectional T-loop spring based on the type of material, Gable angle size and different activation distance, a simultaneous testing using Factorial Experiment 3x2x3 method with 5 observations each cell was performed. The results of the variance analysis can be observed in Table 3.

Based on the statistical testing it was revealed that the sectional T-loop spring produces a force that approaches the optimum 85 gram force was the sectional T-loop spring made of 0.016x0.022 inch NiTi wire with a Gable angle of 20°-20° and activation distance of 1 mm ($t_{calc.}$ -0,13, smaller than 2.78 and bigger than-2.78). In other words, the difference in force produced by 0.016x0.022 inch NiTi sectional T-loop spring with a Gable angle of 20°-20° and activation distance of 1 mm, was not significant compared to the optimum force (Tab. 4).

The size of moment Y (M_y) produced

Table 5 shows the the average M_y produced by NiTi sectional T-loop spring with different Gable angle and activation distance.

Analysis of the size of M_y produced

To determine the difference in average value of the measurement of the M_y produced by sectional T-loop spring based on the type of material, Gable angle size and different activation distance, a simultaneous testing using Factorial Experiment 3x2x3 method with 5 observations each cell was performed. The results of the variance analysis can be observed in Table 7.

Size of moment Z (M_z) produced

Table 1 shows the average M_z values produced by NiTi sectional T-loop spring with different Gable angle and activation distance. Based on the table, it was revealed that the smallest M_z, i.e. 68.8 gram.mm (NiTi1), is produced by the T-loop spring with a Gable angle of 0°-0° when the spring is activated for 1 mm. The biggest M_z is 410.1 gram mm (NiTi9) and was seen when Gable was made for 20°-20° with an activation force of 3 mm.

Analysis of the size M_z produced

To determine the difference in average value of the measurement of the M_z produced by sectional T-loop spring based on the type of material, Gable angle size and different activation distance, a simultaneous testing using Factorial

Table 5. Average moment$_y$ produced by 0.016x0.022 inch NiTi sectional T-loop spring based on Gable angle and activation distance variations (gram mm).

	Gable (α°-β°)	Activation distance variation	Moment$_Y$ (Gram mm)	SD
NiTi1	0⁰-0⁰	1	6.80	1.69
NiTi2		2	13.11	3.58
NiTi3		3	23.33	3.19
NiTi4	10°-10°	1	8.20	2.28
NiTi5		2	13.69	1.31
NiTi6		3	23.73	1.38
NiTi7	20°-20°	1	9.50	1.52
NiTi8		2	14.09	1.53
NiTi9		3	23.89	1.84

Table 6. Average moment$_y$ produced by 0.016 x 0.022 inch TMA sectional T-loop spring based on Gable angle size and activation distance variations (gram mm).

	Gable (α°-β°)	Activation distance variation	Moment$_Y$ (Gram mm)	SD
TMA1	0⁰-0⁰	1	11.09	0.73
TMA2		2	19.85	4.57
TMA3		3	32.36	5.07
TMA4	10°-10°	1	11.55	1.98
TMA5		2	20.48	2.00
TMA6		3	32.62	2.37
TMA7	20°-20°	1	12.10	1.73
TMA8		2	21.16	2.37
TMA9		3	33.46	3.23

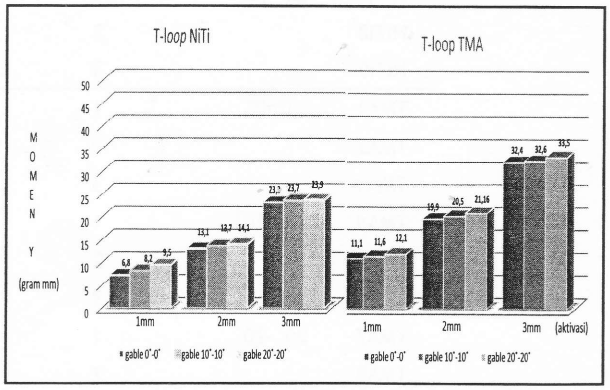

Figure 6. Average value of M_y produced by NiTi and TMA Sectional T-loop Spring with Gable angle size variations and different activation distance.

