Periodontal Conditions after Orthodontic Tooth Movements in the Dog

I. Ericsson, D.D.S.

B. Thilander, D.D.S., Odont. Dr.

J. Lindhe, D.D.S., Odont. Dr.

Conflicting results have been presented regarding the effect of orthodontic treatment on the periodontal tissues. A number of experiments have demonstrated that in animals with a normal gingiva or gingivitis, orthodontic forces will not produce damage to the supra-alveolar connective tissue and that therefore orthodontic treatment will not result in periodontal tissue breakdown and pocket formation. In a clinical study from 1973 to 1974 Zachrisson and Alnaes,[18,19] however, claimed that most children and young adults treated with the edgewise technique develop signs of generalized gingivitis. Although the periodontal tissues showed a great ability to resist the orthodontic treatment when good oral hygiene conditions were maintained, a slight irreversible loss of connective t ssue support had occurred concomitantly with the orthodontic therapy in some of the individuals. Kloehn and Pfeifer,[6] on the other hand, stated that "inflammatory and hyperplastic changes in the gingiva which occurred during treatment were reversible upon appliance removal and the periodontium was in better health following treatment."

Previous results reported from our laboratory[5] have demonstrated that it is possible by orthodontic forces, which tilt and displace teeth to an inferior position, to shift a supragingivally located plaque into a subgingival position. The intrusion of the plaque-infected tooth resulted in the formation of infrabony pockets which tended to cause loss of connective tissue attachment. Since noninfected teeth, which were subjected to the same type of orthodontic treatment, did not display signs of infrabony pocket formation, it was suggested that the apical displacement of the plaque, rather than the tooth movement *per se,* caused loss of connective tissue attachment. The *aim* of the present investigation was to further test this hypothesis by studying the periodontal tissue reactions around plaque infected and noninfected teeth which were dislocated in a mesial direction only.

Material and Methods

Fifteen beagle dogs, 10-12 months old, were used in the study. To establish clinically healthy periodontal tissues the animals were enrolled in a pre-experimental treatment program which included repeated debridement and careful removal of plaque. The tooth cleaning regimen used in this study is identical to that recently described by Ericsson et al.[5] On Day 0 the lower third premolars ($_3P$ and P_3) were extracted. In all dogs a phase of periodontal tissue breakdown was initiated around the lower fourth premolars ($_4P$ and P_4). This was done in order to reduce the height of the supporting apparatus and was achieved by placing cotton floss ligatures around the necks of the teeth. This method was originally described by Swenson[13] and modified by Ericsson et al.[4,5] After three weeks with the plaque collector *in situ,* the breakdown of the supporting apparatus had reached a level which made it possible to insert cotton floss

From the Department of Periodontology and Orthodontics, University of Gothenburg, Gothenburg, Sweden.

ligatures through the bifurcation of $_4P$ and P_4. New cotton floss ligatures were at this time ligated around each of the two roots of $_4P$ and P_4.

On Day 210, when the animals displayed pronounced signs of periodontal tissue breakdown around $_4P$ and P_4, the dogs were randomly divided into three groups of five animals each: A, B and C and the following procedures performed.

All five dogs in Group A were sacrificed at this stage.

For Group B the diseased periodontal tissues in the posterior premolars and molar regions were subjected to treatment. The periodontal pockets were eliminated using a flap technique (modified Widman).[8] The premolars were carefully scaled and planed. A cavity (notch) was prepared in the mesial roots of $_4P$ and P_4 at the level of the marginal termination of the alveolar bone. The notch served as a landmark for measurements to be made later in histological sections. The dogs of this group, following treatment, were placed on a careful plaque control regimen which included toothbrushing twice daily, and was continued until the end of the experiment. Particular care was taken to clean the bifurcation area of the lower fourth premolars.

The cotton floss ligatures around $_4P$ and P_4 of Group C dogs were removed, but the teeth were not subjected to debridement. No attempts were made during the period between Day 210 and Day 370 to clean the teeth of the dogs in this group.

