UNESP – Universidade Estadual Paulista
"Júlio de Mesquita Filho"
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Estudo Clínico da Retração de Caninos e Perda de Ancoragem com a Mola T do Grupo A e Estudos Analíticos da Mola T do Grupo A e B

Tese apresentada ao Programa de Pós-Graduação em Ciências Odontológicas – Área de Concentração: Ortodontia, da Faculdade de Odontologia de Araraquara, da Universidade Paulista "Júlio de Mesquita Filho", para a obtenção do título de Doutor em Ortodontia.

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RENATO PARSEKIAN MARTINS

ESTUDO CLÍNICO DA RETRAÇÃO DE CANINOS E PERDA DE ANCORAGEM COM A MOLA T DO GRUPO A E ESTUDOS ANALÍTICOS DA MOLA T DO GRUPO A E B

COMISSÃO JULGADORA

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À glória do
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À memória do meu

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SUMÁRIO

Título

Estudo Clínico da Retração de Caninos e Perda de Ancoragem com a Mola T do Grupo A e Estudos Analíticos da Mola T do Grupo A e B.

Resumo

Martins RP. Estudo clínico da retração de caninos e perda de ancoragem com a mola T do grupo A e estudos analíticos da mola T do Grupo A e B [tese doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2007.

Objetivo: Avaliar a retração parcial de caninos utilizando a mola "T" (TTLS) do grupo A a e a perda de ancoragem dos molares, analisar mecanicamente a mesma TTLS e também avaliar a pré-ativação da TTLS do grupo B, por curvatura e dobras. **Material e Método:** Quatro artigos científicos foram redigidos e utilizados para a avaliação dos propósitos apresentados. **Resultados:** Os caninos superiores foram retraídos 3,2 mm, enquanto os inferiores foram retraídos 4,1 mm. Os molares superiores e inferiores foram protraídos 1,0 mm e 1,2 mm, respectivamente. Os caninos se movimentam 1,5 mm no primeiro mês e 2,43 mm no segundo. A TTLS do grupo A deve ter 7 X 10 mm, e ao ser ativada 4 mm, ficar posicionada a 2 mm do bráquete anterior e ter a dobra de gable a 4 mm do tubo posterior. A pré-ativação da TTLS do grupo B por curvatura gerou M/F em média 2,5 mm maiores que a pré-ativação por dobras. **Conclusões:** Os caninos superiores foram retraídos por inclinação controlada, enquanto os inferiores foram retraídos por inclinação descontrolada. Os molares superiores e inferiores foram protraídos por inclinação controlada. Em 2,1 meses de retração de caninos, a perda de ancoragem dos molares foi de 0,3 :1. Os caninos se movimentam mais no segundo mês do que no primeiro. Foi possível desenvolver uma padronização e otimização da TTLS pré-ativada para o grupo A. A pré-ativação da TTLS do grupo B por curvatura gerou M/F maiores quando comparada a pré-ativação por dobras.

Palavras-chave: Ortodontia; biomecânica; movimentação dentária.

Abstract

Martins RP. A clinical study on canine retraction and anchorage loss with the Group A TTLS and analytical studies on the Group A and B TTLS [tese doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2007.

Objective: To evaluate both the partial retraction of canines and the loss of anchorage of the molars using a Group A Titanium “T” Loop Spring (TTLS), and also to evaluate the preactivation differences of curvature vs. bends on a group B TTSL. **Materials and Method:** Four research papers were written and analyzed for the evaluation of the aims presented. **Results:** Upper canines were retracted 3.2 mm, while the lower ones were retracted 4.1 mm. The upper and lower molars were protracted 1.0 and 1.2 mm, respectively. The canines were moved 1.5 mm in the first month and 2.43 mm on the second, on average. The group A TTLS should have 7 X 10 mm, and on 4 mm of activation, it should be located 2 mm from the anterior bracket with its preactivation bend positioned 4 mm from the posterior tube. The group B TTLS preactivated by curvature generated M/F ratios 2.5mm larger than the bend preactivation, on average. **Conclusions:** The upper canines were retracted by controlled tipping, while the lower ones were retracted by uncontrolled tipping. The upper and lower molars were protracted by controlled tipping. In 2.1 months of canine retraction, the loss of anchorage was 0.3:1, compared to the canines. The canines were moved more in the first month than on the second. It was possible to develop a standard and an optimization for the group A TTLS. The Group B TTLS preactivated by curvature generated larger M/F when compared to the bend preactivation.

Keywords: Orthodontics; biomechanics; tooth movement.

Introdução Geral

Pacientes biprotusos com falta de selamento labial oferecem um desafio ao ortodontista. Independentemente de como pode ser executado o tratamento deste tipo de paciente, extraindo ou não extraindo, há de se concordar que ambas abordagens são extremamente desafiadoras ao clínico. Dentro da abordagem extracionista, a qual é focalizada no presente estudo, a mecânica para o fechamento de espaços deve ser meticulosamente planejada, se o paciente se enquadrar no perfil de não colaborador, pois é necessário que os dentes anteriores sejam retraídos o máximo possível.

Quando o objetivo do tratamento ortodôntico é a retração máxima dos dentes anteriores, a conseqüente manutenção dos dentes posteriores em suas respectivas posições, ou o seu mínimo movimento, é *conditio sine qua non*. Um primeiro aspecto a ser comentado é que nestes casos de biprotusão e, principalmente, nos casos onde há apinhamento inferior e inclinação mesial dos caninos, a retração parcial dos caninos deve ser indicada num momento anterior à retração dos incisivos.[1] Quando isso não é feito, a vestibularização dos incisivos poderá ocorrer, gerando dois problemas. O primeiro seria a movimentação de “vai-e-vêm”, traduzida do inglês *round tripping*, imposta aos incisivos, e o segundo seria a possível perda de ancoragem desnecessária, uma vez que os incisivos vestibularizados teriam que ser retraídos por uma distância maior. Torna-se então, se não no mínimo razoável, necessário fazer a retração parcial caninos.

A retração parcial dos caninos pode ser realizada de duas formas gerais, através de uma mecânica com atrito, isto é por algum tipo de deslizamento, ou através de uma mecânica sem atrito, isto é, através de alças onde não ocorre deslizamento entre tubos, ou bráquetes, e fios. Apesar de a primeira alternativa se mostrar mais simples à primeira vista, ela gera uma menor quantidade de movimento[2] do que a segunda. Já a mecânica sem atrito, promete retrair os caninos em maior velocidade,[2] e também possibilita a utilização de alças mais elaboradas, tais quais as molas “T”.[3-7]

De acordo com a 3ª. Lei de Newton,[8] a força aplicada para a retração dos caninos, gera uma força horizontal de igual intensidade e sentido oposto, no local onde o princípio gerador da força esta apoiado (ponto de aplicação da força), geralmente localizado nos molares. Essa força recíproca, por gerar um *stress*[1] menor nos dentes geralmente utilizados como unidades de ancoragem (molares e pré-molares) faz com que os caninos se movimentem com maior velocidade.[1,9] Além do mais, essa movimentação pode ser complementada por uma mecânica que aumente ainda mais a diferença de *stress* entre esses dentes.[10,11] Essas mecânicas, apesar de não serem sempre reconhecidas como a Técnica

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[1] Stress = Força / Área (do periodonto)

do Arco Segmentado (TAS)[12] *per se*, sua filosofia é geralmente atribuída ao criador da TAS, o Dr. Charles Burstone (Connecticut, EUA).

Através da utilização de *stress* diferencial entre os dentes, ou segmentos de dentes envolvidos, consegue-se uma diferença entre as velocidades de movimentação dentária.[10,11] Pode-se assim, utilizar-se deste artifício para a potencialização da retração dos caninos, aos quais podemos chamar de unidade ativa, e reduzir a perda de ancoragem dos dentes de apoio da retração, molares e pré-molares, os quais podemos chamar de unidade reativa.

A técnica do arco segmentado (TAS) preconiza a utilização de molas pré-calibradas para o emprego da filosofia de stress diferencial para o fechamento de espaços.[3,12] A mola de escolha para o fechamento de espaços na TAS é a mola “T” de TMA®[2], ou *Titanium T Loop Spring* (TTLS). Esta mola, por ter uma configuração específica, apresenta uma proporção de carga/deflexão baixa e um limite elástico alto e, em segunda análise, por ser feita de TMA® tem as duas qualidades acima melhoradas.[13,14] Outra vantagem da TTLS é a possibilidade de poder-se ativá-la de maneiras diferentes,[3,5-7,15] fazendo com que a mesma produza momentos simétricos ou assimétricos em suas extremidades.[15]

Portanto, na retração parcial de caninos pode-se conseguir gerar *stress* de mesma proporção no ligamento periodontal através da produção de momentos simétricos por uma TTLS. Isso acarretaria em fechamento

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[222] ORMCO CORP., Glendora, CA, EUA

de espaços de maneira simétrica entre as unidade ativa e reativa. Esse fechamento de espaços simétrico é usualmente chamado na literatura de “ancoragem do grupo B”.[3] Da mesma forma, pode-se conseguir um fechamento de espaços assimétrico, através da produção de momentos assimétricos por uma TTLS.[3,6] Por sua vez, o fechamento de espaços pode ocorrer com maior retração do segmento anterior de dente(s), chamado de ancoragem do grupo A. O inverso também pode ser desejado, ou seja, maior protração do segmento posterior de dente(s), e é chamado de ancoragem do grupo C.[3]

Isso ocorre porque é gerado um maior *stress* no ligamento periodontal quanto se inclina um dente, do que quando se translada um dente.[3,6,16] A maneira utilizada na ortodontia para se controlar o tipo de movimento a ser feito por um dente é gerenciando-se a proporção momento-força (M/F) aplicada ao mesmo.[4,6,17] Praticamente isso se dá da seguinte forma, se uma força é aplicada a um dente, perpendicular ao seu longo eixo, a M/F necessária para se produzir translação é determinada pela distância entre o bráquete e o centro de resistência (CRes) do dente. A literatura experimental, que normalmente assume a perpendicularidade da linha de ação de força em relação ao longo eixo dente, sugere M/F de aproximadamente 10/1 para translação e 7/1 para inclinação controlada de um dente, sendo que uma proporção abaixo do último valor passa a caracterizar uma movimentação de inclinação descontrolada.[3,6,17-20] Conforme essa M/F aumenta (sendo menor que a distância da linha de ação de força ao Cres de um dente) gradativamente esse dente deixa de inclinar e passa a transladar. Portanto, para fazer com que um dente se movimente mais que um outro, ambos conectados a uma mola, é necessário, basicamente, que haja uma M/F maior no dente em deseja-se que se movimente menos e uma M/F menor no dente em que se deseja maior movimento.[3]

Entretanto, a literatura disponibiliza diversos tamanhos e formas de de ativação das TTLS para a retração parcial de caninos, tanto simetricamente,[3,5,6,15] quanto assimetricamente,[3,6,7] o que pode gerar um problema para o clínico em ortodontia. Em primeiro lugar, não há consenso sobre qual o tamanho ideal para uma TTLS, tanto em comprimento quanto em altura. Segundo, a TTLS pode ser pré-ativada através de curvaturas ou por meio de dobras concentradas nos segmentos de fio anterior e posterior à mola. Porém, não há mais que um artigo em toda a literatura ortodôntica descrevendo quais são as diferenças do ponto de vista mecânico destas pré-ativações. Terceiro, nas ativações assimétricas há menos consenso ainda, visto que o mesmo problema de “curvatura vs. dobras” é intensificado por não existirem regras quanto a posição onde devem ser colocadas as dobras ou o quanto de curvatura deve ser dada. Ainda nas ativações assimétricas, não existe um consenso na literatura de qual deve ser a posição da mola no sentido ântero-posterior, em relação à distância inter-bráquetes.[3,6,7]

A literatura científica também é escassa no que tange a avaliação clínica da retração de caninos de uma maneira clara, com um sistema de forças definido. Igualmente, não existe nenhum artigo do mesmo tipo que avalie, de maneira geral, a retração de caninos com TTLSs.

Portanto, esta tese de doutorado tem como objetivos:

1- avaliar o tipo de movimento provocado aos caninos superiores e inferiores e aos molares superiores e inferiores pela mola T do Grupo A, pré-ativada de acordo com Marcotte[6,*], bem como suas diferenças;

2- quantificar o movimento causado aos caninos superiores e inferiores (retração) e aos molares superiores e inferiores (perda de ancoragem) pela mola T do Grupo A, pré-ativada de acordo com Marcotte[6,*], bem como suas diferenças, em um espaço de tempo delimitado;

3- avaliar a diferença em velocidade de retração e tipo de movimento causado aos caninos pela mola T do Grupo A, pré-ativada de acordo com Marcotte[6,*], entre o primeiro e segundo mês de retração;

4- desenvolver uma versão otimizada e padronizada da mola T do Grupo A, pré-ativada de acordo com Marcotte[6,3];

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[3] Marcotte M. 2007. Comunicação pessoal.

5- avaliar as diferenças existentes entre as pré-ativações por curvatura ou por dobras concentradas em Molas T do Grupo B.

Apresentação dos Artigos

Artigo 1 – Martins RP, Buschang PH, Gandini JR LG. **The use of Group A “T” loop for differential moment mechanics: an implant study.**

Aceito para publicação no American Journal of Orthodontics e Dentofacial Orthopedics.

Artigo 2 - Martins RP, Buschang PH, GandiniI JR LG, Russouw PE. **Changes over time in canine retraction: an implant study**

Aceito para publicação no American Journal of Orthodontics e Dentofacial Orthopedics.

Artigo 3 - Martins RP, Buschang PH, Martins LP, Gandini JR LG. **Optimizing the design of group A Titanium “T” Loop Spring preactivated according to Marcotte using the Loop Software®**

Aceito para publicação no American Journal of Orthodontics e Dentofacial Orthopedics.

The use of Group A "T" loop for differential moment mechanics: an implant study

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ABSTRACT

When anchorage control is critical and compliance is less than ideal, efficient treatment depends on differential tooth movements. The purpose of this paper was to evaluate the distal tipping of partially retracted canines and mesial movement of the molars. Eleven patients, with metallic bone markers serving as reference, had their maxillary and mandibular canines partially retracted using a TTLS preactivated for group A with a tip back bend. The canines were retracted until enough space was available for alignment of the incisors without proclination. Forty-five degrees radiographs were taken immediately before the initial activation and at the end of the partial retraction. The radiographs were scanned, superimposed on the bone markers and measured digitally. The results showed that the mandibular canines' crowns were retracted (4.1 ±1.9mm) and intruded (0.7 ± 0.3) by uncontrolled tipping. In contrast the maxillary canines' crowns were retracted (3.2 ± 1.4 mm) by controlled tipping. The maxillary and mandibular molars crowns were protracted similar amounts (1.0 ± 0.6 mm and 1.2 ±1.2 mm, respectively) by controlled tipping, without significant extrusion. The molars were protracted approximately 0.3 mm for every 1 mm of canine retraction. We conclude that the TTLS used in this investigation produced controlled tipping of the maxillary canines, but it did not produce controlled tipping of the mandibular canines or translation of the molar as expected.

