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Original article

Biochemical and clinical comparisons of segmental maxillary posterior tooth distal movement between two different force magnitudes

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Summary

Background/objectives: Maxillary tooth distal movement is a treatment option for Class II malocclusion. This prospective clinical study (split-mouth design) was aimed to compare chondroitin sulphate (CS) levels in gingival crevicular fluid (GCF), the rates of tooth movement, and patient pain and discomfort during segmental maxillary posterior tooth distal movement using either 120 or 180 g of retraction force.
Materials and methods: Twenty patients (6 males and 14 females; aged 18.85 ± 4.38 years) with Class II malocclusion were recruited. The force magnitudes were controlled at 120 or 180 g, randomly assigned to either the right or left five-tooth segments. Gingival crevicular fluid samples were collected with Periopaper® strips. Competitive ELISA with monoclonal antibody was used to measure CS levels in GCF. The rates of segmental maxillary posterior tooth distal movement, and the amount of pain and discomfort were evaluated.
Results: The median CS levels during the segmental distal movement period were significantly greater than those before the segmental distal movement period ($P < 0.05$). At each 1-week period during segmental distal movement, the differences between the median CS levels induced by the two different force magnitudes were not significantly different. The rates of segmental distal movement induced by the two different force magnitudes were not significantly different. The mean visual analog scale scores for pain and discomfort with 180 g of retraction force was significantly greater than that with 120 g ($P < 0.05$).
Conclusions: One hundred and twenty grams of retraction force was sufficient to cause segmental distal movement, as indicated by biochemically assessed bone remodeling activity and a similar rate of tooth movement to that caused by 180 g of retraction force; it also produced less patient pain and discomfort.
Trial Registration: The study has been registered as TCTR20170728001.

Introduction

Class II malocclusion exhibits various sub-characteristic and phenotypic features due to its etiology, severity, and functional problems, so Class II treatment modalities may vary (1). In non-growing patients, maxillary posterior tooth distal movement is a treatment option to create space to solve the problem of insufficient space, to correct Class II malocclusion, and to decrease maxillary dentoalveolar protrusion and a large overjet. For single maxillary molar distal movement, force magnitudes vary. A force of 500 g has been suggested for cervical head gear usage, 230–250 g for the Pend-X appliance, 200 g for the Keles Slider, and 200 g for maxillary posterior tooth distal movement with sliding mechanics (2).

We postulate that, with low friction mechanics, 120 g of retraction force is sufficient for segmental maxillary posterior tooth distal movement (five teeth: canine, first premolar, second premolar, first molar, and second molar) as revealed by detectable biochemically assessed bone remodeling activity, a similar rate of tooth movement to that caused by 180 g of retraction force, with less patient pain and discomfort.

Our previous study implied a role for chondroitin sulphate (CS) levels in gingival crevicular fluid (GCF) as a biomarker for alveolar bone remodeling during orthodontic canine movement (3). Chondroitin sulphate comprises approximately 94 per cent of the total glycosaminoglycans in alveolar bone. The fact that a high concentration of CS is found in human alveolar bone suggests that alveolar bone is a major source of CS in GCF. Therefore, altered levels of CS in GCF are likely to reflect early changes in alveolar bone, which cannot be clinically observed (4–7).

In this study, we applied our patented monoclonal antibody, namely WF6, which recognizes an epitope of native CS chains of embryonic shark cartilage proteoglycans (8). This antibody has been used to examine CS levels in GCF samples from patients during orthodontic treatment to monitor the changes in CS levels (3, 9–10). The aim of this study was to compare CS levels in GCF, the rates of tooth movement, and patient pain and discomfort during segmental maxillary posterior tooth distal movement using either 120 or 180 g of retraction force.

Materials and methods

Subjects

Twenty patients (6 males and 14 females; aged 18.85 ± 4.38 years; range 14.17–29.17 years) with either class I (ANB = 2 ± 2°) or Class II (ANB > 4.0°) skeletal relationship were recruited. All patients met the following criteria: 1. Good general and oral health with a healthy periodontium, no radiographic evidence of bone loss, no gingival inflammation, and a probing depth of 3 mm or less around all teeth; 2. Lack of antibiotic therapy during the previous 6 months; 3. Absence of anti-inflammatory drug administration in the month preceding the study; 4. No pregnancy; and 5. Dental Class II tendency or Class II full-step malocclusion, requiring orthodontic treatment by maxillary posterior tooth distal movement with third molar extractions. All patients received repeated oral hygiene instruction, and the gingival health was controlled and maintained throughout the entire study. This study was approved by the Human Experimentation Committee, Faculty of Dentistry, Chiang Mai University, Thailand. Informed consent was obtained from all patients.

