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Effects of force magnitude on relapse: An experimental study in rabbits

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Introduction: The aims of this study were to investigate the effects of 2 force levels on the amount of relapse and to determine whether there is a relationship between the rates of tooth movement and relapse. **Methods:** Approximately 20-g (group I) and 60-g (group II) forces were applied to the maxillary central incisors of 25 young adult (14 weeks of age) New Zealand female rabbits. Active tooth movement lasted 20 days. Then, the appliances were removed, and the incisors were released. The distance between the incisors was measured daily from the midlevels of the crowns by using a digital caliper during the active phase of tooth movement for 20 days, and then relapse was measured at the same level for 37 days. Analysis of variance and the Bonferroni multiple range test were used for statistical analyses. **Results:** After active tooth movement, the mean total opening amounts were 3.98 ± 0.59 mm in group I and 4.82 ± 0.82 mm in group II, and the mean difference was approximately 0.8 mm. A rapid relapse was observed on the initial days in both groups, and its rate decreased with time. Significant relapse was observed in the first 5 and 8 days of the experiment in 20-g and 60-g force groups, respectively. The relapse in group II was significantly greater than in group I only on the first day of experiment. Statistically significant correlations were found between total tooth movement and relapse ($R = 0.896$, $P < 0.001$). **Conclusions:** These results showed a close relationship between the amount of relapse and orthodontic force magnitude. Greater relapse occurred during the initial days after appliance removal, and this indicates that retention appliances are needed immediately after the removal of orthodontic appliances. (Am J Orthod Dentofacial Orthop 2011;140:44-50)

Dental relapse, an undesirable outcome of orthodontic treatment, can be defined as a general tendency of the teeth to return their original positions after tooth movement. Relapse has been recognized as a major clinical problem among orthodontists, perhaps due to lack of understanding of the process, the mechanism of posttreatment relapse, and inadequate data regarding the effects of different treatment approaches on relapse tendency. The origin of this tendency is largely unknown or at least poorly understood, but it is generally accepted that intrinsic factors such as the periodontal ligament (PDL) and alveolar bone, and extrinsic factors such as growth of facial structures, soft tissue pressures, and interdigitation, might be potential factors in relapse.[1]

Reitan[2] evaluated the time required for recovery of different fibers after displacement in various areas of tooth roots of young dogs. He reported that some gingival fiber bundles remain displaced and stretched even after a retention period of 232 days. Periods of 83 and 147 days were required for rearrangement in the ligaments in the apical and middle regions, respectively. This study suggested that periodontal tissues have residual relapse potential even in a long term.

In orthopedic treatment, it has been shown that low force applications or slow displacements during orthopedic maxillary expansion can reduce the relapse potential.[3-6] King and Keeling[7] and King et al[8] evaluated relapse and alveolar bone turnover in rats after removal of the orthodontic appliances. These studies showed that orthodontic relapse and bone remodeling continued for several days after removal of appliances. In an experimental study, van Leeuwen et al[9] evaluated the effects of different intermittent forces on relapse and found no relationship between force magnitude and amount of relapse after active orthodontic tooth movement.

In clinical orthodontics, we usually use continuous forces for tooth movements. Nonetheless, the relationships

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The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.
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Submitted, July 2009; revised and accepted, December 2009.
0889-5406/$36.00

doi:10.1016/j.ajodo.2009.12.035

between continuous orthodontic forces and amount of relapse have not been investigated sufficiently in the literature.

In the previous part of this study, the effects of force magnitude on tooth movement were discussed.[10] Relationships between different continuous forces and amounts of relapse of orthodontically moved teeth are still unclear, and this question needs to be investigated. Therefore, the aims of this study were to examine the effects of 2 orthodontic forces on the amount of relapse and the relationships between the rates of tooth movement and relapse.

MATERIAL AND METHODS

In the previous part of this study, the tooth movement period and the experimental design were explained.[10] The study protocol was approved by the ethical committee board of the School of Dentistry, Atatürk University (protocol number is 2006/13), Erzurum, Turkey. Twenty-five young, healthy female New Zealand rabbits (mean age, 14 weeks) were used. The rabbits were randomly divided into 2 experimental groups, with 12 rabbits in group I and 13 rabbits in group II. The rabbits were individually housed in smooth-walled cages, and fed ad libitum with commercial pellets and water from thick-walled glass dishes. The mean weights of the animals were 2.72 ± 0.60 kg in group I and 2.97 ± 0.38 kg in group II at the beginning of the experiment.

