Aspartate Aminotransferase Activity in Gingival Crevicular Fluid During Orthodontic Treatment. A Controlled Short-Term Longitudinal Study

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Background: During orthodontic tooth movement, the early response of periodontal tissues to mechanical stress involves an acute inflammatory response, with a sequence characterized by periods of activation, resorption, reversal, and formation in both tension and compression sites. This study used a longitudinal design to examine aspartate aminotransferase (AST) activity in gingival crevicular fluid (GCF) in order to assess whether AST in GCF has potential as a possible diagnostic aid to monitor tooth movement and tissue response during orthodontic treatment.

Methods: Eighteen patients (mean age, 16.1 years) participated in the study. An upper first molar from each patient undergoing treatment for distal movement served as the test tooth (TT), with its contralateral (CC) and antagonist (AC) first molars used as controls. The CC was included in the orthodontic appliance, but was not subjected to the orthodontic force; the AC was free from any orthodontic appliance. The GCF around the experimental teeth was collected from both mesial and distal tooth sites immediately before appliance activation, 1 hour after, and weekly over the following 4 weeks. Clinical gingival condition was evaluated at baseline and at the end of the experimental period. AST activity was determined spectrophotometrically at 30°C, and the results were expressed as total AST activity (mU/sample).

Results: Throughout the experiment, AST levels were significantly elevated in all sites from the TT and CC groups compared to the AC group where, conversely, AST activity remained at the baseline level. However, enzyme levels in the TT group were significantly greater than in the CCs at tension sites on day 14, and in compression sites on days 7 and 14. Moreover, AST activity from the TT group was significantly greater in compression sites than in tension sites on day 7; this was not observed for the CCs.

Conclusions: Our results suggest that AST levels in GCF reflect the biological activity which occurs in the periodontium during controlled occlusal trauma and, therefore, should be further evaluated as a diagnostic tool for monitoring correct orthodontic tooth movement in clinical practice. *J Periodontol 2003;74:145-152.*

KEY WORDS

Aspartate transaminase; bone remodeling; dental occlusion, traumatic; diagnosis, oral; gingival crevicular fluid/analysis; orthodontic treatment.

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A number of different studies have evaluated the biochemical and structural responses to mechanical stress in a variety of cells in vivo and in vitro.[1-8] In orthodontics, the early response to mechanical stress involves an acute inflammatory response that is characterized by processes such as vasodilatation[1] and bone resorption.[8] In particular, the mechanism of bone resorption appears related to the release of inflammatory mediators, which can be detected in periodontal tissues and in the gingival crevice.[6,8] In medicine, biochemical methods of measuring specific markers are routinely used to provide information on bone metabolism.[9] In addition, many cellular mediators and enzymes from the gingival crevicular fluid (GCF) have been investigated for their potential as aids for monitoring tissue loss in periodontitis.[10] Moreover, some enzymes may indicate tissue changes not readily discernible by conventional clinical parameters[11] and, hence, their detection is used for diagnostic purposes in certain chairside periodontal diagnostic kits.[12]

To date, only a few studies have focused their attention on

the GCF constituents involved in bone remodeling during orthodontic tooth movement. Lowney et al.[7] reported an increase in tumor necrosis factor-α (TNF-α) in GCF from teeth undergoing orthodontic force, and Grieve et al.[6] found similar results for prostaglandin E (PGE) and interleukin-1β (IL-1β). Uematsu et al.[8] demonstrated that the levels of the different inflammatory mediators IL-1β, IL-6, TNF-α, epidermal growth factor, and β2 microglobulin underwent significant elevations. Insoft et al.[13] described an elevation of alkaline phosphatase in GCF from orthodontically treated teeth.

Bone remodeling during orthodontic tooth movement has been classically described as a continual and balanced process, characterized by bone deposition at sites of tension and bone resorption on the pressure side;[14-17] however, histomorphometric data[18,19] have suggested that in both tension and compression sites, there may be an initial asynchronous phase in which bone resorption is greater than bone deposition. Aspartate aminotransferase (AST) is a soluble enzyme that is normally confined to the cytoplasm of cells, but is released to the extracellular environment upon cell death.[20-22] Since the presence of AST in GCF[20] has been demonstrated, several studies have observed that the levels of GCF AST activity may reflect the magnitude of periodontal tissue destruction in periodontitis.[11,23] Therefore, it has been suggested that AST levels in GCF may represent a potential marker for monitoring the periodontal metabolism.[24,25] However, no earlier studies have investigated a possible role of GCF AST in tissue remodeling incidental to controlled occlusal trauma. Therefore, the aim of this study was to determine whether GCF AST activity reflects changes occurring in periodontal tissues during controlled occlusal trauma, and whether this enzyme has potential as a diagnostic tool in orthodontics. As a longitudinal study, we evaluated AST activity levels in GCF in relation to the time of treatment and the types of stress exerted on the periodontium (tension or compression) by the controlled occlusal trauma.