Experiment 3x2x3 method with 5 observations each cell was performed. The results of the variance analysis can be observed in Table 10.

DISCUSSION

This study was a pure experimental study performed in a laboratory in an in vitro manner to measure the size of force, $moment_y$, and $moment_z$ produced from the activation of 0.016x0.022 inch NiTi and TMA sectional T-loop of 1,2 and 3 mm, and variations of anterior Gable angle (α) and posterior Gable angle (β) of 0°-0°, 10°-10°, and 20°-20°. In orthodontic treatment, to produce the wanted dental movement, a specific force system that is an appropriate mixed of optimum force, $moment_y$, and $moment_z$, is necessary to produce certain M_y/F and M_z/F ratios according to the planned dental movement.[3,9,12]

The force produced from NiTi sectional T-loop spring activation was ranging between 40.1 gram (NiTi1) to 159 gram (NiTi9), while the force produced from TMA sectional T-loop spring was ranging from 75.5 (TMA1) to 339.2 gram (TMA9). The difference in force produced between the NiTi sectional T-loop spring and TMA sectional T-loop spring is caused by different wire physical nature. Modulus of elasticity and the yield strength of NiTi wire is smaller than the TMA wire so that at the same activation distance, the force produced by

Table 7. Results of variance analysis to test the difference of average value of $moment_y$ produced by t-loop spring based on the type of wire, Gable angle size and different activation distance.

SV	dk	JK	RJK	F_{count}	F_{tab}	
Average	1	30434.35	-	-	-	-
A	2	5135.36	2567.68	391.35	3.10	*)
B	1	945.43	945.43	144.10	3.98	*)
C	2	24.73	12.37	1.88	3.10	*)
AB	2	125.50	62.75	9.56	3.10	*)
AC	4	3.01	0.75	0.11	3.10	*)
BC	2	0.54	0.27	0.04	2.50	*)
ABC	4	4.17	1.04	0.16	3.10	*)
Error	72	472.39	6.56	-	2.50	-
Total	90	37145.49	-	-	-	-

Note: F table is gained with a significance level of 95% with dof (2;72)=3.10 and dof(1:72)=3.98 and dof (4;72)=2.50; (SV) Variation source; (B) Type of wire; (dk) Degree of freedom; (C) Gable angle; (JK) Square sum; (AB) Activation distance and type of wire; (RJK) Average square sum; (AC) Activation distance and gable angle; (F_{count}) F calculation; (ABC) Activation distance, type of wire and gable angle; (F_{tab}) F table; (*) Significant; (A) Activation distance; (°) Not significant.

Table 8. Average value of $moment_z$ produced by 0.016x0.022 inch NiTi sectional T-loop spring with gable angle size variations and different activation distance (Gram mm).

	Gable (α°-β°)	Activation distance variation (mm)	$Moment_Y$ (gram)	SD
NiTi1	0^0-0^0	1	101.2	0.68
NiTi2		2	168.8	0.80
NiTi3		3	190.7	0.58
NiTi4	10°-10°	1	402.5	14.66
NiTi5		2	434.0	10.06
NiTi6		3	430.2	6.16
NiTi7	20°-20°	1	517.2	11.24
NiTi8		2	575.6	9.41
NiTi9		3	591.4	6.16

Table 9. Average value of $moment_z$ (M_z) produced by 0.016x0.022 inch TMA sectional T-loop.

	Gable (α°-β°)	Activation distance variation (mm)	$Moment_z$ (gram)	SD
TMA1	0^0-0^0	1	242.9	10.06
TMA2		2	386.8	32.39
TMA3		3	461.0	13.77
TMA4	10°-10°	1	272.1	9.41
TMA5		2	411.4	10.10
TMA6		3	501.4	6.16
TMA7	20°-20°	1	703.8	12.82
TMA8		2	787.0	38.95
TMA9		3	874.7	5.03

Table 10. Variance analysis the difference of average value of moment$_z$ (M_z) produced by T-loop spring based on the type of wire, Gable angle size and different activation distance.