The animals in each group were anesthetized at the first session by an intramuscular injection of ketamine (37.5 mg/kg) and xylazine (5 mg/kg). A small notch was made with a bur on the labial surface of the maxillary first incisors at 1.5 to 2 mm above the gingival margin, and then the notches were drilled in a vestibulo-palatal direction with a bur. Cooling was achieved with a syringe filled with physiologic saline solution.

The appliance used in this study was an expansion spring. This spring was previously used by Storey[11] and Stark and Sinclair,[12] and modified by Karadede.[13] The spring arms were 13 mm long with an angle of 70° (Fig 1). To produce 2 forces, 0.012-in and 0.014-in round stainless steel archwires were used. The forces generated by the springs were measured with a gauge (040-713; Dentaurum, Ispringen, Germany) before application. When the free ends of the springs were closed to 4 mm, which corresponded to the width between the holes prepared in the rabbit incisors, the springs of the thin archwire initially exerted a force of 20 ± 3 g, and the other springs exerted a force of 60 ± 5 g. Springs exerting a force of 20 g were used in group I, and those with a 60-g force in group II.

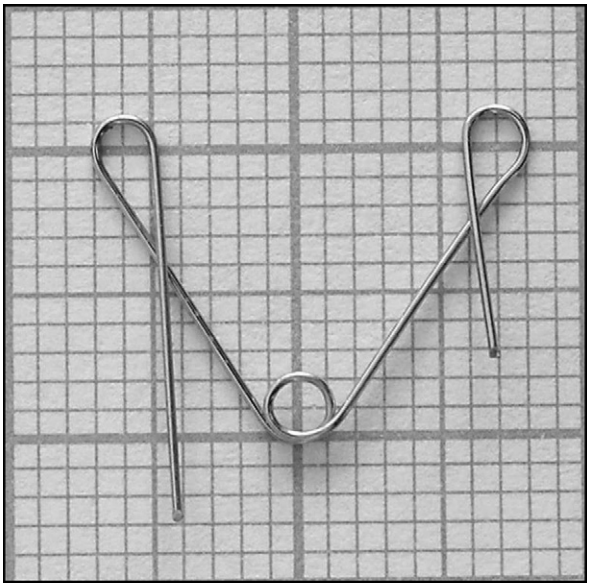

Fig 1. A helical torsion spring prepared on millimetric graph paper.[10] Used by permission of Oxford University Press.

The free ends of the springs were placed into the holes in the incisors. The residual ends were bent distally and cut to stabilize the springs in the mouth (Fig 2).

Active tooth movement lasted 20 days. Occlusal radiographs were taken from 2 rabbits in each group to observe whether sutural opening occurred. The springs were removed at the end of the 20th day. The incisors of all animals were allowed to relapse without any retention appliance. The distance between the incisors was measured every morning at the same time from the visible midlevel of the crowns (*arrows* in Fig 2) by using a digital caliper with accuracy of 0.01 mm by the same author (M.E.).

To obtain reliable measurements, 3 successive measurements were made at each session, and their mean values were used for statistical analysis. Relapse measurements were made on all successive days until day 12. Because little relapse movement occurred during the remaining days, 3 measurements were made arbitrarily on days 16, 23, and 37.

Statistical analysis

To compare the amounts of relapse movement within and between groups, analysis of variance for repeated measurements was used. In addition, the changes in daily relapse movements were analyzed by the Bonferroni multiple range test.

All statistical analyses were performed with the Statistical Package for Social Sciences (Windows 98, version 10.0; SPSS, Chicago, Ill).

Fig 2. A helical torsion spring placed on a rabbit's incisors.[10] Used by permission of Oxford University Press.

Fig 3. Pre- and postexperiment occlusal radiographs of 1 rabbit showing midpalatal suture.[10] Used by permission of Oxford University Press.

RESULTS

Tipping movements were observed in both groups at the end of active tooth movement, and there was no sutural opening in the animals of either group for whom occlusal radiographs were obtained (Fig 3).

