Impact of retraction force magnitudes on mobility of maxillary canines: a split-mouth design

Nehal F. Albelasy* and Yasser L. Abdelnaby

Abstract
Objective: Prospective evaluation of the maxillary canine mobility during retraction using two different force levels over 5 months of retraction.

Materials and methods: Thirty patients indicated for maximum retraction of maxillary canines with age range of 14.7–18.9 years were included in the study. After complete leveling and alignment and immediately before canine retraction, the mobility of the maxillary canines was measured using the Periotest device and repeated monthly. A split-mouth design was applied where on the one side, the retraction force was 100 g, while on the other side 200 g of force. Four subgroups were investigated: A1 (R3 100 g), A2 (L3 200 g), B1 (R3 200 g) and B2 (L3 100 g). The total amount of canine retraction was measured for each side using the pre- and post-retraction dental casts.

Results: The collected data were normally distributed. ANOVA test showed insignificant statistical difference in Periotest values (PTVs) among the four subgroups pre-retraction and monthly \( p > 0.05 \). However, each group showed a statistically significant difference in PTVs over the 5 months. The independent sample \( t \) test showed a statistical insignificant difference in PTVs between the 100 g and 200 g retraction force. Pearson correlation of the PTVs to the period of retraction was statistically significant \( p < 0.05 \) while being in significant to the retraction force \( p > 0.05 \).

Conclusion: Increasing the retraction force of maxillary canines up to 200 g of force does not significantly increase the teeth mobility during orthodontic treatment. There is a positive correlation between the PTVs and the duration of tooth movement regardless the magnitude of force.

Keywords: Canine retraction, Canine mobility, Retraction force, Periotest, PTVs

Introduction
The supporting structure of the tooth "periodontium" includes the gingiva, alveolar bone, cementum and periodontal ligaments (PDLs). The PDL is a thin collagen membrane that transmits applied forces on the crown to the surrounding alveolar bone. According to Schwartz [1], upon application of the orthodontic force, the PDL is folded on the compression side and stretched on the tension side with resultant bone resorption and deposition.

However, it has recently been demonstrated that the distribution of compressive and tensile strains in the periodontal tissues is more complex than initially believed [2]. This remodeling process is repeated resulting in a reduced stiffness of the PDL and increased tooth mobility with movement of the tooth along the direction of the orthodontic force [3]. It has been settled that force magnitude is one of the factors that determine the extent of the hyalinization areas.

In the past, most researchers claimed that a range of force magnitude results in a maximum rate of tooth movement, while below this range little movement occurs and above this range tooth movement is slowed.
down [4]. According to Quinn [5], most clinical strategies
to move teeth were based on the assumption that rate of
movement is sensitive to changes in force magnitude and
for a given tooth there is a force that will move that tooth
at a maximum rate. More recent studies have shown that
no correlation was found between force magnitudes and
tooth movement [6, 7].

Tooth mobility is one of the methods for assessing
the biomechanical characteristics of the PDL [8]. Tooth
mobility is also affected by the remodeling process of
the PDL, the anatomical variations in the PDL space and
alveolar bone height. The primary outcome of this split-
mouth designed study was to compare the effect of using
two force magnitudes on mobility of maxillary canine
during retraction. The secondary outcome was to meas-
ure the resultant total amount of canine retraction done
utilizing these force magnitudes.

Materials and methods
The present study was conducted on 30 consecutive
patients (22 females, 8 males) with the age range of
14.7–18.9 years and diagnosed for class II division 1 mal-
occlusion or bimaxillary protrusion without crowding
in the maxillary arch who were indicated for extraction
of maxillary first premolars. The exclusion criteria were
established as existence of periodontal diseases, bone
resorption or inability to maintain good oral hygiene. The
Research Ethics Committee of the Faculty of Dentistry,
Mansoura University, Egypt approved the study proto-
col. All the patients were informed of the procedures and
signed the informed consent.

The patients were hierarchically distributed with 1:1
allocation ratio for groups A and B. In group A, the right-
side canine was retracted by 100 gm of force and the left
side by 200 gm, where in group B, the right-side canine
was retracted by 200 gm of force and the left side by
100 gm.

All patients were treated with fixed metal orthodontic
appliance of Roth prescription: 0.022-inch slot size brack-
ets. Leveling and alignment were done utilizing different
sequence of arch wires following the extraction of maxil-
lar first premolars. Orthodontic miniscrews of 1.6 mm
diameter and 8 mm length (Jeil, Seoul, Korea) were self-
drilled between the maxillary second premolars and the
first permanent molars for maxillary canine retraction.
The miniscrews were inserted at 6–8 mm from the alveo-
lar crest and 80°–90° to the surface of the alveolar bone.
A NiTi-closed coil spring was used for maxillary canine
retraction on 0.017 × 0.025-inch stainless steel arch wire
(Fig. 1). The retraction force was adjusted according to
the allocated side.