SV	dk	JK	RJK	F_{count}	$F_{tab}{}^*$	
Average	1	18121377.71	-	-	-	-
A	2	296298.47	148149.23	687.04	3.10	*)
B	1	403471.50	403471.50	1871.08	3.98	*)
C	2	2659069.45	1329534.72	6165.67	3.10	*)
AB	2	67537.26	33768.63	156.60	3.10	*)
AC	4	3781.56	945.39	4.38	2.50	*)
BC	2	323011.58	161505.79	748.98	3.10	*)
ABC	4	5918.83	1479.71	6.86	2.50	*)
Kekeliruan	72	15525.73	215.64	-	-	-
Total	90	21895992.09	-	-	-	-

Note: F table is gained with a significance level of 95% with dof (2;72) = 3.10 and dof(1:72) = 3.98 and dof (4;72) =2.50

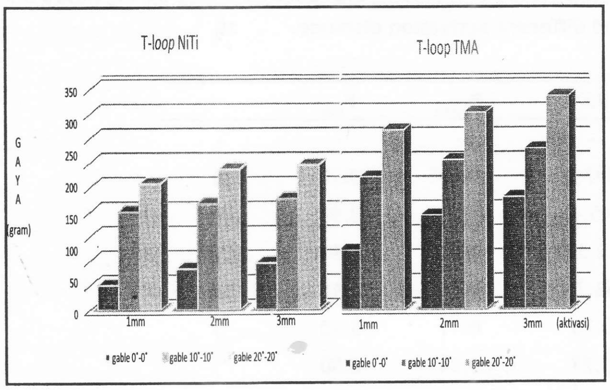

Figure 7. Average value of M_z produced by NiTi and TMA Sectional T-loop Spring with gable angle size variations and different activation distance (gram).

NiTi sectional T-loop is smaller than that produced by TMA sectional T-loop spring. Not all force from the study result meets the requirements for optimum force. Therefore, the orthodontist can choose specific optimum force according to the patient's case based on the types of teeth to be moved, number of teeth to be moved or type of dental movement planned.[9,13,16]

Optimum dental movement, especially during the post extraction space closing through maxillary canine and the four incisive retraction, is a very important and basic movement in orthodontic treatment. The appropriate maxillary canine and the four incisive positions at the end of the treatment affect the function, stability and patient's esthetic very much. During this dental movement, it is expected that controlled translation or tipping, depend on the initial position and planned final dental position, will be achieved.[4]

When moving the teeth, the pressure received by the periodontal ligament should be attended. The optimum force is determined by the size of the ligament surface size covering the root surface of the teeth to be moved. In the case of upper canine retraction using sectional T-loop spring, a force of 85 gram is needed to produce translation movement.[9] Based on the results of this study, the optimum force was gained from NiTi sectional T-loop spring with a Gable angle of 20°-20° when activated for 1 mm. This result is in line with the results from Bourauel et al.[14] who recommend the use of NiTi sectional T-loop spring to produce optimum force.

To get the planned dental movement in orthodontic treatment, in addition to the optimum force, another factor is necessary, i.e. moment/force ration. Variations of moment/force variation will cause various dental movement variations. Moment$_y$/force ratio (M_y/F) affects dental movement at Y axis. For canine, to get translation move and to prevent rotation, an M_y/F ratio of 3.5 is needed.[9,12,13]

The result of the study showed that the biggest M_y/F ratio was gained from NiTi T-loop spring with a Gable angle of 0°-0° when it was activated for 3 mm, producing an M_y/F ratio of 0.19 will produce rotation. Overall, the M_y/F produced will create rotation on teeth, where, according to the statement from Raboud et al.[12] and Katona et al.[17] the size of Gable angle will not affect the moment$_y$ and M_y/F ratio produced. To get higher moment$_y$ and M_y/F ratio that produce translation on canine, bend in first order direction is needed.

