# A Comparison between Beta Titanium Wire, Nickel Titanium Wire and Stainless Steel Wire as Distal Spring of Pendulum

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**Thesis Title** *A comparison between beta titanium wire, nickel titanium wire and stainless steel wire as distal spring of pendulum*

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## บทคัดย่อ


การเคลื่อนฟันกรามบนถอยหลังเป็นวิธีแก้ไขการสบฟันแบบที่สองให้ได้การสบฟันปกติ เพื่อให้ได้ผลการรักษาที่ดีจึงได้มีการพัฒนาเครื่องมือที่ไม่ต้องอาศัยความร่วมมือของผู้ป่วยขึ้น ซึ่งเครื่องมือเพนดูลัมเป็นเครื่องมือตัวหนึ่งที่มีประสิทธิภาพการในการเคลื่อนฟันกรามบนไปทางด้านหลัง ส่วนประกอบสำคัญที่ทำหน้าที่ให้แรงในการเคลื่อนฟันทำมาจากลวดเบตา-ไทเทเนียม แต่เมื่อเปรียบเทียบกับลวดชนิดอื่นที่ใช้ในทางทันตกรรมจัดฟันพบว่า ลวดนิกเกิล-ไทเทเนียมเป็นลวดที่ให้แรงในขนาดที่น้อยแต่คงที่และต่อเนื่องได้ดีที่สุดซึ่งแรงลักษณะเช่นนี้จะทำให้เนื้อเยื่อรอบรากฟันมีการตอบสนองที่ดีขณะที่ฟันเคลื่อนที่ แต่อย่างไรก็ตามในทางคลินิกพบว่าลวดเหล็กกล้าไร้สนิมที่มีขนาดและการดัดเป็นรูปร่างที่เหมาะสมก็สามารถให้แรงที่มีลักษณะเช่นนี้ได้ **วัตถุประสงค์** เพื่อนำลวดนิกเกิล-ไทเทเนียม และลวดเหล็กกล้าไร้สนิมมาประยุกต์ใช้ในเครื่องมือเพนดูลัม และเพื่อเปรียบเทียบประสิทธิภาพในการเคลื่อนฟัน เช่น ลักษณะของการเคลื่อนฟัน,อัตราเร็วในการเคลื่อนฟัน, และปริมาณการสูญเสียหลักยึดระหว่างการเคลื่อนฟันระหว่างลวดทั้ง 3 ชนิด **วัสดุและวิธีการ** ผู้ป่วย 20 รายเป็นผู้ชาย 4 คนและผู้หญิง 16 คนมีลักษณะการสบฟันแบบที่สองได้รับการรักษาด้วยการเคลื่อนฟันกรามบนถอยหลัง โดยผู้ป่วยจะถูกแบ่งเป็น 2 กลุ่ม กลุ่มที่ 1 จำนวน 5 คน กลุ่มที่ 2 จำนวน 15 คน โดยผู้ป่วยในกลุ่มที่ 1 จะได้รับการรักษาโดยใช้เครื่องมือเพนดูลัมที่ส่วนของสปริงเคลื่อนฟันด้านหนึ่งทำจากลวดนิกเกิล-ไทเทเนียมชนิดกระตุ้นด้วยความร้อน [HANT] ขนาด 0.018”x0.025” [Neosentalloy F200™; GAC, Islip, NY] ซึ่งให้แรงขนาด 200 กรัม โดยที่อีกด้านหนึ่งจะใช้ลวดเบตา-ไทเทเนียมชนิดดัดสำเร็จรูปสำหรับเครื่องมือเพนดูลัมขนาด 0.032” [TMA; Ormco corp, Glendora, CA] ในผู้ป่วยกลุ่มที่ 2 จะใช้เครื่องมือเพนดูลัมที่สปริงเคลื่อนฟันด้านหนึ่งทำจากลวดเหล็กกล้าไร้สนิม[SS] ขนาด 0.018”x0.025” ส่วนอีกด้านหนึ่งจะใช้ลวดเบตา-ไทเทเนียมชนิดดัดสำเร็จรูปสำหรับเครื่องมือเพนดูลัมขนาด 0.032” [TMA] โดยสปริงเคลื่อนฟันที่ทำจากลวด SS และ TMA จะได้รับการปรับที่ 60° และ 45° ตามลำดับเพื่อให้สปริงมีแรง 200 กรัมก่อนที่จะทำการใส่ให้ผู้ป่วย และในผู้ป่วยทั้ง 2 กลุ่มจะถูกเรียกกลับมาทุก 4 สัปดาห์เพื่อปรับสปริงเคลื่อนฟันที่ทำจากลวด SS และ TMA ให้มีแรง 200 กรัม จนกระทั่งการสบ

ฟันกรามอย่างน้อยด้านหนึ่งมีลักษณะเป็นแบบที่ 3 ประมาณ 2 มม. ในการศึกษานี้ผู้ป่วยจะได้รับการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง [lateral cephalometric film] จำนวน 2 ครั้ง ครั้งแรกถ่ายก่อนทำการยึดเครื่องมือเพนดูลัม [T1] ครั้งที่สองถ่ายหลังจากทำการเคลื่อนฟันกรามบนจนได้ตำแหน่งที่ต้องการอย่างน้อยหนึ่งด้าน [T2] โดยที่ฟันกรามบนซี่ที่ 1 และฟันกรามน้อยบนซี่ที่ 1 ด้านซ้ายและด้านขวาในฟิล์มกะโหลกศีรษะด้านข้างจะถูกแยกโดยการใช้ลวดที่ดัดต่างกันมายึดติดที่ฟันก่อนทำการถ่ายภาพรังสี ภาพรังสีที่ได้จะทำการลอกลาย และซ้อนทับกันในแต่ละด้านของขากรรไกร จากนั้นทำการวัดปริมาณการเคลื่อนฟันเปรียบเทียบกันระหว่างลวดทั้งสองชนิด โดยในกลุ่มที่ 1 ระหว่างลวด HANTกับ TMA และในกลุ่มที่สองระหว่างลวด SS กับ TMA โดยใช้สถิติ independent *t*-test **ผลการทดลอง** เนื่องจากผลการทดลองในกลุ่มที่ 1 เกิดการเคลื่อนของฟันกรามบนที่ไม่ต้องการเช่น เกิดการหมุนในแนว disto-buccal, เกิดการขยายออกทางด้านใกล้แก้ม, เกิดการยื่นยาวของ ปุ่มฟันด้านเพดาน รวมไปถึงมีอัตราการเคลื่อนฟันที่ช้ามาก ซึ่งสปริงที่ทำจากลวด HANT ได้ถูกออกแบบใหม่หลายครั้งแต่ผลการเคลื่อนฟันก็ไม่ดีขึ้นดังนั้นจึงหยุดทำการทดลองในกลุ่มที่ 1 และให้การรักษาต่อตามปกติ ส่วนผู้ป่วยในกลุ่มที่สองจำนวน 15 คน มีอายุเฉลี่ย 17.13 ± 5.99 ปี ระยะเวลาที่ทำการทดลองเฉลี่ยอยู่ที่ 6.03±2.15 เดือน สำหรับการเคลื่อนที่ของฟันกรามบนซี่แรกเปรียบเทียบระหว่างลวด SS และ TMA พบว่าสามารถเคลื่อนที่ไปข้างหลังได้ระยะทาง 4.37±1.45 มม และ 4.57±1.58 มม, เกิดการล้มเอียงไปทางด้านหลัง 8.63°±5.31° และ 10.97°+7.34° รวมไปถึงเกิดการ ยื่นยาว 0.37±1.14 มม และ 0.50±1.09 มม ตามลำดับ โดยไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ สำหรับการเคลื่อนที่ของฟันกรามน้อยบนซี่แรกเปรียบเทียบระหว่างลวด SS และ TMA พบว่าทั้งคู่เกิดการเคลื่อนที่มาทางด้านหน้าเฉลี่ย 0.50+1.32 มม และ 1.60+1.31 มม, เกิดการล้มเอียงมาทางด้านใกล้กลางเฉลี่ย 0.53°+3.25° และ 1.30°+4.41° ร่วมกับเกิดการยื่นยาว 1.07±1.27 มม และ 0.90±1.69 มม. ตามลำดับ โดยค่าที่พบว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติคือ ค่าการเคลื่อนมาทางด้านหน้าของฟันกรามน้อยบนซี่แรกเพียงค่าเดียว สปริงทั้งสองชนิดให้อัตราการเคลื่อนฟันกรามบนไปทางด้านหลังเฉลี่ยโดยในลวด SS คิดเป็น 0.80+0.31 มม/เดือน และในลวด TMA คิดเป็น 0.83+0.31 มม/เดือน และไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างลวดทั้งสองชนิด **สรุป** ลวดเหล็กกล้าไร้สนิมที่มีขนาดและมีการดัดเป็นรูปร่างที่เหมาะสมสามารถใช้เป็นสปริงเคลื่อนฟันในเครื่องมือเพนดูลัมได้โดยมีอัตราและลักษณะของการเคลื่อนฟันที่ใกล้เคียงกับการใช้ลวดเบตา-ไทเทเนียมชนิดดัดสำเร็จรูปสำหรับเครื่องมือเพนดูลัมแต่ทำให้เกิดการสูญเสียหลักยึดที่น้อยกว่าลวดเบตา-ไทเทเนียม ส่วนลวดนิกเกิล-ไทเทเนียมชนิดกระตุ้นด้วยความร้อนไม่สามารถนำมาใช้เป็นสปริงได้เนื่องจากลวดมีความอ่อนตัว [flexible] ที่มาก และลวดมีการเคลื่อนที่ในทั้งสามมิติในขณะที่ให้แรงไปที่ฟัน