On Day 270 orthodontic appliances were inserted for Groups B and C to ensure *bodily* movements in a horizontal-mesial direction of the lower *left* premolars (P_4) of all the ten dogs. The orthodontic appliance consisted of cast silver bands cemented on P_4 (test tooth) and M_1 (anchoring tooth) (Fig. 1). A sectional arch (.018 x .022) was attached to buccal tubes (.018 x .022) welded on the crowns of M_1 and P_4. An active coiled spring (.007 x .025 Elgiloy) provided the force (50-70 gm) for moving P_4 in a mesial direction. A stress and tension gauge was used to assess the magnitude of the force. Since the orthodontic force approached a zero value at each three-week interval, the coiled spring and the sectional arch had to be replaced by devices producing the same force (50-70 gm) as the original appliances. In each dog the fourth premolar of the *right* lower jaw served as a control and was not subjected to orthodontic treatment.

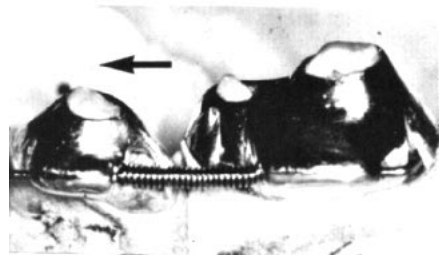

Fig. 1 The experimental appliance. Silver bands are cemented on the lower left fourth premolar (P_4) and first molar (M_1). The active coiled spring provides the force in a mesial direction to the premolar (arrow).

To eliminate occlusal interference between the upper and lower posterior premolars and first molars, the crowns of the *maxillary* third and fourth premolars were removed. The pulps of these teeth were extirpated and the canals filled with gutta-percha.

Radiographical determinations

Radiographs of the lower premolar regions were obtained on Days 270 and 370 using a modification of the technique described by Eggen[3] and Lindhe et al.[7] The radiographs were developed in a standardized manner and placed in a Diavisor (Esselte, Sweden) which produced a magnified (x 10) image of the structures on a glass screen. The outlines of the marginal alveolar bone, the contours of the teeth, as well as particular landmarks were traced on transparent paper. By using the tracings from Day 270 as a reference it was possible, in the radiographs obtained on Day 370, to determine the horizontal and apical displacement of the test teeth (P_4).

Histological assessments

The animals were sacrificed either on Day 210 (Group A) or on Day 370 (Groups B and C). The mandibles were dissected and divided along the midline. The technique used for tissue harvesting as well as methods utilized for fixation, decalcification, and sectioning have been described in a previous publication by Ericsson et al.[5] From each biopsy 5 sections (150 μm apart) were selected and magnified (x 98.4) in a microscope. Their images were traced on white paper. In the drawings the following linear distances at the mesial aspect of $_4P$ and P_4 were measured (Fig. 2): Groups A, B and C, 1) the cemento-enamel junction (CEJ)—the most apical cells of the junctional epithelium (JE) and 2) CEJ-apex of the mesial root. Loss of connective tissue attachment was expressed as the quotient $\frac{\text{CEJ-JE}}{\text{CEJ-Apex}} \times 100$ (%).

For Groups B and C the size of the marginal 2 mm of the periodontal ligament area (PLA) was determined by the use of a planimeter (Ingut Ltd., Sweden).[12] In addition, the vascular cross-sectional area (VCA) of PLA was assessed. The vascularity $(\frac{\text{VCA}}{\text{PLA}} \times 100)$ for each specimen was calculated. The number of osteoclasts present on the alveolar bone surface bordering the PLA was determined.

For Group B only the distance CEJ—the apical border of the notch (A), and the quotient $\frac{\text{CEJ-A}}{\text{CEJ-Apex}} \times 100$ (%) were determined.

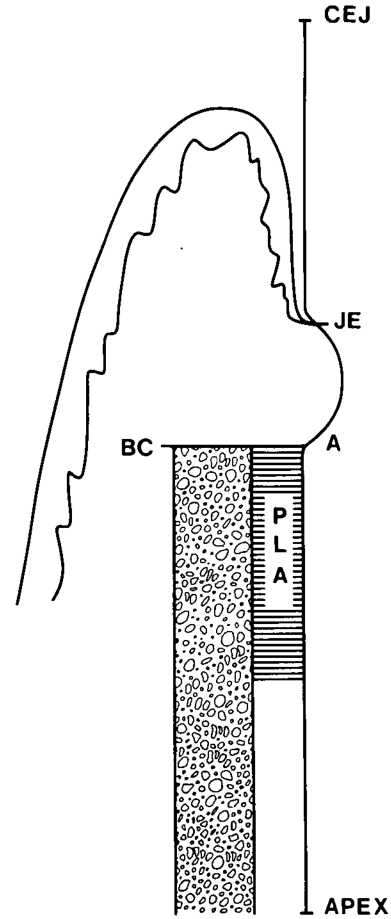

Fig. 2 Schematic drawing illustrating the various linear distances and areas which were measured in the histological sections. CEJ, cemento-enamel junction; JE, most apical cells of the junctional epithelium; A, apical border of the notch; BC, marginal bone crest, and PLA, periodontal ligament area.