MATERIALS AND METHODS

Study Population

Eighteen orthodontic patients, 10 females and 8 males (aged 11 to 22; mean, 16.1 ± 3.8 years), participated in the study. Inclusion criteria were: 1) the need for fixed appliance therapy involving distal retraction of one maxillary first molar; 2) healthy systemic condition; 3) no use of anti-inflammatory drugs in the month preceding the beginning of the study; 4) probing depth values not exceeding 4 mm in the whole dentition; 5) no loss of periodontal attachment exceeding 2 mm in any interproximal site; 6) no radiographic evidence of periodontal bone loss after a full-mouth radiographic periapical examination; and 7) a full-mouth plaque score (FMPS) and a full-mouth bleeding score (FMBS) ≤ 20%. FMPS and FMBS were recorded as the percentage of tooth surfaces with the presence of supragingival plaque or bleeding within 15 seconds after probing with a 20 g controlled-force probe.‖ During the 2 months preceding the baseline examination, all subjects received repeated oral hygiene instructions about the correct use of a toothbrush, dental floss, and an interdental brush. Moreover, 2 weeks before the baseline examination, all patients underwent a session of supra- and subgingival ultrasonic scaling. Finally, the study subjects were not allowed to take any anti-inflammatory drugs during the study in order to avoid unreliable results.[6,8] Informed consent was obtained from the patients or the parents of patients under 18 years of age prior to the commencement of the study, and the protocol was reviewed and approved by the Ethical Committee of the G. D'Annunzio University Medical Faculty.

Orthodontic Appliance

In each patient, a maxillary first molar undergoing distal movement was used as the test tooth (TT), with the contralateral (CC) and antagonist (AC) first molars used as controls. Orthodontic brackets¶ were placed on the buccal surfaces of the teeth in the maxillary arch, including incisors, canines, premolars, and both the TT and CC. A monolateral 0.018 inch circular cross-sectional dimension nickel titanium orthodontic wire¶ was then used to activate the orthodontic appliance. The first maxillary molar wearing the monolateral arch was considered as the TT. Moreover, the teeth from the maxillary incisors to the second premolar, wearing the arch wire, were laced together with a continuous steel wire (0.010 inch) ligature to provide a stable anchorage, according to Samuels and Peak.[26] To distally move the TT, a nickel titanium open coil spring,# exerting a constant force over its range of activation of 250 g, was included in the appliance as reported by Perinetti et al.[27] The entire orthodontic appliance was placed in a single clinical session. No orthodontic appliance was placed on the mandibular arch.

Clinical Monitoring and GCF Collection

Six sites in each TT, CC, and AC tooth (mesio-, mid-, and disto-buccal; mesio-, mid-, and disto-lingual/palatal) were clinically examined as follows: 1) supragingival plaque (PL+), assessed by visual criteria; 2) gingival bleeding within 15 seconds after probing (BOP+) with a 20 g controlled-force probe; and 3) probing depth (PD). The same operator collected all clinical data. Contamination of the GCF samples was minimized by recording the PL+ before carefully cleaning the tooth with cotton pellets, collecting GCF from the isolated

‖ Vivacare TPS Probe, Vivadent, Schaan, Lichtenstein.
¶ MBT, 3M-Unitek, Monrovia, CA.
# American Orthodontics, Sheboygan, WI.

area, and then recording the PD and BOP+, as previously described.[28] These clinical parameters were assessed twice: at baseline, prior to orthodontic appliance placement, and on day 28. Verification of dental movement was determined as previously described.[6]