Introduction

Full-step Class II extraction cases, bimaxillary protrusive patients with lip incompetence, and asymmetric extraction cases often require maximum anchorage in the posterior segment. When anchorage control is critical and compliance is less than ideal, efficient treatment depends on differential movements of teeth. This can be accomplished by translating the posterior segment, which effectively minimizes tooth movement by distributing force over a larger root surface area,[1,2] and controlled tipping of the anterior segment, which maximizes crown movements while maintaining the position of the apex. The actual tooth movement that occurs depends on the point of force application (i.e. bracket), the line of force application (LFA), the tooth's center of resistance (CRes), the moment produced when the force is not applied to the CRes, and the moment-to-force ratio (M/F) (Fig.1A). Practically, if the force applied to a tooth is perpendicular to its long axis, the M/F needed to produce translation is determined by the distance between the bracket and CRes. The experimental literature, which usually assumes that the LFA is perpendicular to the tooth's long axis, suggests that MF ratios of approximately 10/1 and 7/1 are required for translation and controlled tipping, respectively.[3-8]

Due to confounding factors that could alter the perpendicular distance of the CRes to the LAF, theoretical MF ratios might not be expected to translate into clinical reality. For example, teeth are usually not located perpendicular to the occlusal plane, which effectively reduces the vertical distances between the CRes and the LFA and alters the MF ratio required for translation (Fig. 1 B). For the same reason, longer teeth will require more moment for translation than smaller teeth.[9-11] The MF ratio could also be affected by the height of the alveolar crest, root shape and the distance from the LFA to the CRes, which could change due to root resorption or periodontal disease.[9,10,12] Finally, various tooth movements, such as tipping, extrusion and intrusion, could also change the force system.[13]

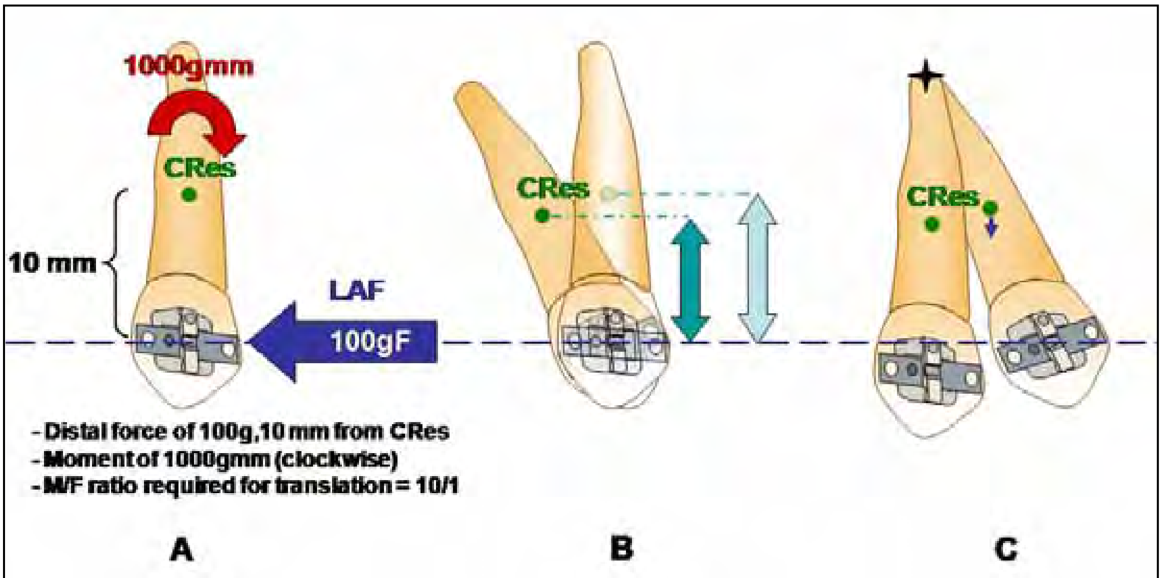

Figure 1a – System of forces acting on a tooth when a single force is applied away from the center of resistance (evaluated in 2 dimensions); Figure 1b – The effects of tipping and the changes in angulation of the LFA on the distance of the LFA to the CRes; Figure 1c – The effect of true controlled tipping on the vertical position of the CRes.

In 1990, Marcotte introduced a .017”X .025” TMA “T” (10 mm X 6 mm) Loop Spring (TTLS) preactivated with a 45° gable bend distal to the loop.[4] It theoretically generates a MF ratio of 7/1 on the anterior extremity and 10/1 in the posterior extremity of the TTLS.[3,4] In order to achieve equilibrium, an intrusive force at the canines and an extrusive force at the molars are generated (Fig. 2). This TTLS holds promise in group A anchorage cases requiring controlled tipping of the canines and translation of the posterior segment because it generates asymmetrical moments[3,4]. It is important to determine whether unwanted tooth movement occurs with TTLS because its effects have not been systematically evaluated in a clinical situation.

The purpose of this prospective clinical investigation was to evaluate the movements produced during partial retraction of maxillary and mandibular canines with a group A TTLS.[4] Uniquely this study used 45^{o} oblique radiographs and metallic bone markers to ensure accurate and precise measures of tooth movement. The specific aims were to:

- Determine if controlled tipping occurs in the anterior segment.
- Determine whether translation occurs in the posterior segment.

MATERIALS AND METHODS

This prospective sample consisted of eleven patients (7 females and 4 males) approximately 18.5 ± 3.7 years of age at the start of treatment, selected according to the following criteria:

- Class I molar relationships;
- Treatment requiring 4 premolar extractions;
- Maxillary and mandibular dental protrusion;
- Good hygiene and healthy dentition.

Four tantalum bone markers were placed into the maxilla (one apical to the first molars and one on each side of the midpalatal suture, apical to the central incisors) and three were placed into the mandible (one apical to the first molars and one in the symphysis, apical and between the central incisors) according to the methods used by Björk and Skieller.[14,15] All patients provided informed consent, as approved by the human subjects committee of the Araraquara School of Dentistry - UNESP (Araraquara, Brazil).

Theoretical system of force for group A retraction

The segmented arch technique[3] advocates the consolidation of teeth into segments to allow easier planning and more predictable systems of forces. The posterior segment (Fig. 2), also called beta, has the posterior teeth on each side united by a large and stiff wire. Both right and left sides are connected by a stiff transpalatal arch (TPA), transforming the several posterior teeth into one large "multirooted tooth" with one CRes. The anterior segments, also called alpha, included the right and left maxillary canines.

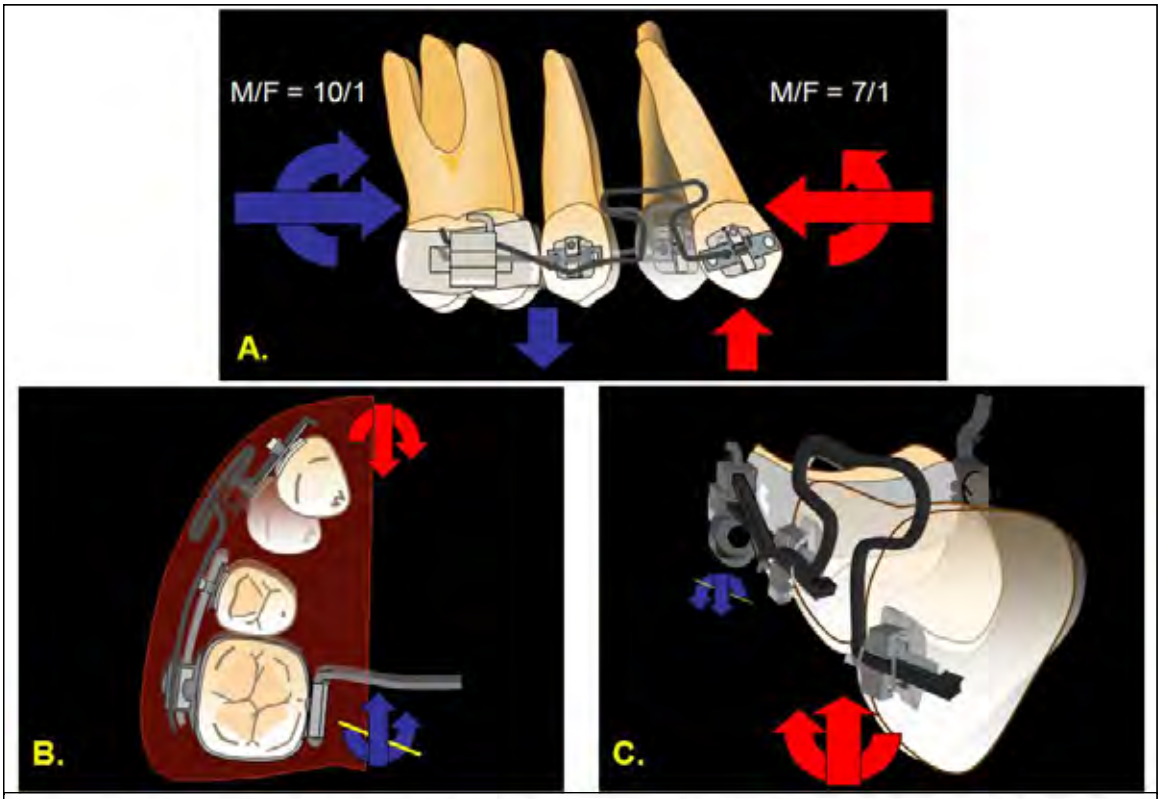

Figure 2 – Theoretical system of force of a group A TTLS. A. Lateral view. B. Occlusal view. C. AP view

The partial retraction is accomplished by the group A preactivated TTSL. It develops a MF ratio of 10/1 on the beta extremity, to produce translation, and a MF ratio of 7/1 on the alpha extremity, to produce controlled tipping (assuming that the CRes of both alpha and beta segments are located 10 mm perpendicular to the LFA). That difference of MF ratios generates vertical forces to achieve equilibrium (Fig.2A and 2C). These forces are extrusive on beta, which are expected to neutralized by the occlusal forces, and intrusive in alpha, helping to maintain crown level. The canine rotation expected due to moments associated with retraction (LFA is buccal to the CRes) are be neutralized by the anti-rotation bends incorporated to the TTLS (Fig.2B). The reciprocal moments do not occur in beta because the force is bilateral and moments are canceled out (the TPA connects the right and left segments). Small changes in the buco-lingual inclinations of the canines can occurs because the intrusive force (Fig.2C) is applied buccal to the CRes; the reciprocal moments in beta are cancelled due to the TPA

Treatment Protocol

Patients had their first molars banded and brackets (slot .022”) bonded to their second premolars. After leveling and alignment of the segments, the molars and premolars were held as a segment by a .019” X .025” stainless steel (S.S.) wire, tied with SS ligatures. Passive TPAs and lingual arches made with 0.9 mm (.036”) S.S. wires were used to consolidate the left and right segments. Brackets were bonded to the canines and standardized 45^{o} radiographs where taken 14 days after the first premolars were extracted.

One .017” X.025” TTLS of group A anchorage, with dimensions of 6 mm X 10 mm,[4] was placed in each patient’s quadrant using the following protocol:

- The TTLS where made of straight TMA wires (.017” X .025”) and adjusted to be passive to the canine bracket and molar auxiliary tube on each side;
- A 45^{o} preactivation bend was placed directly below the posterior limit of the loop.[16]
- Anti rotational bends where applied to the TTLS.[4]
- The TTLS was positioned with the anterior extremity of the loop located directly above the canine bracket. They were secured with SS ties (.25 mm) and activated 4 mm (measured based on the separation of the lower vertical extremities of the loop).

The patients were evaluated every 28 days. During each appointment, the springs where removed, standardized 45^{o} radiographs were taken of both sides, pictures were taken and the springs were reactivated 4 mm. This schedule continued until enough space was created for leveling and alignment of the teeth without incisor proclination. One patient required only one appointment, eight required two appointments and two required three appointments.

The radiographs were scanned, along with a ruler for calibration, at 450 dpi. The Viewbox Software® (dHAL Orthodontic Software, Athens, Greece) was used to digitize the radiographs and to perform the measurements. The final radiograph was superimposed on the initial radiograph using the best fit of the bone markers. Each quadrant was evaluated separately. The radiograph that most clearly showed the apex and the tip of canine and molar (not necessarily the same radiographs) was used to standardize each subject's tooth size.

Eight landmarks were digitized in each quadrant, including the canine apex, the canine cusp tip, the canine's CRes (1/3 of the total distance from the alveolar crest to the apex),[5,12,17] the center of the canine bracket, the second premolar cusp tip (average of lingual and buccal cusps), the first molar mesial cusp tip, the first molars' CRes (furcation of the molar),[18,19] and the auxiliary tubes of the first molars (located vertically in the middle of the tube and horizontally at the entrance of the tube).

The T1 functional occlusal plane, defined by the cusp tip of the 2nd premolar and the mesial cusp tip of the 1st molar, was used as the reference plane for the measurements. After superimposing on the bone markers, the T1 functional occlusal plane was transferred by the software to the T2 image. The interbracket distance (IBD), vertical and horizontal distances between the brackets and the CRes of the canines, the vertical distance from the auxiliary tubes to the CRes of the molars, the inclination of the canines, and the vertical and horizontal displacements of the cusps and apices of molars and canines were measured. The centers of rotation (CRot) were estimated based on the intersection of the perpendiculars bisectors of the lines joining the T1 and T2 apices and cusps.

The measurements were transferred to the SSPS® software, version 12.0 (Chicago, Illinois) for the statistical analyses. The skewness and kurtosis statistics indicated approximately normal distributions. Paired t-tests were used to compare side and jaw effects. Replicate analyses showed that systematic errors ranged between 0.006- 0.075 mm; random method errors[20] ranged between 0.036 to 0.178 mm.

The Loop Software®, version 1.7 (dHal, Athens, Greece) was used to estimate the TTLS force system. The forces estimated by the software were corrected as described by Halazonetis[21] to 396 gF horizontally and 35.4 gF vertically (Fig 3). The forces were distal and extrusive on the anterior bracket, producing a MF ratio of 4.1/1; they were anterior and intrusive on the posterior bracket, producing a MF ratio of 2.1/1.

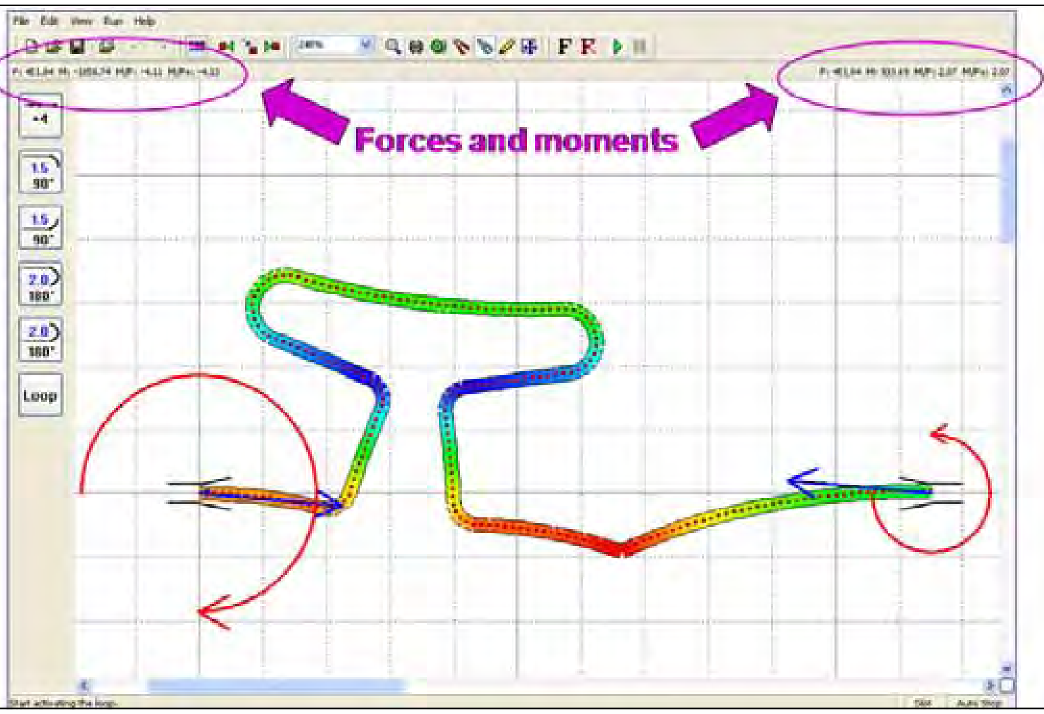

Figure 3 – Approximate system of forces of the TTLS used in this investigation, estimated by the Loop Software®. The left bracket is the canine bracket, and the right bracket is the molar tube. Gross forces and moments need to be corrected by a factor of .88. Each square scales 4 mm^2.

Results

Because there were no significant (p>.05) differences between the right and left sides, they were averaged to simplify the presentation of the results.

The interbracket distance, the horizontal and vertical distances to the CRes and the inclination of the canines showed no significant (p<.05) differences between maxilla and mandible (Table I). The average interbracket distance was 23.2 mm, the canine bracket was located 2.1 mm anterior and 8.8 mm occlusal to the CRes. The auxiliary tube was located approximately 6.0 mm occlusal to the CRes of the molars. (Table I and Fig.4).