Results

At the start of the experiment (Day 0) the gingivae in the premolar and molar regions of all the dogs were either clinically healthy or exhibited only minute signs of inflammation. The alveolar bone had a normal height (Fig. 3). Following ligature placement and

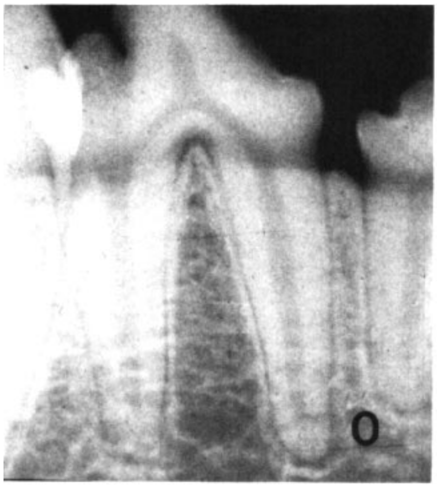

Fig. 3 Radiographic appearance of one lower premolar region at the start of the experiment, Day 0.

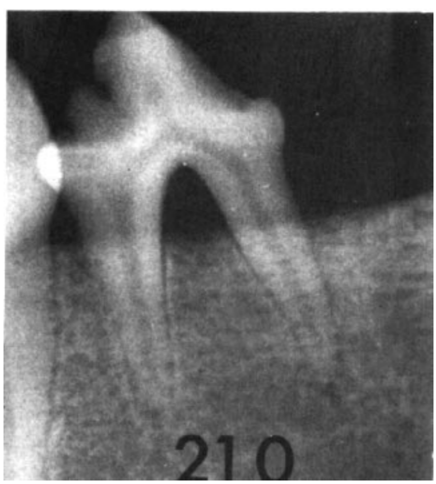

Fig. 4 Radiographic appearance of one lower premolar region after 210 days of experiment.

after 210 days without active tooth cleaning, the animals had accumulated abundant amounts of plaque. The gingival tissues around $_4P$ and P_4 displayed signs of extensive inflammation. Radiographs revealed loss of marginal alveolar bone (Fig. 4).

On Day 270, the gingivae of all the dogs in Group B had regained health

Fig. 5 At the termination of the experiment (Day 370) the gingivae of the P_4 region in Group B are clinically normal. The gingival margins are located 3-4 mm apical to CEJ.

but their margins were located 3-4 mm apical to the cemento-enamel junction (CEJ). In these dogs, clean teeth and gingival health was maintained until the end of the experiment, Day 370 (Fig. 5). The radiographs obtained on Days 270 and 370 revealed that during this period of time no change had occurred regarding the level of the marginal alveolar bone around the mesial root of P_4 (Fig. 6). No difference regarding the alveolar bone level could be observed in the radiographs between the orthodontically moved teeth and the control teeth.

The gingivae of all the dogs in Group C on Days 270 and 370 exhibited signs of inflammation. Radiographs obtained on Days 270 and 370 revealed that in the right jaws (control teeth $_4P$) no change of the alveolar bone had occurred during the 100 days of experiment (Fig. 7, above). In the left jaws of all the dogs a widened periodontal ligament and small vertical bony defects had developed at the mesial root of P_4 (test teeth) (Fig. 7, below).