GCF was collected for the AST activity assay at the mesial and distal aspects of the TT, CC, and AC immediately before the appliance placement and activation, at 1 hour, and at 1, 2, 3, and 4 weeks afterwards. Each crevicular site included in this study was isolated with cotton rolls. Before GCF collection, any supragingival plaque, if present, was removed by cotton pellets, and a gentle air stream was directed towards the tooth surface for 5 seconds to dry the area.[22] The GCF was collected using #30 standardized sterile paper strips inserted 1 mm into the gingival crevice and left *in situ* for 30 seconds. Immediately after collection, the paper points were transferred to plastic vials. Total GCF volume was determined for each sample as previously described.[22]

Aspartate Aminotransferase Assay

The GCF AST activity was determined spectrophotometrically [29**] at a constant 30°C with less than 0.05°C fluctuation. The cone sample was incubated for 5 minutes in a substrate containing 0.15 M L-aspartate, 0.1 M 2-oxoglutarate, 0.2 mM reduced nicotinamide adenine dinucleotide (NADH), 400 mU/ml malate dehydrogenase, and 0.1 M phosphate buffer (pH 7.4 ± 0.1 at 30°C), to a total volume of 1.0 ml. In the presence of AST, L-aspartate and 2-oxoglutarate exchange an amino group to yield oxalacetate and L-glutamate. The rate of this reaction was monitored by the use of an indicator reaction in which the oxalacetate formed is reduced to L-malate by an excess of malate dehydrogenase, with the simultaneous oxidation of NADH. The change in absorbance at 340 nm was monitored as the NADH was consumed. A 1 cm path length was used, and a value of 6.22×10^3 was considered as the NADH millimolar absorptivity. Results were converted into enzyme activity units (1 U = 1 µmol of NAD^+ released per minute at 30°C) and expressed as total AST activity (mU/sample).

Data Processing

A software program[††] was used to perform the data analysis. At baseline and on day 28, the percentage of tooth sites positive for plaque (%PL+), bleeding on probing (%BOP+), and the mean PD were calculated for the TT, CC, and AC groups considering the tooth as the statistical unit. A Friedman test and a Bonferroni-corrected Wilcoxon paired signed rank test were used to evaluate the statistical significance of the differences of the clinical data among the experimental categories at baseline and 28 days. The Bonferroni-corrected Wilcoxon paired signed rank test was also used to assess the significance of the differences in clinical data within each group over time. Clinical data obtained from the corresponding GCF collection sites were further processed to statistically assess differences in clinical conditions between the mesial and distal aspects within groups. The number of PL+ and BOP+ sites was processed as paired dichotomous data by using a McNemar test, while the PD scores were assessed performing a Wilcoxon paired signed rank test.

The measurements of GCF volume and AST activity were expressed as the overall value for each experimental group, considering the tooth as the statistical unit, throughout the study. The Friedman and Bonferroni-corrected Wilcoxon paired signed rank tests were employed to examine the significance of the differences in the overall GCF volume and AST activity among the experimental categories. The GCF AST activity was also reported for each experimental category by time point, again considering the tooth as the statistical unit. The Friedman and Bonferroni-corrected Wilcoxon paired signed rank tests assessed the statistical significance of the differences across the groups, by time point, and among the time points within each group. The Wilcoxon paired signed rank test was employed to analyze whether any statistically significant difference in the GCF AST activity occurred between mesial and distal sites, within the groups, at each time point. A probability of $P < 0.05$ was accepted for rejection of the null hypothesis.

RESULTS

The test teeth underwent a mean distal movement of 1.9 ± 0.5 mm. No dental displacement was seen in the CC and AC groups. Clinical parameters were similar in all 3 experimental groups at baseline without statistically significant differences (Tables 1, 2, and 3). On day 28, all clinical parameters in the TT and CC groups had significantly worsened, compared to baseline; in the ACs, these parameters showed no significant changes. Significant differences were observed for the clinical parameters among the 3 groups at the day 28 examinations (Tables 1, 2, and 3). Clinical data from the AC group, compared to the TT and CC groups for %PL+ and %BOP+, and to the TT group only for the PD, showed statistically significant differences (Tables 1, 2, and 3). No statistically significant differences in clinical conditions were found for PL+, BOP+, and PD when they were processed with respect to the corresponding GCF collection sites, between mesial and distal sites within each category, both at baseline and on day 28 (data not shown).

The overall GCF volumes in microliters for each experimental group are reported in Table 4. There was a significant difference among the groups; GCF volume was significantly greater in the TT and CC groups in comparison to the AC group; however, there was no

** Model 8453, Hewlett Packard, Waldgrohn, Germany.
†† SPSS Inc., Chicago, IL.

Table 1.