Experimental design

Forty segments of five maxillary posterior teeth from 20 patients undergoing distal movement were used as experimental teeth. Sample size was calculated with two dependent means (matched pairs), an effect size of 0.766 at a significance level of $\alpha = 0.05$ and power of test of $1\text{-}\beta = 0.8$, using G*Power (11). The calculation yielded at least 16 samples for each group. However, 20 samples per group were used in this study.

In all recruited orthodontic patients, if a maxillary third molar was present, the extraction was performed as soon as possible to let the healing process conclude before the experimental period to avoid the effect of the regional acceleratory phenomenon. All such extractions occurred more than 10 months before the experiment. In addition, under the inclusion criteria, samples that also had symmetrical needs (extraction or non-extraction on both sides) were chosen first, because if a tooth was extracted on only one side the bone consistency distal to the second molars would have been different on each side, and might have affected the rate of distal movement. And in our samples, only 2 of 20 required unilateral maxillary third molar extraction.

The experimental design was divided into two periods as follows (Figure 1):

Period I: leveling period (before segmental distal movement)

After general status assessment and informed consent, orthodontic direct bonded pre-adjusted brackets (Roth prescription slot 0.018 × 0.025 inches; 3M Unitek Inc., Monrovia, California, USA) were attached to both maxillary and mandibular teeth. The teeth were leveled and aligned using progressively larger wires until 0.016 × 0.022-inch stainless steel rectangular wire was used. The maxillary teeth were then allocated into three groups: right maxillary posterior teeth (right canine, first premolar, second premolar, first molar, and second molar), anterior teeth (four incisors), and left maxillary posterior teeth (left canine, first premolar, second premolar, first molar, and second molar). All teeth in each group were Figure 8 ligated by 0.012-inch round ligature wire in order to unite them as a segment (Figure 2). Care was taken to confirm that there was no remaining space between each tooth in the maxillary posterior segment. Then the passive posterior arch wires were inserted. The Gurin locks (Dental Morelli Ltda, Sorocaba, Sao Paulo, Brazil) were placed in front of the maxillary first premolar brackets in order to be used as the retraction point. The 0.016 × 0.022-inch stainless steel rectangular wire was used for the anterior arch wire, bent up at both ends and welded to the gingival slot of the rectangular double tube connector (Bat number B47779, American Orthodontics, Sheboygan, Wisconsin, USA) (Figure 3a and 3b) distal to the lateral incisors. The posterior arch wires were joined with the double tube connector and were free to move away though the occlusal slot (Figure 3c). This wire bending and welding design was aimed to decrease or to eliminate friction during segmental maxillary posterior tooth distal movement. The five posterior teeth were not moved along the arch wire, but were moved simultaneously and distally with the posterior arch wire. In addition, the anterior arch wire with the double tube connector was used to control the arch form, and to prevent buccal outward tipping of the posterior segment during the distal movement. Before segmental maxillary posterior tooth distal movement, the maxillary posterior teeth were left without any further activation for 60 days in order to intentionally allow alveolar bone remodeling activity to decrease.

Twenty eight days before segmental distal movement, two temporary anchorage devices (2.0 mm in diameter and 10.0 mm in length; Bio-Ray, Syntec Scientific Corporation, Chang Hua, Taiwan) were placed buccally at both right and left modified infrazygomatic crest sites in every patient to serve as skeletal anchorage (Figure 4). GCF was collected every 7 days from the maxillary canine, first