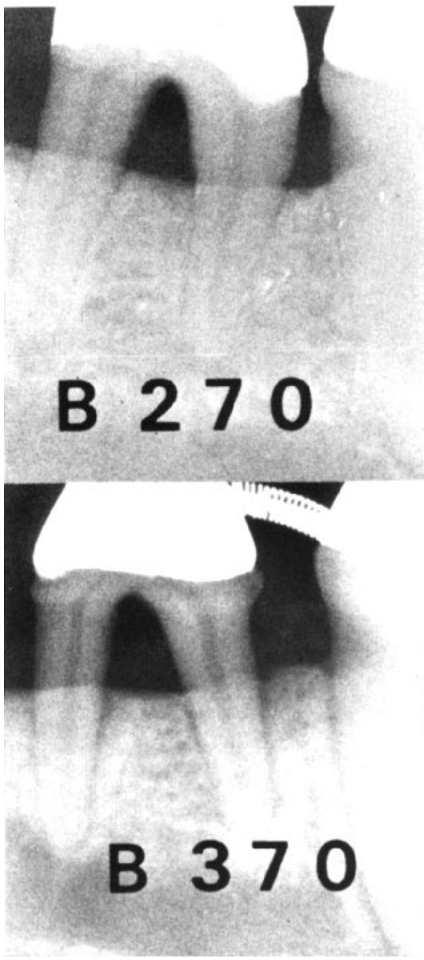

Fig. 6 Radiographic appearance of P_4 in Group B on Day 270 (above) and at the end of the experiment (below) on Day 370.

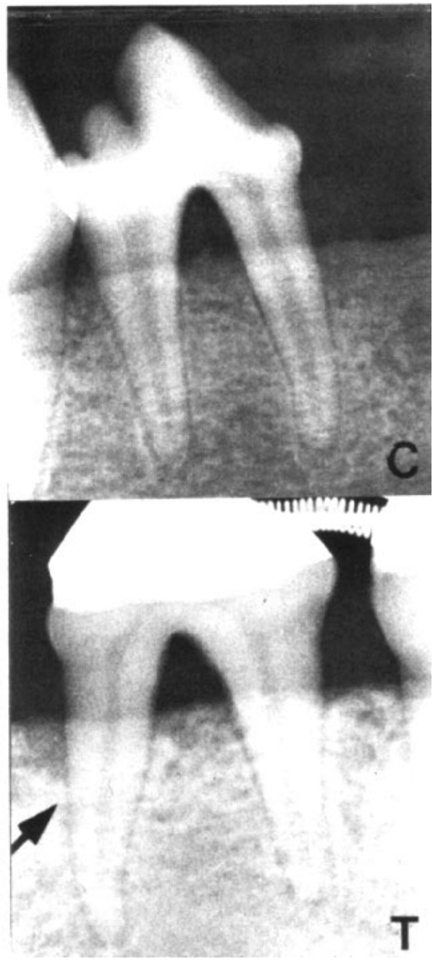

Fig. 7 Radiographic appearance of $_4P$ (C) in Group C at the termination of the experiment, Day 370. Note the vertical bony defect (arrow) present at the mesial root of P_4 (T). This bony defect was the most pronounced in all animals examined.

TABLE I

Displacement (in mm) of the test teeth that occurred in Groups B and C between Day 270 and Day 370. The displacement was the result of the utilization of orthodontic forces and was measured at the apical level of the crown preparations. The dogs of Group B were maintained plaque-free during the displacement period whereas the dogs of Group C were allowed to accumulate plaque freely.

GROUP	B		C		
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	
Horizontal	2.0 mm	0.7	2.5 mm	0.9	NS
Apical	0.2 mm	0.5	0.1 mm	0.5	NS

Radiographic Determinations

Table I presents the average displacement of the test teeth (P_4) in Groups B and C. The d'splacement, which was determined after measurements made in the Diavisor, is expressed as the linear distance between landmarks in the mesial surfaces of $_4P$ and P_4 identified in radiographs obtained on Days 270 and 370. The apical

TABLE II

Results from histometric assessments. 1) The average size (in units) of the Periodontal Ligament Area (PLA) 2) the vascularity within PLA (%), and 3) the average number of osteoclasts. X = mean. S.D. = standard deviation of the mean.

	GROUP B				GROUP C			
	Test		Control		Test		Control	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
PLA	605.6	135.8	361.3‡	56.3	803.1	245.6	487.2†	64.5
$\frac{VCA}{PLA} \times 100$ (%)	10.4	4.0	14.5*	2.5	10.4	1.6	12.0*	4.0
Number of osteoclasts	7.4	2.6	0.9§	0.6	8.3	1.5	1.2§	0.5

* NS
† $p < 0.02$
‡ $p < 0.01$
§ $p < 0.001$

and horizontal displacement of the apical border of the crown preparation was similar in Groups B and C. The average figures reveal that the test teeth were displaced in a mesial but not in an apical direction.