Moment$_z$/force (M_z/F) ratio affects dental movement in Z axis. For canine to get translation and prevent tipping, an M_z/F ratio of 9.4 mm is needed.[9,12,13] The result of the study shows that the highest M_z/F ratio is achieved by NiTi T-loop spring with a Gable angle of 20°-20° when it is activated for 1 mm that will produce an M_z/F ratio of 6.10 mm will produce controlled tipping movement. Overall, the M_z/F ratio produced in this study is in line with the statement of Bourauel et al.[6] stating that from the study it is seen that activation of various types of NiTiT-loop spring will produce M_z/F ratio for controlled tipping.

Based on the study results it was revealed that the activation distance and Gable angle size affect force and moment$_z$ produced. The average value of M_z showed that the bigger the Gable angle and activation distance, the bigger the M_z produced. In the Gable group with an angle of 0°-0°, overall M_z produced was the smallest compared to the M_z produced by T-loop spring with bigger Gable angle while in 20°-20° Gable the overall M_z produced was the biggest. In each group, based on the same Gable angle size, when the activation distance is increased starting from 1 mm to 3 mm, the M_z produced will be bigger. In the three groups, the activation distance of 1 mm was the distance that produce the smallest M_z, and then in the activation distance of 2 mm the M_z produced increased while the 3 mm distance will produce the biggest M_z. This result was similar to Raboud et al.[5,6,12]

Based on the study results, it was revealed that the activation distance and type of wire affect the moment$_y$ produced. The bigger the activation distance, the higher the moment$_y$ produced. Overall, the moment$_y$ produced by NiTi T-loop spring was smaller compared to moment$_y$ produced by TMA T-loop spring based on different activation distance. The average value of M_y showed that in each group, based on the same Gable angle, when the activation distance increases starting from 1 mm to 3 mm, the M_y produced was bigger. In the three groups, the activation distance of 1 mm was the distance that produces the smallest M_y, while at 2 mm activation distance, the M_y produced increases. Furthermore, at the distance of 3 mm, the biggest M_y was produced. Overall, M_y produced by TMA T-loop spring was bigger compared to the M_y produced by NiTi T-loop. This result was similar to the results of Raboud et al.[12] The difference in Gable angle did not significantly affect moment$_y$ produced. For each type of wire, both in NiTi and TMA T-loop spring, the Gable angle variation did not produce significant difference in moment$_y$. The result of this study was similar to the result of Katona et al.[17] who stated that moment$_y$ would not be affected by second order Gable bend but would be affected by the first order bend.

CONCLUSION

Based on the data analysis and testing of the study results using ANAVA, it was concluded that there was a significant difference in the force produced by 0.016x0.022 inch NiTi and TMA sectional T-loop spring with a Gable angle of 0°-0°, 10°-10°, and 20°-20° if each was activated with 1, 2, and 3 mm distance. There was no significant difference in the M_y produced by 0.016x0.022 inch NiTi and TMA sectional T-loop spring with a Gable angle of 0°-0°, 10°-10°, and 20°-20° if each was activated with 1, 2, and 3 mm distance. There was a significant difference in M_z produced by 0.016x0.022 inch NiTi and TMA sectional T-loop spring with a Gable angle of 0°-0°, 10°-10°, and 20°-20° if each was activated with 1, 2, and 3 mm distance. In this study, the size of forced produced by 0.016x0.022 inch NiTi sectional T-loop spring was ranging from 40.1-159.2 gram, while the force produced by 0.016x0.022 inch TMA sectional T-loop was ranging between 75.5-201.7 gram. Based on the laboratory result on the retraction of 0.016x0.022 inch NiTi and TMA sectional T-loop spring with a Gable angle of 0°-0°, 10°-10°, and 20°-20° if each is activated with 1,2, and 3 mm distance, combinations of type of wire, Gable angle and activation distace that can produce optimum force that is very much needed by canine retraction is achieved. It was shown that the NiTi sectional T-loop with a Gable angle of 20°-20° and activation distance of 1 mm will create optimum force.

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