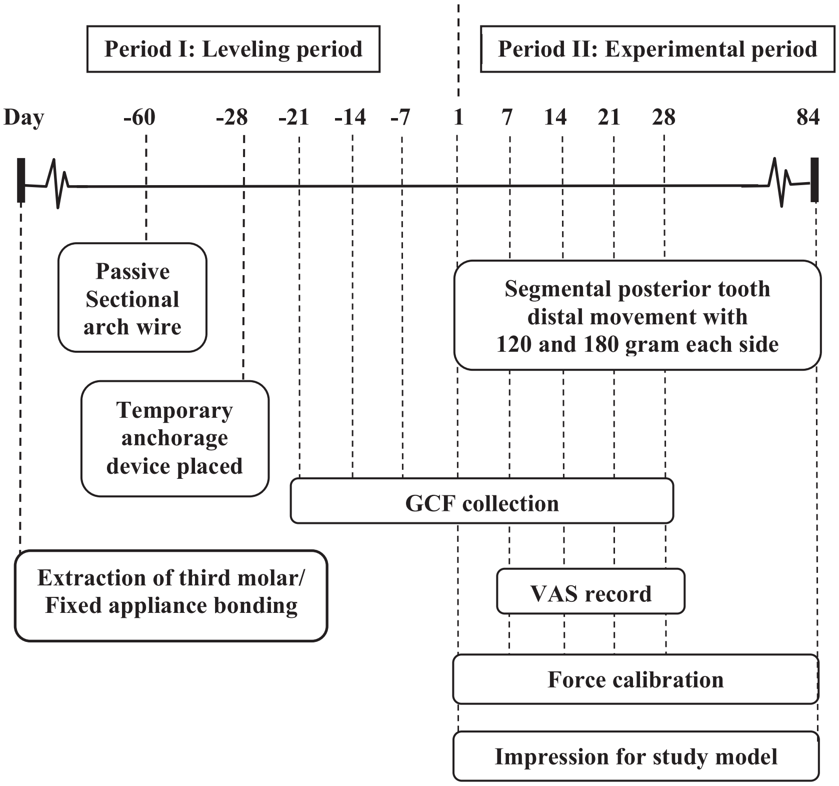

Figure 1. Timeline of the experimental design: in the leveling period, the passive sectional arch wires were placed and left without further activation for 60 days before the distal movement was begun, and the distal movement took place during the experimental period for an additional 84 days.

Figure 2. Maxillary posterior teeth were Figure 8 ligated in order to unite them as a group.

premolar, and second premolar beginning 21 days before segmental distal movement, as follows: after isolating the teeth with a cotton roll, supragingival plaque was removed without touching the marginal gingiva, and the crevicular site was gently dried with an air syringe (12). Periopaper® strips (ProFlow Inc., Amittyville, New York, USA) were placed into the distal gingival sulcus of the teeth until light resistance was felt (Figure 5). Care was taken to avoid mechanical injury to the periodontal tissue. Strips contaminated with blood or exudates were discarded. Immediately after collection, two millimeters of the wetted area of the strips were cut and transferred to microcentrifuge tubes. All strips were stored at −80°C until further processing (Days −21, −14, −7, and 1).

On the day that segmental distal movement was begun, after GCF collection, a study model of the maxillary teeth of each patient was fabricated to record the dental position. The model was then scanned to obtain a digital model using a 3Shape desktop scanner at the Hexa Ceram Dental Lab, Chiang Mai, Thailand.

Period II: the experimental period (during segmental distal movement)

On the day that segmental distal movement was begun, after GCF collection and model fabrication, Nickel–titanium closed coil springs (OrthoForce® TAD springs, G4™ NiTi, size C2, G&H Wire company, Franklin, Indiana, USA) were used. The distal end of the spring was tied to the head of the temporary anchorage device. The ligature wire was tied at the mesial end of the spring. Then the spring was pulled mesially 17.5 mm to generate a retraction force of 120 g and the ligature wire was tied to the Gurin lock anterior to the first premolar bracket in order to generate light continuous force for segmental maxillary posterior tooth distal movement (Figure 6). On the maxillary counterpart posterior segment, the spring was pulled mesially 27.0 mm to generate a retraction force value of 180 g. The ligature wire was tied to the Gurin lock in a similar manner.

The GCF collection was continued every 7 days for 4 weeks after loading to monitor the remodeling activities of alveolar bone on both sides. The recalibration of force magnitude was, in addition, performed using a force strain gauge (Dentaurum, Ispringen, Germany) for 120 and 180 g every seven days during the experimental period and every 4 weeks for 12 weeks after segmental distal movement. The maxillary models were fabricated and scanned to record the dental positions after segmental distal movement.