Daily measurements of the distances between the incisors are shown in Table I. The mean total amounts of opening were 3.98 ± 0.59 mm in group I and 4.82 ± 0.82 mm in group II, and the difference between the groups was approximately 0.8 mm at the end of active tooth movement. The mean total amounts of relapse were 3.45 ± 0.58 mm in group I and 3.89 ± 0.77 mm in group II. Time-displacement curves of tooth and relapse movements in both groups are shown in Figure 4.

The means and standard deviations of daily decreases in the gap between the incisors, and their within-group and between-group comparisons are shown in Table II. Rapid immediate relapses (37% in group I, 41% in group II) were observed on the first day after spring removal, and the rates gradually decreased during the following days. Relapse movements were statistically significant only during the first 5 days in group I and the first 8 days in group II (Table II).

According to the between-group comparisons (Table II), a significantly different relapse movement occurred only on the first day of the experiment; it was greater in group II. There was no statistically significant difference between the groups on the other days.

Statistically significant correlations were found between total tooth movement and total relapse movement (R = 0.896; P <0.001).

Table I. Means and standard deviations of the distances (mm) between the incisors on each measurement day and the total relapse during the experimental period

	Group I (20-g force, n = 12)		*Group II (60-g force, n = 13)*	
	Mean	*SD*	*Mean*	*SD*
Day 0	3.98	0.59	4.82	0.82
Day 1	2.52	0.48	2.85	0.64
Day 2	2.12	0.36	2.41	0.57
Day 3	1.82	0.31	2.15	0.57
Day 4	1.52	0.21	1.90	0.46
Day 5	1.33	0.18	1.74	0.45
Day 6	1.20	0.17	1.61	0.43
Day 7	1.12	0.17	1.54	0.42
Day 8	1.03	0.16	1.41	0.38
Day 9	0.99	0.17	1.36	0.37
Day 10	0.96	0.18	1.31	0.35
Day 11	0.88	0.17	1.21	0.33
Day 16	0.83	0.22	1.18	0.31
Day 23	0.73	0.18	1.09	0.28
Day 37	0.53	0.30	0.92	0.32
Total relapse	3.45	0.58	3.89	0.77

DISCUSSION

An active tooth-movement period of 20 days was chosen in the previous part of this study[10] because it

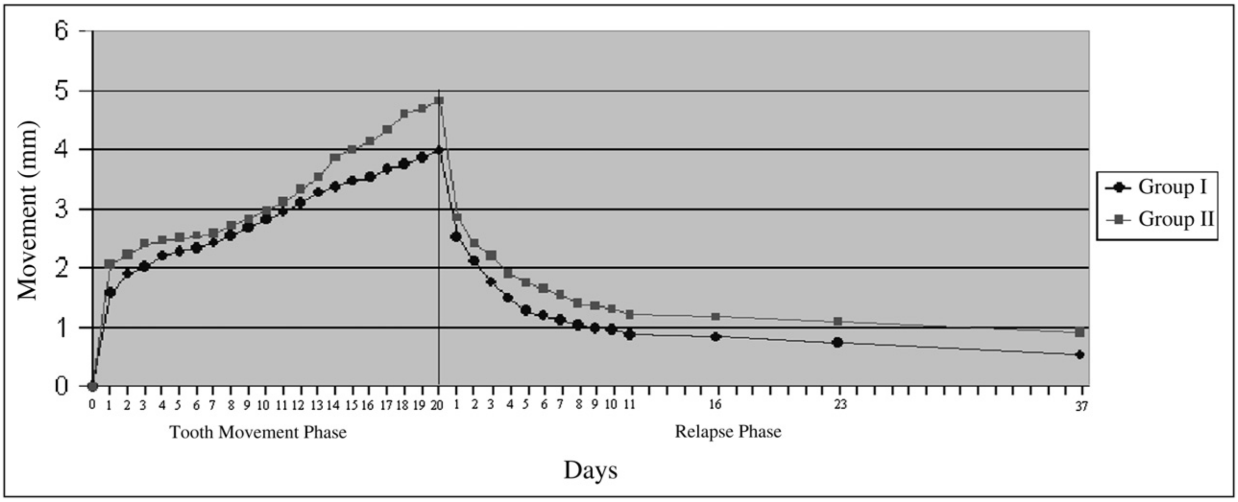

Fig 4. Time-displacement curves of tooth and relapse movements in group I (20-g force) and group II (60-g force).