**Thesis title** A Comparison between Beta Titanium Wire, Nickel Titanium Wire and Stainless Steel Wire as Distal Spring of Pendulum

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## ABSTRACT

The molar distalization has been regularly used to correct Class II dental relation to Class I occlusion. To achieve predictable result, the several of non-compliance molar distalization appliances have been developed. Pendulum appliance is one of these appliances that can distalized molar effectively. Beta-titanium wire is regular used for pendulum spring. When compared among wires used in orthodontics, nickel titanium has the best force delivery due to its constantly light continuous force. Better tissue respond is expected when nickel titanium is used. However, in clinical practice, stainless steel wire with particular size and bending can possible deliver similar type of force too. **Objectives**: To apply nickel titanium wire and stainless steel wire as distal springs of pendulum appliance and to compare quality of tooth movement in terms of type of tooth movement, rate of movement and the loss of anchorage during tooth movement between pendulum appliances that using beta-titanium wire, nickel-titanium wire and stainless steel wire as distal springs. **Materials and methods**: Twenty patients (4 male and 16 female) with Class II molar relationships were selected and planned to correct by the maxillary molar distalization. Patients were randomly divided in 2 groups, 5 patients for group I and 15 patients for group II. For group I, maxillary molars were distalized by pendulum appliances using 0.018”x0.025” heat activated nickel-titanium [HANT] wire [NeoSentalloy F200™; GAC, Islip, NY] that also generated 200g force and 0.032” preformed beta-titanium wire [TMA™; Ormco corp, Glendora, CA] regular used for pendulum, as distal springs. In group II patient, the pendulum springs were made by 0.018”x0.025” stainless steel [SS] wire and 0.032” preformed TMA. All of SS and TMA spring were pre-activated about 60° and 45° respectively, to generated 200g force. Both groups of patient were recall every 4 weeks for SS and TMA springs reactivated, to obtain 200g force, until molar relationship was slightly class III about 2mm for one side at least. The lateral cephalometric films were taken at the beginning [T1], before appliance fixation, and after one of molars was moved to designed position [T2]. The right and left maxillary first molars and first premolars in the films were identified with jigs that placed before exposure. The films were traced and superimposted for each side. The amount of tooth movement were compared between HANT and TMA spring in group I, SS and TMA spring in group II using independent *t*-test. **Results**: From clinical observation, in group I patient, the HANT springs showed unwanted tooth movement such as severe disto-buccal rotation, buccal expansion, palatal cusp extrusion and very slow rate of movement. The HANT spring was redesigned but no improvement was noticed so the experiment in group I was discontinued. In group II patient, the mean age at the start of treatment was 17.13 $\pm$ 5.99 years, range from 10 to 32 years. The average activation time was 6.03$\pm$2.15 months. The maxillary first molars with SS and TMA springs were moved distally 4.37$\pm$1.45mm and 4.57$\pm$1.58mm, distal tipping about 8.63°$\pm$5.31° and 10.97°$\pm$7.34° while some extrusion were found about 0.37$\pm$1.14mm and 0.50$\pm$1.09mm, respectively, no statistically significant different found between SS and TMA springs. Whereas, maxillary first premolars using SS and TMA springs were moved mesially approximate 0.50$\pm$1.32mm and 1.60$\pm$1.31mm, mesial tipped of 0.53°$\pm$3.25° and 1.30°$\pm$4.41° incorporated with 1.07$\pm$1.27mm and 0.90$\pm$1.69mm extrusion, respectively, only mesial movement parameter was found statistically significant different between two springs. Both types of spring were generate rate of molar distalization about 0.80$\pm$0.31mm/month for SS spring and 0.83$\pm$0.31mm/month for TMA spring without statistically significant different. **Conclusion**: The SS wire with particular size and bending can apply as distal spring of pendulum appliance with comparable rate and type of maxillary first molar movement, but created less anchorage loss than TMA wire. The HANT wire cannot apply as pendulum spring because the spring is too flexible and moves in three dimensions at deactivation period. **Key words:** Molar distalization; pendulum appliance; nickel titanium wire; beta titanium wire; stainless steel wire

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## LISTS OF DIAGRAMS/ FIGURES

## LISTS OF ABBREVIATIONS AND SYMBOLS

| | | |
|---|---|---|
| DL | = | disto-lingual rotation |
| et al | = | and others |
| FH | = | Frankfurt horizontal plane |
| Fig. | = | Figure |
| g | = | gram |
| HANT | = | heat-activated nickel titanium wire |
| ML | = | mesio-lingual rotation |
| mm | = | millimeter |
| NiTi | = | nickel titanium |
| PP | = | palatal plane |
| PTV | = | pterygoid vertical plane |
| SD | = | standard deviation |
| SS | = | stainless steel wire |
| T1 | = | time before molar distalization |
| T2 | = | time after molar distalization |
| TMA | = | beta-titanium wire |
| ™ | = | trade mark |
| / | = | per |
| ” | = | inch(es) |

# CHAPTER 1

# INTRODUCTION

**Background and rationale**

One of common strategies to correct Class II malocclusions without extraction is to move the maxillary molars distally in the initial stage of treatment to convert the Class II molar relationship into Class I relationship. To achieve this objective, a variety of treatment modalities have been suggested. From the past, headgear is the common appliance which uses for molar distalization. However, headgear requires patient compliance to be effective. The recommendatory time for using headgear is 12-14 hours per day but many patients do not willing to wear it.[1] To overcome this problem, several alternative methods have been proposed. These new molar distalizing appliances have been possible because of advance in technology especially new materials capable of delivering light and constant forces over the wide range of deactivation, and a better understanding of biomechanics and tissue reaction to orthodontic tooth movement.[2] However, non-compliance treatment modalities are not necessarily to be reserved for the "non-compliance" patients, but may have useful application with "compliance" patients to produce more predictable result.[3]

These appliances can be classified into three groups depended on anchorage manner, inter-maxillary, intra-maxillary and absolute anchorage.[3] The inter-maxillary appliances are fixed between upper and lower jaws so the effects are move upper molar distally while protract lower teeth and jaw forward, such as Herbst appliance, Jasper Jumper™, adjustable bite corrector™, Eureka spring™, Saif spring, mandibular anterior repositioning appliance and Klapper SUPERSpring™. The intra-maxillary appliances are only fix within maxillary teeth and jaw so the effect is only move upper molar distally, such as Pendulum appliance, distal jet, Nance with NiTi coil spring/wire, magnet, Jones Jig™, Lokar distaling appliance and molar distalizing bow. In absolute anchorage group, anchorage value is reinforced by implant to achieve maximum tooth movement from these appliances.

Pendulum appliance is one of various effective appliances for moving upper molar distally without patient cooperation. The active component of the pendulum appliance is its distal spring which delivers distal force to molar. Beta titanium wire is recommended for distal spring fabrication. Compared among wires used in orthodontics, nickel titanium has the best force delivery due to its constantly light continuous force. Better tissue respond is expected when nickel titanium is used. However, in clinical practice, stainless steel wire with particular size and bending can possible deliver similar type of force.

Nickel titanium wires were designed as buccal spring for molar distalization[4] but both nickel titanium wires and stainless steel wires never designed to incorporate with pendulum.

**Review of the literature**

The standard pendulum appliance (Fig.1) was first described by Hilger[5] in 1992 and was later subjected to numerous modifies.[6, 7, 8, 9] The pendulum appliance was a hybrid that used a large Nance acrylic button in the palate for anchorage along with 0.032” preformed TMA springs that delivered a light, continuous force to the upper first molar without affecting the palatal button. Thus, the appliance produced a broad, swinging arc [pendulum] of force from the midline of the palate to the upper first molar. The recommendatory force magnitude was about 200g.-250g. The anterior portion of appliance was retained with premolar occlusally-bonded rests. These occlusally-bonded rests were acted as selective biteplane to discluded posterior occlusion that allowed maxillary first molar moved distally without occlusal interference.