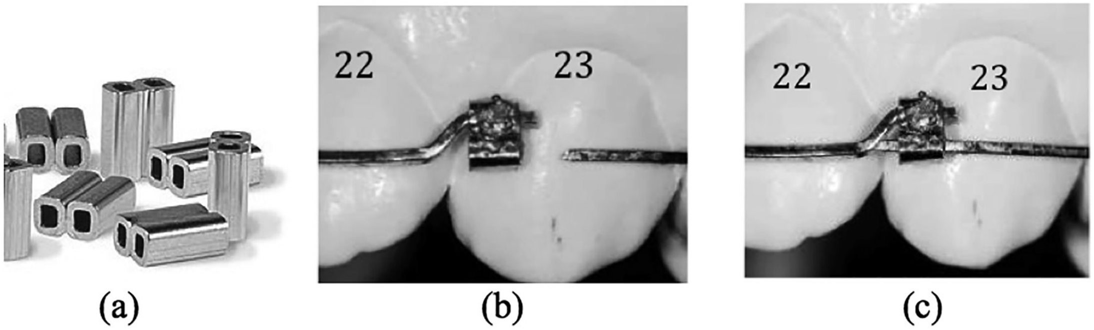

Figure 3. (a) Rectangular double tube connector; (b) rectangular double tube connector welded to distal end of anterior sectional arch wire; (c) mesial end of posterior sectional arch wire inserted through occlusal slot of double tube connector.

Figure 4. Intra-oral photographs after maxillary segmental arch wire with temporary anchorage devices (before segmental distal movement).

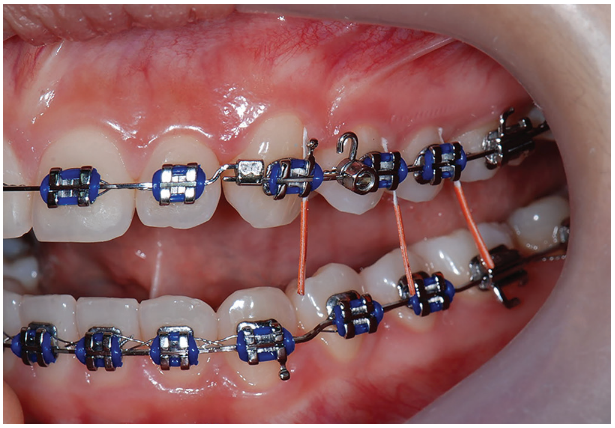

Figure 5. GCF collection around maxillary canine, first premolar and second premolar using Periopaper® strips placed into distal gingival sulcus before segmental distal movement.

Rates of segmental maxillary posterior tooth distal movement

The distances from the cusp tip of the maxillary canine to the head of the temporary anchorage device were measured using ImageJ software (National Institutes of Health, Bethesda, Maryland, USA). The differences between these distances before segmental distal movement (Day 1; Figure 7a) and Day 84 post segmental distal movement (Figure 7b) were measured and calculated as the rates of segmental maxillary posterior tooth distal movement (revealed by maxillary canine distal movement) within a 12-week period (mm/12 weeks). The intra-observer calibration, calculated using the Intraclass Correlation Coefficient (ICC), was 0.989 ($P < 0.05$).

Protocol for temporary anchorage device placement

The patients' mouths were rinsed with 0.02% chlorhexidine mouthwash, and topical iodine tincture was applied to the gingival tissue for infection control and surface contamination prevention. Under local anesthesia, both right and left temporary anchorage devices were placed 1.0–1.5 mm apical to the mucogingival junction perpendicular to the contact point between the maxillary first molar and maxillary second molar teeth. Initially, the insertion direction was perpendicular to the surface mucosa. The insertion angle of the temporary anchorage devices axis in relation to the occlusal plane was gradually increased to 60–70 degrees, in order to achieve greater contact between the bone and temporary anchorage device, as well as better and greater bone quality and quantity to reduce the risk of root surface damage. Both temporary anchorage devices were then monitored for four additional weeks before orthodontic loading.

Competitive ELISA with WF6 monoclonal antibody

Microtiter plates (Maxisorp®, Nunc, Roskilde, Denmark) were coated overnight at room temperature with 10 µg/ml shark PG-A1 fraction (100 µl/well) in a coating buffer (20 mM sodium carbonate buffer, pH 9.6). The following morning, the plates were washed three times with PBS-tween 150 µl/well and dried. Bovine serum albumin (BSA) 1% (w/v) 150 µl/well was added to all plates in the incubating buffer for 60 minutes at 37°C to block non-specific adsorption of other proteins to the plate. After washing, 100 µl/well of the mixture, sample or standard competitor (Shark PG-AlDl fraction: range 39.06–10 000 ng/ml) in mAb WF6 (1:100), were added. After incubation for 60 minutes at 37°C, plates were washed and then the IgM-specific peroxidase conjugated anti-mouse immunoglobulin (100 µl/well; 1:2000) was added and incubated for 60 minutes at