Table I – Initial values of the position of teeth and brackets in the group studied

	Maxillary		Mandibular		Group Differences
	Mean	**SD**	**Mean**	**SD**	**p value**
Interbracket distance (mm)	22.98	1.97	23.32	2.07	.730
Horizontal distance do Canine Cres (mm)	2.11	1.37	2.07	1.93	.389
Vertical distance to the Canine CRes (mm)	8.87	1.80	8.84	1.73	.560
Vertical distance to the Molar CRes (mm)	5.94	0.94	6.08	0.97	.973
Inclination of the Canine (degrees)	101.04	12.76	102.91	6.49	.196

The maxillary and mandibular canine crowns were significantly retracted (3.2 mm and 4.1 mm, respectively) and intruded slightly (.1mm and .7mm, respectively). The maxillary and mandibular canine apices were intruded 0.7 mm and 0.6 mm, respectively (Fig.5). The mandibular canine apices were moved mesialy approximately 1.2 mm, which was significantly ($p<.05$) more than the 0.1 mm mesial movement of the maxillary canines (Table II).

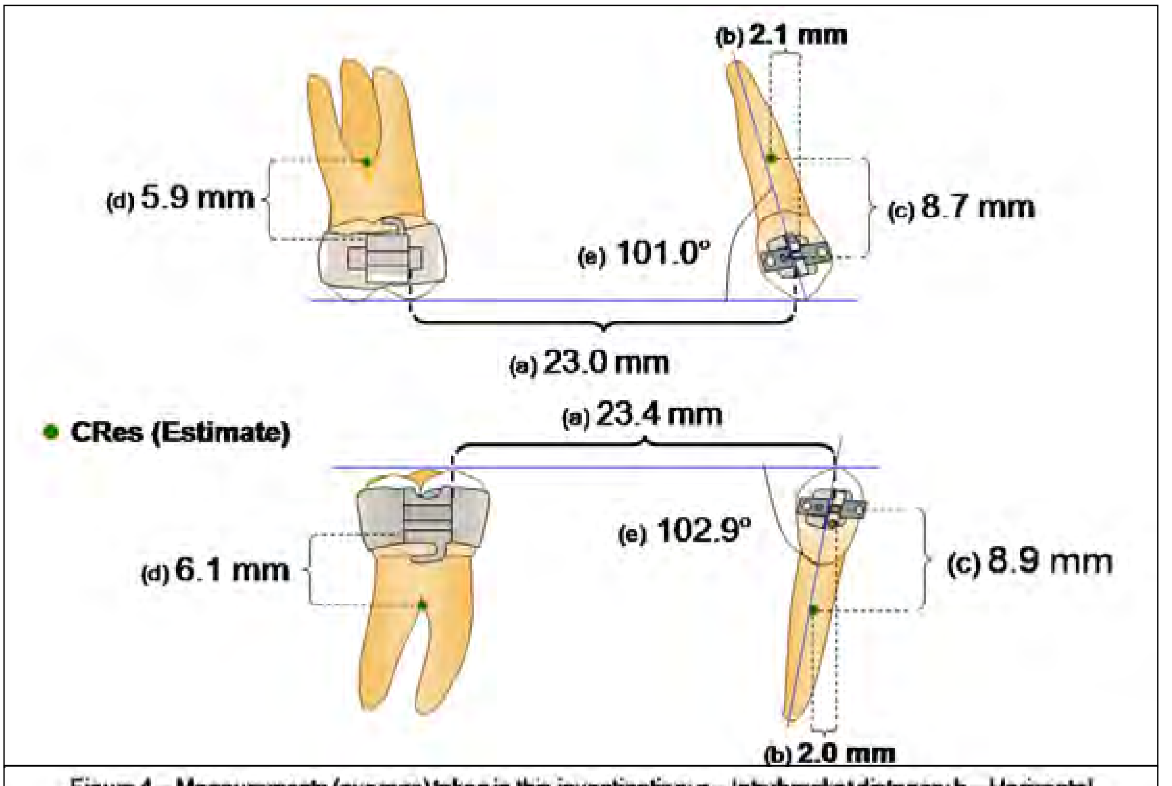

Figure 4 – Measurements (average) taken in this investigation: a – Interbracket distance; b – Horizontal distance from the bracket to the canine CRes; c – Vertical distance from the bracket to the canine CRes; d – Vertical distance from the auxiliary tube of the molar to the CRes (of the molar); e – Inclination of the canines.

Table II - Horizontal and vertical treatment changes of the canines and molars (negative values indicate anterior and apical movements measured relative to the occlusal plane)

	Maxillary		Mandibular		Group Differences
Canine	**Mean**	**S.D.**	**Mean**	**S.D.**	**p value**
Cusp Horizontal	3.22•	1.41	4.06•	1.89	.090
Cusp Vertical	0.07	0.38	-0.66•	0.27	.214
Apex Horizontal	-0.13	0.13	-1.18•	0.58	<.001*
Apex Vertical	-0.68•	0.28	-0.60•	0.79	.838
Molar					
Cusp Horizontal	1.02•	0.58	1.22•	1.21	.415
Cusp Vertical	-0.27	0.48	-0.15	0.39	.538
Apex Horizontal	-0.03	0.69	-0.15	0.77	.850
Apex Vertical	-0.23•	0.46	0.06	0.61	.087

• Significant movement (p<.05) * Significant changes (p<.05)

The maxillary and mandibular molar crowns were significantly protracted (1 mm and 1.2 mm, respectively) with no significant vertical movements. With the exception of a slight intrusion of the apex of the maxillary molars (0.2 mm), the apices of both maxillary and mandibular molars were not moved significantly.

Vertically, the average CRots for the maxillary canines and the molars were at the level of the apices (Fig 5), indicating controlled tipping. For the mandibular canines, the CRot was between the apex and the CRes, indicating uncontrolled tipping. Controlled tipping was assumed when the CRot was approximately at the level of the apex; uncontrolled tipping was assumed when the CRot was located between the apex and the estimated CRes. Horizontally, the average CRot was anterior to the CRes for both the maxillary and mandibular canines, indicating intrusion, and around the apex for both molars, indicating vertical control.

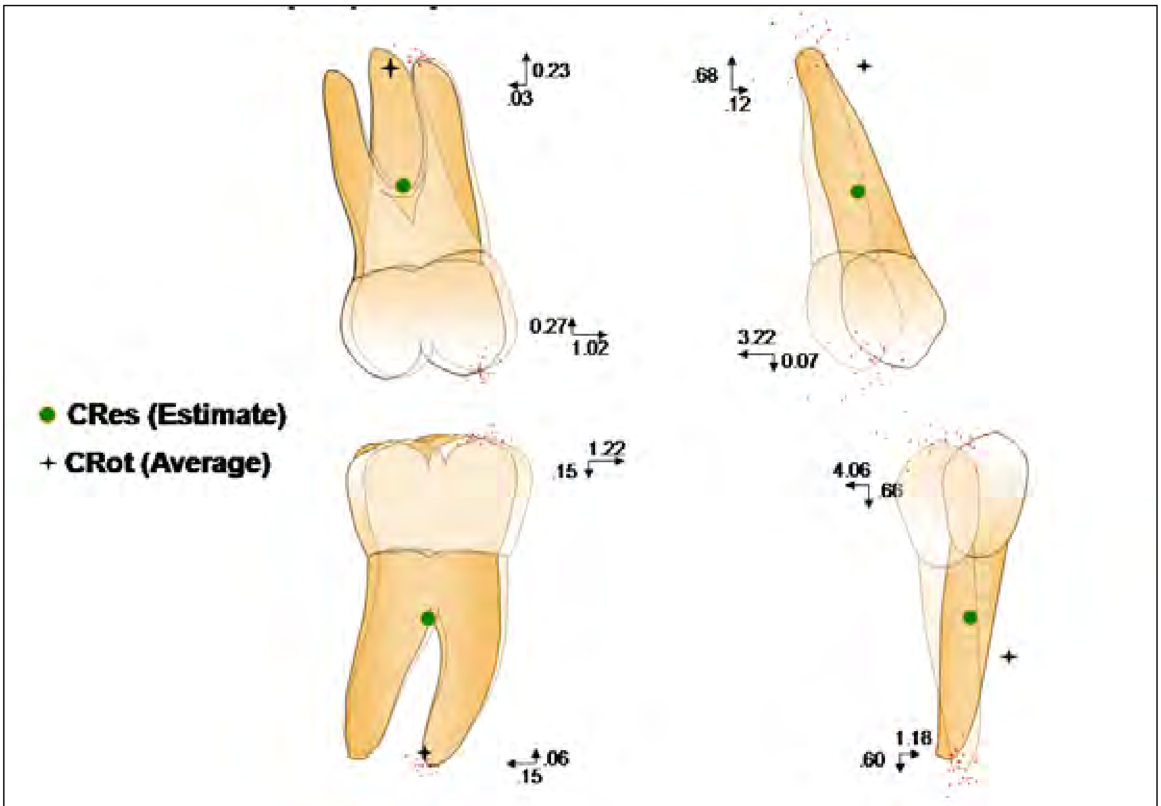

Figure 5 – Average displacements of apices and cusps tips of canines and molars and relations of CRots and CRes. Individual variability is depicted by red dots.

Discussion

The mandibular canines were intruded and retracted with uncontrolled tipping using the TTLS. The crowns were displaced distally approximately 4.1 mm and intruded 0.7 mm, and the apices were moved anteriorly and intruded approximately 1.2 mm and 0.6 mm, respectively. The CRot was located between the apex and the CRes. The TTLS did not produce controlled tipping expected for the mandibular canines. According to the relationship between MF ratios and tooth movements,[3,22] only a small change of the MF ratio would have been needed to produce controlled tipping. Uncontrolled tipping was due to insufficient moment on the canines. This was caused by the design of the loop, which should have been larger, the position of the loop, which should have been placed more anterior and/or the location of the tip back bend, which was too anterior. Although more moment was needed on the canine, efforts must be made to ensure that the posterior moment is always greater than the anterior moment. This difference rotates the occlusal plane by intruding the canine and extruding the molar to achieve equilibrium. This also helps to control the canine retraction because such rotation, together with an intrusive force anterior to the canine's CRes, make it possible to produce controlled tipping with a lower moment on the canines.[23] During deactivation of the spring, the whole system of forces can change by the movement of teeth, requiring the use of a self corrective loop with proper compensation[13] or the spring must be readjusted every month.

There was greater control of the maxillary than mandibular canines during retraction. They showed controlled tipping on average. Vertically, the CRot was located closer to the apex of the maxillary than the mandibular canines, and the apex did not move anteriorly as much as the apex of the mandibular canine. This indicates that the maxillary canines intruded, which maintained the vertical level of the crowns (Fig.1 B, C), and were tipped with a MF ratio sufficient for controlled tipping. The crowns of the maxillary canines were also not retracted as much as the mandibular canines and there was no intrusion of the crown. Differences between jaws in canine movement might have been due to the larger distance between the LAF and the CRes in the mandible. If the mandible offers more resistance to movement than the maxilla, it shifts the mandibular CRes apically, which could also explain the differences observed.

The maxillary and mandibular molar crowns were protracted approximately 1.1 mm by controlled tipping, without significant intrusion or extrusion. Anchorage control was greater than previously reported by some[24-26] and less than reported by others.[1,2] The primary objective of the TTLS in the posterior region was to produce translation of the molar, which occurred in only a minority of the cases. The MF ratios were too low, higher ratios would have been necessary to produce pure translation. The low MF ratio posteriorly was probably caused by the location of the tip back bend, which should have been positioned in relation to the molar tube rather than in relation to the spring itself. Whenever the bend was located closer to the molar tube than to the canine bracket, there was more moment produced on the molar tube and the canine was intruded (Fig. 6a). When it was closer to the canine there was more moment produced on the canine bracket and the molars were extruded (Fig 6b). Both of these situations can be seen in figure 5, even though the canines intruded on average. Because both the maxillary and mandibular canines were intruded, molar extrusion was expected, but occlusal forces probably played a role in maintaining the molars' vertical positions. This implies that the moment was smaller at the canines than at the molars, because otherwise, the canines would have extruded and molars intruded. Due to anatomical differences and a lack of standardization of the loop's tip back bend, the estimates of the Loop software can not be applied, on average, to the cases studied.

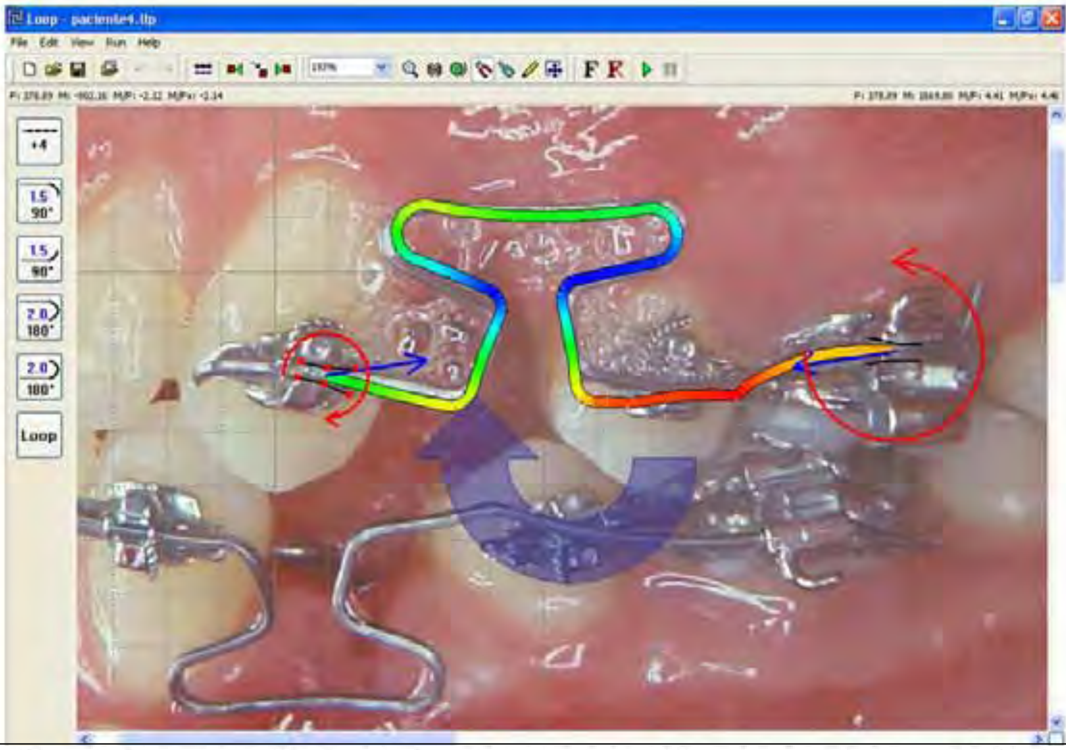

Figure 6a – Approximated force system in a subject with desirable force directions (estimated with Loop Sotware®). Blue arrow (added by the authors) demonstrates the moment produced by the vertical forces on canines and posterior segments, in order to achieve equilibrium.

As previously mentioned, the planned tooth movements of our sample, especially for the mandibular teeth, required higher MF ratios. This can be accomplished by increasing the moment, by decreasing the force or by changing the MF required to produce the desired movements. The easiest way to increase the moment is by altering the dimensions of the spring,[13,27,28] by bringing the TTLS closer to the bracket[29] or by increasing the angulation between wire and bracket.[3] On the anterior segment, the moment could have been increased by preactivating the TTLS anteriorly, as shown by Burstone.[3] In the posterior segment the moment could have been increased by bringing the distal gable closer to the molar (about 4 mm from the tube). Alternatively, a headgear could have been added to produce distal crown tipping of the posterior segment. The denominator of the MF ratio can be decreased by diminishing the activation of the spring, or by increasing the amount of wire used in the spring. Finally, it is possible to change the moment required for a desired movement by changing the LAF, while maintaining the MF ratio of the spring. This can be done by ensuring that the LAF passes closer to the CRes, either by bonding the brackets more cervically or by having higher intrusive forces anterior to the CRes.