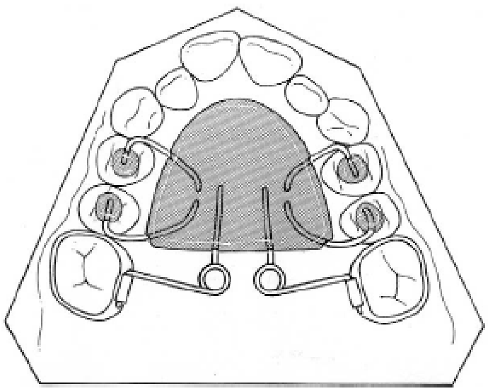

**Fig.1** standard pendulum appliance

## Dental movement from pendulum appliance

### Maxillary first molar movement

The amount of molar distalization was reported in several clinical studies.[10-19] Ghosh and Nanda[10] reported from 41 patients treated with standard pendulum, the amount of maxillary first molar moved distally was 3.4mm similar to Byloff and Darendelier' s result[11] found in 13 patients. Fuziy et al[19] reported from 31 patients using standard pendulum, the amount of maxillary first molar moved distally was 4.6 mm. Greater movement was found from Bussick and McNamara[13]'s study in 101 patients using standard pendulum, the amount of maxillary first molar moved distally was 5.7mm. Whereas, Joseph and Butchart[14] observed from only 7 patients using standard pendulum, the amount of maxillary first molar moved distally was 5.1mm. Similar result presented in Chaques-Asensi and Kalar's study[15] introduced in 26 patients using standard pendulum, the amount of maxillary first molar moved distally was 5.3mm.

In modified pendulum studies, the appliances were incorporated with molar uprighting bend[12] and both molar uprighting bend and distal screw was called as pendulum K.[16-18] Byloff and Darendelier[12] reported from 20 patients, the amount of maxillary first molar moved distally was 4.1mm. Kinzinger et al[16-18] conducted 3 studies in 36, 30 and 66 patients using pendulum K, the amount of maxillary first molar moved distally was 3.1, 3.9 and 3.5mm, respectively.

The distal tipping of maxillary first molar also simultaneously cooperated with its distal movement. In standard pendulum studies, Ghosh and Nanda[10] found tipping of maxillary first molar about 8.4° relative to SN plane. Byloff and Darendelier[12] observed tipping of maxillary first molar about 14.5° relative to palatal plane. Bussick and McNamara[13] examined tipping of maxillary first molar and found tipping of about 10.6° relative to Frankfurt horizontal plane. Joseph and Butchart[14] found tipping of maxillary first molar about 14.5° relative to palatal plane. Chaques-Asensi and Kalar[15] found tipping of maxillary first molar about 13.1° relative to SN plane. Fuziy et al[19] found tipping of maxillary first molar about 18.5° relative to Frankfurt horizontal plane.

In modified pendulum studies, Byloff and Darendelier[12] found tipping of maxillary first molar about 6.1° relative to palatal plane. However, Kinzinger et al[16-18] found less tipping of maxillary first molar of about 3.3°, 4.2° and 4.7° relative to palatal plane and 3.1°, 4.6° and 4.2° relative to SN plane, respectively.

The vertical movement of maxillary was reported as either extrusion and intrusion from previous studies. The extrusive changes of maxillary first molar were reported about 0.6mm [14, 16] and 0.4mm[18] relative to palatal plane. The intrusive changes were observed at approximately 1.7mm[11], 1.4mm[12], 1.2mm[15] relative to palatal plane however, in some studies, the small change were found as 0.1mm[10, 13] and 0.2mm[17]

Transverse changes of maxillary first molar were reported in some studies. Ghosh and Nanda[10] found only the intermolar width measured between mesio-buccal cusps, was increased about 1.4mm. Kinzinger et al[16] reported the increase of intermolar width measured between mesio-buccal cusps, central fossa and disto-buccal cusps about 2.1mm 1.8mm and 1.7mm, respectively. Kinzinger et al[18] reported the increase of intermolar width measured between mesio-buccal cusps, central fossa and disto-buccal cusps about 1.8mm 1.3mm and 1.2mm, respectively.

For rotational changes, Kinzinger et al reported some maxillary first molars rotation of about 5.2°[16] with 4.5°[18] on the right side, 4.3°[16, 18] on the left side indicated that molars were either mesio-buccal or disto-palatal rotated. However, when the transverse and rotational changes were incorporated, the results from Kinzinger's studies[16, 18] eventually indicated that molars were mesio-buccal rotated.

**Anchorage loss**

While maxillary molars were moved distally, the reciprocal force was applied to four maxillary premolars and anterior portion of hard palate followed by mesial movement the anchorage unit. In almost previous studies, anchorage loss were explained as the mesial movement and mesial tipping of maxillary premolars and incisors while the vertical changes of these teeth were also indicated. Ghosh and Nanda[10] found that maxillary first premolar moved mesially about 2.6mm, tipped 1.3° and also extruded 1.7mm, whereas the central incisor was proclined about 2.4°. Byloff and Darendeliler reported about 1.6mm[11] and 2.2mm[12] for mesial movement of maxillary first premolar, 0.8mm[11] and 1.4mm[12] for premolar extrusion, 0.9mm[11] and 1.5mm[12] for incisor mesial movement, about 0.5mm[11, 12] for incisor extrusion and 1.7° and 3.2° for incisor proclination. Bussick and McNamara[13] found that maxillary first premolar moved mesially about 1.8mm, mesial tipping 1.5° and also extruded 1.0mm. Joseph and Butchart[14] reported only the movement of maxillary central incisor, with mesial movement about 3.7mm and proclined by 4.9°. Chaques-Asensi and Kalar[15] presented that maxillary first premolar moved mesially about 2.2mm, tipped 4.8° and also extruded 1.2mm, whereas the central incisor was moved mesially for 2.1mm, proclined about 5.1° and 0.8mm extrusion. Kinzinger et al[17] found that maxillary first premolar moved mesially about 1.0mm and tipped 0.4°, whereas the central incisor was moved mesially for 2.1mm and proclined about 3.3°. Kinzinger et al[18] reported only the movement of maxillary central incisor, with mesial movement about 1.3mm and proclined by 3.1°. Fuziy et al[19] observed the maxillary first premolar moved mesially about 2.7mm with mesial tipped 2.5° and about 1.5mm for mesial movement of central incisor, 3.4° for central incisor proclination.

**Rate of molar distalization**

The rates of molar distalization by pendulum appliance were reported approximate 0.6-0.8 mm/month reported by various studies.[10, 11, 12, 13, 15, 19] Gianelly[20] stated there were two important factors when maxillary molar were distalized. First, maxillary first molars were easier to move distally before the eruption of second molars.[21] Second, the continuous forces could move teeth faster than intermittent forces.[22] Similarity to Kinzinger's conclusion[16], in case of both maxillary first and second molars were moved distally together by pendulum appliance, a longer treatment time and greater forces should be expected. However, Ghosh and Nanda[10] found that the eruption of maxillary second molars had minimal effect on first molar distalization.

**Wire properties**

The wire that regularly used as distal spring of pendulum appliance was beta-titanium; it was commercially available as TMA™ [Ormco corp, Glendola, Calif.]. Beta-titanium was first introduced by Burstone and Goldberg[23] in 1980. This wire was developed base on three important characteristics. First, a large springback, the ability that wire could be deflected over long distance without permanent deformation. At the same size, a beta-titanium wire could be deflected almost twice as much as stainless steel wire without permanent deformation, in other word, at the same range of wire deflection, beta-titanium also generated about half the amount of force as do comparable stainless steel wire.[23] Second, a stiffness and modulus of elasticity of this wire was lower than stainless steel wire that allowed beta titanium wire to fit into bracket slot while lower force was generated.[24] Finally, the good formability of beta-titanium wire allowed wire to bend as loops or stops. However, this wire should not be bended as sharp angle that caused wire fracture.[23] Due to low modulus of elasticity and high springback properties, the beta-titanium wire allowed to simplify mechanics and appliance designs by eliminating the need to placed loop or helices in the wire.[24]

For the multipurpose wire using in orthodontics, stainless steel wire was the one that used in various clinical applications. Because of its properties, high yield strength, high stiffness and high modulus of elasticity, stainless steel wire also generated high force compared to beta-titanium and nickel-titanium wire, but with particular wire bending, as loops and coils, incorporated with heat treatment could enhanced the elastic properties of the wire.[25] However, high stiffness was advantageous in resisting deformation caused by tractional forces.[26] The low springback and low stored energy properties of stainless steel wire implied this wire produced higher forces that dissipated over shorter periods of time than the titanium-based alloys [beta-titanium wire and nickel-titanium wire], thus requiring more frequent activations.[26]

Nickel-titanium [NiTi] alloy was first introduced for use in orthodontic in 1971.[27] Nickel-titanium alloy was divided into 3 subdivisions: conventional alloy and 2 superelastic alloys [pseudoelastic and thermoelastic].[28] A conventional nickel-titanium alloy was developed to exhibit a shape memory effect. However, this first 50:50 composition of nickel and titanium was a shape memory alloy in composition only. It was a passive martensitic-stabilized alloy that was capable of being deformed, clamped, heated, and cooled into a specified shape, so that when it was later deformed into a new shape and subsequently heated, the material remembered its previous post-heat treatment shape.[29] Nickel-titanium alloy had a low stiffness, large working range, and produce very low force however, limited formability, produce higher frictional forces and cannot be solder. The other 2 subgroups of superelastic alloy, pseudoelastic and thermoelastic, these alloys exhibited some form of shape memory effect and superelasticity. In pseudoelastic NiTi, at the constant temperature, the austenitic-to-martensitic phase transformation occurred with increasing applied force. As the force was subsequently removed, the reverse phase transformation occurred. For thermoelastic NiTi, described by when the temperature was decreased, the austenitic-to-martensitic phase transformation should be occurred. This phase transformation could be reversed by increasing the temperature to its original value. Clinical application for using superelastic NiTi wire to moved maxillary molars distally was reported by Locatelli[4] that using 0.018”x0.025” superelastic NiTi wire applied as “U-loop” with two stop on the buccal side of maxillary first molar and second premolar, the molars were moved with approximate rate of movement about 1 mm/month.