The Periotest device was used to check the mobility of
the maxillary canine immediately before retraction and
repeated monthly for 5 months. The Periotest device
was used according to the manufacturer’s instructions
where the patients head was adjusted for making the
maxillary canines perpendicular to the floor. The sleeve
of the handpiece of the Periotest was perpendicularly
positioned at less than 4 mm distance from the middle of
the incisal–labial third of the canines. The measurements
were repeated five times, and the mean was calculated for
each reading. The data were divided into four subgroups
according to the side and the retraction force of the max-
illary canines as the following:

Group A  A1 (R3 100 g): the maxillary right canine
retracted by 100 g of force.

A2 (L3 200 g): the maxillary left canine
retracted by 200 g of force.

Group B  B1 (R3 200 g): the maxillary right canine
retracted by 200 g of force.

B2 (L3 100 g): the maxillary left canine
retracted by 100 g of force.

Immediately before maxillary canine retraction (T0)
and after 5 months (T6), impressions were taken and
poured. The casts were scanned and superimposed using
Ortho Analyzer™ software program of the 3Shape Ortho
System. The total amount of canine retraction was meas-
ured from the cusp tip of the maxillary canine of T0 to
the same point in T6 for both sides (Fig. 2).

Statistics
The Periotest values (PTVs) were collected, and the mean
of the five measurements for every tooth was calculated.
Statistical analysis was performed using the SPSS ver-
ion 20.0 software for Windows (IBM, USA). All meas-
urements were tested for normality using Shapiro–Wilk’s
test. Means and standard deviations of the PTVs of max-
illary canine mobility were determined before and during
retraction using 100 and 200 g of force over 5-month
Results

Means and standard deviation of the whole PTVs of the maxillary canines’ pre-retraction and monthly are presented in Fig. 3. Means, standard deviation and the mean changes in the PTVs of the right and left canines loaded by either 100 or 200 g of force are presented in Table 1. The table shows a significant increase in the PTVs after 5 months of retraction for all groups \( p < 0.05 \). The maxillary left canine loaded by 100 g of force showed the highest PTV \( 17.60 \pm 2.67 \). The maxillary left canine loaded by 200 g of retraction force showed the highest change in the PTVs \( (10.40 \pm 2.41) \). The maxillary left canine retracted by 100 gm of force showed the lowest change in the PTVs \( (9.50 \pm 3.06) \). ANOVA test showed insignificant statistical difference between the four groups before retraction and in every month \( p > 0.05 \) (Table 2). However, ANOVA and LSD tests revealed that each group showed a statistically significant difference in PTVs over the 5 months \( p < 0.05 \) (Table 2). The right and left sides were pooled, and an independent sample t test was performed comparing the PTVs of maxillary canine subjected to 100 and 200 g of retraction forces. The results showed a statistical insignificant difference in the PTVs \( p > 0.05 \) (Table 3). Pearson correlation of the PTVs with the period of retraction was statistically significant \( p < 0.05 \), while with the amount of retraction force, it was insignificant \( p > 0.05 \) (Table 4). Independent sample t test showed insignificant difference in the total amount of canine retraction using either 100 or 200 g of retraction force \( p > 0.05 \) (Table 5).

Discussion

Orthodontic tooth movement occurs as a result of a cellular remodeling process of the periodontium in response to the applied orthodontic load. This response depends upon the intensity and duration of the applied force which in turn produces stresses and strains in the surrounding tissues. Many studies [5, 6, 9] compared measured regarding the 100 and 200 g of retraction force. Significance for all statistical tests was predetermined at \( p < 0.05 \).

period. N-way ANOVA test and least significant difference (LSD) were performed to investigate the effect of retraction force, side of canine and duration of retraction on the canine mobility represented by the PTVs. Independent sample t test was performed comparing the PTVs of maxillary canines retracted by 100 g and 200 g of force over the 5-month period. Pearson correlation was used to test if there is a correlation between the Periotest measurements and the force of retraction and the duration of retraction. Independent sample t test was used to compare the total amount of canine retraction

| Table 1 | Means, standard deviations, the changes in the PTVs prior to canine retraction and the 5th month and the \( p \) value of the paired Student’s t test |
|----------------------------------|----------------------------------|--------------------------|-----------------|-----------------|
| Pre-retraction Mean ± SD | 5th month Mean ± SD | 5th month—pre-retraction Mean ± SD | \( p \) value |
| R3 100 gm | 7.60± 1.96 | 17.20± 3.58 | 9.60± 2.46 | 0.000* |
| L3 100 gm | 7.70± 1.70 | 17.60± 2.67 | 9.50± 3.06 | 0.000* |
| R3 200 gm | 6.90± 2.33 | 17.00± 3.56 | 10.10± 2.41 | 0.000* |
| L3 200 gm | 7.10± 1.79 | 17.50± 1.51 | 10.40± 2.41 | 0.000* |

