

IMPACT OF FIXED ORTHODONTIC APPLIANCES ON ENAMEL MINERALIZATION AND SALIVARY MINERAL BALANCE

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Relevance of the Study: Orthodontic treatment with fixed appliances remains one of the most widely used approaches for correcting malocclusion, but it is consistently associated with clinically significant changes in enamel integrity. White spot lesions (WSLs), representing the earliest clinical manifestation of enamel demineralization, are frequently observed during multibracket therapy and may negatively affect both esthetic outcomes and long-term caries risk [1,2]. Recent systematic reviews indicate that the prevalence of WSLs during orthodontic treatment remains high worldwide, confirming the persistent clinical relevance of this complication [1].

The development of enamel demineralization during orthodontic therapy is multifactorial.

Fixed appliances create plaque-retentive areas, impair effective oral hygiene, and promote the formation of localized acidic microenvironments around brackets, shifting the balance toward mineral loss [3,4]. Experimental studies have demonstrated that demineralization can develop rapidly adjacent to orthodontic brackets under cariogenic conditions, and its severity may depend on bracket design and surface characteristics [5].

In addition to local biofilm effects, alterations in salivary composition may contribute to enamel vulnerability. Saliva plays a critical protective role by supplying calcium and phosphate ions necessary for remineralization and by buffering acidic challenges. Changes in salivary biochemical parameters during orthodontic treatment, including variations in mineral content, have been reported, suggesting a possible disturbance of mineral homeostasis [6].

Given the high prevalence of enamel demineralization and the complexity of its pathogenesis during orthodontic treatment, further investigation of mineral balance and enamel mineralization processes is essential for improving preventive strategies and optimizing orthodontic care protocols [1,2].

Aim of the Study

The aim of this study was to evaluate the impact of orthodontic appliances on enamel mineralization processes and to assess changes in mineral balance during orthodontic treatment.

Materials and Methods

This prospective controlled study included 60 patients aged 12–18 years. The orthodontic group consisted of 30 patients treated with fixed orthodontic appliances (metal bracket systems) for at least 6 months. The control group included 30 age- and sex-matched individuals without orthodontic treatment.

Unstimulated saliva samples were collected in the morning under standardized conditions.

The concentrations of calcium (Ca), phosphorus (P), and magnesium (Mg) were measured using an automated biochemical analyzer.

Enamel condition was assessed clinically using the ICDAS index, and oral hygiene status was evaluated using the OHI-S index.

Statistical analysis was performed using SPSS 26.0. Quantitative data were expressed as mean \pm standard deviation ($M \pm SD$). Intergroup differences were analyzed using the Student's t-test. A p-value < 0.05 was considered statistically significant.

Results: The mean salivary calcium level in the orthodontic group was 1.42 ± 0.18 mmol/L, which was significantly lower compared to the control group (1.71 ± 0.21 mmol/L; $p < 0.01$). Phosphorus concentration was also reduced in patients with fixed appliances (4.12 ± 0.35 mmol/L) compared to controls (4.48 ± 0.29 mmol/L; $p < 0.05$).

Magnesium levels demonstrated a statistically significant decrease in the orthodontic group (0.68 ± 0.09 mmol/L) versus the control group (0.82 ± 0.11 mmol/L; $p < 0.01$). Clinically, white spot lesions were detected in 36.7% of patients undergoing orthodontic treatment, whereas only 10.0% of controls showed initial enamel changes ($p < 0.01$).

The OHI-S index was significantly higher in the orthodontic group (2.1 ± 0.4) compared to the control group (1.3 ± 0.3 ; $p < 0.001$), indicating poorer oral hygiene during orthodontic treatment.

Table 1. Salivary Mineral Levels in the Study Groups

| Parameter | Orthodontic group (n=30) | Control group (n=30) | p-value |
|------------------------|--------------------------|----------------------|----------|
| Calcium (mmol/L) | 1.42 ± 0.18 | 1.71 ± 0.21 | <0.01 |
| Phosphorus (mmol/L) | 4.12 ± 0.35 | 4.48 ± 0.29 | <0.05 |
| Magnesium (mmol/L) | 0.68 ± 0.09 | 0.82 ± 0.11 | <0.01 |
| White spot lesions (%) | 36.7% | 10.0% | <0.01 |
| OHI-S index | 2.1 ± 0.4 | 1.3 ± 0.3 | <0.001 |

Table 1. Comparative analysis of salivary mineral levels, enamel condition, and oral hygiene status in patients undergoing orthodontic treatment and controls. Data are presented as mean \pm standard deviation ($M \pm SD$). Statistical significance was set at $p < 0.05$.