Burstone[30] described "variable modulus orthodontic" concept that was explained as "the overall stiffness of the orthodontic appliance" [S] was determined by "the wire stiffness" [Ws] and "design stiffness" [As] as represented by:

$$S = Ws \times As$$

Design stiffness [As] was dependent on factors such as interbracket distance and the incorporation of loops and coil into the wire. Changed in wire stiffness [Ws] could be brought about by altering the cross-sectional stiffness [Cs] and/or the material stiffness [Ms] as designed by the formula:

$$Ws = Ms \times Cs$$

The cross-sectional stiffness was determined by a cross-sectional property such as moment of inertia of the wire and the material stiffness was depended on the modulus of elasticity of the alloy. Therefore, an increase in appliance stiffness [S] could be brought about not only by changed in appliance design or increased in cross-sectional thickness of the wire, but also by selecting a material with a higher modulus of elasticity. The relationships of material stiffness for stainless steel, cobalt-chromium, nickel-titanium, and beta-titanium wires were in the ratio of 1:1.2:0.26:0.42.

**Objective**

This clinical study aim to apply nickel titanium wire and stainless steel wire as distal spring of pendulum appliance and to compare quality of tooth movement such as type of tooth movement, rate of movement and the loss of anchorage during tooth movement between pendulum appliance that using beta-titanium wire, nickel-titanium wire and stainless steel wire as distal spring.

**Hypothesis**

Pendulum appliance which using nickel-titanium wire and stainless steel wire as distal springs can move maxillary first molar distally with the distance, rate, type of molar movement, and affect the loss of anchorage comparable to beta-titanium wire.

**Significance of the study**

Treatment time could be reduced when nickel titanium wire is designed as active component of the pendulum.

Treatment cost could be reduced when stainless steel wire is used instead of TMA wire for distal spring of pendulum.

# CHAPTER 2

# RESERCH METHADOLOGY

A sample of 20 patients were randomly selected from the new patient pool at the postgraduate orthodontic clinic of Prince of Songkla university.

The inclusion criteria for the study are as follows:

- Bilateral Class II molar relationship [1mm different was allow]
- Skeletal class I or class II relationship with deep or normal vertical configuration
- Extraction or non-extraction treatment plan
- All of teeth [ central incisor to first molar ] in maxillary arch are presented and fully eruption
- Maxillary second and third molars were presented or not but just symmetrical for both sides of maxilla, in each patient.
- All patients and their parent(s) were advised for the purpose of this study. The patients and parent(s) were signed a consent form.

The exclusion criteria for the study are as follows:

- Patient who present bony pathologic lesion in maxilla
- In case of the maxillary first molar(s) were showed some unwanted movement, such as severe rotation, extrusion or very slow rate of movement that affect the treatment plan and treatment time.

Patients were randomly divided for two groups, 5 patients for group I and 15 patients for group II.

**Appliance design**

Two designs of pendulum appliance were used for each group of patient. All of the components of pendulum appliance used in this study, Nance acrylic button, stainless steel wire for occlusal rest on maxillary first and second premolars and 0.032” titanium molybdenum [TMA™; Ormco corp, Glendora, CA] for distal spring are the same as described by Hilger[5]. But in this study the one side of distal spring is made by 0.018”x0.025” heat activated nickel titanium [HANT] wire, NeoSentalloy F200™ [GAC, Islip, NY] that generated 200g force, (Fig. 2) or 0.018”x0.025” stainless steel [SS] wire (Fig. 3)

**Fig.2** Pendulum appliance with modified 0.018”x0.025” HANT spring [Lt. side]

For the HANT distal spring, the length of 0.018”x0.025” HANT wire, was estimated by the distance between the posterior border of Nance button that wire emerge from acrylic to the mesial aspect of lingual sheath on the new position that the maxillary first molar intend to place after distalization, add with the distance of wire that embedded in the Nance button and the another part that was inserted in the lingual sheath, 2mm was added for over correction. A stop was crimped 6 - 7mm away from distal end of HANT wire for inserting into the lingual sheath on first molar band.

**Fig.3** Pendulum appliance with modified 0.018”x0.025” SS spring [Lt.side]

For the SS spring, the shape of 0.018”x0.025” SS wire was bended as 0.032” preformed TMA™ [Ormco corp, Glendora, CA] that regular used for pendulum appliance and use as control in this study.

In group I, pendulum appliance which distal spring using 0.032” preformed TMA wires and 0.018”x0.025” HANT wires were compared (Fig.2). In group II, pendulum appliance which distal spring using 0.032” preformed TMA wire and 0.018”x0.025” stainless steel wires were investigated (Fig.3). The right or left maxilla’s side of each patient was randomly selected for each type of wire.

**Clinical management**

Maxillary first molars were separated, bands were tried and impression for pendulum appliance fabrication was taken. In the visit that pendulum appliance was fixed, the springs were pre-activated.

For 0.018”x0.025” HANT wire activation, The wire was activated by placing the distal end into the lingual sheath with deflected a part of wire that proximally to the stop as “S” curve and parallel to slope of the hard palate. (Fig. 4)

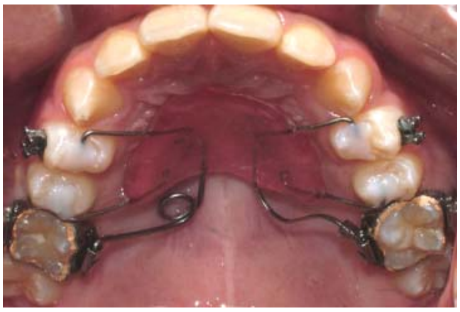

**Fig.4** Spring activation; 0.018”x0.025” HANT [Lt. side]

For TMA spring and SS spring pre- activation, the moving spring arm were activated about 45° and 60° respectively start from the initial angle, 60°, to exert force 200 g (Fig. 5). The force magnitude was confirmed by force gauge.

**Fig.5** Spring activation; Rt.: 0.032" preformed TMA / Lt.: 0.018"x0.025" SS

After spring pre-activation, pendulum appliance was fixed by using composite resin on occlusal surface of maxillary first and second premolars, and then maxillary first premolars were bonded with pre-adjusted edgewise brackets (Roth prescription) for wire jigs placement. Finally, the initial records [T1] were taken immediately [impression, lateral cephalogram].

All patients were recalled every 4 week for spring reactivation to maintain 200g of force [Except 0.018"x0.025" HANT wire]. The spring reactivation method was done as same as Hilger[5] described. Before spring reactivated, the remaining forces were measured and record. The springs were reactivated until obtain slightly class III [2 mm.] molar relationship, one side at least and then final record, T2 were taken [impression, lateral cephalogram]

**Cephalometric analysis for determining of maxillary first molar, first premolar and incisor movement**

All radiographs were taken with the same cephalostat (Orthophos® CD, Siemens, Germany). For each patient, lateral cephalogram films were taken two times. First [T1], immediately, after pendulum appliance was fixed. Second [T2], when obtain slightly class III [2 mm.] molar relationship on one side. Tooth positional locating devices [wire jig] were fabricated from sections of 0.016" x 0.022" stainless steel wires with different bend at the end to attach to the maxillary first molar tube and first premolar bracket before film exposure (Fig. 6) to identify right and left occlusion in lateral cephalogram. (Fig. 7)

**Fig.6** Wire jigs placement on right and left side of maxilla

**Fig.7** Wires jigs showed in lateral cephalogram

The radiographies were traced, superimposed and measured the parameters by one investigator. The amount of horizontal movement of maxillary first molars and first premolars were determined from superimposition of lateral cephalogram tracings on the pterygoid vertical plane [PTV], where as the vertical movement were determined from superimposition on the palatal plane [PP]. The long axis of the maxillary first molars and first premolars were obtained by drawing a perpendicular to the midpoint of a line connecting the most convex points on the crowns of these teeth. Angular difference in tooth position were determined by inclination of long axis of maxillary first molar, first premolar and central incisor to the palatal plane. All distance and angular parameters were described in Fig. 8. The rate of molar distalization were determined by the distances that maxillary first molars move distally (T1-T2) within 1 month compared between TMA and HANT in group I and between TMA and SS in group II.