*Statistically significant at \( p \) value < 0.05
different force magnitudes from 10 to 300 cN for either tipping or bodily movement of different teeth using different appliance systems. These studies have shown that there was no correlation between the magnitude of force and the rate of tooth movements.

Quinn et al. [5] advocated three major problems that complicate clinical studies of force magnitude and tooth movement including inability to maintain the type of tooth movement caused by the appliances used, non-linear time-dependent course of tooth movement following appliance activation and the measurements errors as well as the large variations in the rate of tooth movement between patients and even quadrants in an individual patients. Pilon et al. [9] found that the individual characteristics are the major decisive factor in determining the rate of orthodontic tooth movement rather than the magnitude of force.

Since tooth mobility is considered as one of the methods for evaluating the biomechanical characteristics of the PDL, the present study aimed to investigate the effect of force magnitudes on mobility of the maxillary canines and if they were affecting the rate of retraction.

Two magnitudes of force, 100 g and 200 g, were used for maxillary canine retraction with 0.017 × 0.025″ SS wire over a period of 5 months using the Periotest device. The Periotest has been approved to be a simple and accurate method for clinical evaluation and quantification of the teeth mobility and, accordingly, the viscoelastic behavior of the periodontium [10, 11].

### Table 2

Means and standard deviations of Periotest values of the right and left canines loaded by 100 and 200 g of force and the p value of ANOVA test

|          | R3 100 gm Mean ± SD | L3 100 gm Mean ± SD | R3 200 gm Mean ± SD | L3 200 gm Mean ± SD | p value |
|----------|---------------------|---------------------|---------------------|---------------------|---------|
| Pre-retraction | 7.60 ± 1.96<sup>abcd</sup> | 7.70 ± 1.70<sup>abcd</sup> | 6.90 ± 2.33<sup>bcde</sup> | 7.10 ± 1.70<sup>bcde</sup> | 0.762   |
| 1st Month | 10.50 ± 3.03<sup>ab</sup> | 11.00 ± 2.82<sup>cd</sup> | 9.80 ± 2.49<sup>cd</sup> | 10.90 ± 3.90<sup>cd</sup> | 0.820   |
| 2nd Month | 12.50 ± 2.71<sup>b</sup> | 14.70 ± 3.37<sup>cd</sup> | 12.22 ± 3.17<sup>be</sup> | 12.00 ± 2.00<sup>cd</sup> | 0.137   |
| 3rd Month | 13.50 ± 3.50<sup>ac</sup> | 14.40 ± 2.88<sup>cd</sup> | 13.30 ± 3.49<sup>ce</sup> | 14.30 ± 2.11<sup>cd</sup> | 0.802   |
| 4th Month | 15.20 ± 3.79<sup>ad</sup> | 16.20 ± 2.86<sup>c</sup> | 14.90 ± 3.87<sup>ad</sup> | 15.90 ± 1.52<sup>ad</sup> | 0.779   |
| 5th Month | 17.20 ± 3.58<sup>abc</sup> | 17.60 ± 2.67<sup>bd</sup> | 17.00 ± 3.56<sup>bcde</sup> | 17.50 ± 1.51<sup>bcde</sup> | 0.967   |

*Means with the same superscript letters in column are significantly different at p < 0.05 according to the least significant test (LSD) test. *Statistically significant at p value < 0.05

### Table 3

Means, standard deviations, the changes in the PTVs prior to canine retraction and monthly till the 5th month regarding the force magnitude and the p value of the independent sample t test

|          | PTV—100 g Mean ± SD | PTV—200 g Mean ± SD | Md of PTV Mean ± SD | p value |
|----------|---------------------|---------------------|---------------------|---------|
| Pre-retraction | 7.65 ± 1.79 | 7.00 ± 2.02 | 0.65 ± 0.60 | 0.289   |
| 1st Month | 10.75 ± 2.86 | 10.35 ± 3.23 | 0.40 ± 0.97 | 0.681   |
| 2nd Month | 13.60 ± 3.19 | 12.05 ± 2.59 | 1.55 ± 0.92 | 0.099   |
| 3rd Month | 13.95 ± 3.15 | 13.80 ± 2.86 | 0.15 ± 0.95 | 0.876   |
| 4th Month | 15.70 ± 3.31 | 15.40 ± 2.91 | 0.30 ± 0.99 | 0.762   |
| 5th Month | 17.40 ± 3.09 | 17.25 ± 2.67 | 0.15 ± 0.91 | 0.870   |