Table II. Means and standard deviations of decreases in the distances (mm) between the incisors and within-group and between-group comparisons

	Group I (20-g force, n = 12)			*Group II (60-g force, n = 13)*			
Days	*Mean decrease*	*SD*	*Within-group significance*	*Mean decrease*	*SD*	*Within-group significance*	*Between-group significance*
1	1.46	0.24	‡	1.97	0.58	‡	*
2	0.40	0.22	†	0.44	0.21	†	NS
3	0.30	0.11	‡	0.26	0.18	*	NS
4	0.29	0.19	*	0.25	0.19	*	NS
5	0.19	0.09	†	0.17	0.11	*	NS
6	0.13	0.13	NS	0.13	0.10	*	NS
7	0.08	0.06	NS	0.11	0.08	*	NS
8	0.09	0.07	NS	0.13	0.10	*	NS
9	0.04	0.03	NS	0.05	0.03	NS	NS
10	0.04	0.03	NS	0.05	0.04	NS	NS
11	0.08	0.06	NS	0.10	0.06	NS	NS
16	0.05	0.12	NS	0.04	0.06	NS	NS
23	0.09	0.07	NS	0.08	0.08	NS	NS
37	0.21	0.25	NS	0.17	0.15	NS	NS

NS, not significant.
**P* <0.05; †*P* <0.01; ‡*P*<0.001

was similar to other studies with rabbits.[14,15] Tipping movements were observed after active orthodontic tooth movement because of the root length of rabbit incisors, the application point of the force, and the spring design used in this experiment.

A number of force systems have been used, such as archwires and bands,[16] elastics,[17,18] coil springs,[17,19,20] and springs with various designs[21-23] to move the teeth of experimental animals. Under some conditions, some of these force elements might be detrimental to the periodontal tissues of the experimental animals.[16] Some experimental designs necessitate difficult laboratory or surgical procedures.[9,16,20,24] Preparation of the springs used in this study required minimal laboratory preparation, and they were easily applied to the rabbits' incisors. No unfavorable effects, such as food retention, periodontal tissue damage, dislocation, mobility, poor retention, or lost springs, were observed.

Various experimental animals such as rats,[23-26] dogs,[9,20,27] rabbits,[21,22,28] and cats[29] have been used to study tooth movement. Rats and rabbits are commonly used in such studies because of their availability. In our study, only female rabbits were used to prevent sex differences in metabolic activity and behavior of the animals toward the procedures applied to them.

The magnitude of orthodontic forces has received much attention, but most studies carried out on this subject investigated the effects of orthodontic forces with different magnitudes on active tooth movement. The relationships between continuous orthodontic forces and amounts of relapse have not been investigated sufficiently in the literature.

Relapse after successful treatment has been a major clinical problem in orthodontic practice. However, little interest has been shown about this problem.[9,17,30] Relationships between continuous force magnitude and amount of relapse have not been studied sufficiently. In this study, we aimed to investigate the effects of the 2 forces on relapse after active orthodontic tooth movement. Twenty-gram and 60-g forces were applied to the incisors of rabbits to create tooth movement, and then the teeth were allowed to relapse freely without any retention appliance.

In all animals, relapse started immediately when the springs were removed. A rapid relapse occurred initially, and then the relapse rate gradually decreased until it stabilized. On the first day, relapses of 37% and 41% occurred in 20-g and 60-g force groups, respectively. This result is coincident with the previous studies in which relapse of the moved teeth started rapidly, and the rate reduced in the forthcoming days.[9,11,17]

The results of the Bonferroni multiple range test of the daily relapse for the within-group comparisons are shown in Table II. Statistically significant relapse movements were observed in the first 5 and 8 days of the experiment in the 20-g and 60-g force groups, respectively. No statistically significant relapse movement was observed during the following days in either group. This means that application of a 60-g force results in a greater and longer-lasting relapse than that with 20 g of force. The results of the between-group comparisons also showed that significantly greater relapse movements occurred in the 60-g force group only on the first day of the experiment (Table II). However, the mean total relapse amounts were 3.45 ± 0.58 and 3.89 ± 0.77 mm in groups I and II, respectively.