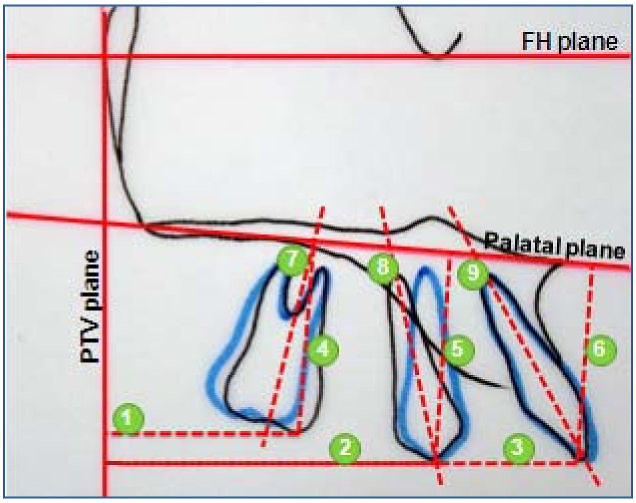


**Fig.8** Cephalometric analysis: dental linear and angular measurements:

1) 6 to PTV [mm.]; mesiobucal cusp of maxillary first molar to PTV
2) 4 to PTV [mm.]; bucal cusp of maxillary first premolar to PTV
3) 1 to PTV [mm.]; incisal edge of maxillary central incisor to PTV
4) 6 to PP [mm.]; mesiobucal cusp of maxillary first molar to PP
5) 4 to PP [mm.]; bucal cusp of maxillary first premolar to PP
6) 1 to PP [mm.]; incisal edge of maxillary central incisor to PP
7) 6 to PP [degree]; long axis of maxillary first molar to PP
8) 4 to PP [degree]; long axis of maxillary first premolar to PP
9) 1 to PP [degree]; long axis of maxillary central incisor to PP

**Dental cast analysis for determining of maxillary first molar rotational and transverse changes**

Rotational and transverse changes in maxillary first molar position were measured from the dental casts. For rotational change**,** mid-palatal suture and central groove of maxillary first molars were defined in dental cast. Imaginary line was duplicated from central groove of maxillary first molars to intersect mid-palatal suture line (Fig. 9). Angular measurement from T1 and T2 record were measured and compared for each side.

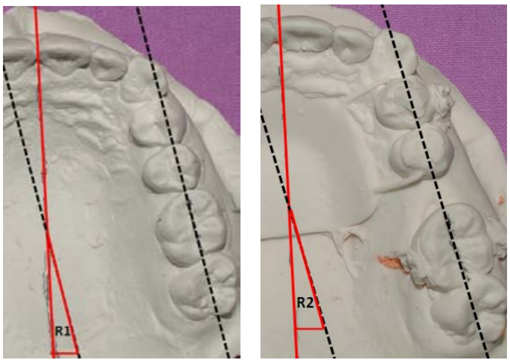


**Fig.9** Rotation measurement at T1 and T2

For transverse change, imaginary perpendicular line from central fossa of maxillary first molars to mid-palatal suture line were measured and compared between T1 and T2 record for each side (Fig.10)

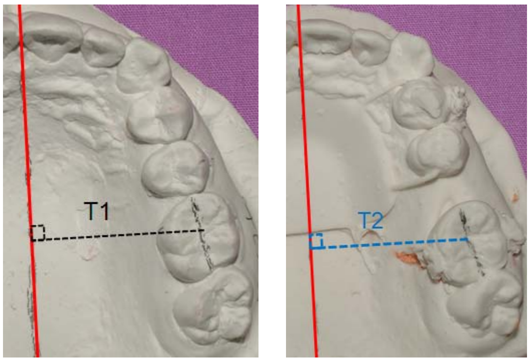


**Fig.10** Transverse measurement at T1 and T2

**Error of method**

All clinical measurements were analyzed by a single investigator. Another 10 dental casts and 10 cephalograms obtained at least 2 months later were arbitrarily picked for analysis. In accordance with Dahlberg, the accidental errors in duplicate measurements were calculated from the equation

$$S_x = \sqrt{\frac{\sum D^2}{2N}}$$

where $S_x$ is the error of the measurement, $D$ is the difference between duplicated measurements, and $N$ is the number of double measurements. The error in this study was found to be 0.20 mm for linear measurements, 0.30° for rotational angular measurements and 0.30° for tipping angular measurements.

**Statistical methods**

These data were statistically analyzed by using SPSS version 13.0 for windows. The results were shown as means ± standard deviations. After the parametric assumptions would be tested to see whether the variables were suitable for parametric tests, the differences between the 2 dependent measurements would be evaluated with pair *t*-test, an alpha significance level of 0.05.

# CHAPTER 3

# RESULTS

From the clinical observation in group I patients, who received the pendulum appliance using 0.018”x0.025” HANT as distal spring on one side of maxillary first molars showed unwanted tooth movement such as severe disto-buccal rotation, buccal expansion, palatal cusp extrusion and very slow rate of movement [Fig. 11] . The distal spring was redesigned but no improvement was noticed so the experiment in group I was discontinued. The pre-adjusted edgewise appliance was replaced to correct that side effect and to continue the treatment.

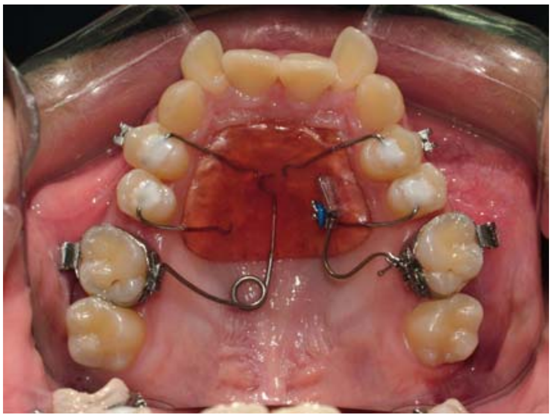

**Fig.11** Rotation and expansion of maxillary first molar in group I patient

Thus, in this chapter, only the results from group II patients, who received the pendulum appliance using 0.018”x0.025” SS and 0.032” TMA as distal springs were reported.

A total of 30 maxillary first molars for comparison from 15 patients; there were 1 male and 14 females, ranging in age from 10 to 32 years-old (mean 17.13 $\pm$ 5.99).

Table 1: Measurements [T1] compared between 0.018”x0.025”SS side and 0.032” TMA side, [*] $p$ = 0.05

| **Measurements [T1]** | **0.018”x0.025” SS** | **0.032”TMA** | **Sig.*** |
|---|---|---|---|
| **6-PTV [mm.]** | 27.77±4.20 | 27.73±4.09 | 0.98 |
| **4-PTV [mm.]** | 43.37±4.27 | 43.47±4.21 | 0.95 |
| **1-PTV [mm.]** | 62.70±4.18 | 62.70±4.18 | 1.00 |
| **6-PP [mm.]** | 22.60±1.98 | 22.73±1.90 | 0.85 |
| **4-PP [mm.]** | 25.17±2.89 | 25.17±2.51 | 1.00 |
| **1-PP [mm.]** | 27.07±3.71 | 27.07±3.71 | 1.00 |
| **6-PP [°]** | 80.00±7.28 | 80.87±6.34 | 0.73 |
| **4-PP [°]** | 96.03±5.35 | 97.53±5.22 | 0.44 |
| **1-PP [°]** | 121.23±10.80 | 121.23±10.80 | 1.00 |
| **Central fossa 6-Palatal suture [mm.]** | 23.43±0.62 | 23.37±0.67 | 0.78 |
| **central groove 6-Palatal suture [°]** | 14.00±2.40 | 13.93±3.31 | 0.95 |

Table 1 showed no statistically significant differences existed between SS and TMA sides at baseline [T1], indicating similarities between the two groups.

Table 2: Effect of treatment on the maxillary first molars, [*] $p = 0.05$

| Measurements [T1-T2] | 0.018”x0.025” SS | 0.032”TMA | Sig.* |
|---|---|---|---|
| **6-PTV [mm.]** <br> **{+:Distal, -:Mesial}** | 4.37±1.45 | 4.57±1.58 | 0.72 |
| **6-PP [mm.]** <br> **{+:intrude, -:extrude}** | -0.37±1.14 | -0.50±1.09 | 0.75 |
| **6-PP [°]** <br> **{+:Distal, -:Mesial}** | 8.63±5.31 | 10.97±7.34 | 0.33 |
| **Central fossa 6** <br> **-Palatal suture [mm.]** <br> **{+:decrease, -:increase}** | -0.80±0.53 | -0.83±0.52 | 0.37 |
| **central groove 6** <br> **- Palatal suture [°]** <br> **{+:MB, -:ML}** | 4.53±2.91 | 4.97±1.91 | 0.63 |

Effect of treatment on the maxillary first molars is presented in Table 2. Improvement in the molar toward Class I relationship with 2 mm overcorrection was recorded on both groups with the mean of 4.37 mm in SS group and 4.57 mm in TMA group with no significant difference between these 2 groups.