Histological Assessments

In tissues sampled from the dogs of Group A, it was observed that the loss of connective tissue attachment on Day 210 was on the average 15.9% (S.D. 2.3) of the root length (CEJ-Apex) on the left side (P_4) and 15.1% (S.D. 3.1) on the right side ($_4P$) of the mandible. This difference is not statistically significant. In biopsies obtained on Day 370 from the dogs of Groups B and C the corresponding attachment loss amounted to around 38%. There was no difference regarding the degree of attachment loss, neither between the dogs of Groups B and C, nor between the test and control teeth within the respective groups, i.e., between left and right lower fourth premolars. Group B: test (P_4) 39.9% ± 6.7; control ($_4P$) 39.8% ± 5.8; Group C: test: 36.7% ± 5.6; control 37.0% ± 11.2).

The quotient $\frac{\text{CEJ-A}}{\text{CEJ-Apex}} \times 100$ (%) which was calculated in Group B revealed that the degree of periodontal breakdown between Day 0 and 210 was similar in test and control teeth, but also that no further tissue destruction recurred between Day 210 and Day 370.

Table II shows that teeth subjected to orthodontic tooth movement had a wider periodontal ligament area (PLA) than the controls, but that the vascularity of the periodontal ligament of the displaced and nondisplaced teeth was similar. The number of osteoclasts lining the mesial surface of the alveolar bone adjacent PLA was 6-8 times larger in the test than in the control tooth regions. There were no differences, however, between the test teeth of Groups B and C.

The gingivae at the mesial surface of all fourth lower premolars of Groups A and C contained an inflammatory cell infiltrate. In all sections from Groups A and C the entire dentogingival epithelium had the character of a pocket epithelium. A microbial plaque could always be found between the pocket epithelium and the tooth surface. The gingivae at the mesial surface of the premolars of Group B was free from inflammatory cell infiltrate; there was no plaque present on the tooth surface; the dentogingival epithelium could be characterized as a junctional epithelium without rete pegs.

Discussion

The present experiments demonstrated that orthodontic treatment which resulted in a sagittal displacement of single teeth caused a marked widening of the periodontal ligament of the pressure side but not an increased vascularity of the periodontal ligament tissue or loss of periodontal tissue support. The results furthermore revealed that a horizontal displacement of the teeth with normal gingiva did not cause inflammatory reactions in the supra-alveolar tissue and that a similar displacement of teeth surrounded by diseased periodontal tissues neither resulted in an apical downgrowth of the microbial plaque, nor in a further deterioration of the attachment apparatus.

If the present findings are viewed in context with data recently reported by Ericsson et al.[5] who tipped infected and noninfected teeth in dogs, it becomes evident that orthodontic tooth movements *per se* will neither jeopardize periodontal health nor aggravate a preexisting gingival or periodontal inflammation. If, however, orthodontic treatment results in an intrusion of plaque infected teeth, conditions may evolve which can cause additional loss of periodontal tissue support.[5]

Histometric assessments made in tissue sections from the dogs of Groups B and C revealed that the number of osteoclasts facing the periodontal ligament of the "pressure" side was around eight times larger in the test than in the control sections. This demonstrates that at the time of necropsy the orthodontic appliance used to move the test teeth was still active. There was no difference, however, between the test sections of Groups B and C regarding osteoclastic activity. The similar number of osteoclasts present in sections on Day 370 and the fact that the test teeth, in Group B as well as in Group C, had been displaced a similar distance during the experiment (Table I) show that the conditions of the supracrestal connective tissue did not influence tissue alterations in the periodontal ligament produced by orthodontic forces. This suggestion is further validated by the observation that the vascularity of the periodontal ligament tissue of the test and control teeth of Groups B and C was similar.