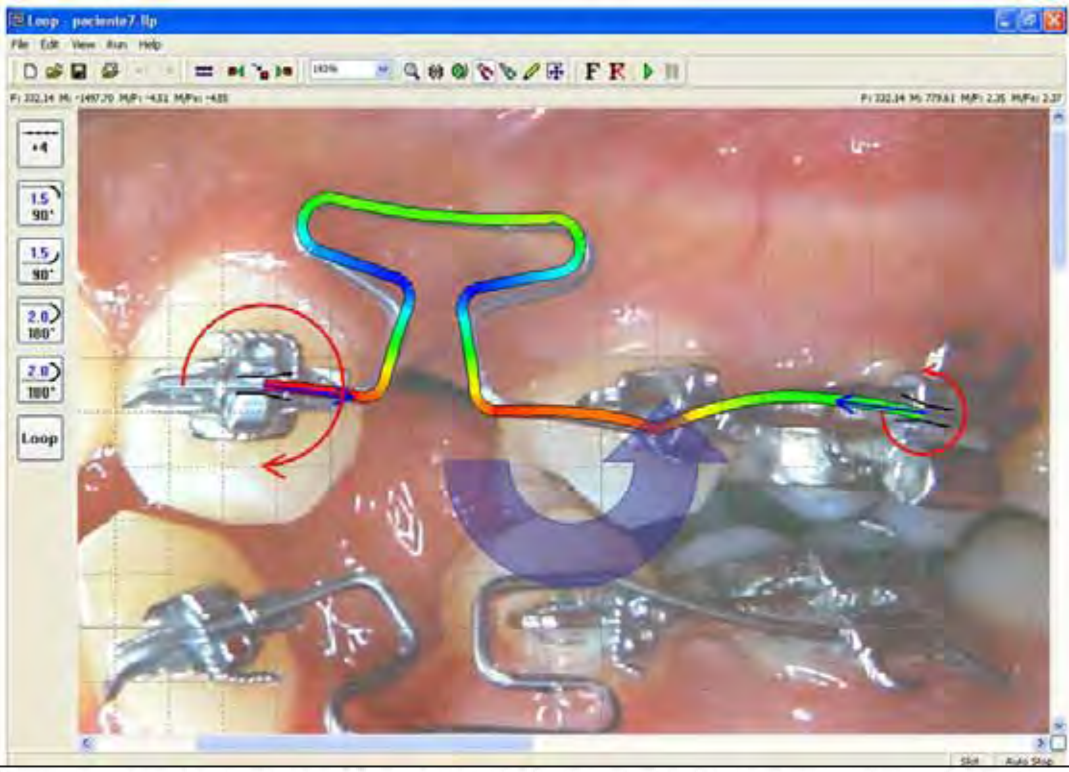

Figure 6b – Approximated force system in a subject with undesirable of force directions (estimated with Loop Sotware®). Blue arrow (added by the authors) demonstrates the moment produced by the vertical forces on canines and posterior segments, in order to achieve equilibrium.

Based on the results of this study, the MF ratios typically recommended [3-6,8] are excessive and should be different for the posterior and anterior segments (or canines). With the exception of the 8/1 MF ratio suggested for translation of the incisors[7,12] and values raging from 4.1 and 6.7 (location of CRes) apical to the brackets in anterior segments,[30] most laboratory and experimental estimates of MF ratios to produce translation vary from 10 to14, [5,31-33] which are too high based on the findings of the present study. The differences are due to the LAF, which is usually evaluated perpendicular to the teeth and overestimates the resistance offered by the bone. When teeth are initially tipped, the distance between the LAF and the CRes becomes smaller than when they are upright (Fig. 1B). The smaller the distance, the less moment required to produce the same movement. Although the same spring was used in both jaws (presumably the MF ratio was the same) and the estimated distances from the LFA and CRes were also the same, mandibular canines showed less control than the maxillary canines. This suggests that more moment is required for the mandibular canines than the maxillary canines to perform the same kind of movement. Lower MF ratios are required in molars than in canines to produce the same amount of movement because the LAF is closer to the CRes. Since the molar auxiliary tube is positioned further apical than the canine bracket, it further decreases the MF ratio required for tooth movement.

Conclusions

Based on a sample of 11 patients whose canines were partially retracted with the TTLS for approximately 2.1 months:

1 – The mandibular canines were intruded and retracted by uncontrolled tipping. The crowns were retracted 4.1 mm and intruded 0.7 mm, the apices were protracted 1.2 mm and intruded 0.6 mm.

2 – The maxillary canines were also intruded and retracted, by controlled tipping. The crowns were retracted 3.2 mm and the apex was intruded 0.7 mm.

3 – The maxillary and mandibular molars crowns were protracted similar amounts (1.0 and 1.2 mm, respectively) by controlled tipping, without significant extrusion. Their apices maintained their positions vertically and horizontally.

4 – The molars crowns were protracted approximately 0.3 mm for every 1 mm of canine crown retraction.

Acknowlegements

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Changes over time in canine retraction: an implant study

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Abstract

Objective: To analyze rates of canine movement over the initial two months of continuous retraction, when rate changes may be expected. **Materials and Methods:** Ten patients with bone markers placed into the maxilla and mandible had their canines retracted over a two month period. Retraction was accomplished with TMA "T" Loop Springs. Standardized 45^{o} oblique cephalograms where taken initially and every 28 days, thereafter. The radiographs were scanned and digitized twice (the average was used for the analyses). The radiographs were superimposed using the bone markers and oriented on the functional occlusal plane. Paired t-tests were used to compare side and jaw effects. **Results:** There were no significant differences between sides. The maxillary cusp was retracted 3.2 mm, with less movement during the first (1.1mm) than during the second four weeks (2.1 mm). The maxillary apices were not moved horizontally. There were no significant vertical movements in the cusps and apices of the maxillary canines. The mandibular cusp was retracted 3.8 mm, 1.1 mm during the first and 2.7 mm during the second four weeks. The mandibular apices were protracted 1.1 mm. The cusps and apices were intruded 0.6 mm and 0.7 mm, respectively. The only difference between jaws was the greater protraction of the mandibular than the maxillary apices, during the second four weeks and in overall movement. **Conclusions:** The rate of canine cusp retraction was greater during the second than first four weeks. Mandibular canines were retracted by uncontrolled tipping while the maxillary were retracted by controlled tipping

Introduction

Knowing the rate of tooth movement provides the orthodontist important physiologic and clinical information. Physiologically, rates of movement are indirect indicators of bone turnover and remodeling. Clinically, differences in rates of tooth movement determine whether and when to use intermaxillary mechanics during space closure. Understanding how teeth move is the basis for making treatment more efficient.

Animal studies show four phases of tooth movement following force application.[1,2] The tooth first shows an immediate slight movement, followed by a lag phase associated with hyalinization, followed by a third phase during which rates accelerate, and, finally, by a fourth phase of constant movement. Of the human studies describing canine movements[3-21] (Tables 1 and 2), most do not provide sufficient information to evaluate the lag phase, two[3,16] support a clear lag phase and four[5,6,11,14] do not. For example, Iwasaki et al.[11] was not able to detect the lag phase when very low forces and high moments were applied to the canine, suggesting an even stress distribution to the root surface. The four studies that did not identify a lag phase based their rates of tooth movement on intraoral or model measurements, due to the lack of stable references both measurements might be expected to be less reliable than radiographic assessments, which have been show to be adequate in 45^{o} radiographs.[22] With respect to frictionless mechanics, the only evidence of a lag phase is based on graphs of space closure showing decreased rates between the first and second weeks of canine retraction.[16]

Table I – Human clinical studies on canine retraction with mechanics involving some kind of friction (1 month = 4 weeks)

Author	Clear evidence of lag phase	Movement /month	Number of patients	Arch used	Measurement
Storey and Smith, 52[3]	Yes	.21 mm	5	Md	Models
Hixon et al , 69[4]	N/A	.85 mm	8	Md	Oblique (25°) Radiographs
Andreasen and Zwanziger, 80[5]	No	.96 mm	14	Both	Clinical
Huffman and Way, 83[6]	No	1.37 and 1.20 mm	25	Mx	Clinical
Yamasaki et al, 84[7]	N/A	1.3 mm (0.16)	8	Both	Clinical
Ziegler and Ingervall, 89[8]	N/A	1.33 mm (0.58)	21	Mx	Clinical
Daskalogiannakis and McLachlan, 96[9]	N/A	1.22 mm	6	Mx	Model
Lotzof et al, 96[10]	N/A	2.34 mm	12	Mx	Model
Iwasaki et al, 00[11]	No	1.27 and 0.87 mm	7	Mx	Model
Hayashi et al, 04[12]	N/A	1.81 mm (0.19)	4	Mx	Model
Herman et al, 06[13]		1.34 mm (1st 2 months)	14	Mx	Model
Limpanichkul et al, 06[14]	No	0.37 mm	12	Mx	Model
Bokas and Woods, 06[15]	N/A	1.75 mm	12	Mx	Model

Table II - Human clinical studies on canine retraction with frictionless mechanics (1 month = 4 weeks)

Author	Clear evidence of lag phase	Movement /month	Number of patients	Arch used	Measurement
Boester and Johnston, 74[16]	yes	.98 mm	10	Mx/Md	Oblique (22.5°) Radiographs
Ziegler and Ingervall, 89[8]	N/A	1.79 mm (0.39)	21	Mx	Clinical
Dincer and Iscan, 94[17]	N/A	.85 mm (.41) .59 (.35) Mx and 1.03 mm(.85) .39 (.15) Md	12 Mx/8 Md	Mx/Md	Lateral Radiographs
Tanne et al, 95[18]	N/A	2.43 mm	10	Mx	N/A
Lee, 95[19]	N/A	2.24 mm	7	Mx	Clinical
Daskalogianakis and McLachlan, 96[9]	N/A	0.63 mm	6	Mx	Model
Darendeliler et al, 97[20]	N/A	1.43 mm (0.58)	15	Mx	Lateral Radiograph
Hasler et al, 97[21]	N/A	0.91 mm	22	Mx	Model
Hayashi et al, 04[12]	N/A	1.95 mm(0.34)	4	Mx	Model

N/A – Information not available

In addition to uncertainty concerning the lag phase, the existing clinical literature reports highly variable rates of canine retraction. Rates range from approximately 0.2 mm/month[3] to over 2.5 mm/month.[18] Since the rates of tooth movement are also highly variable among individuals,[7,23-25] the small sample sizes often reported could explain some of the differences across studies. It has also been established that continuous forces produce faster tooth movement than intermittent forces,[9,26] and that, generally, higher forces will produce higher rates of tooth movement up to a point.[27] Moreover, friction mechanics produces lower rates of tooth movement then frictionless mechanics because the net force transmitted to the tooth to be moved might be smaller due to friction. The rate of movement can also be influenced by the type of tooth movement. Bodily movement, for example, will show lower rates than tipping;[28,29] and retraction of teeth into recent extraction sites is faster than retraction into healed sites.[21] Of the available literature pertaining to frictionless retraction, only one used oblique radiographs necessary to reliably evaluate apical movements of each side.

The objective of this paper was to analyze rates of canine movement over the initial two months of continuous retraction, when rate changes may be expected due to a lag phase.[1-3,16] To more accurately superimpose the maxilla and mandible, tantalum bone markers were used, and 45^{o} oblique cephalograms made it possible to better distinguish the right and left canines. The aims were to determine if the rates of movements were the same over time, whether differences exist between left and right sides, and whether the maxillary and mandibular canines display similar movement patterns.

Materials and Methods

This prospective study included 10 patients (6 females and 4 males) who were 17.4 ± 2.6 years of age at the start of treatment, selected according to the following criteria:

- Class I molar relationships;
- Treatment requiring four premolar extractions;
- Maxillary and mandibular dental protrusion;
- Good hygiene and healthy dentition.

Four tantalum bone markers were placed into the maxilla (two apical to the first molars and one on each side of the midpalatal suture, apical to the central incisors) and three were placed into the mandible (two apical to the first molars and one in the symphysis, apical and between the central incisors) according to the methods used by Björk and Skieller.[30,31] All patients provided informed consent, as required by the human subjects committee of our university, who also approved the execution protocol of the study.

Treatment Protocol

Patients had their first molars banded and brackets (slot .022") bonded to their second premolars. After leveling and alignment of the segments, the molars and premolars were held as a segment by a .019" X .025" stainless steel (SS) wire, tied with SS ligatures. Passive TPAs and lingual arches made with 0.9 mm (.036") SS wires were used to consolidate the left and right segments. Brackets were bonded to the canines and standardized 45^{o} oblique cephalograms where taken 14 days after the first premolars were extracted (Fig.1).

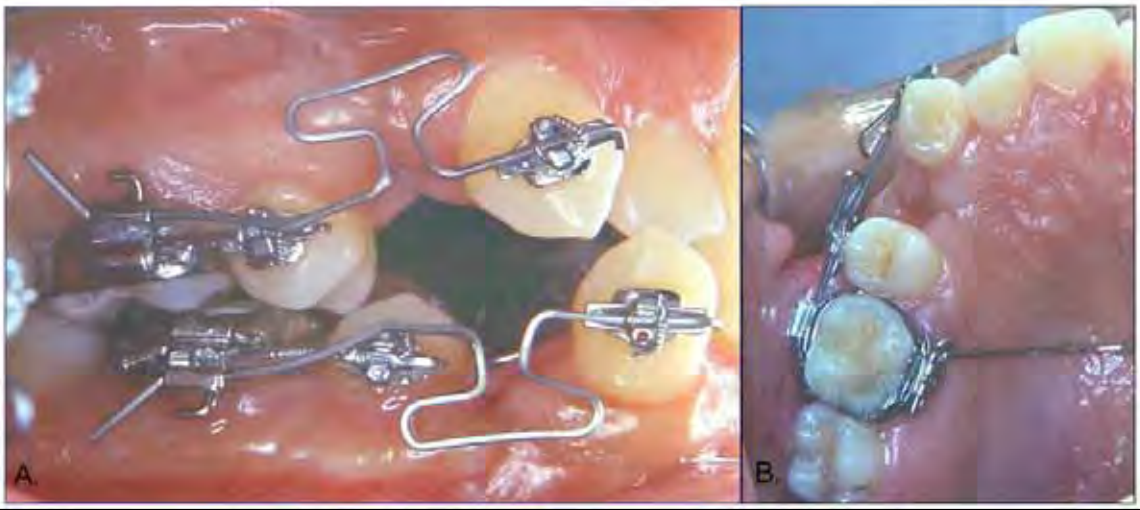

Figure 1 – A.Lateral view of the segmented system used for the canine retraction; B – Occlusal view.

One .017" X.025" TMA "T" Loop Spring (TTLS), preactivated for group A anchorage, with dimensions of 6 mm X 10 mm,[32] was placed in each patient's quadrant using the following protocol:

- The TTLS was made of a straight TMA wire (.017" X .025") and adjusted to be passive to the canine bracket and molar auxiliary tube on each side;
- A 45^{o} preactivation bend (second order) was placed directly below the posterior ear of the loop.[33]
- Anti-rotational bends (first order) where applied to the TTLS.[32]
- The TTLS was positioned with the anterior extremity of the loop located directly above the canine bracket, secured with SS ties (.25 mm), and

reactivated 4 mm (based on the separation of the lower vertical extremities of the loop).

The patients were evaluated every 28 days, exactly, for a total of eight weeks. All the patients were aware of the importance of the study and none of them were absent at their appointments. During each appointment, the springs where removed, standardized 45^{o} oblique cephalograms were taken of both sides and the springs were reactivated to 4 mm.

The radiographs were scanned, along with a ruler for calibration, at 450 dpi. Viewbox Software® (dHAL Orthodontic Software, Athens, Greece) was used to digitize the radiographs and to perform the measurements. Six landmarks were digitized in each quadrant, including the canine apex, the canine cusp tip, the 2nd premolar cusp tip, the mesial cusp tip of the 1st molar, and both mesial and distal bone markers used for superimposition by the software. The digitization was performed twice by the same investigator and measurements were averaged to reduce error. T2 (4 week) and T3 (8 week) radiographs were superimposed on the initial (T1) radiograph using the best fit of the bone markers. Each quadrant was evaluated separately. The radiograph that most clearly showed the apex and the tip of canine (not necessarily the same radiographs) was used to standardize each subject’s tooth size.

The T1 functional occlusal plane, defined by the cusp tip of the 2nd premolar and the mesial cusp tip of the 1st molar, was used as the reference plane for the measurements. After superimposing on the bone markers, the T1 functional occlusal plane was transferred by the software to the T2 and T3 images and used for orientation. The vertical and horizontal displacements of the cusps and apices of the canines were measured and recorded by subtracting the values found in T2 and T3 from T1.

The measurements were transferred to SSPS® software, version 12.0 (Chicago, Illinois) for the statistical analyses. The skewness and kurtosis statistics indicated approximately normal distributions. Paired t-tests were used to compare side and jaw effects. Replicate analyses showed that systematic errors ranged between 0.006-0.075 mm; random method errors[34] ranged between 0.036 to 0.178 mm.

Results

The movements of the right and left canines were averaged because there were no significant ($p>.05$) differences between sides.