Vertical maxillary molar changes were very similar for the 2 groups with small extrusion (0.37 mm for SS group and 0.50 mm for TMA group). No significant differences between the 2 groups were apparent.

The superimposition showed more distal tipping in TMA group (10.97°) than that in SS group (8.63°). However, the difference between these 2 groups could not be statistically noticed.

The transverse change and rotation of the maxillary first molars in both groups are statistical comparable. Both groups showed 0.8 mm expansion with approximately 4-5°mesio-buccal rotation.

Table 3: Effect of treatment on the maxillary first premolars, [*] $p$ = 0.05, [**] significant different

| Measurements [T1-T2] | 0.018”x0.025” SS | 0.032”TMA | Sig.* |
|---|---|---|---|
| **4-PTV [mm.]**<br>**{+:Distal, -:Mesial}** | -0.50±1.32 | -1.60±1.31 | 0.03** |
| **4-PP [mm.]**<br>**{+:intrude, -:extrude}** | -1.07±1.27 | -0.90±1.69 | 0.76 |
| **4-PP [°]**<br>**{+:Distal, -:Mesial}** | -0.53±3.25 | -1.30±4.41 | 0.59 |

Effect of treatment on the maxillary first premolars is presented in Table 3. Only one parameter that showed statistically significant difference is 4-PTV (mm). The measurement explained that the maxillary first molars in SS side were moved mesially less than that in TMA side (0.50 mm for SS group and 1.60 mm for TMA group).

Similar to the vertical changes of the maxillary molars, the maxillary first premolars in both groups were also extruded with very small distance of 1.07 mm in SS group and 0.90 mm in TMA group. No significant differences between the 2 groups were found.

Mesial tipping of the maxillary first premolars was presented in both groups. SS side exhibited mesial tipping of 0.53° which was less than that of TMA side of 1.30°. However, there was no statistically significant difference was noticed.

Table 4: Effect of treatment on the maxillary incisors

| Measurements [T1-T2] | 0.018”x0.025” /SS0.032”TMA |
|---|---|
| **1-PTV [mm.] {+:Distal, -:Mesial}** | -0.40±1.31 |
| **1-PP [mm.] {+:intrude, -:extrude}** | -0.50±1.20 |
| **1-PP [°] {+:Distal, -:Mesial}** | -0.40±4.51 |

Effect of treatment on the maxillary incisors is presented in Table 4. Very small labial movement of 0.40 mm, labial tipping of 0.4° and extrusion of 0.50 mm were found.

Table 5: Activation time and rate of 6 distalization, [*] $p = 0.05$

| Measurements | 0.018”x0.025” SS | 0.032”TMA | Sig.* |
|---|---|---|---|
| **Time [mo.]** | 6.03±2.15 | 6.03±2.15 | - |
| **Rate of 6 distalization [mm/mo.]** | 0.80±0.31 | 0.83±0.31 | 0.80 |

The mean time period for spring activation was 6.03 months in both groups. Rate of maxillary first molar move distally was compared and test significant difference between two wires, no significant difference was found.

# CHAPTER 4

# DISCUSSIONS

**Why HANT pendulum spring cannot move the teeth in this study?**

According to Locatelli et al[4] in 1992, the 0.018”x0.025” superelastic NiTi wires that also generate 100g of force were applied as “U-loop” with two stops on the buccal side between maxillary second premolars and first molars for molar distalization. Maxillary first molars were moved distally at the rate of approximately 1mm/month while some anchorage lost was found. However, in our study, the 0.018”x0.025” HANT were applied as pendulum spring that force applied at the palatal side of crown and wire activation as “S-curve” with two stops, [one use the border of Nance button that wire emerged and the other using climpable stop at 4-5mm prior to the distal end of wire] same as above study but the difference were the distance between stop and the path of movement during wire deactivation. Locatelli recommended 5-6mm longer than space between bracket of second premolar and mesial aspect of first molar tube. In our study, the space between stops was estimated by the distance between distal border of Nance button that wire emerged to the mesial aspect of lingual sheath welded with the first molar band plus the amount of distalization. Thus, the length of wire in our study was longer than Locatelli’s study so that the wire had more flexibility. In Locatelli’s study the wire movement during deactivation was almost in A-P plane, caused the bracket slot level of second premolar and first molar tube was the same or nearly, so that molar was only pushed backward. But, in this study, the moving part of wire at deactivation phase were moved in three planes [A-P, transverse, and vertical], because of the discrepancy between level of lingual sheath on first molar band and level of HANT wire that emerged from Nance button, that allowed maxillary first molar movement in numerous directions.

**Stainless steel wire selection**

In this study, the size of SS wire using as spring was selected base on result from our pilot study. The objective of this pilot study was to find the size of SS wire and degree of spring activation to generate 200 g. of force. The pilot study was done by using three sizes of SS wire [0.016”x0.022”, 0.017”x0.022” and 0.018”x0.025”]. The SS wires were imitated the shape of 0.032” preformed TMA™ [Ormco corp, Glendora, CA] that regularly use for pendulum spring [Fig. 12]

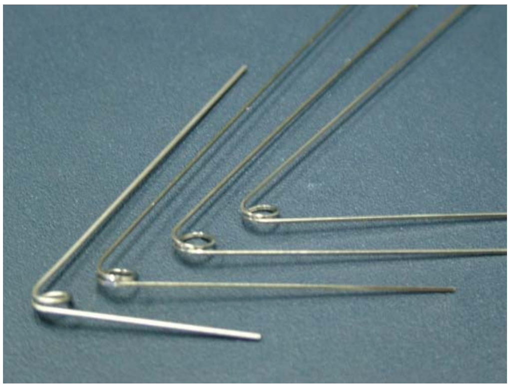

**Fig.12** The sizes and shape of SS wire used in pilot study

The SS and TMA springs were activated at five level [15°, 30°, 45°, 60°, 75°] started from initial angle, 60° [Fig. 13].

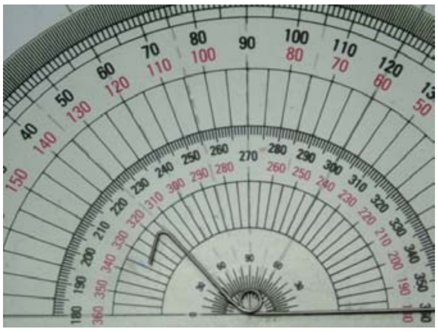

**Fig.13** Spring activation at 75°

After activation, springs were pulled back to the initial angle with force gauge [Fig 14]. The force magnitudes that used to pull back springs were recorded [Table 6].

**Fig.14** Force measurement after spring activation

Table 6: Force generate from spring at different level of activation [g.]

| **Angle of activation[°]** | **15** | **30** | **45** | **60** | **75** |
|---|---|---|---|---|---|
| **0.032" TMA** | 90 | 135 | 200 | 240 | 330 |
| **0.016"x0.022"SS** | 30 | 75 | 120 | 150 | 175 |
| **0.017"x0.022"SS** | 50 | 90 | 135 | 165 | 195 |
| **0.018"x0.025"SS** | 60 | 120 | 160 | 200 | 220 |

The result from Table 1 showed that 0.018"x0.025" was activated about 60° while 0.032" TMA was activated 45° to generate 200g of forces approximately.

**Maxillary first molar movement**

Distal movement of maxillary first molars in this study showed that SS group [4.37±1.45mm] was comparable to TMA group [4.57±1.58mm], with only 0.2mm differences. Due to the amount of force in both groups were at optimum level as adjusted for every month. The results of both groups were similar to the other studies that using TMA wire as spring, the means molar distalization were ranged between 3.4-5.7mm.[10-19]

Distal tipping of maxillary first molars found in SS group [8.63°] was less than TMA group [10.97°] but no significant difference found. The tipping movement caused by the forces was applied above to center of resistance that located about trifurcation of maxillary first molar. Similar trend to other studies, Ghosh and Nanda[10], Byloff and Darendeliler[11], Bussick and McNamara[13], Joseph and Butchart[14] and Chaques-Asensi and Kalra[15] found molar tipping about 8.4°, 14.5°, 10.6°, 15.7° and 13.1°, respectively. However, in some studies[12, 16, 17, 18] that distal spring modified with molar uprighting bend, distal tipping would not be eliminated and eventually presented about 6.1°, 3.3°, 4.2°, and 4.7° distal tipping, respectively.