Percentages of Tooth Sites Positive for the Presence of Bacterial Plaque (%PL+, 6 sites per tooth) at Baseline and Day 28 Examinations in the Different Groups (N = 18)

Time	Group	Mean ± SD	Median	Minimum	Maximum
Baseline	TT	14.1 ± 8.6	17	—	33
	CC	16.8 ± 11.3	17	—	33
	AC	11.2 ± 11.4	17	—	33
Friedman test		NS			
28 days	TT	27.8 ± 11.2*†	33	17	50
	CC	26.9 ± 16.2*†	0	—	50
	AC	14.1 ± 10.3	0	—	33
Friedman test		$P = 0.008$			

NS: no statistically significant difference.
* Difference statistically significant compared to the corresponding baseline value ($P = 0.003$ and $P = 0.022$ for the TT and CC groups, respectively).
Pairwise comparisons at the 28-day examinations: † Significantly different from the AC group.

Table 2.

Percentages of Tooth Sites Positive for Bleeding on Probing (%BOP+, 6 sites per tooth) at Baseline and Day 28 Examinations in the Different Groups (N = 18)

Time	Group	Mean ± SD	Median	Minimum	Maximum
Baseline	TT	14.1 ± 10.3	17	—	33
	CC	14.9 ± 11.2	17	—	33
	AC	14.0 ± 11.7	17	—	33
Friedman test		NS			
28 days	TT	25.1 ± 15.2*†	17	—	50
	CC	25.9 ± 15.2*†	25	—	50
	AC	11.3 ± 10.0	17	—	33
Friedman test		$P = 0.010$			

NS: no statistically significant difference.
* Difference statistically significant compared to the corresponding baseline value ($P = 0.039$ and $P = 0.028$ for the TT and CC groups, respectively).
Pairwise comparisons at the 28-day examinations: † Significantly different from the AC group.

statistically significant difference between the TT and CC groups. Overall values of GCF AST for each group are also reported in Table 4. A statistically significant difference in the enzymatic activity among the experimental teeth was seen; in particular, it was greater in the TT group compared to both the CC and AC groups; moreover, in the CC group, it was also greater compared to the AC group. Changes in GCF AST activity in the groups, by time points, are reported in Table 5. At baseline and 1 hour, the enzymatic activity was similar among the 3 groups, without statistically significant differences. Enzyme activity was significantly greater in the TT group compared to the CC group on days 7 and 14, while a significant difference between the TT and AC groups was seen from day 7 to 28. The GCF AST activity from the CC group was significantly greater in comparison to the AC group from day 7 to the end of the study. In the TT and CC groups, a statistically significant change in the GCF AST activity was seen during the study period. Results of pairwise comparisons showed a significantly greater enzymatic activity on days 7 and 14 in the TT group compared to baseline. In the CC group, a statistically significant difference in the GCF AST activity was seen on days 7, 14, and 21, compared to baseline. In the TT group only, on day 7, the GCF AST activity significantly differed between mesial and distal sites at $P = 0.001$, with activity being greater in the compression sites (distal sites, data not shown).

DISCUSSION

We designed a short-term longitudinal study to evaluate the GCF AST activity occurring during orthodontic treatment, with the aim of investigating the relationship between the enzymatic GCF levels and periodontal tissue remodeling incidental to controlled occlusal trauma. The results showed significant elevation in AST activity in the TT and CC groups, compared to the AC group from day 7 to the end of the study; moreover, in the TT group undergoing controlled occlusal trauma, enzyme elevation was significantly greater as compared to the CC group on days 7 and 14. In the AC group, the GCF AST activity did not demonstrate such elevations.

In periodontal tissues, orthodontic tooth movement produces a biological process previously described as a continuous phenomenon, leading to bone resorption in pressure sites and bone deposition in tension sites.[14-17] Histological animal research[18,19] has demonstrated that both bone deposition and resorption take place in both tension and compression sites in the alveolar bone undergoing mechanical stress by tooth movement. According to these data,[18,19] an early wave of resorption, which requires 3 to 5 days, is followed by its reversal (5 to 7 days), and by a late wave of bone formation that continues for 7 to 14 days. This process appears to occur on both pressure and tension sides of the alveolar wall.[18] This model is delineated by an initial asynchronous phase in which bone resorption is

Table 3.