The maxillary canine cusp tip was moved distally 3.2 mm over the eight week period of retraction (Table 3). The changes that occurred during the first four weeks (1.1 mm) were significantly ($p=0.03$) less than changes during the second four weeks (2.1 mm). There was no significant vertical movement of the cusp tip. The maxillary apices were maintained in place, both vertically and horizontally, during the two months of retraction.

Table III – Changes in maxillary and mandibular canine cusp tips and apices during the first (T1-T2) and second (T2-T3) four weeks of retraction, as well over the entire eight week period (Total Change), with statistical comparisons over time and between jaws

		Cusp Tip							Apex							
		T1-T2		**T2-T3**		**Prob.**	**Total Change**		**T1-T2**		**T2-T3**		**Prob.**	**Total Change**	
		Mean	SD	Mean	SD	Sig.	Mean	SD	Mean	SD	Mean	SD	Sig.	Mean	SD
Horizontal	**Maxillary**	1.06•	.55	2.14•	1.24	.028*	3.20•	1.41	.08	.45	-.13	.63	.487	-.05	.53
	Mandibular	1.05•	.88	2.73•	1.43	.002*	3.78•	2.01	-.16	.34	-.92•	.37	.001*	-1.08•	.47
	Prob.	.967		.261			.292		.289		.005*			<.001*	
Vertical	**Maxillary**	-.21	.95	.33	.54	.499	.12	1.37	-.38	.79	-.15	1.2	.699	-.53	.96
	Mandibular	-.22	.62	-.38	1.2	.752	-.59•	.94	-.46•	.57	-.20	.96	.562	-.66•	.83
	Prob.	.981		.405			.286		.830		.941			.785	

• Significant movement (p<.05) * Significant differences (p<.05)

The mandibular canine cusp tip was retracted 3.8 mm, again with significantly (p=0.002) less movement during the first (1.1 mm) than second interval (2.7 mm). The cusp tip was intruded significantly (0.6 mm) over the eight week period. The mandibular apices were protracted 1.1 mm anteriorly and intruded 0.7 mm. During the first month of retraction, the apices of the mandibular canines maintained their position horizontally and were intruded 0.5 mm, while during the second month they were protracted 0.9 mm and maintained their position vertically.

With the exception of the apices during the second four week, the mandibular and maxillary canines showed similar amounts of movement. The anterior movement of the mandibular apices were significantly (p=.005) greater than the anterior movements of the maxillary canines (0.9 mm vs. 0.1 mm) during the second four weeks, and were largely responsible for the greater overall anterior movements (1.1 vs. 0.05 mm) observed.

Discussion

The rates of canine cusp tip movements were greater during the second than first four weeks of retraction (Fig. 2). This provides indirect evidence of a "lag phase" during the first month of movement. Of the nine papers pertaining to human canine retraction with frictionless mechanics (Table 2), only one reported a clear lag phase during the first month of movement.[16] The remaining papers[8,9,12,17-21] do not provide sufficient information (e.g. only initial and final records were taken; large force variation, etc.) to identify a lag phase. The present results support animal studies showing an initial lag phase.[1,2] The findings also indicate that the lag phase of space closure reported by Boester and Johnson[16] was, at least in part, associated with an arrest of canine retraction. Clinically, this is important because canines should be expected to move slower during the first month of retraction than during the subsequent months.

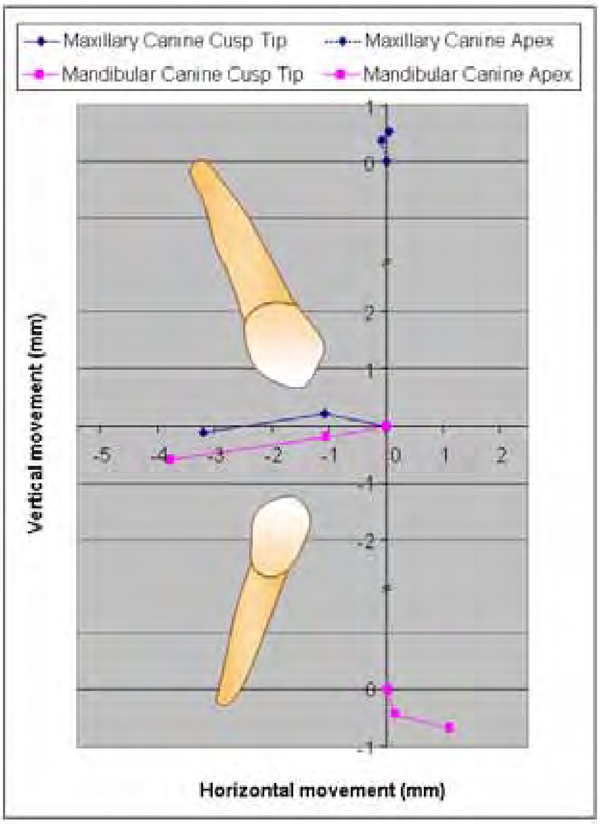

Figure 2 - Movements of maxillary and mandibular canines cusp tips and apices during the period of two months of retraction. Markers on the lines distinguish movements during the first and second month of treatment.
Negative values indicate extrusion and retraction of the maxillary canines, and intrusion and retraction of the mandibular canines.

Rates of maxillary and mandibular canine cusp retraction fall approximately midway between the rates previously reported for frictionless mechanics. Monthly movements were approximately 0.2-0.5mm or 12-33 % greater (Figure 3) in the present study than the computed monthly average of canine retraction (limited to the first two months when possible) from previous studies.[9,16,17,20,21] While various biological and biomechanical factors could explain the high variability in rates of canine retraction across studies, the use of models and clinical assessments to determine tooth movements must be considered as potentially problematic.

Differences between the maxillary (1.6 mm/4 weeks) and the mandibular (1.9 mm/4 weeks) canine cusp tips were small and insignificant. Theoretically, greater movement of the mandibular canine crown might have been expected because it underwent uncontrolled tipping (i.e. the crown moved distally 1.9 mm and the apex moved mesially 1mm) compared to the controlled tipping in the maxilla. Uncontrolled tipping might be expected to produce a greater amount of movement assuming it generates more stress than controlled tipping, because the rates of crown movements have been shown to be inversely proportional to the amounts of stress generated by the root moving through bone,[35] Iwasaki et al.[36] has recently demonstrated this relationship clinically. Differences between controlled and uncontrolled tipping are clinically relevant because rates of tooth movement can be slowed down or increased, relatively, by moving teeth in different ways (i.e. uncontrolled tipping, controlled tipping and translation).[28,29] Importantly, post hoc tests revealed that the present study had insufficient power to rule out the possibility of a difference between jaws in the amounts of canine cusp retraction.

The results suggests that the TTLS preactivation and/or design should be different for upper and lower canine retraction. The four millimeters of activation of the TTLS delivered 396 gF horizontally and 35.4 gF vertically, with a MF ratio of 4.1/1.[37] While the ideal force for tooth movement has not yet been determined, higher forces generally produce higher rates of tooth movement, up to a point.[27,32] Also, the MF ratio produced by the TTLS, although not high enough according to the literature,[32,35,38,39] produced controlled tipping in the maxillary canines and uncontrolled tipping in the mandibular canines. That suggests that a higher MF ratio is needed to retract the mandibular canines by controlled tipping. It is also possible that lower MF ratios than the reported in the literature could be used for maxillary canine retraction.

Conclusions

1. Rates of canine cusp tip retraction were greater during the second than first four weeks of retraction.

2. The only significant difference in tooth movements between jaws pertained to the canine apices, which moved anteriorly 1 mm in the mandible and did not move in the maxilla.

Acknowlegements

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Optimizing the design of group A Titanium “T” Loop Spring preactivated according to Marcotte using the Loop Software®

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Abstract

While a TMA "T" Loop Spring (TTLS), preactivated with a gable bend distal to the loop, holds promise for producing controlled tipping of the canines and translation of the posterior segment, there is currently no consensus as to where the preactivation gable bend or the loop should be placed, what the height of the loop should be, and how the interbracket distance changes the moments produced. Using the Loop Software program, a 017"X .025" TTLS (10 mm X 6 mm) preactivated with a 45° gable bend distal to the loop was systematically modified and the effects were simulated. As the gable bend was moved posteriorly, the moment increased at the posterior bracket more than it decreased at the anterior bracket; as the loop was brought closer to the anterior bracket, the posterior moment decreased at the same rate that it increased anteriorly; as the loop was increased in size, the moments increased both posteriorly and anteriorly and; as the interbracket distance increased, the posterior moment decreased and the anterior moment remained constant. We conclude that the size of the loop should be slightly increased to 10 X 7 mm, and it should be placed 2 mm away from the anterior bracket, with a preactivation bend of 45^{o} , 4-5 mm from the posterior bracket (after 4 mm of activation).

Introduction

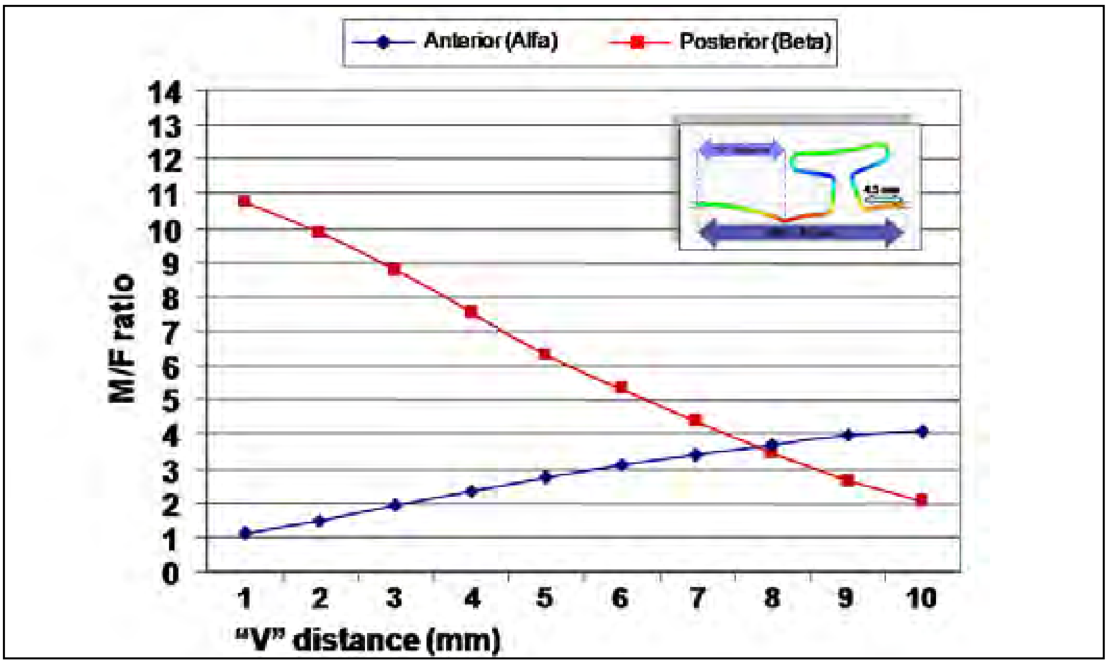
Partial or *en masse* retraction of anterior teeth using segmental mechanics offers more control and predictability than continuous arch mechanics. The advantages of using two brackets for retraction (auxiliary tube of the molar and canine, or a vertical tube crimped on the anterior segment) rather than several brackets include a greater interbracket distance (IBD), simpler planning, greater control of the force, and the possibility of using differential moment mechanics[1]. Although there are only two brackets, careful planning is needed to determine the force system required. Because the system is statically indeterminate, it can not be easily described.

A .017” X .025” TMA “T” Loop Spring (TTLS) has been proposed for group A anchorage control using a two bracket system[2,3]. The 10 X 6 mm TTLS is displaced anteriorly to produce controlled tipping (less moment) and preactivated posteriorly with a gable bend in order to produce translation (more moment). The moment to force (MF) ratios recommended for controlled tipping and translation are 7/1 and 10/1, respectively[4-7]. Importantly, the recommended values (which reflect the distance between the line of application of force and the tooth’s center of resistance in the experimental model analyzed) are too high for protrusive canines’ with crowns inclined mesially. Intrusive forces with protrusive canines further reduce the MF ratio required for any particular kind of movement[8]. The 10/1 MF ratio recommended for producing translation of the posterior teeth might also be expected to be too high since the posterior teeth are shorter and wider than the canines. This locates the centers of resistance closer to the bracket (which is also more apical with the use of auxiliary molar tubes) than the center of resistance of the canines. Vertical loops[9] and symmetrical designs of TTLS[10-12] have been well analyzed by the literature, asymmetrical designs of TTLS, however, have not been as widely studied.

Although asymmetrical TTLS has been widely used in a two bracket system for retraction, and the effects of a gable ("v") bend between two brackets in a straight wire have been reported,[13,14] there is no consensus as to where this gable bend should be placed when using a TTLS. Assuming a 23 mm interbracket distance, a gable bend below the posterior extremity of the loop (with 4 mm of activation) is located approximately half way between the two brackets. In this position, the TTLS produces higher moments anteriorly than posteriorly. This is an inappropriate force system for retraction with group A anchorage. In order to determine the optimal force system for the TTLS, clinicians need to understand the effects of changing the springs' physical characteristics (i.e. location of the gable bend, height of the TTLS etc.). Because patients present with various tooth sizes, it is also important to understand how the IBD affects the force system.

The Loop Software® (dHal, Athens, Greece) predicts the forces and moments that a spring produces at the level of the brackets[15,16]. It can be used to evaluate existing springs and plan future designs and modifications. This study will demonstrate the application of Loop Software to the TTLS[2], modified and preactivated according to Marcotte (group A anchorage)[3,17] in order to maximize its design. Our specific aims are to evaluate the effects of antero-posterior (AP) gable (v) bend displacement, loop height, AP position of the loop and changing the IBD.

Our findings show that, as the bend is moved posteriorly (i.e. as the "v" distance decreases), the MF ratio at the posterior bracket increases substantially more than the MF ratio decreases anteriorly (Figure 1). More specifically, the posterior ratio increases approximately three times as much as the anterior ratio decreases, regardless of how much the bend moves. The ratios increase more at the posterior bracket because there is less wire behind the bend, which makes it stiffer and less flexible. While moving the bend backwards increases the MF ratio posteriorly, there is a trade-off due to a loss of moment anteriorly, which could lead to uncontrolled tipping. Maximizing MF ratios posteriorly could lead to tipping and extrusion of posterior teeth, causing canting of the occlusal plane. The differences between the anterior and posterior moments imply in the existence of vertical forces, necessary to achieve equilibrium. In the simulated scenario, the vertical forces, which are in opposite directions on each bracket, shift directions when the gable bend is placed about 8 mm (roughly 1/3 of the IBD) from the



posterior bracket. The anterior moment increases when the loop is moved anteriorly.

