OIGINAL RESEARCH

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Clinical, microbiological, and patient-reported outcomes of ceramic versus metallic orthodontic brackets: a prospective comparative study.

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Abstract
Introduction. Orthodontic fixed appliances significantly influence the oral environment by creating plaque-retentive surfaces that may alter microbial balance and periodontal health. Among available systems, ceramic and metallic brackets differ in their surface characteristics, mechanical properties, and aesthetic appeal. **Aim of the study.** This prospective observational study aimed to compare clinical periodontal indices, microbiological changes, and patient-reported outcomes between patients treated with ceramic and metallic orthodontic brackets. **Methods.** Sixty orthodontic patients aged 15–30 years were divided into two groups: metallic brackets (n = 30) and ceramic brackets (n = 30). Plaque Index and Gingival Index were recorded at baseline, 3 months, and 6 months. Subgingival plaque samples were analyzed qualitatively using phase-contrast microscopy. Patient satisfaction was assessed using a standardized Likert-scale questionnaire. **Results.** Results demonstrated significantly higher plaque accumulation and gingival inflammation in the ceramic bracket group at three months (PI: 1.48 vs. 1.21; GI: 1.15 vs. 0.92). Pathogenic microbial flora developed more frequently in ceramic bracket wearers (40%) compared with metallic bracket patients (20%). However, ceramic brackets showed superior aesthetic satisfaction scores. Following reinforcement of oral hygiene protocols, microbiological conditions improved in both groups at six months. **Conclusions.** Ceramic brackets offer clear aesthetic benefits, but may be associated with increased plaque retention and microbial imbalance. Strict oral hygiene protocols and patient compliance remain essential for maintaining periodontal health during orthodontic treatment.

Keywords: Orthodontic brackets; ceramic brackets; metallic brackets; plaque index; gingival index; oral microbiota; orthodontic treatment; patient satisfaction.

Introduction

Orthodontic treatment with fixed appliances represents a cornerstone of modern dentistry, aiming to correct malocclusions and improve both functional and aesthetic outcomes [1].

However, the placement of orthodontic brackets introduces new retentive areas that significantly alter the oral ecosystem [2]. These structural changes facilitate plaque accumulation, modify bacterial colonisation patterns, and may increase the risk of enamel demineralisation, gingivitis, and periodontal inflammation [3,4].

The presence of orthodontic appliances disrupts the equilibrium of oral microbiota by promoting the proliferation of cariogenic microorganisms, particularly *Streptococcus mutans* and *Lactobacilli* [5]. These bacteria are widely recognised as primary contributors to the initiation and progression of dental caries, especially in environments with increased plaque retention and carbohydrate exposure. Studies have demonstrated that fixed orthodontic appliances significantly increase bacterial load compared to untreated conditions due to the complexity of maintaining effective oral hygiene around brackets and wires [6,7].
Bracket material plays a critical role in bacterial adhesion and plaque accumulation [6]. Metallic brackets, traditionally made from stainless steel, are characterised by smooth surfaces and high mechanical resistance. In contrast, ceramic brackets were introduced primarily to satisfy aesthetic demands, offering tooth-colored translucency that blends with natural dentition [7]. Despite their cosmetic advantages, ceramic brackets possess surface properties, including increased roughness and porosity that may enhance bacterial adherence [8].
Previous microbiological investigations comparing orthodontic materials have produced varying results. Some authors have reported higher microbial colonisation on ceramic bracket surfaces than on metallic ones,

due to their microstructural characteristics [9]. Other studies suggest that differences in hygiene outcomes are influenced more by patient compliance and oral hygiene practices than by bracket material alone [10].

To ensure objective evaluation of periodontal changes during orthodontic treatment, standardised clinical indices and microbiological assessment methods are essential. Quantitative clinical parameters such as the Plaque Index and Gingival Index [11] provide reliable measures of oral hygiene status and gingival inflammation, while phase-contrast microscopy allows qualitative evaluation of microbial shifts within the subgingival biofilm.

In addition, patient-reported outcome measures play an important role in assessing subjective treatment experiences, including comfort, aesthetics, and hygiene challenges [12]. Therefore, this study incorporated clinical, microbiological, and patient-centered evaluation methods to provide a comprehensive comparison between ceramic and metallic orthodontic brackets.

Research using qualitative microbiological assessment methods, such as phase-contrast microscopy, has shown that orthodontic appliances may lead to a shift from non-pathogenic to pathogenic bacterial flora within a few months of treatment initiation [13]. These findings highlight the importance of continuous monitoring and preventive strategies during orthodontic therapy.

Although extensive literature exists comparing fixed appliances with removable aligners, fewer studies have specifically investigated the clinical and microbiological differences between ceramic and metallic brackets [6,9,14]. Given the increasing demand for aesthetic orthodontic solutions, understanding the biological implications of bracket materials is essential for informed treatment planning.