Clinical studies by Zachrisson and collaborators[17,18,19] and Tersin[14,15] have indicated that orthodontic treatment utilizing the edgewise technique may result in the development of gingivitis and some loss of periodontal attachment. They were, however, not able to correlate the periodontal changes to any specific etiologic factor. The results from the present study in the dog may appear to be in variance with the clinical findings earlier reported. The differences observed, however, can probably be explained by the different techniques utilized for assessing gingivitis and periodontal tissue destruction and/or by the differences in the design of the orthodontic appliances that were used. In the present study, presence or absence of gingival inflammation and loss of connective tissue attachment was always assessed in histological sections, whereas Zachrisson and co-workers utilized clinical measurements to determine attachment level alterations. Caton and Zander[2] and Armitage et al.[1] have recently demonstrated that clinical assessments of attachment levels do not properly reflect that true amount of remaining connective tissue attachment to the tooth. In addition, in the present study the orthodontic bands were applied on the teeth in such a way that the marginal border of the appliance was always located several millimeters above the gingival margin. In the clinical studies the marginal portion of the orthodontic bands were often left in a subgingival position. It has been shown by Waerhaug[16] and Silness[9,10,11] that the placement of restorations subgingivally complicates effective plaque removal and may thus favour the development and maintenance of gingivitis and periodontitis. The differences between the present findings and those reported earlier may therefore simply reflect differences in achieved degree of plaque control.

The ligature placement around the neck of the lower fourth premolars and the subsequent accumulation of plaque resulted in a marked destruction of the surrounding periodontal tissues. This breakdown of the supporting apparatus which can be calculated by the quotient $\frac{\text{CEJ-JE}}{\text{CEJ-Apex}}(\%)$ appeared to be highly predictable. Thus, after 210 days of experiment with the plaque retaining ligature *in situ,* the loss of attachment was similar on the lower right and left premolar regions (Group A: 15.9%—left and 15.1%—right). This extent of the periodontal tissue breakdown is in agreement with data reported by Ericsson et al.[4,5]

In histological sections from Group B, the apical level of the notch (A) represents the marginal termination of the alveolar bone on Day 210 and the quotient $\frac{\text{CEJ-A}}{\text{CEJ-Apex}}(\%)$ thus expresses the reduction of the periodontal support at this time. The destruction observed was about the same in the right (control: 40.9% ± 4.4) and the left (test: 47.2% ± 11.5) sides and similar to that in Group A. The percentage periodontal tissue breakdown within Group B seems to be somewhat higher than that calculated for Group A. This discrepancy is probably due to the fact that the measures CEJ-A (Group B) and CEJ-JE (Group A) represent somewhat different distances. From these data it seems reasonable to suggest that on Day 210 the destruction of the periodontal tissues surrounding the lower fourth premolars in all three groups, given identical treatment, is almost the same. This hypothesis is also indicated by the radiographs obtained.

The removal of the cotton floss ligatures from $_4P$ and P_4 in Group C on Day 210 seemed to convert the active destructive periodontal disease into a resting lesion. This statement is based on the fact that the percentage values of the periodontal tissue breakdown in Group C measured on Day 370 are very similar to those calculated for Groups A and B for Day 210. Thus, it is obvious that the plaque-collecting cotton floss ligature in contact with the marginal gingiva is the determining factor for the induction and aggravation of the periodontal lesion. It is also obvious that, on the other hand, the orthodontic forces, kept within physiological limits, do not aggravate the disease of the periodontal tissues.

Summary

The aim of the present investigation was to study if orthodontic forces moving individual teeth in a so-called "bodily" fashion may produce injury to the periodontal ligament tissues and shift a gingival inflammation into a progressive and destructive periodontitis.

The experiments were performed on 15 beagle dogs. On Day 0 the lower third premolars ($_3P$ and P_3) were extracted. A phase of periodontal tissue breakdown around $_4P$ and P_4 was initiated by placing cotton floss ligatures (plaque collectors) around the neck of the teeth. On Day 210 the animals were randomly divided into three groups of five animals each: A, B and C. At this time the dogs of Group A were sacrificed. The periodontal pockets around $_4P$ and P_4 of the dogs of Group B were surgically eliminated and a notch was

prepared in the root at the level of the marginal termination of the alveolar bone. On the same day a plaque control program was started and continued until the end of the experiments on Day 370. The plaque collectors around $_4P$ and P_4 of the dogs of Group C were removed. After 60 days of healing, on Day 270 orthodontic appliances moving P_4 (test) of the animals of Groups B and C were inserted. $_4P$, which received no appliance, served as a control tooth. The animals of Group B were subjected to tooth-brushing twice daily, while the dogs of Groups C were permitted to accumulate dental plaque. The results demonstrated that, in the absence of plaque, orthodontic forces moving individual teeth bodily in the dog do not induce gingivitis. In the presence of plaque, similar forces are not capable to convert a gingival inflammation into a destructive and progressive periodontitis.

Faculty of Odontology
Univ .of Gothenburg
Gothenburg 33, Sweden
S-40033

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