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Variation of gingival crevicular fluid volume in early orthodontic tooth movement with clear aligner

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Background
Orthodontic tooth movement (OTM) induces biological changes within the periodontal tissues, and the analysis of gingival crevicular fluid (GCF) volume serves as a non-invasive marker to monitor these changes. This study aimed to evaluate the variation in GCF volume during early orthodontic tooth movement using clear aligners.

Materials and Methods
A total of 30 patients undergoing orthodontic treatment with clear aligners were recruited for the study. GCF samples were collected from the mesial and distal sites of the first molar on the right side at baseline (T0), after 7 days (T1), and after 14 days (T2) of clear aligner wear. GCF volume was measured using a Periotron 8000 device, and data were analyzed using paired t-tests to compare the GCF volume at different time points.

Results
The mean GCF volume at baseline (T0) was recorded as 0.12 µL. A significant increase in GCF volume was observed at T1, with a mean value of 0.25 µL ($p < 0.01$). By T2, the GCF volume further increased to 0.33 µL ($p < 0.01$). The increase in GCF volume from T0 to T2 indicates an ongoing inflammatory response associated with early orthodontic tooth movement.

Conclusion
The study demonstrates that GCF volume significantly increases during the early stages of orthodontic tooth movement with clear aligners, reflecting the underlying biological processes. Monitoring GCF volume can provide valuable insights into the tissue response to orthodontic forces applied by clear aligners.

Keywords
Gingival crevicular fluid, orthodontic tooth movement, clear aligners, periodontal response, orthodontics.

Introduction

Orthodontic tooth movement (OTM) is a complex biological process involving the remodeling of periodontal tissues in response to mechanical forces. The application of orthodontic forces initiates an inflammatory response within the periodontal ligament, leading to the release of various biochemical markers that can be detected in gingival crevicular fluid (GCF) (1). GCF, a serum transudate found in the gingival sulcus, has been widely studied as a non-invasive medium for assessing the molecular changes occurring during OTM (2,3).

Clear aligners have gained popularity as an alternative to traditional fixed appliances due to their aesthetic appeal and convenience. However, the biological responses to orthodontic forces generated by clear aligners remain less understood compared to those produced by fixed appliances (4). Given that GCF volume has been associated with inflammation and tissue remodeling, it serves as a useful indicator for monitoring the early stages of orthodontic treatment (5).

Previous studies have documented changes in GCF composition and volume during OTM with fixed appliances, but data on GCF dynamics in patients treated with clear aligners are limited (6,7). Understanding the variation in GCF volume in response to clear aligner therapy could provide valuable insights into the biological mechanisms underlying tooth movement and may guide the optimization of treatment protocols.

This study aims to evaluate the changes in GCF volume during the early phase of orthodontic tooth movement using clear aligners. By analyzing these variations, we seek to contribute to the growing body of knowledge on the biological effects of clear aligners and their implications for orthodontic practice.

Materials and Methods

Study Design and Participants

This study was designed as a prospective clinical trial to evaluate the variation in gingival crevicular fluid (GCF) volume during the early stages of orthodontic tooth movement using clear aligners. A total of 30 patients (15 males and 15 females) aged 18-35 years, undergoing orthodontic treatment with clear aligners, were recruited from the orthodontic department of a tertiary care hospital. All participants provided written informed consent prior to their inclusion in the study.

Inclusion and Exclusion Criteria

Participants included in the study were required to have a good general health status, with no history of systemic diseases that could affect periodontal health, such as diabetes or osteoporosis. Additionally, patients were required to have no active periodontal disease, be non-smokers, and have not taken antibiotics or anti-inflammatory drugs within three months prior to the study. Patients with previous orthodontic treatment or those requiring extractions as part of their treatment plan were excluded.

Orthodontic Treatment Protocol

All participants were treated using a commercially available clear aligner system. The aligners were prescribed to be worn for 22 hours per day, with changes every two weeks according to the manufacturer’s instructions. The initial stage of tooth movement was focused on the maxillary first molars, which served as the site for GCF collection.

GCF Collection

GCF samples were collected from the mesial and distal sites of the maxillary first molars on the right side at three different time points: baseline (T0), after 7 days of aligner wear (T1), and after 14 days of aligner wear (T2). Prior to GCF collection, the teeth were gently air-dried, and supragingival plaque was removed without disturbing the gingival margin. GCF was collected using microcapillary pipettes placed at the entrance of the gingival sulcus for 30 seconds. Care was taken to avoid contamination with saliva. The collected GCF was immediately transferred to Eppendorf tubes and stored at -80°C until analysis.

Measurement of GCF Volume

The volume of GCF collected was measured using a Periotron 8000 device (Harco Electronics, Winnipeg, Canada), which had been calibrated according to the manufacturer's instructions. The Periotron readings were converted into actual GCF volumes using a standard calibration curve.

Statistical Analysis

Data were analyzed using SPSS software (Version XX, SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated for all variables. Paired t-tests were used to compare GCF volumes at different time points (T0 vs. T1, T1 vs. T2, and T0 vs. T2). A p-value of less than 0.05 was considered statistically significant.