Vertical changed of maxillary first molars in this study were slightly extruded in both groups [0.37±1.14mm. in SS group, 0.50±1.09mm. in TMA group]. The extrusion in this study might caused by the composite resin that fixed occlusal rest on the maxillary premolar. The composite resin acted as bite plane to discluded posterior occlusion to eliminated cusp interference while maxillary molar moved. So, maxillary molars might erupted to the space while move distally. However, the length of moving spring arm, the part of spring between coils and mesial aspect of lingual sheath welded with first molar band, might play the important role to allow the vertical change. In case of this length was the same or longer than the distance between lingual sheath and where the spring arm fixed in Nance palatal button. When intra-oral spring reactivation, the plane of moving spring arm might change and cause some molar extrusion. Whereas, if the length of moving spring arm was shorter than that distance, it might cause maxillary first molar intrusion or no changed in vertical relation. In previous studies, the various results were found, extrusion about 0.4-0.6mm[14, 16, 18] and intrusion about 1.2-1.7mm [11, 12, 15] and in some studies[10, 13, 17] the change was very small or no clinical significant.

For transverse changes, this result indicated that each maxillary first molar in both groups were expanded about 0.8 mm. relative to the palatal suture. These changes might cause by while maxillary first molars moved distally, they also moved to the wider part of dental arch too. This value was also comparable to Kinzinger studies[16, 18] that found some increased of intermolar width, 1.8 mm. and 1.3 mm, respectively. So, if these values were calculated per side, the values also showed approximately 0.9 mm. and 0.7 mm. respectively.

Rotational changes of maxillary first molars were also found in this study. The changed of central groove's axis relative to the palatal suture were calculated, about 4.5° and 5° by mean in SS group and TMA group, respectively. Unfortunately, these values could only indicate the rotational changed but could not prove the direction. These angular changes could only tell about the maxillary molars were mesio-buccal rotated or disto-palatal rotated or both.

Although, the force was applied palatal to center of resistance of the maxillary first molar would ordinary cause disto-buccal or mesio-palatal rotated, the arc described by the spring during its distal movement combined with rigidity of wire might causes a mesio-buccal or disto-palatal rotation instead. However, according to Kinzinger[16, 18] who incorporated this angular change with intermolar width [two measurements; between mesio-buccal cusp and between disto-buccal cusp] changes, the rotation were mesio-buccal rotated.

**Anchorage loss**

When maxillary molars were moved, the reciprocal force was delivered to anchorage unit of appliance that consisted of four maxillary premolars and pre-maxilla region included maxillary incisors. In previous studies, the anchorage loss was reported as mesial movement, mesial tipping and extrusion of maxillary premolars and incisor.

Form this study, maxillary first premolar in TMA group [1.6$\pm$1.3mm] was moved mesially more than SS group [0.5$\pm$1.3mm] with statistically significant different. In TMA group, the value was comparable with the other studies of 2.6mm [10], 1.6mm[11], 2.2mm, [12] and 1.8mm[13]. Whereas, SS group showed less mesial movement when compared to other studies that using TMA wire. These result indicated that the spring made form SS wire was created less anchorage loss than TMA wire. These might cause by SS wire had high load-deflection rate than TMA wire.[26] So, at the same initial force level, when springs were deactivated or molars were moved, the force remaining from SS wire would much less than TMA wire. In other word, TMA wire could generate more continuous force than SS wire.[23] Thus, after molars moved, the reciprocal force that applied to anchorage unit in SS group was less than TMA group. These followed by less mesial movement of maxillary first premolar in SS side.

The vertical changed of maxillary first premolars in this study, both groups were extruded and there was no significant difference between two groups, 1.07mm for SS group and 0.9mm for TMA group. When the direction of forces that initially applied to the maxillary first molar were considered, due to the arc movement of spring, maxillary molar also received distalization force combined with intrusive force. These action forces also generated reaction forces, which mesialized and extruded the anchorage unit. This result was quite similar to other studies that showed some extrusion of maxillary first premolar, about 1.7mm [10], 0.8mm[11], 1.4mm[12], and 1.0mm[13].

The mesial tipped of maxillary first premolar in TMA [1.30°+4.41] group was increased than SS group [0.53°+3.25] but not found statistically significant difference between groups. In TMA group, the result was quite similar to other studies, 1.3° [10] and 1.5°[13]. In SS group, just the same result as mesial movement, the value was less than TMA group in this study and previous studies. The explanation was the same, the remaining force when molar was moved in SS side was less than in TMA side so the reciprocal effected on anchorage unit of SS group was less than TMA group too.

The movement of maxillary incisor, in this study, the right and left central incisors in quadrant I and quadrant II could not be identified at the time when lateral cephalogram were taken. So, the measurements of maxillary incisor showed in chapter 3 between SS group and TMA group were the same values caused by the films were traced at the average position of two central incisors. The result from this study showed that the incisor was slightly mesialized [0.4±1.3mm.], proclined [0.4±4.5°] and extruded [0.5±1.2mm.]. These results showed also similar trend to Byloff and Darendeliler's studies[11, 12] that reported 0.9 mm. and 1.5 mm. of mesial movement, 1.7° and 3.2° for proclination, 0.45 mm. and 0.5 mm. for extrusion.

**The rate of maxillary first molar movement**

In this study, the mean time period during appliance activation between SS group and TMA group was the same. Because of when only one side of maxillary first was moved to the designed position the post-activation records [T2] were taken immediately. To estimated rate of molar distalization, the distance that each molars move distally was divided by treatment time in each patients. The result showed no significant difference between two groups, about 0.8 mm/month. A major factor that effected to the rate of tooth movement was the force magnitude. In this study, the initial force level was approximately 200g in both sides and then patients were recalled every 4 weeks for springs reactivated, to maintained about 200g force. However, from clinical observation, the remaining force before springs reactivated from SS side was less than TMA side in all patients, about 100-120g for SS group and 150-170g for TMA group. This result was supported our discussion that TMA springs were generated continuous than SS springs. To compare the rate of molar distalization from other studies, the initial force level was similar to our study, about 180-250g[10-19] but the activation methods were discriminated. Ghosh and Nanda[10] used only one time activation with 230g of force so that the rate of molar movement showed about 0.6mm/month. Kinzinger[17] used pendulum K, that combined distal screw as a part of distal spring, with spring pre-activation 180-200g of forces and spring reactivated by screw turning. The rate of molar movement showed about 0.75mm/month.

# CHAPTER 5

# CONCLUSION

The SS wire with particular size and bending can apply as distal spring of pendulum appliance with comparable rate and type of maxillary first molar movement, but created less anchorage loss than TMA wire. Although, TMA wire can generate more continuous force than SS wire, but at the low initial force level [200g in this study], after 1 month both, SS and TMA springs are need to be reactivated because the remaining forces, 100-120g for SS wire and 150-170g for TMA wire, are not enough to move molar distally.

The HANT wire cannot apply as pendulum spring in this study because the spring is too flexible and moves in three dimensions during deactivation period.

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# APPENDIX

# ใบเชิญชวน

ขอเชิญเข้าร่วมโครงการวิจัยเรื่อง การศึกษาเปรียบเทียบระหว่างลวดเบตาไททาเนียม (beta titanium), ลวดนิกเกิลไททาเนียม (nickel titatium), และลวดเหล็กกล้าไร้สนิม (stainless steel) ที่ใช้เป็นสปริงในการเคลื่อนฟัน (distal spring) ในเครื่องมือเพนดูลัม (pendulum)

เรียน ท่านผู้อ่านที่นับถือ

ข้าพเจ้า นายภาณุรัตน์ ลิมปศิริสุวรรณ ใคร่ขอเล่าถึงโครงการวิจัยที่กำลังทำอยู่ และขอเชิญชวนท่านเข้าร่วมโครงการนี้ โดยผู้วิจัยต้องการเปรียบเทียบผลของการเคลื่อนฟันกรามแท้ซี่ที่ 1 บนทั้งสองข้างไปทางด้านหลังโดยใช้เครื่องมือเพนดูลัม (pendulum) ที่ออกแบบเป็นพิเศษ โดยสปริงที่ใช้ในการเคลื่อนฟันทั้งสองข้างจะไม่เหมือนกัน ด้านหนึ่งจะใช้ลวดเบตาไททาเนียม (beta-titanium) เป็นสปริงในการเคลื่อนฟันเช่นเดียวกับที่ใช้ในเครื่องมือเพนดูลัม (pendulum) ทั่วไป และอีกข้างหนึ่งจะใช้ลวดนิกเกิลไททาเนียม (nickel-titatium) หรือลวดเหล็กกล้าไร้สนิม (stainless steel) เป็นสปริงในการเคลื่อนฟัน [ดังรูป]

โดยระหว่างการรักษาอาจจะมีการเปลี่ยนแปลงของการสบฟันบ้างเนื่องจากฟันถูกเคลื่อนไปจากตำแหน่งเดิมซึ่งถือว่าเป็นปกติสำหรับการจัดฟัน และคาดว่าด้านที่ใช้ลวดนิกเกิลไททาเนียม (nickel titatium) จะมีอัตราการเคลื่อนฟันที่เร็วกว่าทำให้สามารถลดเวลาในการรักษาลงได้ ในขณะที่ด้านที่เป็นลวดเหล็กกล้าไร้สนิมถ้าสามารถนำมาใช้เคลื่อนฟันได้ก็จะช่วยลดค่าใช้จ่ายในการทำเครื่องมือ ซึ่งจะเป็นประโยชน์ต่อผู้ป่วยเองและในการรักษาทันตกรรมจัดฟันแก่ผู้ป่วยรายอื่นๆต่อไป