Probing Depth (PD, 6 sites per tooth) at Baseline and Day 28 Examinations in the Different Groups (N = 18)

Time	Group	Mean ± SD	Median	Minimum	Maximum
Baseline	TT	1.8 ± 0.6	2.0	1.0	2.5
	CC	1.6 ± 0.7	1.5	1.0	3.0
	AC	1.7 ± 0.7	2.0	1.0	3.0
Friedman test		NS			
28 days	TT	2.3 ± 0.8*†	2.5	1.0	3.5
	CC	2.2 ± 0.9*†	2.5	1.0	3.5
	AC	1.5 ± 0.7	1.5	1.0	3.5
Friedman test		$P = 0.005$			

NS: no statistically significant difference.
*Difference statistically significant compared to the corresponding baseline value ($P = 0.040$ and $P = 0.008$ for the TT and CC groups, respectively).
Pairwise comparisons at the 28-day examinations: † Significantly different from the AC group.

Table 4.

Overall GCF Volumes and Total GCF AST Activities (in µl and mU/sample, respectively) throughout Study in the Different Groups (N = 18)

	Group	Mean ± SD	Median	Minimum	Maximum
GCF volume (µl)	TT	0.16 ± 0.04†	0.15	0.10	0.29
	CC	0.17 ± 0.03†	0.18	0.12	0.23
	AC	0.14 ± 0.02	0.14	0.10	0.19
Friedman test		$P = 0.002$			
Total GCF AST activity (mU/sample)	TT	293 ± 59*†	276	205	374
	CC	236 ± 52†	214	178	316
	AC	179 ± 35	183	122	236
Friedman test		$P = 0.000$			

Pairwise comparisons: *Significantly different from the CC group; † significantly different from the AC group.

greater than bone deposition, while, at later times, resorption and deposition may become synchronous.[18,19]

Tissue remodeling incidental to controlled occlusal trauma may be detectable by changes in GCF, as previously observed in cross-sectional[13] and longitudinal human studies.[28] In particular, some studies[6-8] have found an increase in certain GCF mediators, i.e., cytokines, that can act as markers of the clinical condition during orthodontic treatment. AST is widely distributed in tissues, with the highest levels in heart and liver.[30] Since this enzyme is normally confined to the cytoplasm, the increase in its extracellular levels is considered to be a sign of increased cell necrosis.[20-22] Indeed, its serum levels are considered to be a biochemical marker of myocardial infarction or hepatitis.[31,32] Since significant AST activities in GCF have been described,[20] different investigations have documented a positive relationship between the enzyme activities and the severity of tissue destruction, using both the experimental gingivitis model[21] and periodontitis patients.[23] AST activity in GCF has been correlated with clinical parameters of periodontal health, including attachment loss,[23] alveolar bone levels,[22] and gingival index.[21] Moreover, it has been demonstrated that an increase in the AST activity in GCF is related to periodontitis activity.[23] The present study was designed to evaluate GCF AST activity of orthodontic patients under different conditions: 1) when the tooth undergoes controlled occlusal trauma by an orthodontic appliance (TT); 2) when the tooth does not undergo any mechanical stress, but wears an orthodontic appliance which may interfere with the gingival condition (CC); and 3) when the tooth is free from any mechanical stress or orthodontic appliance (AC).

A clinically detectable dental displacement was seen in the TT group only. As previously seen in several investigations,[33-35] in the present study, the placement of fixed orthodontic appliances was associated with a significant worsening of gingival health (Tables 1, 2, and 3). In particular, while the clinical data recorded in each experimental tooth were often significantly different among the categories, the corresponding GCF sampling site clinical data did not show such differences at a statistically relevant level between the mesial and distal sites within each experimental tooth.

A positive correlation between the amount of GCF and gingival inflammation has previously been documented,[36] indicating that this fluid can reflect the periodontal state of health. According to our data, there was no significant difference in GCF volume from the TT and CC groups; this probably means that the rate of fluid exudation may be independent of the controlled occlusal trauma. Moreover, in the AC group, the rate of exudation was significantly lower as compared to the GCF volume from both the TT and CC groups. If we consider that the TT and CC groups showed a comparable increase in gingival inflammation, while in the AC group this remained at baseline scores throughout the study (Tables 1, 2, and 3), the view that GCF volume is influenced by gingival inflammation,[36] as a consequence of the orthodontic appliance,[28] is reinforced.