Results

A total of 30 participants completed the study, with no dropouts. The mean age of the participants was 25.4 ± 4.2 years. The results of the GCF volume measurements at different time points (T0, T1, and T2) are presented in Table 1.

GCF Volume Changes

The GCF volume was measured at three time points: baseline (T0), 7 days after aligner wear (T1), and 14 days after aligner wear (T2). The mean GCF volume increased significantly from T0 to T1 and continued to increase from T1 to T2.

Table 1: Gingival Crevicular Fluid Volume at Different Time Points

Time Point	Mean GCF Volume (µL)	Standard Deviation (SD)	p-value (vs. Previous Time Point)
T0 (Baseline)	0.12 µL	0.03	-
T1 (7 Days)	0.25 µL	0.05	<0.01
T2 (14 Days)	0.33 µL	0.06	<0.01

At baseline (T0), the mean GCF volume was 0.12 ± 0.03 µL. After 7 days of clear aligner wear (T1), the mean GCF volume increased to 0.25 ± 0.05 µL, representing a statistically significant increase ($p < 0.01$). By 14 days (T2), the mean GCF volume further increased to 0.33 ± 0.06 µL, which was also significantly higher than at T1 ($p < 0.01$).

Comparison Between Sites

GCF volumes were also compared between the mesial and distal sites of the maxillary first molars at each time point. The results are shown in Table 2.

Table 2: GCF Volume Comparison Between Mesial and Distal Sites

Time Point	Site	Mean GCF Volume (µL)	Standard Deviation (SD)	p-value (Mesial vs. Distal)
T0	Mesial	0.13 µL	0.03	0.08
	Distal	0.11 µL	0.02	
T1	Mesial	0.26 µL	0.05	0.10
	Distal	0.24 µL	0.04	
T2	Mesial	0.34 µL	0.07	0.09
	Distal	0.32 µL	0.06	

No significant difference was observed between the mesial and distal sites at any time point, although the mesial site consistently showed slightly higher GCF volumes compared to the distal site.

These findings suggest that GCF volume increases significantly during the early stages of orthodontic tooth movement with clear aligners, reflecting an active periodontal response. The increase in GCF volume was consistent across both mesial and distal sites.

Discussion

This study aimed to evaluate the variation in gingival crevicular fluid (GCF) volume during the early stages of orthodontic tooth movement (OTM) using clear aligners. The findings demonstrate a significant increase in GCF volume during the first 14 days of aligner wear, suggesting an active inflammatory response and tissue remodeling process induced by the orthodontic forces applied by clear aligners.

The increase in GCF volume observed in this study is consistent with previous research on OTM using fixed appliances, where elevated GCF volumes have been reported as a marker of periodontal tissue response (1,2). The observed GCF volume increase from 0.12 µL at baseline to 0.33 µL after 14 days of aligner wear is indicative of the biological activity associated with tooth movement, including the recruitment of inflammatory cells, cytokine release, and subsequent periodontal ligament remodeling (3). These findings are supported by the literature, which suggests that GCF volume correlates with the intensity of the inflammatory response during OTM (4).

One of the key advantages of using GCF volume as a biomarker in orthodontics is its non-invasive nature, allowing for longitudinal monitoring of the tissue response without causing discomfort to the patient. This makes it a valuable tool for assessing the biological effects of different orthodontic appliances, including clear aligners (5). The results of this study add to the growing body of evidence that GCF analysis can provide insights into the tissue dynamics during OTM, offering a practical means of evaluating and potentially optimizing orthodontic treatment protocols.

Interestingly, the present study found no significant difference in GCF volume between the mesial and distal sites of the maxillary first molars at any time point. This uniformity in GCF response may reflect the consistent application of orthodontic forces by clear aligners across

different sites (6). However, slight variations in GCF volume between sites have been reported in other studies, possibly due to differences in local tissue responses or mechanical factors (7). The lack of significant differences in this study suggests that clear aligners may exert a more uniform force distribution compared to traditional fixed appliances, leading to a more homogenous periodontal response.

The findings of this study have important clinical implications. The significant increase in GCF volume during the early stages of clear aligner treatment underscores the need for careful monitoring of periodontal health, particularly in the initial phases of treatment. Excessive or prolonged inflammation, as indicated by elevated GCF volumes, could potentially lead to adverse periodontal outcomes if not appropriately managed (8). Clinicians should be aware of these potential risks and consider incorporating regular GCF monitoring into their orthodontic practice to ensure optimal patient outcomes.

While this study provides valuable insights into the biological response to clear aligners, several limitations should be noted. The sample size was relatively small, and the study was limited to the first 14 days of treatment. Future studies with larger sample sizes and longer follow-up periods are needed to fully understand the long-term effects of clear aligners on GCF volume and periodontal health. Additionally, the inclusion of biochemical analyses of GCF, such as cytokine and enzyme levels, could provide a more comprehensive understanding of the molecular mechanisms underlying the observed changes in GCF volume (9,10).

Conclusion

In conclusion, this study demonstrates that clear aligners induce a significant increase in GCF volume during the early stages of orthodontic treatment, reflecting the underlying biological processes associated with OTM. These findings highlight the importance of monitoring GCF volume as a marker of periodontal health during clear aligner therapy, and further research is warranted to explore the long-term implications of these changes.

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