As the loop is moved closer to the anterior bracket (Figure 2), the MF ratio increases anteriorly and decreases posteriorly. This concept has been already reported in a similar manner in a different preactivation.[12] For every mm that the loop is moved forward, the anterior and posterior MF ratios increase and decrease similarly. Since the loop's primary deficiency is its relatively low anterior MF ratio, it often helps to place the spring as close as possible to the anterior bracket. The anterior MF ratio stabilizes at about 2.5 mm from the anterior bracket, while the posterior ratio continues to decrease. A two millimeter distance from the anterior bracket offers a reasonable position to place the loop clinically. Clinicians can also alter both MF ratios by changing the vertical aspect of the loop, which

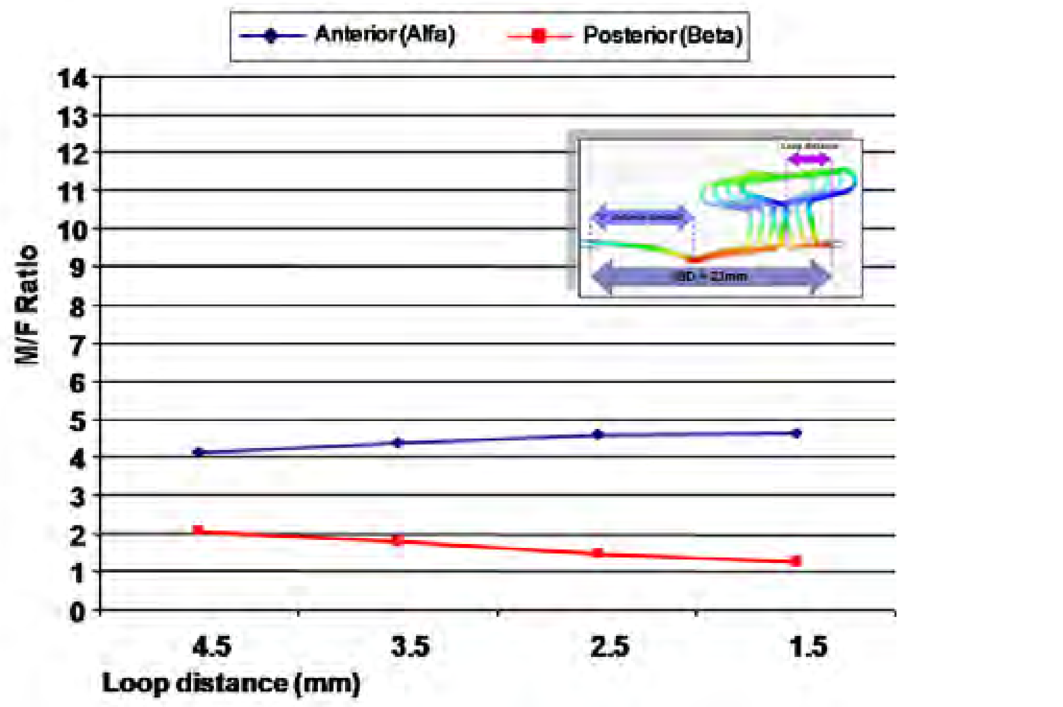


Figure 2 - Changes of the M/F ratios at the anterior and posterior brackets, separated by an IBD of 23 mm produced by anterior loop displacement in increments of 1 mm.

effectively increases its size.

By maintaining the gable bend in the same place and only lengthening the vertical extensions of the loops, both MF ratios increase (Figure 3). This may be partially explained by the increase in the amount of wire, which provides more flexibility and less force, which has been added to the system. This has already been demonstrated in different designs of TTLSs.[10,11] The difference in the MF ratios between the anterior and posterior brackets diminishes as the height of the loop increases, since the posterior MF ratio increases at a slightly greater rate than the anterior. It is reasonable to assume that as the differences decrease, the vertical forces acting on the system also decrease. However, the anatomy of the vestibule limits the advantages associated with longer loops, since excessive loop

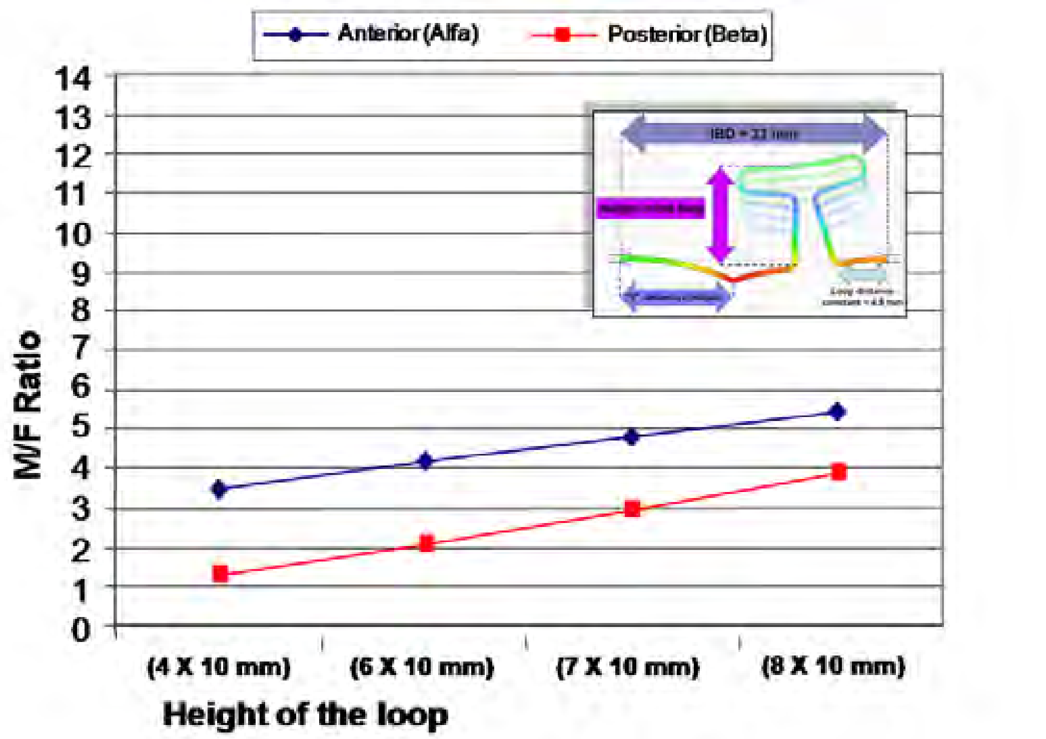


Figure 3 - Changes of the M/F ratios at the anterior and posterior brackets, separated by an IBD of 23 mm, produced by changes only in the loop height by increments of 1 mm, only on the vertical extensions.

height will impinge soft-tissue.

If the bend maintains its position relative to the loop and the IBD is increased by increasing the amount of wire behind the gable bend, the anterior M/F ratio remains relatively constant as IBD increases from 23mm to 30 mm (Figure 4). However, the M/F ratio at the posterior bracket decreases at a decelerating rate over the same range and approaches zero M/F ratio at 30 mm. This is equivalent to the application of a simple force, without control, such as finger springs produce. By maintaining the same distance from the bend to the distal bracket, as the IBD increases, the force system remains relatively constant.

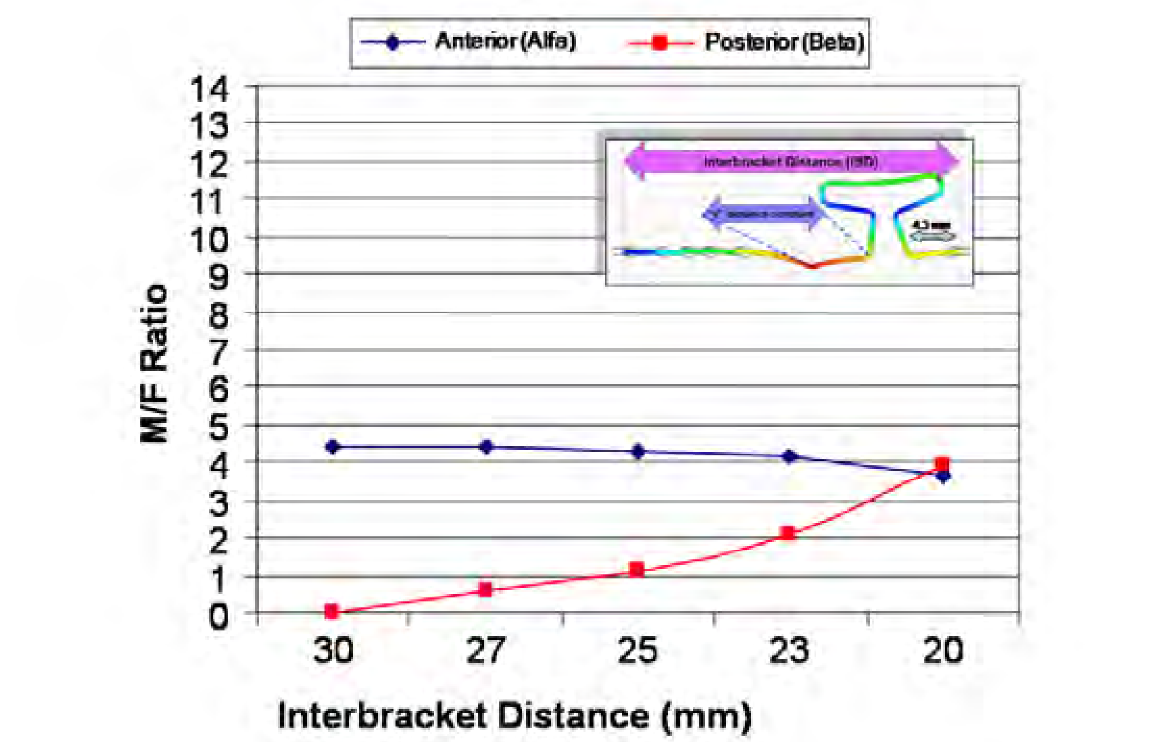


Figure 4 - Changes of the M/F ratios at the anterior and posterior brackets produced by an increase of the IBD, without modifications on the loop distances and the gable distance from the loop itself.

Because the position of the bend produces the greatest effect on the force system, and IBD difference are commonly found among patients, it is clinically important to understand how these two components work together to alter the force system (Figure 5). Overall, the relationships between relative IBD and M/F ratio resemble those previously described for changing the position of the bend (Figure 6). Relative to the “V” distance, the effects of different IBDs are small at the anterior bracket, probably because there is no change in the relation between the loop itself and the anterior bracket. The effects are larger on the posterior bracket due to the increase in flexibility allowed by the greater length of wire. Inversion of the moments (or the vertical forces) occurs relatively closer to the posterior bracket as the IBD increases. In cases with large IBD, the gable bend should be placed more distal, if greater moment is required posteriorly.

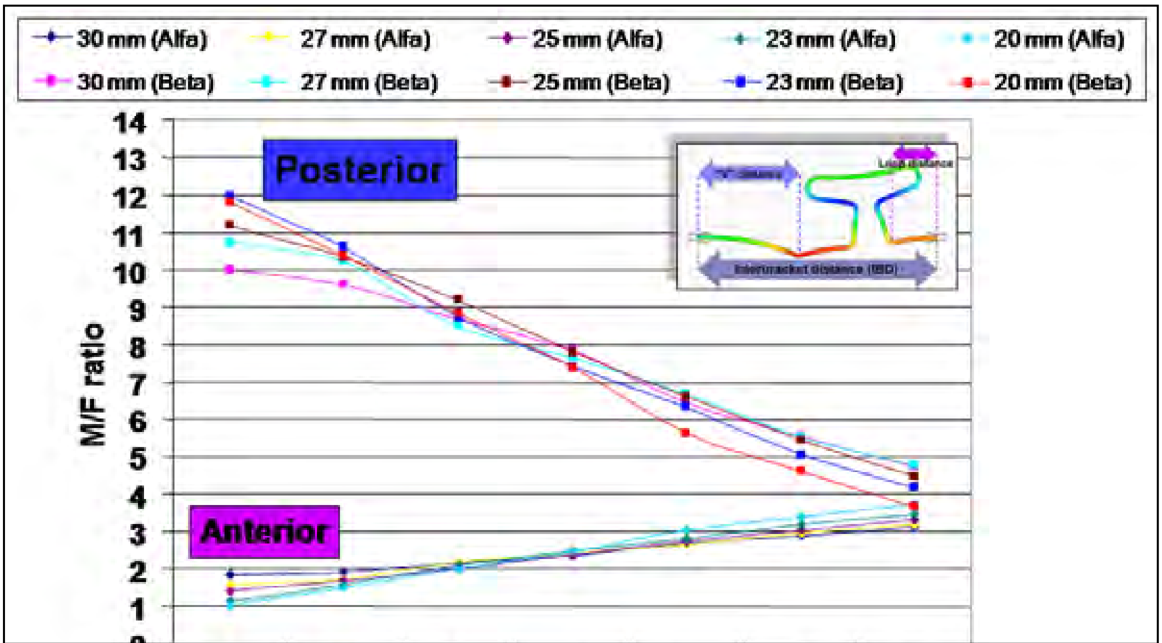


Figure 5 - Changes of the M/F ratios at the anterior and posterior brackets at various IBDs produced by the mesial displacement of the gable bend in millimeters from the distal bracket .The loop distance is kept constant at 4.5mm.

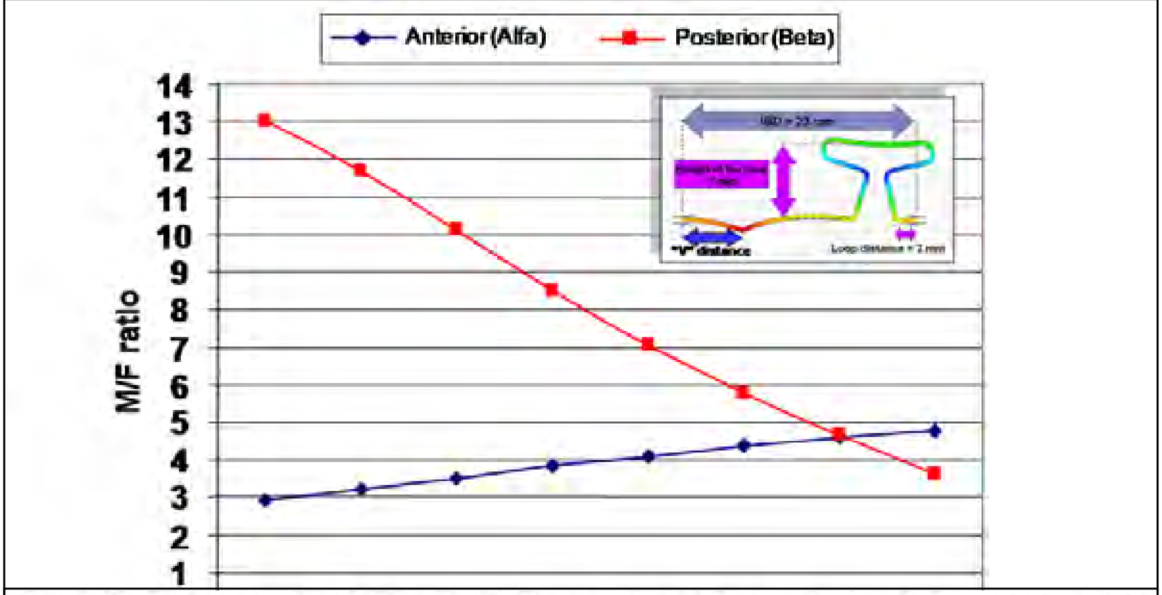


Figure 6 - Changes of the M/F ratios at the anterior and posterior brackets, separated by an IBD of 23 mm, produced by the mesial displacement of the gable bend in millimeters from the distal bracket. The loop distance is kept constant at 2 mm and the height of the loop is 7 X 10 mm.

The Loop Software indicates that this specific TTLS used can be optimized by changing the parameters evaluated in this study. First, it is better to place the gable bend relative to the posterior bracket (Figure 5) rather than the spring (Figure 4) because there is less variation of the posterior M/F ratio. Placing the spring approximately 2-2.5 mm from the anterior bracket also offers clinical advantages, because this position provides the best compromise between the anterior and posterior M/F ratios. Although a longer TTLS provide higher anterior and posterior M/F ratios, the depth of the vestibule will limit TTLS' actual heights. Based on our clinical experience, a height of 7 mm appears reasonable for maximizing the M/F ratio and minimizing impingement of the vestibule, although longer loops have been proposed[5,15,18]. Figure 6 provides an example of such a spring, illustrating the changes in M/F ratios on both anterior and posterior brackets as the gable bend is moved along the IBD. The authors suggest the gable bend to be positioned approximately 4-5 mm from the posterior bracket, when using a TTLS of the Group A anchorage. Although this is an acceptable configuration of the TTLS, other factors alter the system of forces, including:

- preactivations in other areas of the spring,
- the horizontal limits of the loop, and
- the deactivation of the spring that occurs with movement.

Clinicians should consider all of these dynamic factors when using this TTLS.

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Curvature vs ‘V’ Bends in a Group B Titanium T Loop Spring (TTLS)

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ABSTRACT

Objective: To compare the system of forces acting on curvature and preactivated V-bends in Titanium T Loop Springs, (TTLS) made of 0.017” X 0.025” TMA wire.

Materials and Methods: Pictures of TTLS preactivated by curvature and V-bends were inserted in the Loop Software® program to design both TTLS. Symmetry was assured using the program. Both TTLSs used the same amount (length) of wire and had the same angulation between their anterior and posterior extremities when passive. The loops were activated 7 mm and forces and moments were registered after each 0.5 mm of deactivation. The brackets were at the same height, separated by 23 mm and angulated zero degrees.