As presented in Table 1, patients undergoing orthodontic treatment demonstrated significantly lower salivary mineral levels compared to the control group. The mean calcium concentration was reduced by 16.9% ($p < 0.01$), phosphorus by 8.0% ($p < 0.05$), and magnesium by 17.1% ($p < 0.01$).

Additionally, white spot lesions were observed 3.7 times more frequently in the orthodontic group (36.7%) than in controls (10.0%) ($p < 0.01$). The OHI-S index was significantly higher in patients with fixed appliances ($p < 0.001$), indicating compromised oral hygiene during orthodontic treatment.

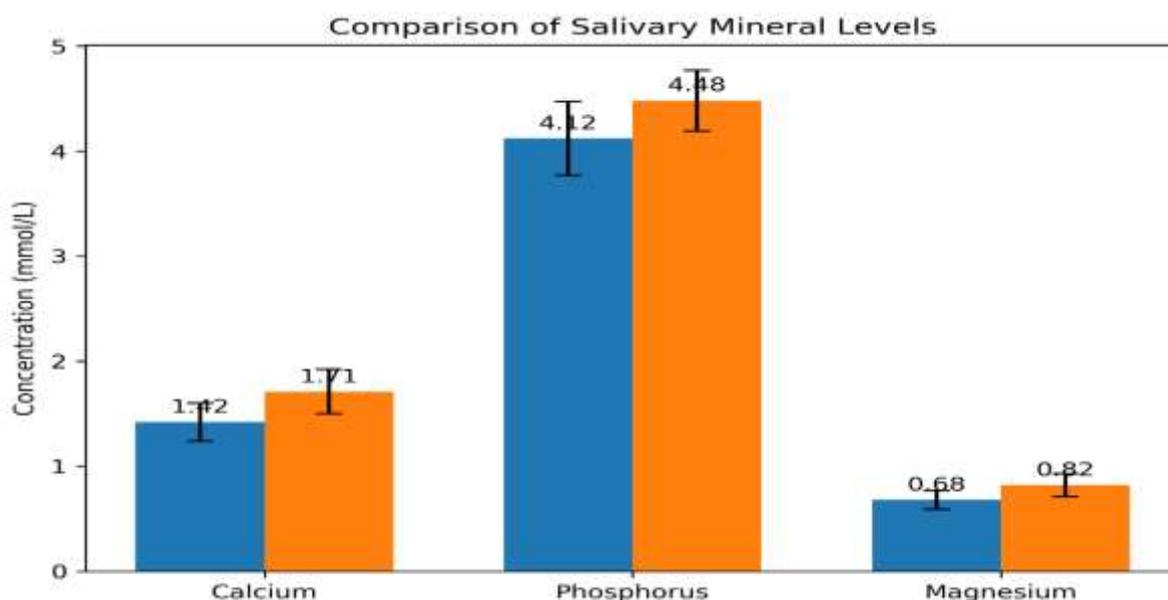


Figure 1. Comparison of salivary calcium, phosphorus, and magnesium levels between the orthodontic and control groups. Bars represent mean values, and error bars indicate standard deviation. Statistically significant differences were observed for calcium and magnesium ($p < 0.01$) and phosphorus ($p < 0.05$).

Discussion: The present study demonstrates that patients undergoing fixed orthodontic treatment exhibit significant alterations in salivary mineral composition, accompanied by a higher prevalence of early enamel demineralization lesions. A statistically significant reduction in salivary calcium and magnesium levels was observed in the orthodontic group compared to controls. Calcium and phosphate ions play a critical role in maintaining the dynamic equilibrium between enamel demineralization and remineralization. A decrease in their availability may impair enamel resistance to acid challenge and promote the formation of white spot lesions.

The reduction in magnesium levels may further contribute to compromised enamel structure, as magnesium participates in crystal lattice stabilization and mineral metabolism regulation. The higher OHI-S index values in patients with fixed appliances indicate impaired oral hygiene, which may enhance biofilm accumulation around brackets and wires. This creates localized acidic microenvironments that favor mineral loss. The 3.7-fold increase in white spot lesion prevalence in the orthodontic group confirms the clinical relevance of these biochemical changes. These findings are consistent with previous reports suggesting that fixed orthodontic appliances act as plaque-retentive factors and increase the risk of enamel demineralization.

However, while most earlier studies focused primarily on clinical manifestations, the present research additionally highlights measurable biochemical shifts in mineral balance, emphasizing the systemic and local factors contributing to enamel vulnerability during orthodontic treatment. The clinical implications of these results underscore the importance of preventive strategies, including intensified oral hygiene protocols, fluoride therapy, and monitoring of mineral status during orthodontic care. Early identification of patients at risk may help reduce the incidence of enamel demineralization and improve long-term treatment outcomes.

Further longitudinal studies are warranted to determine the reversibility of mineral changes after appliance removal and to explore targeted preventive interventions.

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