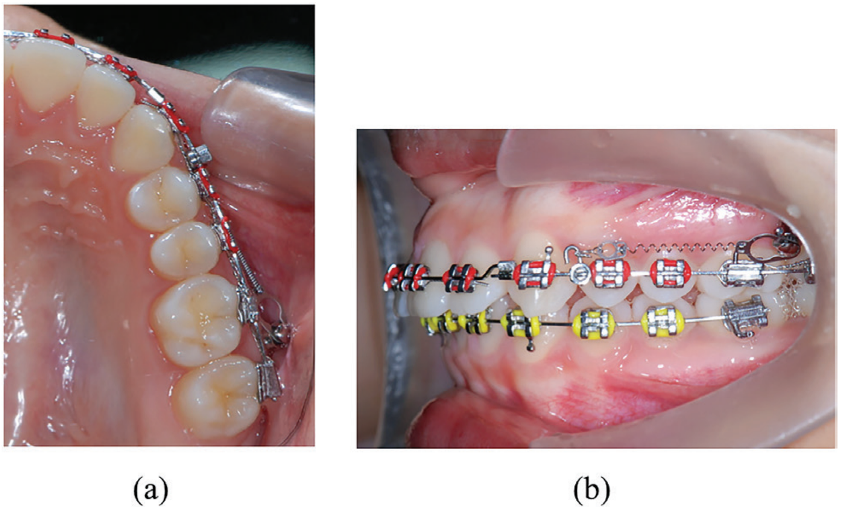

Figure 6. Nickel–titanium closed coil spring connects temporary anchorage device head and the Gurin lock anterior to first premolar bracket to generate continuous force for the segmental maxillary posterior tooth distal movement; (a) occlusal view and (b) buccal view.

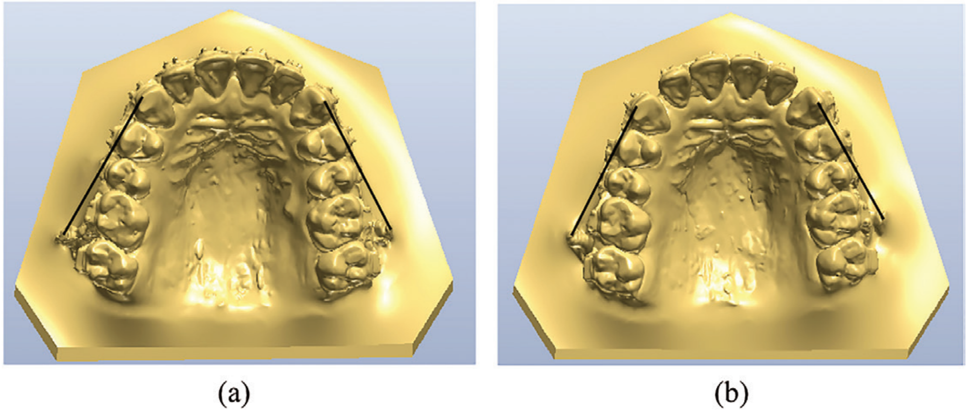

Figure 7. The distances from the cusp tip of maxillary canine to the head of the temporary anchorage device were measured (Sample No. 4): (a) distance measurement on model before segmental distal movement, (b) segmental distal movement created a space between laterals and canines; so, the distances on the model after segmental distal movement model were shorter than those on the model before segmental distal movement. The shortened distances were then used to calculate rates of tooth movement. In the case of the plateau on the canine cusp tip (for example in the right maxillary canine), the point of intersection between the labio-incisal line angle and the labial-ridge line angle was used as the reference point.

37°C. Then, the plates were washed again. After that, the peroxidase substrate (100 µl/well) was added and incubated at 37°C for 20 minutes to allow the color to develop. The reactions were stopped by the addition of 50 µl/well of 4M H_2SO_4. Eventually, the absorbance ratio at 492:690 nm was measured using a Titertek Multiskan® MCC/340 multiplate reader (ICN/Flow Laboratories, Costa Mesa, California, USA). Pertaining to the blinding of the outcome assessment to obliterate bias, the sample identification code was given, and confidentially kept until all data had been analyzed.

Protein assay

Total protein concentration was determined using the Bio-Rad protein assay (Bio-Rad Laboratories, Hercules, California, USA), based on the Bradford dye-binding procedure. It was a simple colorimetric assay for measuring total protein concentration. The Bio-Rad protein assay was based on the color change of Coomassie Brilliant Blue G-250 dye in response to various concentrations of protein. The dye bound to primarily basic (especially arginine) and aromatic amino acid residues. Bovine serum albumin standards (0–1000 µl/well) and samples were added to the microtiter plates (10 µl/well) in triplicate. Dye Reagent concentration and deionized distilled water were mixed together (1:4) and added to each well (200 µl/well). The plates were incubated at room temperature for 5 minutes and the absorbance was measured at 620 nm. Protein concentrations were determined from a standard curve.