Table 5.

AST Changes in GCF by Time Point and Group (N = 18)

Time	TT	CC	AC	Friedman Test
Baseline	227(162;264)	183(140;235)	206(135;251)	NS
1 hour	238(170;304)	214(148;254)	186(157;236)	NS
7 days	351(287;510)*†	291(211;390)†	173(118;220)	$P = 0.000$
14 days	405(364;434)*†	226(204;312)†	146(134;172)	$P = 0.000$
21 days	276(229;374)†	234(194;262)†	187(132;206)	$P = 0.002$
28 days	205(159;271)†	189(161;315)†	163(130;192)	$P = 0.006$
Friedman test	$P = 0.000$‡	$P = 0.001$§	NS	

Median (25th;75th percentiles) of total activity (mU/sample), from mesial and distal sites, of each group.
Results of pairwise comparisons among the groups at each time point:
* Significantly different from the CC group.
† Significantly different from the AC group.
Results of pairwise comparisons over the time points within each group:
‡ Baseline versus days 7 and 14.
§ Baseline versus day 7 to 21.
NS: no statistically significant difference.

The behavior of the GCF AST activity in the TT group is shown in Tables 4 and 5. AST activity peaks were seen in the TT group, with respect to baseline and on days 7 and 14. This AST activity elevation in the TT group may be explained as a consequence of tissue remodeling; the controlled occlusal trauma may have produced cell necrosis as a consequence of mechanical stress exerted on the periodontal ligament and alveolar bone.[37,38] Indeed, the compression of the periodontal ligament induces a hyalinization of the most compressed area.[38] This hyaline zone is described as an area of focal aseptic necrosis[16,17,39] that is resistant to degradation and persists in the pressure zone, depending on the magnitude of the force.[38] Moreover, histomorphometric findings[18] that evaluated the alveolar bone cycle during orthodontic tooth movement in rats described an early wave of resorption, which requires 3 to 5 days, followed by its reversal (5 to 7 days), and a late wave of formation that continues for 7 to 14 days, in both the pressure and tension sites. Other authors who have studied bone cycling in humans have reported a sudden initial activation phase that is followed by resorption, which lasts 10 days[9] or 3 weeks.[40,41] These observations may explain why GCF AST activity was significantly elevated in both the tension and compression sites at days 7 and 14 in the present study.

The AST activity in the TT group reported from compression sites on day 7, as compared to the tension sites, was significantly greater ($P = 0.001$). As there were no significant differences in clinical conditions between the mesial and distal sites in the TT group, this greater GCF AST activity was probably due to the prevalence of the tissue destruction process over that of synthesis.[14-17]

The AST activity in the CC group was significantly greater than in the AC group from days 7 to 28 (Table 5). This should be combined with the gingival inflammation recorded for the CC group, as the scores of clinical data in this category (Tables 1, 2, and 3), and was probably due to the orthodontic appliance presence.[42] Considering further that GCF AST activities in the TT group were similarly significantly greater than in the CC group (days 7 and 14, Table 5), while the clinical parameters did not vary between the 2 groups (Tables 1, 2, and 3), it can be proposed that the GCF AST activity increases were produced by gingival inflammation in the CC group and by a combination of gingival inflammation and controlled occlusal trauma in the TT group. These results underline the properties of the GCF AST activity in distinguishing between moving and non-moving teeth, and demonstrate that this enzyme has potential for further studies as a diagnostic tool in orthodontics.

Conversely, in the AC group, where no tooth movement occurred and no orthodontic appliance that could interfere with gingival health was placed, the GCF AST activity remained at baseline levels during the entire experimental term. Thus, our results suggest that AST activity in GCF is indeed affected by controlled occlusal trauma, which causes tissue remodeling, and that its value may also be partially influenced by factors other than mechanical stress, such as gingival inflammation, as indicated by the data from the CC group. However, when gingival inflammation is kept under control, AST activity in GCF may be considered to be a suitable indicator of the biologic effects produced by orthodontic treatment.

In conclusion, our study initially demonstrated a low increase in GCF AST in teeth wearing an orthodontic appliance even if not undergoing controlled occlusal trauma. While this is probably a consequence of gingival inflammation produced by the presence of the plaque-retentive appliance, this enzyme activity is also further affected by the different stresses exerted on the periodontium by orthodontic forces, with levels also being further elevated in dental sites undergoing compression stress.

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