### Table 4

Pearson correlation and p value of the PTVs to the duration of retraction and the force of retraction

|          | Duration of retraction | Force of retraction |
|----------|------------------------|---------------------|
| PTVs     | r value | p value |
| Pre-retraction | 0.747 | 0.000* |
| 1st Month | 0.747 | 0.000* |
| 2nd Month | 0.747 | 0.000* |
| 3rd Month | 0.747 | 0.000* |
| 4th Month | 0.747 | 0.000* |
| 5th Month | 0.747 | 0.000* |

*Statistically significant at p value < 0.05

### Table 5

Means, standard deviations and the p value of the independent sample t test of the total amount of canine retraction by 100 and 200 g of force

|          | Mean ± SD 100 g | Mean ± SD 200 g | t | df | p value |
|----------|----------------|----------------|---|----|--------|
| Total amount of canine retraction | 6.26 ± 0.52 | 6.52 ± 0.58 | 1.518 | 38 | 0.137   |

Different force magnitudes from 10 to 300 cN for either tipping or bodily movement of different teeth using different appliance systems. These studies have shown
variability, a split-mouth design was applied where on the one side the canine was retracted by 100 g and on the other side of the same patient, the canine was retracted by 200 g of force. These sides were reversed in the other group. The PTVs were calculated for each canine tooth immediately before starting application of retraction forces and analyzed statistically for all groups and subgroups, and they were found to be insignificant as presented in Table 2 (p > 0.05).

The PTVs of the maxillary canines were recorded monthly using the Periotest device. Previous studies [10, 12] reported a range of 5–10 of the PTVs of healthy incisor teeth, while others [11] reported 10.8 for healthy upper central incisor. The PTVs of the maxillary canines in the present study ranged from 4 to 10 immediately before starting retraction. This can be explained by the absence of anterior crowding in the selected cases, thus diminishing the effect of leveling and alignment forces. It also might be due to the good periodontal support of the maxillary canines in comparison with the central incisors.

The increase in PTVs over the 5 months indicates the increase in remodeling process where bone resorption occurs as a result of the light continuous force. However, no difference was found between the retraction forces, 100 g and 200 g, which might indicate that both forces are within the physiologic limit where the process and the rate of bone remodeling were similar for both forces. This was also confirmed by the correlation found between the PTVs and the duration of retraction (r = 0.747) where there was no correlation found between the PTVs and the magnitude of the retraction forces (r = 0.079). Also, the results showed that there was no statistically significant difference in the total amount of canine retraction between the two groups with a 6.26 ± 0.52 mm total mean of retraction for the 100 g and 6.25 ± 0.58 mm for the 200 g group as presented in Table 5 (p > 0.05).

**Limitations**

1. Evaluation of the tipping degree of canine retraction regarding different force levels was not considered.
2. The available research data suggesting the ideal timing of mobility assessment regarding the remodeling process was not established yet.
3. Comparison with different force mechanics was not considered.

**Conclusion**

1. Increasing the retraction force of maxillary canines up to 200 g of force does not increase the teeth mobility during orthodontic treatment.
2. There is a positive correlation between the PTVs and the duration of tooth movement regardless the magnitude of force being either 100 or 200 g.
3. No significant difference in the amount of canine retraction by using either 100 g or 200 g of force.
9. Pilon JJ, Kuijpers-Jagtman AM, Maltha JC. Magnitude of orthodontic forces and rate of bodily tooth movement. An experimental study. Am J Orthod Dentofac Orthop. 1996;110(1):16–23.
10. Tanne K, Yoshida S, Kawata T, Sasaki A, Knox J, Jones ML. An evaluation of the biomechanical response of the tooth and periodontium to orthodontic forces in adolescent and adult subjects. Br J Orthod. 1998;25(2):109–15.
11. Tanaka E, Ueki K, Kikuzaki M, Yamada E, Takeuchi M, Dalla-Bona D, et al. Longitudinal measurements of tooth mobility during orthodontic treatment using a Periotest. Angle Orthod. 2005;75(1):101–5.
12. Andresen M, Mackie I, Worthington H. The periotest in traumatology. Part I. Does it have the properties necessary for use as a clinical device and can the measurements be interpreted? Dent Traumatol. 2003;19(4):214–7.

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