Evaluation of patient pain and discomfort

Visual analog scale (VAS) scores were used to evaluate the patient pain and discomfort experience. The patients rated their pain or discomfort on a linear scale from 0 (absence of pain or discomfort) to 10 (worst possible or unbearable pain). They were asked to indicate their perceptions of pain or discomfort for each side with a 2-minute resting interval between each request. They were asked to raise their right hand, touch their right cheek to indicate the side in question, and record their pain perception of the segmental distal movement on the right side. Then they were asked to rest for 2 minutes, raised their left hand, touch their left cheek, and record their pain perception on the left side. This evaluation was performed on Days 7, 14, 21, and 28 during segmental distal movement.

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences version 17.0 for Windows (SPSS Inc., Chicago, Illinois, USA). The Kolmogorov–Smirnov test was used to determine the distribution of CS levels, the rates of segmental maxillary posterior tooth distal movement (revealed by maxillary canine distal movement) and VAS scores for patient pain and discomfort. The Wilcoxon signed-rank test was used to determine the differences in the median CS levels before and during the segmental distal movement. The differences in CS levels between the two different force magnitudes (120 and 180 g) during each 1-week experimental period were determined using the Mann–Whitney *U*-test. The difference between the mean rate of segmental maxillary posterior tooth distal movement with 120 g and that with 180 g of retraction force was determined using the Independent-*t*-test. The differences in VAS scores for patient pain and discomfort between the two levels of force magnitude (120 and 180 g) during each experimental period were determined using the Mann–Whitney *U*-test. The results were considered statistically significant at $P < 0.05$.

Results

All patients had good oral hygiene, and had no clinical signs of gingival or periodontal inflammation, especially on the experimental teeth, implying that patient oral hygiene was well controlled throughout the study.

CS levels in GCF around experimental teeth during segmental distal movement

Before segmental distal movement, the median CS levels around the experimental maxillary canines, first premolars, and second premolars, all of which were loaded with 120 g of retraction force, were 8.62 (0.33–27.25), 7.06 (0.83–28.81), and 4.19 (0.28–24.97) ng/μg of total protein, respectively (Figure 8). The median CS levels around the experimental teeth, which were loaded with 180 g of retraction force, were 6.48 (0.33–19.13), 4.16 (0.56–25.08), and 6.48 (0.24–28.25) ng/μg of total protein, respectively. There were no statistically significant differences in median CS levels for each tooth type between these two groups. During the 28 days after segmental distal movement, the median CS levels around the experimental canines, first premolars, and second premolars, which were loaded with 120 g of retraction force, were raised to 18.46 (3.9–58.96), 11.37 (3.9–43.88), 11.08 (3.65–35.13) ng/μg of total protein, respectively, and were significantly greater than those before segmental distal movement. Whereas the median CS levels around the experimental teeth that were loaded with 180 g of retraction force, were raised to 13.98 (5.3–58.96), 13.05 (3.73–40.28), and 9.5 (1.16–29.55) ng/μg of total protein, respectively, the CS levels of only the canines and first premolars were significantly greater than before segmental distal movement. On the other hand, the median CS levels around the experimental teeth that were loaded with 120 g of retraction force, and those that were loaded with 180 g of retraction force were not significantly different.

Rates of segmental distal movement induced by two different force magnitudes

The rates of segmental distal movement induced by either 120 or 180 g retraction force were 1.33 (0.27–3.23) and 1.41 (0.47–2.95) mm/12 weeks (0.44 and 0.47 mm/month), respectively, and were not significantly different ($P = 0.77$; Table 1).