<u>ความเสี่ยงที่ประชากรที่เข้าร่วมในโครงการวิจัยจะได้รับ</u>

ในขั้นตอนการสร้างเครื่องมือ เครื่องมือ เพนดูลัม (pendulum) ที่ใช้ในการทดลองนี้จะทำการออกแบบโดยเปลี่ยนจากการใช้แบนด์ (band) ที่ฟันกรามน้อยซี่ที่ 1 มาเป็นการใช้การยึดส่วนของลวดบนด้านบดเคี้ยวของฟันกรามน้อยบนซี่ที่ 1 และ 2 แทน ซึ่งจะทำให้ลดความเสี่ยงจากการทำอันตรายต่ออวัยวะปริทันต์ลงได้

ในขั้นตอนการเคลื่อนฟันกรามแท้บนไปทางด้านหลังด้วยเครื่องมือ pendulum เป็นเครื่องมือที่ใช้กันอย่างแพร่หลาย มีการศึกษาหลายการศึกษายืนยันว่าเครื่องมือชนิดนี้มีประสิทธิภาพในการเคลื่อนฟันกรามแท้บนซี่ที่ 1 ไปทางด้านหลัง และยังได้มีการศึกษาเกี่ยวกับการใช้ลวด nickel titanium ในการเคลื่อนฟันกรามแท้บนซี่ที่ 1 ไปทางด้านหลังพบว่าสามารถเคลื่อนฟันได้ด้วยอัตราเร็ว 1 มม. ในเวลา 1 เดือนซึ่งถือว่าเป็นอัตราเร็วที่เหมาะสม ในขณะที่ลวดเหล็กกล้าไร้สนิมก็เป็นลวดที่ใช้ประโยชน์ได้อย่างหลากหลายในทางทันตกรรมจัดฟัน เช่นการดึงฟันหน้าเพื่อลดการยื่นของฟัน

ในขั้นตอนของการเก็บข้อมูลนั้น ผู้เข้าร่วมวิจัยจำเป็นที่จะต้องได้รับการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง (lateral cephalogram) เพิ่มจากขั้นตอนการจัดฟันปกติจำนวน 2 ฟิล์ม ซึ่งได้มีการตีพิมพ์ข้อมูลเกี่ยวกับปริมาณรังสีที่ผู้ป่วยจะได้รับจากการถ่ายภาพรังสีด้วยวิธีการต่างๆ บริเวณกะโหลกศีรษะ พบว่าปริมาณรังสีจากการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง 1 ฟิล์มจะใกล้เคียงกับการถ่ายภาพรังสีภายในช่องปาก (periapical / bitewing) ซึ่งถือว่าเป็นการถ่ายภาพรังสีที่ใช้ในการวินิจฉัยโรคในช่องปากเป็นประจำอยู่แล้ว และจะน้อยกว่ามากเมื่อเทียบกับการถ่ายภาพรังสีนอกช่องปากด้วยวิธีอื่นๆ เช่นการถ่ายแบบ CT scan และเมื่อเปรียบเทียบกับการถ่ายภาพรังสีปอด (chest x-ray) จะพบว่าปริมาณรังสีที่ได้รับจากการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง (lateral cephalogram) จะน้อยกว่าประมาณ 10 เท่า และผู้เข้าร่วมวิจัยจะได้รับการใส่เสื้อตะกั่วทุกครั้งที่ถ่ายภาพรังสีเพื่อเป็นการป้องกันไม่ให้อวัยวะที่ไม่เกี่ยวข้องได้รับรังสีไปด้วย

<u>ถ้าท่านตัดสินใจเข้าร่วมในโครงการนี้จะมีขั้นตอนของการวิจัยที่เกี่ยวข้องกับท่านคือ</u>

ผู้ป่วยและผู้ปกครองของผู้ป่วยทุกคนที่เข้าร่วมโครงการวิจัย จะได้รับการอธิบายขั้นตอนการรักษา และมีความสมัครใจที่จะเข้าร่วมโครงการวิจัย จากนั้นจะถูกเคลื่อนฟันกรามแท้บนซี่ที่ 1 ไปทางด้านหลังด้วยเครื่องมือเพนดูลัม (pendulum) จนได้ระยะทางที่ต้องการตามแผนการรักษาที่วางไว้ จากนั้นจึงทำการรักษาด้วยเครื่องมือทันตกรรมชนิดติดแน่นตามขั้นตอนการรักษาตามปกติ โดยจะทำการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง (lateral cephalogram) เพิ่มจากขั้นตอนการจัดฟันปกติจำนวน 2 ฟิล์ม ครั้งแรกจะทำการถ่ายก่อนทำการเคลื่อนฟันกรามแท้บนซี่ที่ 1 ไป

ทางด้านหลังด้วยเครื่องมือเพนดูลัม (pendulum) และครั้งที่สองจะทำการถ่ายหลังจากเคลื่อนฟันด้วยเครื่องมือเพนดูลัม (pendulum) จนได้ระยะทางที่ต้องการ

**แบบยินยอมเข้าร่วมการศึกษา**

ข้าพเจ้า............................................ อายุ..........ปี อาศัยอยู่บ้านเลขที่........... หมู่ที่................
ถนน................. ตำบล..................... อำเภอ..................... จังหวัด.............................

ได้รับทราบถึงรายละเอียดของการศึกษาวิจัยเรื่องการเปรียบเทียบลวด beta-titanium ลวด nickel titatium และลวด stainless steel ที่ใช้เป็น distal spring ในเครื่องมือ pendulum

ผู้เข้าร่วมวิจัยจะต้องได้รับการถ่ายภาพรังสีกะโหลกศีรษะด้านข้างเพิ่มจากการรักษาปกติเป็นจำนวน 2 ฟิล์มโดยที่ผู้เข้าร่วมวิจัยจะได้รับการยกเว้นค่าใช้จ่ายในการถ่ายภาพรังสีส่วนเกินจากการรักษาปกตินี้

หากข้าพเจ้ามีข้อสงสัยประการใด หรือเกิดผลข้างเคียงจากการวิจัย สามารถติดต่อได้กับ ทพ. ภาณุรัตน์ ลิมปศิริสุวรรณ หรือ ผศ.ทพ. ไชยรัตน์ เฉลิมรัตนโรจน์ ได้ที่ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ หมายเลขโทรศัพท์ 074-429875, 287669, 287674 (ในเวลาราชการ) หรือหมายเลข
01-8763413 (นอกเวลาราชการ) หรือเมื่อมีปัญหาใดๆเกิดขึ้นเนื่องจากการทำวิจัยเรื่องนี้ ข้าพเจ้าสามารถร้องเรียนไปที่ คณบดี คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90110 หมายเลขโทรศัพท์
074-287510

หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษของการวิจัยนี้ ผู้วิจัยจะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็วโดยไม่ปิดบัง

ข้าพเจ้ามีสิทธิ์ที่จะของดการเข้าร่วมโครงการวิจัย โดยจะแจ้งให้ทราบล่วงหน้า โดยการงดเข้าร่วมโครงการวิจัยนี้จะไม่มีผลต่อการรักษาที่ข้าพเจ้าจะได้รับแต่ประการใด

ข้าพเจ้าได้รับทราบจากผู้วิจัยว่า จะไม่ปิดเผยข้อมูลหรือผลการวิจัยของข้าพเจ้าเป็นรายบุคคลต่อสาธารณชน

ข้าพเจ้าได้ทราบ และซักถามผู้วิจัยจนหมดข้อสงสัยโดยตลอดแล้ว และยินดีเข้าร่วมการวิจัยจึงได้ลงลายมือชื่อไว้เป็นหลักฐาน

กรณีผู้ที่บรรลุนิติภาวะแล้ว

ลงชื่อ..................................................ผู้ยินยอม

ลงชื่อ.................................................หัวหน้าโครงการ

ลงชื่อ..................................................พยาน

ลงชื่อ..................................................พยาน

**หรือ** ในกรณีที่ผู้ถูกทดลองยังไม่บรรลุนิติภาวะจะต้องได้รับการยินยอมจากผู้ปกครอง **ให้ผู้เกี่ยวข้องเซ็นชื่อดังนี้**

ลงชื่อ..................................................ผู้ยินยอม

ลงชื่อ..................................................บิดา/ผู้ปกครอง

ลงชื่อ..................................................มารดา

ลงชื่อ.................................................หัวหน้าโครงการ

ลงชื่อ..................................................พยาน

ลงชื่อ..................................................พยาน

# VITAE

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**Student ID** 4862012

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| Degree | Name of Institution | Year of Graduation |
|---|---|---|
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**Work-Position and Address**

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