Results: The preactivated curvature TTLS delivered horizontal forces ranging from 34 to 456 gF, while the TTLS preactivated by V-bends delivered forces ranging from 54 to 517 gF. The forces decreased more (30 vs. 33 gF) with every 0.5 mm of activation on the preactivated V-bend TTLS than on the preactivated curvature TTLS. Vertical forces were low and clinically insignificant for both TTLSs. The MF ratios were systematically higher on the preactivated curvature than on the preactivated V- bend TTLS (from 5.8 to 38.8 mm versus 4.7 to 28.3 mm).

Conclusions: Although both loops show symmetrical moments in their anterior and posterior extremities and can be used for group B anchorage, the curvature preactivated TTLS delivers lower horizontal forces and higher MF ratios than the acute preactivated V-bend TTLS.

Key words: T-Loops; Moment to force rations; Group B anchorage; TMA; Loop Software

INTRODUCTION

Efficient space closure is an important objective in orthodontics. Segmental space closure can be more efficient due to frictionless mechanics and large interbracket distances (IBD). The “T” loop used for group B or reciprocal anchorage has a low load/deflection ratio and, if similar vertical dimensions are compared, delivers a more constant force over a larger deactivation span than vertical loops,[1] such as bull loops. The load/deflection ratio can be further improved with the use of TMA.[1-3] The Titanium T Loop Spring (TTLS) allows for more predictable tooth movements over longer spans of activation than vertical loops and can be used for specific types of movements, including translation. The various designs of the TTLS for group B anchorage[1,4-7] that have been introduced differ primarily in terms of loop size and preactivations.

Although it has been established that increasing the height of the loop also increases the MF ratio,[8-10] the effects of different types of preactivation are not completely understood. More specifically, differences between TTLS preactivated by a curvature vs. TTLS preactivated by a V-bend have not yet been systematically studied. Manhartsberger et al.[5] reported less horizontal force and higher MF ratios in the preactivation bend with a large activation and more force and a lower MF with smaller activation. Their study, however, was not designed to compare curvature and bends. Moreover, the angulations between both anterior and posterior extremities of the loops they used were different, which could confound their results.

The purpose of this study was to evaluate the differences in force levels and MF ratios between group B TTLS preactivated by a curvature versus those preactivated by a V-bend. The Loop software® (DHal, Athens, Greece) was used to perform the preactivations precisely and to estimate forces and moments.

MATERIALS AND METHODS

Two group B TTLS, one with curvature preactivation [4] and one with V-bend preactivation [7] (Figure 1), were designed and tested using the Loop Software® (DHal, Athens, Greece). The TTLS were designed from

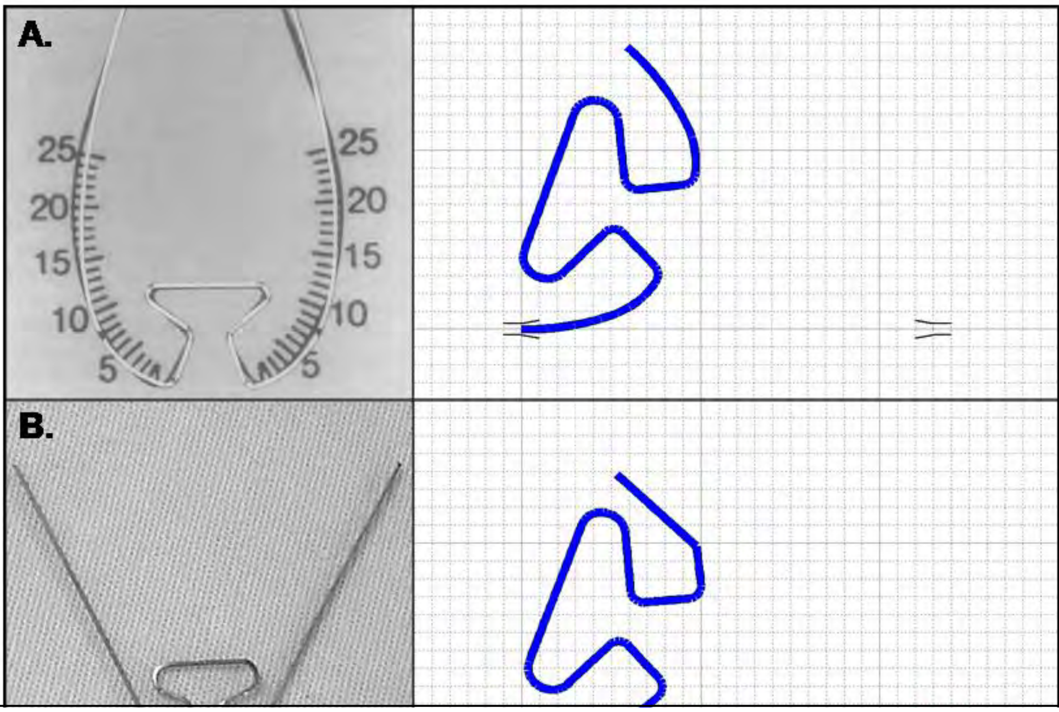

Figure 1. Templates used for the design of the TTLSs (left) and simulated by the Loop Software (right). A. Curvature preactivated TTLS; B. Bend preactivated TTLS (Each square is 1 cm²).

0.017” X 0.025” TMA to be 10mm long and 6mm high. An interbracket distance (IBD) of 23 mm, from the canine bracket to the molar tube, was used. Both brackets were positioned at the same level with the same orientation.

Because the planned activation of the loops was 5 mm, the anterior and posterior lengths of wire were estimated to be 9 mm based on the following formula[6,7]:

(IBD – Activation)/2

After the loop was designed, it was saved as two files, one for each of the preactivations. The curvature preactivation TTLS was performed by inserting a template[4] as a figure on the software and checked to ensure that both sides were symmetrical (Figure 1). The preactivation V-bend was performed by inserting a picture of a TTLS preactivated according to Marcotte[7] (picture was taken after trial activation) following trial activation on the software as well.

TTLS total wire length, distance to bracket, angulation to bracket and number of segments were standardized using the software to ensure comparability of the two TTLS without activation of the springs. The total amount of wire used in both TTLSs was 47.21 mm and, when passive, the angulation between the extremities of the loops was 42^{o}. The linear distances from the unengaged extremity of the TTLS to the bracket were slightly different between the TTLSs (0.77 mm).

The TTLSs were activated from 5 mm to -2 mm [negative values are due to the overlapping of the vertical extensions of the TTLSs in their neutral positions (i.e. defined two dimensionally with the extremities of the loop positioned at 180^o (Figure 2)], for a total of 7 mm, in increments of 0.5 mm. At each of the increments the horizontal forces (Fx), vertical forces

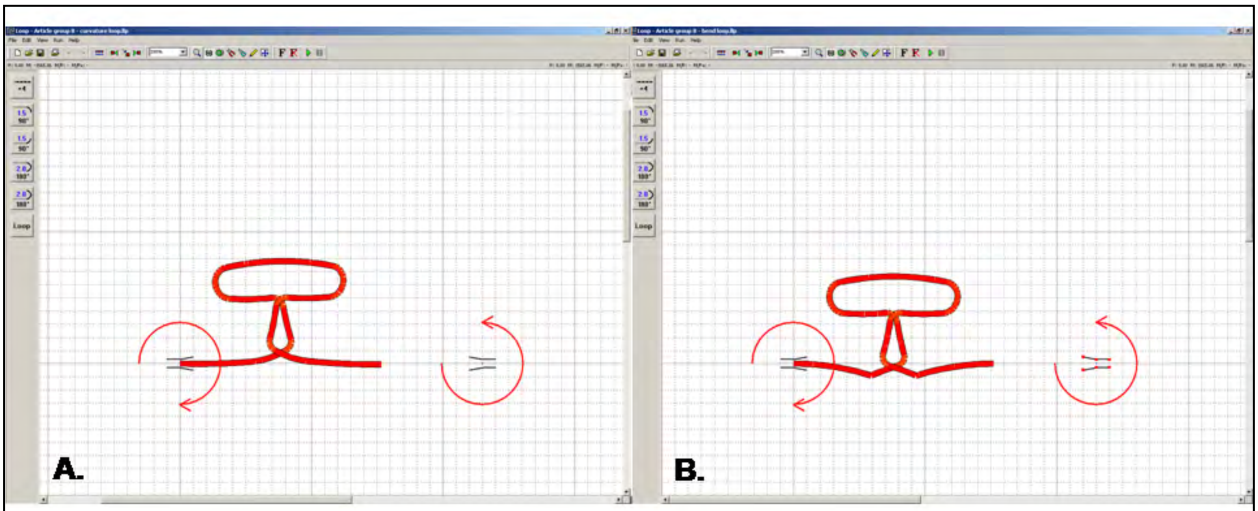

Figure 2. Characteristics of the TTLSs when in neutral position. Note the similar amount of overlapping between the vertical extensions of the loop of the two TTLSs. A. TTLS preactivated by curvature; B. TTLS preactivated by bends.

(Fy) and moment/force ratios (M/Fx) were estimated by the software and copied to a Microsoft Excel worksheet. The absolute values of the forces and moments were corrected by a factor of 0.88.[11,12] Changes in forces were estimated at each 0.5 mm increments of activation. No statistical testing was performed because the software mathematically calculates the M/F iteratively based on theoretical beam equations which produce similar results for the same wire configuration.

RESULTS

The TTLS preactivated by curvature delivered horizontal forces increasing from 34 to 456 gF between -2 and 5 mm of activation respectively (Table 1; Figure 3). The force decreased approximately 30 gF for every 0.5 mm of deactivation (Table 2). Vertical forces ranging from 1.5 gF of intrusive force to 3.5 gF of extrusive force were low and clinically insignificant. The MF ratios increased with deactivation from 5.8 to 38.8 mm on the anterior bracket (alpha) and from 5.9 to 37.9 mm on the posterior bracket (beta) (Figure 4 and Table 1).

Table 1 – Values for force (horizontal and vertical) and M/F ratios in alfa (anterior bracket) and beta (posterior bracket) and differences between curvature and bend preactivation in a 7 mm range of activation of the TTLS tested (Negative values of activation pertain to the horizontal force generated by the neutral position)

	Curvature preactivation				Bend preactivation				Difference			
Activ. (mm)	Fx (gF)	Fy (gF)	M/Fx (alfa)	M/Fx (beta)	Fx (gF)	Fy (gF)	M/Fx (alfa)	M/Fx (beta)	Fx (gF)	Fy (gF)	M/Fx (alfa)	M/Fx (beta)
5.0	456.7	-0.9	5.8	5.9	516.6	-0.7	4.7	4.7	60.0	0.2	1.2	1.2
4.5	430.1	-1.4	6.1	6.1	481.0	0.3	4.9	4.9	51.0	1.7	1.1	1.2
4.0	400.3	0.4	6.4	6.4	455.5	0.1	5.1	5.1	55.2	-0.2	1.2	1.2
3.5	374.4	0.5	6.7	6.6	419.6	0.2	5.4	5.4	45.2	-0.3	1.2	1.2
3.0	343.4	-1.5	7.0	7.1	398.4	3.2	5.7	5.5	55.0	4.7	1.3	1.6
2.5	316.8	3.5	7.5	7.3	361.2	4.3	6.1	5.9	44.4	0.7	1.4	1.4
2.0	292.2	0.9	7.9	7.8	334.1	5.3	6.5	6.2	42.0	4.5	1.4	1.6
1.5	262.8	1.0	8.4	8.4	298.8	4.0	7.0	6.7	36.1	3.0	1.5	1.6
1.0	228.1	3.3	9.3	9.1	266.2	3.6	7.6	7.3	38.1	0.3	1.8	1.7
0.5	197.7	2.7	10.3	10.0	232.7	4.0	8.4	8.1	35.0	1.3	1.9	1.9
0.0	166.6	3.3	11.7	11.3	198.7	4.2	9.5	9.1	32.1	0.9	2.2	2.3
-0.5	135.4	3.1	13.7	13.3	163.8	4.5	11.0	10.5	28.4	1.3	2.6	2.7
-1.0	103.5	3.2	16.9	16.3	129.1	3.9	13.3	12.8	25.6	0.7	3.5	3.5
-1.5	72.2	2.1	22.7	22.2	92.4	4.1	17.7	16.9	20.2	2.0	5.0	5.2
-2.0	39.2	2.1	38.8	37.9	54.4	4.3	28.3	27.0	15.2	2.2	10.5	10.9
								Avg.	**38.9**	**1.5**	**2.5**	**2.6**

Table 2 – Variation in force for every 0.5 mm of activation in the curvature and bend preactivation TTLS

	Variation in force (gF)	
Range (mm)	**Curvature**	**Bend**
5.0 – 4.5	26.6	35.6
4.5 – 4.0	29.8	25.5
4.0 – 3.5	25.9	35.9
3.5 – 3.0	31.0	21.2
3.0 – 2.5	26.6	37.2
2.5 – 2.0	24.7	27.1
2.0 – 1.5	29.4	35.3
1.5 – 1.0	34.6	32.6
1.0 – 0.5	30.4	33.5
0.5 – 0.0	31.1	34.0
0.0 – (-0.5)	31.2	34.9
-0.5 – (-1.0)	31.9	34.7
-1.0 – (-1.5)	31.3	36.7
-1.5 – (-2.0)	33.0	38.0
Average	29.8	33.0

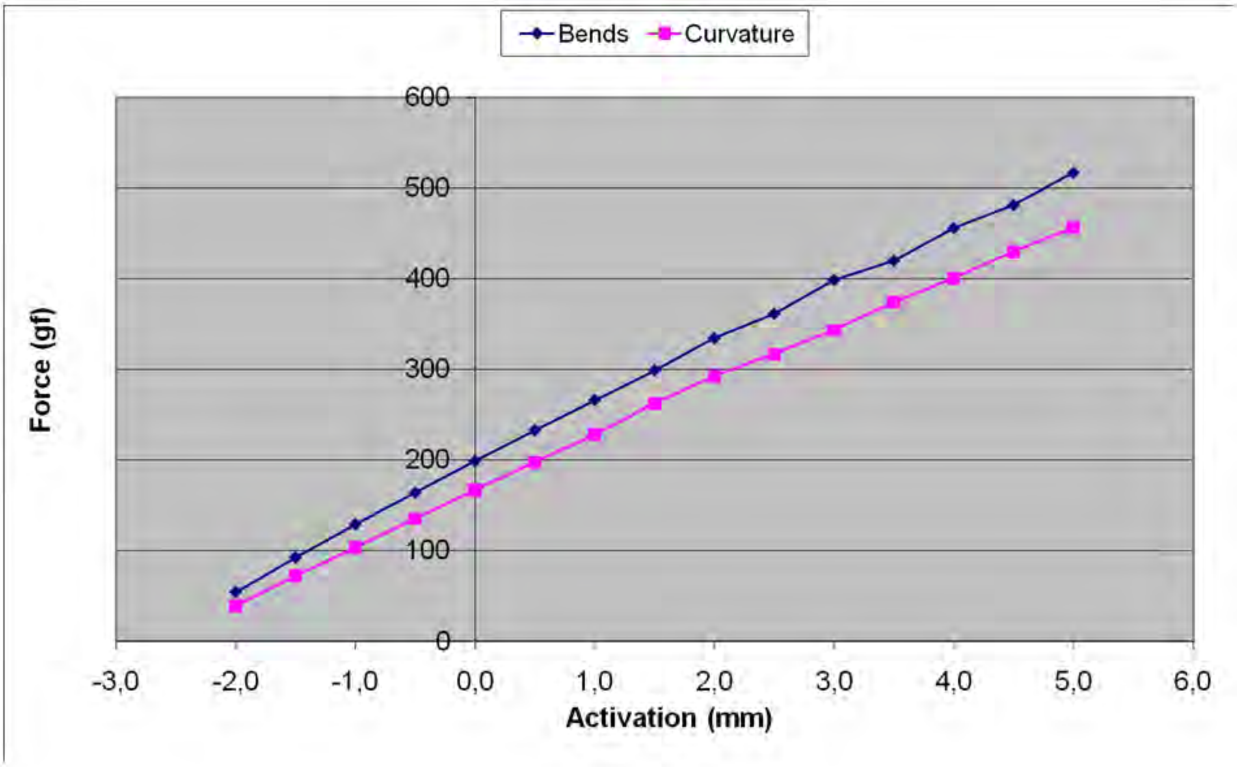

Figure 3. Horizontal force variation in the TTLSs preactivated by bends and by curvature over a range of 7 mm of deactivation.