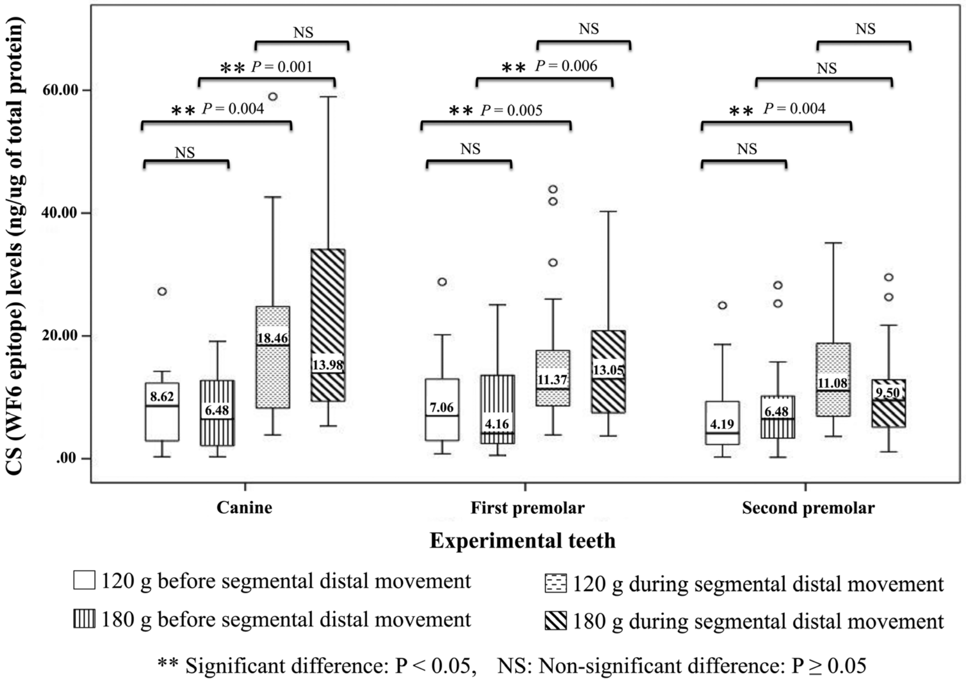

Figure 8. Boxplot graph of chondroitin sulphate (CS; WF6 epitope) levels around the experimental maxillary canines, first premolars and second premolars before segmental distal movement and during segmental distal movement (with 120 and 180 g of retraction force). Boxes represent values from the 25th to the 75th percentile. Middle lines represent medians. The vertical lines extend from the minimal to the maximal values, excluding the outliers, marked with small open circles. Data points that were located more than 1.5 times the interquartile range above the upper quartile or below the lower quartile were regarded as outliers.

Table 1. Minimum, maximum, and mean rates of segmental distal movement (mm/12 weeks) induced by two different force magnitudes.

	Rates of segmental distal movement (mm/12 weeks)		
Force magnitudes	Minimum	Maximum	Mean ± SE
120 g	0.27	3.23	1.33 ± 0.19
180 g	0.47	2.95	1.41 ± 0.15
P value			0.770

Significant difference: $P < 0.05$.

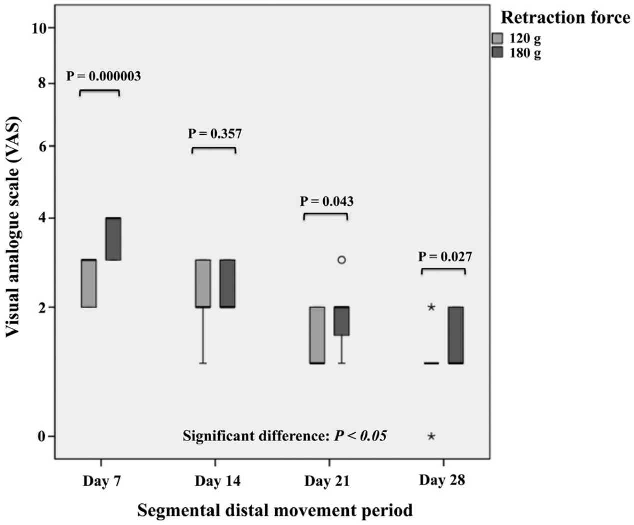

Figure 9. Box plot graph of median VAS score distributed by either 120 or 180 g of retraction force during segmental distal movement.

Patient pain and discomfort induced by segmental distal movement

The mean VAS scores on Days 7, 14, 21, and 28 after segmental distal movement, induced by 120 g of retraction force were 2.55 (2.0–3.0), 2.15 (1.0–3.0), 1.45 (1.0–2.0), and 1.00 (0.0–2.0), respectively, and those induced by 180 g of retraction force were 3.65 (3.0–4.0), 2.35 (2.0–3.0), 1.80 (1.0–3.0), and 1.30 (1.0–2.0), respectively. The mean VAS scores were significantly lower with 120 g of retraction force on Days 7, 21, and 28 after segmental distal movement (Figure 9).