King et al[8] found that rat molars relapsed at a rate of approximately 14 μm (0.014 mm) per day after 16 days of orthodontic treatment. In our study, the incisors of the rabbits in groups I and II showed 0.093 and 0.105 mm per day of relapse, respectively. This disagreement might have resulted from the differences in experimental designs and orthodontic force magnitudes.

In this study, correlation analysis also showed a statistically significant correlation between total tooth movement and total relapse ($R = 0.896$). This result agrees with the findings of van Leeuwen et al.[9]

The most striking finding of our study was the rapid relapses in the initial days, especially on the first day, after the teeth were released. This finding indicates that a significant amount of relapse tendency occurred due to stretched periodontal tissues after orthodontic treatment. In addition, this tendency was higher in 60-g force group than in the 20-g force group during the early days of relapse. In the first 24 hours of this experiment, mean relapse amounts of 1.46 and 1.97 mm occurred in the 20-g and 60-g force groups, respectively. van de Velde et al[22] reported that rabbits' maxillary incisors showed 1.8 mm of opening with a 50-g force in 24 hours of the experiment. It is well known that the PDL width of a rabbit's mandibular incisor is approximately 0.5 mm.[31,32] Relapse measurement greater than the PDL space of 2 incisors (approximately 1 mm) in the first day might have resulted from the relapse of the tipping movement observed during the tooth-movement phase apart from the stretching effects of collagen fibers. It was well documented in a previous study that dominant collagen fiber bundles of the rabbit PDL run almost from the teeth to the alveolar bone, and polarized light microscopy observations showed dense, thick, well-organized collagen fibers in the incisal regions of rabbits.[32]

It is commonly accepted that stresses and strains stored in the transseptal and gingival fiber system during tooth movement are the main causative factors for relapse,[2,33,34] although this assumption was not proved in other studies.[35,36] This assumption was based on the following opinions: (1) supra-alveolar fibers are not embedded in a bone wall, (2) release of the stress in these fibers takes a long time, and (3) remodeling and reconstruction of these fibers occur slowly.

It has been shown in experimental studies that elastic-like oxytalan fibers can play an important role in the relapse of moved teeth.[37] Edwards[38] stated that elastic-like oxytalan fibers aroused some interest as a contributing factor in the relapse of orthodontically moved teeth. In a later article, however, Edwards[39] questioned this belief and claimed that there was no substantial evidence to explain the mechanism by which the gingival soft tissues might apply a force capable of moving the teeth.

Experimental studies are designed to determine the role of both the PDL and the alveolar bone during relapse. Yoshida et al,[17] in an electron microscopy study, showed that rapid remodeling of the PDL and surrounding alveolar bone was the main cause of relapse after active tooth movement. It was also claimed that the changes in periodontal vasculature and the increased appearance of glucose aminoglycans in intercellular substances of connective tissues could be a factor in the production of tissue forces that can cause relapse.[40]

A higher relapse force was produced in the periodontal and surrounding structures of the 60-g force group, and this caused a greater relapse during the initial days of the relapse phase. However, there is a significant amount of relapse potential in the periodontal structures with lower orthodontic forces that can produce active tooth movement. For this purpose, researchers commonly advocate long-term use of retainers and overcorrection to overcome any relapse.[33,41]

Surgical procedures such as supracrestal fibrotomy and transsection of free gingival or transseptal fibers are also advocated by some authors to alleviate the stresses and strains, reducing the extent of relapse and enhancing the stability of tooth positions.[33,39]

CONCLUSIONS

1. At the beginning, the mean total amounts of opening were 3.98 ± 0.59 mm in group I and 4.82 ± 0.82 mm in group II.
2. Total relapse amounts were 3.45 ± 0.58 mm in group I and 3.89 ± 0.77 mm in group II.
3. Rapid relapses were observed during the initial days after appliance removal in both groups, and the rate decreased after that.
4. Significant relapses were observed in the first 5 and 8 days after appliance removal in the 20-g and 60-g force groups, respectively.
5. When compared with group I, significantly greater relapses occurred in group II only on the first day after appliance removal.
6. A statistically significant correlation was found between total tooth movement and relapse ($R = 0.896$; $P < 0.001$).

We thank Oxford University Press for the imprimatur of the figures in this article.

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