The TTLS preactivated by the V-bends delivered horizontal forces increasing from 54 to 517 gF in the same range of activation as the preactivated curvature TTLS (Figure 3). The force decreased more (30 vs. 33 gF) more with every 0.5 mm of activation than the preactivated curvature TTLS (Table 2). Vertical forces ranged from 0.7 gF of intrusive force to 5.3 gF of extrusive force. The MF ratio at 5 mm of positive activation was 4.7 and increased gradually to 28.3 millimeters in alpha and from 4.7 to 27.0 millimeters in beta (Figure 4 and Table 1).

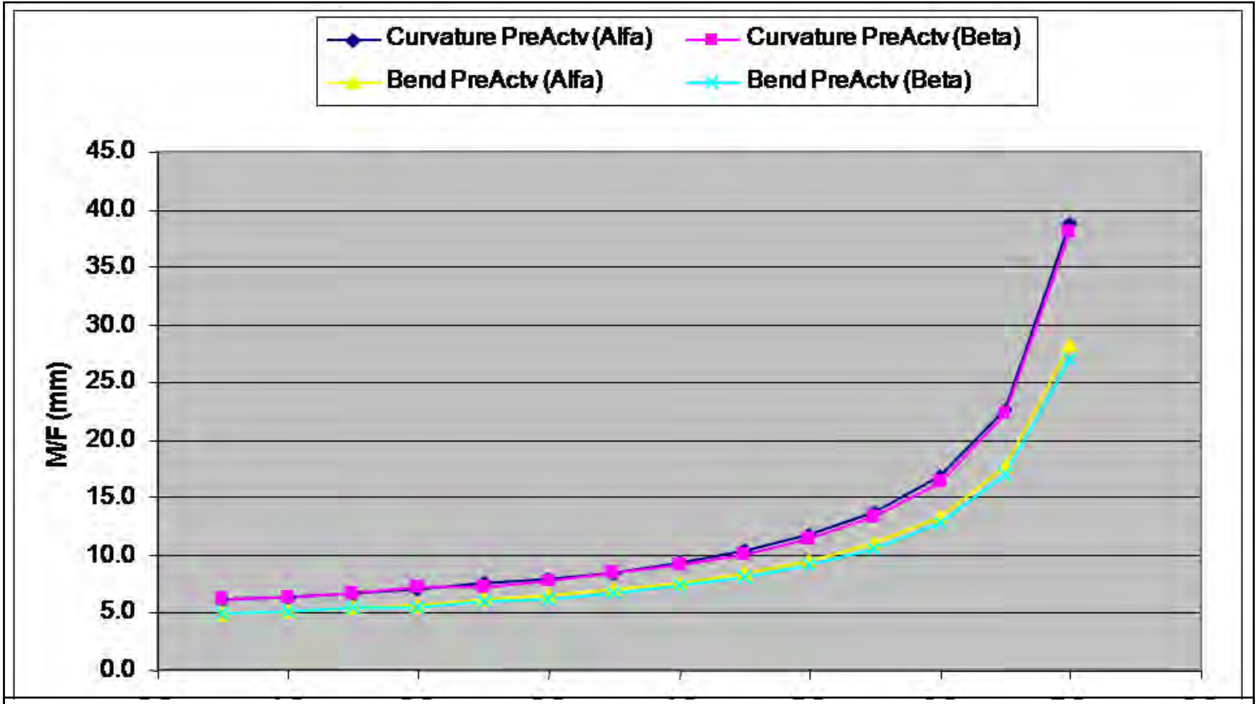

Figure 4. Data from the present study on the moment to force ratios variation over activation in both TTLS preactivations, in alfa (anterior bracket) and beta (posterior bracket).

DISCUSSSION

The force delivered by the bend preactivated TTLS was systematically higher than the force delivered by the preactivated curvature TTLS. These results appear to be different from the findings of Manhartsberger et al.[5] (Figure 5 A and B), which showed initially higher forces for the preactivated V-bend TTLS. While residual stresses/plastic deformation could help to explain this difference, it is more likely that the higher forces they report for the preactivated curvature TTLS are due to an error of activation, caused by greater activation of the curvature than the V-bend TTLS. Their data (Figure 5A) shows a sudden depression between 0.5 and 0 mm of activation for the curvature bend TTLS, which dramatically alters the slope of the line representing its load-deflection rate. Within their elastic limit, TMA loops should display a constant load/deflection rate.[2,7,10,13,14] The limited increases in MF ratios at the curvature preactivated TTLS (Figure 5B) is also indicative of a problem. The lines on the graph should follow the same slopes until they cross the x-axis (Figure 5C), at which point the force delivered by the TTLS would be zero (neutral position). This indicates that the curvature preactivated TTLS was systematically overactivated by 1.43 mm when compared to the bend preactivated TTLS. In order to compare the differences between loops, their y and x-intercepts should be made to coincide. When the x-intercepts are made to coincide, measurements are registered at the same increments of activation from neutral position (which does not necessarily mean that the activation measured by the vertical extensions separation will be the same). When the same procedure is performed in the y-intercept, the activations can be measured from zero (neutral position of each loop). With these adjustments, the results of Manhartsberger et al's data[5] (Figure 5D) are similar to the present study (Figure 6).

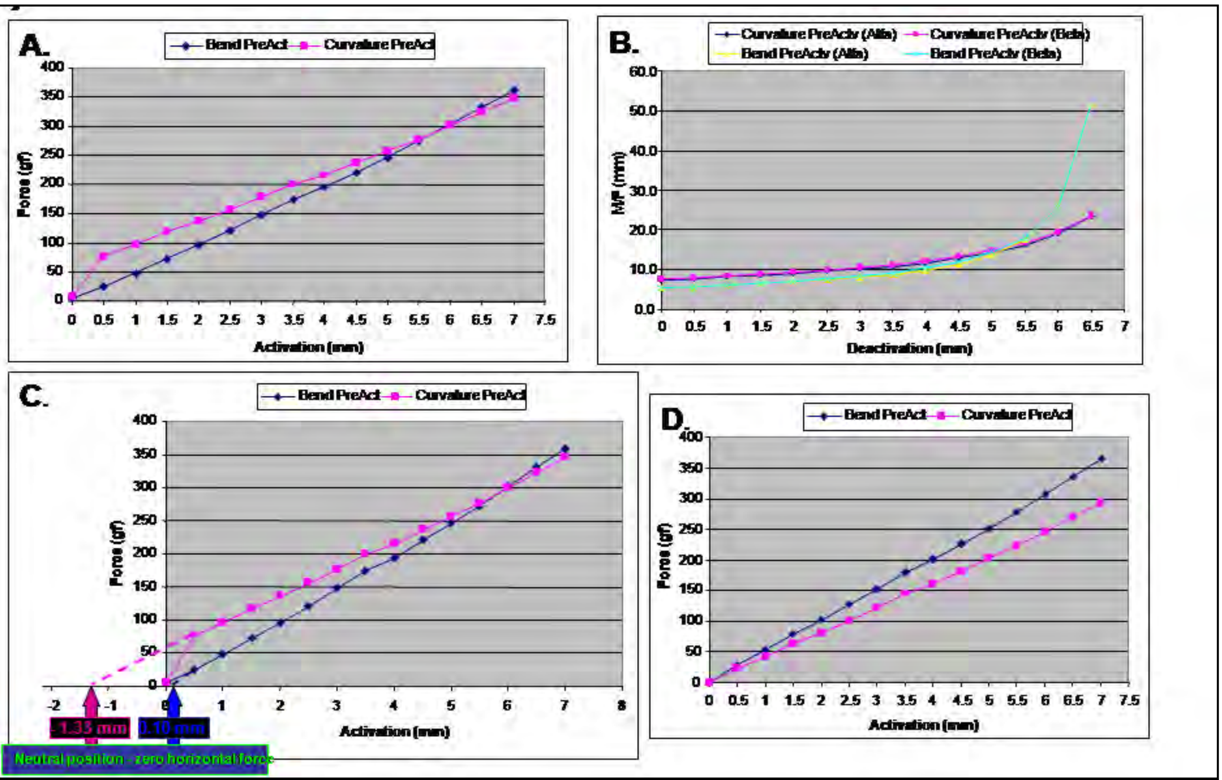

Figure 5. Plotted graph of the data from Mannhasberger et al. (ref) on a 0.017"X 0.025" group B TTLS on the effect of deativation. A. On MF ratios; B. On the horizontal force produced; C. Graph A modified - The values pointed by the arrows depict the approximate relative "activation" where horizontal force produced by the TTLSs would be zero. C. Graph A adjusted so both activations are the same at zero.

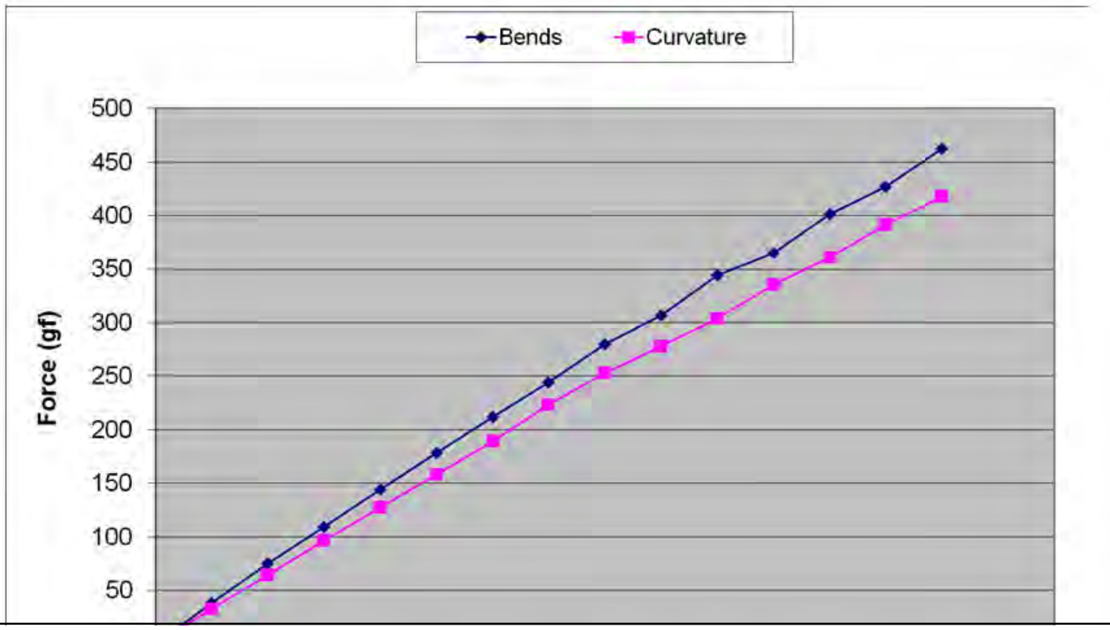

Figure 6. Plotted data, from the present study on the effects of preactivation on the horizontal force on a 0.017"X 0.025" group B TTLS, mathematically adjusted so both activations are the same.

These adjustments are necessary due to the overlapping of the vertical extensions of the TTLSs (or any other loop) in neutral position, which increases when more angulation is added between the anterior and posterior extremities. Because the angulations of both of the TTLSs used in the present study were similar, the difference was small (0.17 mm), and resulted in an insignificant increase in force (15 gF/0.5 mm) for the bend preactivated TTLS. This demonstrates that the distance between the vertical extremities of the loop used to access activation is error-prone and should be not used when comparing different loops. Also, the clinician should be aware that the horizontal force increases when extra curvature is added adjacent to the loop or even to archwires with bull loops (i.e. when adding more "gable" to a bull loop, the same 1 mm of activation generates more force).

It can be concluded that a preactivated curvature TTLS delivers lower forces with the same range of activation than the preactivated V-bend TTLS. Because both force deactivation rates are roughly the same, the curvature preactivation maintains a lower force throughout the entire range of deactivation. However, it appears to be harder to preactivated the TTLS with a specific curvature without the use of a chair-side template, whereas the bend preactivated one should not require the use of a template.

The force decrease per unit of activation was lower on the curvature preactivation than the V-bend preactivation. The difference on average, 3gF per 0.5 mm of deactivation, is larger than the 1gF reported by Manhartsberger et al.,[5] but clinically insignificant. This implies that both loops have similar slopes and produce similar load/deflection ratios.

Both TTLS tested in this investigations delivered symmetrical moments throughout the activations. This was expected, since the loops were symmetrically designed and there was no difference in height or angulations between the brackets. This finding agrees with Manhartsberger et al.,[5] who reported relatively symmetrical MF ratios of the preactivations. Their ratios were less symmetric than ours because the height differences in the vertical extensions of the loop generate greater discrepancy between the alpha and beta brackets. This implies that curvature or bend preactivations can be used for reciprocal space closure without major effects on the vertical position of the posterior and anterior segments.

Both TTLSs produced initial MF ratios that were too low for controlled tipping, assuming 7/1 mm produces this movement (Figure 4 and Table 1). This is important because the theory of reciprocal space closure with a TTLS depends on moving the teeth initially by controlled tipping, then by translation and finally by root correction, all of which occur as the MF increases.[1,7] Manhartsberger et al.[5] found higher MF ratios with bend, and lower with the curvature preactivated TTLS, which can be partially explained by the different sizes of loops, interbracket distances and the higher degree of curvature used. If higher MF ratios are required initially, the height of the TTLSs used in the present study could be increased. For example, the Loop Software® indicates that the MF ratios would have increased by 1.2 mm if the TTLSs had been 1 mm higher.

The TTLS preactivated by curvature delivered higher MF ratios. This happened because both the force is lower and the moments are higher in the curvature preactivation. The average 2.5 mm of difference in MF ratios of the TTLSs is equivalent to the difference between a vertical loop 6 mm high, which has a MF ratio of approximately 2 mm,[1] and a simple force being applied to a tooth, such as elastic chains without wires through the brackets. Approximately the same difference in MF ratio will produce controlled tipping of teeth (7/1 mm) from uncontrolled tipping (5/1 mm), when a force is applied 10 mm from the center of resistance of a tooth vertically oriented. Thus, in addition to increasing the height of a TTLS, the MF ratios can be increased by changing its preactivation from bend to curvature. Curvature bends promote better internal stress distribution during bending. Also, it helps to minimize post-insertional permanent deformation by avoiding a compromise in the microstructure of the wire due microcracks in areas of stress concentration.[15] As a consequence, more preactivation can be theoretically incorporated to the wire by curvature than by acute bends.

CONCLUSIONS

- Both curvature and bend preactivated TTLSs produced symmetrical moments, with small vertical forces, ranging from -1.5 to 4.5 gF. They also produced low MF ratios when activated 7 mm (5.9 mm and 4.7 mm for curvature preactivated and bend preactivated, respectively).
- The curvature preactivated TTLS produced horizontal forces that were lighter, 38.9 gF on average, than the bend preactivated TTLS.
- The curvature preactivated TTLS produced MF ratios that were approximately 2.5 mm higher than the bend preactivated TTLS.
- The curvature preactivated TTLS showed less force decrease per 0.5 mm of deactivation (29.8 gF) than the bend preactivated TTLS (33 gF).

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Considerações Finais

Baseado nos resultados e conclusões apresentados pelos artigos, podemos tecer as seguintes considerações gerais:

1. os caninos superiores foram retraídos por inclinação controlada (3,2 mm), enquanto os inferiores foram retraídos por inclinação descontrolada (4,1 mm);
2. os molares, tanto os superiores (1,0 mm) quanto os inferiores (1,2 mm), foram protraídos por inclinação controlada;
3. em 2,1 meses de retração parcial de caninos, para cada 1 mm de retração dos caninos, os molares foram protraídos 0,3 mm;
4. levando-se em conta os dois primeiros meses de retração, os caninos se movimentam mais no segundo mês (102% a mais nos superiores e 160% a mais nos inferiores) do que no primeiro mês de retração;
5. foi possível desenvolver uma padronização e otimização da TTLS pré-ativada para o grupo A, de acordo com Marcotte. A alça deve ter 7 X 10 mm e deve estar posicionada a 2 mm do bráquete ou tubo anterior. A pré-ativação deve ser uma dobra de 45º, conforme já relatado, porém localizada a 4 mm do tubo posterior;

6. a pré-ativação da TTLS do grupo B por curvatura gera M/Fs maiores em 1 mm, inicialmente, e 2,5 mm, em média, comparada a pré-ativação por dobras concentradas. A força horizontal também é menor na pré-ativação por curvatura, inicialmente (60 g) e em média (38.9 g) .

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