Discussion

Our novel low-friction mechanics for maxillary posterior tooth distal movement may be useful in treating adult patients with Class II malocclusion with an aesthetic profile and anterior crowding due to mesial migration of the posterior segment. In such cases, extractions of premolars should be avoided (if possible) in order to maintain an aesthetic patient profile. The space created by the third molar extraction can be used for segmental maxillary posterior tooth distal movement with our novel low-friction mechanics.

The importance of force magnitude in relation to tissue reaction during orthodontic tooth movement has been extensively investigated (13–20). With friction due to sliding mechanics, our previous study suggests that 70 g of retraction force is sufficient for single maxillary canine distal movement (3). Two hundred grams of retraction force is sufficient for group distal movement (2). Moving teeth with a force magnitude of less than 200 g may be possible, provided that the friction is eliminated. With our novel low-friction segmental arch wire mechanics, the 180 g of retraction force was selected to be the upper limit, and the 120 g the lower limit. However, tipping of posterior maxillary teeth was found in some samples. Because we selected a smaller diameter posterior sectional arch wire (a 0.016 × 0.016 inch stainless steel wire) to reduce friction in the double tube connector during distal movement, we considered the posterior arch wire to be strong enough to control the arch form but may not have been stiff enough to control tipping in some cases. Such tipping should be the subject of a further investigation.

It should be noted that our research design was different from those of some previous studies (3, 9–10). In this study, the experimental teeth were orthodontically leveled and aligned before segmental distal movement in order to eliminate confounding factors, such as undesired force distribution, and poor integrity during tooth movement. Teeth subjected to orthodontic loading unavoidably resulted in biochemical changes, especially the CS levels in GCF. Accordingly, after inserting passive segmental archwires, the well-aligned segmental maxillary posterior teeth were left without reactivation for 60 additional days before distal movement, to allow stresses and stains in the periodontal tissue to decrease before beginning the segmental distal movement (21–23), because very small changes in pressure can induce the biologic responses necessary for the induction of bone turnover. A minute force, leading to a minute change in pressure, might be able to switch on tooth movement (15).

A cyclical pattern of alveolar bone remodeling has been reported, as revealed by CS levels in GCF, even when a continuous orthodontic force has been applied (3). Both force magnitudes (120 and 180 g) are within the optimal range for stimulation of osteoclast activity, resulting in alveolar bone remodeling, and segmental maxillary posterior tooth distal movement.

The rates of tooth distal movement of five maxillary posterior teeth (canine, first premolar, second premolar, first molar, and second molar) in our study ranged from 0.27 to 3.23 mm (with 120 g of retraction force), and from 0.47 to 2.95 mm (with 180 g of retraction force). The rates were slightly less than the rate of tooth distal movement reported in previous studies (2, 3, 14, 15, 17, 24, 25). It should be noted that, with our simultaneous posterior tooth distal movement, overall orthodontic treatment time might be decreased.

Our investigation shows that both 120 and 180 g of retraction force was sufficient to trigger the alveolar bone remodeling activity for segmental maxillary posterior tooth distal movement as shown by the raised CS levels. However, the rate of tooth movement resulting from 180 g of retraction force was not significantly greater than that resulting from 120 g. But the rate of tooth movement might be individualized, and might not be associated with the force magnitude. This fact concurs with the findings of studies by the Nijmegen group pertaining to the relationship between force magnitude and rate of tooth movement (26–29).

Although the VAS scores for patient pain and discomfort resulting from 120 g of retraction force were significantly lower than those from 180 g, it should be noted that the degrees of pain, as revealed by the scores, were relatively low. This finding shows that, with low-friction mechanics, the low force magnitude was sufficient and preferable.

Although both 120 and 180 g of orthodontic force are within the optimal range, we propose that 120 g is more suitable than 180 g because there was no difference in biochemically assessed bone remodeling activity or rate of tooth movement, and patient comfort was better with 120 g. However, this study did not evaluate the amount of root resorption produced by the two amounts of retraction force and it should be the subject of a further investigation.

Conclusions

With low-friction mechanics either 120 or 180 g of retraction force is enough for segmental maxillary posterior tooth distal movement, as revealed by biochemical assessment of alveolar bone remodeling using CS levels in GCF around moved teeth. The rates of segmental maxillary posterior tooth distal movement induced by either 120 or 180 g were 0.44 and 0.47 mm per month, respectively. The difference between the rates of movement was not statistically significant. The VAS scores for patient pain and discomfort induced by 180 g were significantly higher than those induced by 120 g of retraction force. One hundred and twenty grams of retraction force is sufficient for segmental maxillary posterior tooth distal movement with low-friction mechanics.

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Conflicts of Interest

None to declare.

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