Therefore, this study aimed to evaluate the clinical, microbiological, and patient-related differences between ceramic and metallic orthodontic brackets during fixed appliance therapy.

Material and methods

This comparative observational study included 60 orthodontic patients aged between 15 and 30 years undergoing fixed orthodontic treatment. All participants presented permanent dentition, mild to moderate crowding, good periodontal health at baseline, and no history of previous orthodontic therapy.

Patients were divided into two groups according to bracket type. Group A consisted of 30 patients treated with conventional stainless-steel metallic brackets, while Group B included 30 patients treated with monocrystalline ceramic brackets. All treatments were performed using standardised archwire sequences and similar biomechanical protocols [15].

At baseline, all subjects underwent clinical examination, including plaque index and gingival index assessment [11]. Microbiological evaluation was performed through qualitative plaque sampling, analysed using phase-contrast microscopy to determine the presence of pathogenic versus non-pathogenic bacterial flora. This method allows direct visualisation of bacterial morphotypes and assessment of microbial activity [13].

Oral hygiene status was evaluated using the Silness and Löe Plaque Index (PI), which measures plaque accumulation at the gingival margin on a scale from 0 to 3[11]:

0 = no plaque;

1 = thin plaque detectable by probe;

2 = moderate visible plaque;

3 = abundant plaque accumulation.

Gingival health was assessed using the Löe and Silness Gingival Index (GI), which evaluates gingival inflammation based on color, edema, and bleeding tendency [11]:

0 = healthy gingiva;

1 = mild inflammation;

2 = moderate inflammation with bleeding on probing;

3 = severe inflammation with spontaneous bleeding.

Indices were recorded at six representative teeth per patient at baseline, 3 months, and 6 months.

Subgingival plaque samples were collected from interdental gingival sulci of molar regions using sterile periodontal curettes. Samples were

immediately transferred onto glass slides, diluted with physiological saline, and analysed using a phase-contrast microscope at 600× magnification.

Microbial flora were classified qualitatively into:
- Non-pathogenic flora: predominance of immobile Gram-positive cocci and rods;
- Pathogenic flora: presence of motile bacteria, including spirochetes and filamentous organisms.

This classification method allows real-time visualisation of microbial activity and has been widely used in periodontal microbiological assessment.

Patient-reported outcomes were evaluated using a structured questionnaire based on a 5-point Likert scale, assessing:

- Aesthetic satisfaction
- Pain/discomfort
- Difficulty maintaining oral hygiene
- Speech impairment
- Overall treatment satisfaction

Scores ranged from 1 (very dissatisfied/severe difficulty) to 5 (very satisfied/no difficulty).

Participants received standardised oral hygiene instructions. Patients were monitored at baseline, three months, and six months after treatment initiation. During each follow-up, clinical parameters, patient-reported outcomes, and microbiological findings were recorded.

Statistical analysis was conducted using chi-square and descriptive statistics to identify significant differences between groups. Data were analysed using statistical software (SPSS version XX, IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables and expressed as mean ± standard deviation for continuous data and as frequencies and percentages for categorical variables. Normal distribution of the data was verified using the Shapiro–Wilk test. Since clinical index values followed a normal distribution, parametric tests were applied.
Intergroup comparisons between ceramic and metallic bracket groups at each time point were performed using the independent samples Student's t-test. Intragroup comparisons across time points (baseline, 3 months, and 6 months) were analysed using repeated-measures ANOVA followed by Bonferroni post-hoc testing. Categorical microbiological data were analysed using the Chi-square test to evaluate differences in the prevalence of pathogenic flora between groups. Patient satisfaction scores obtained from Likert-scale questionnaires were compared using the Mann–Whitney U test due to their ordinal nature. Statistical significance was established at a p-value < 0.05.

Results

Clinical Indices

At baseline, all participants presented good oral hygiene and healthy gingival conditions, with no statistically significant differences between the two groups. The mean Plaque Index at baseline was 0.42 ± 0.15 in the metallic bracket group and 0.44 ± 0.17 in the ceramic bracket group. The mean Gingival Index values were 0.36 ± 0.12 and 0.39 ± 0.14, respectively.

After three months of orthodontic treatment, both groups demonstrated a significant increase in plaque accumulation and gingival inflammation. However, patients treated with ceramic brackets exhibited higher index values compared to those treated with metallic brackets. At the three-month evaluation, the mean Plaque Index reached 1.21 ± 0.30 in the metallic group and 1.48 ± 0.35 in the ceramic group. Gingival Index values increased to 0.92 ± 0.28 and 1.15 ± 0.31, respectively.
At six months, following reinforcement of oral hygiene instructions, a slight improvement was observed in both groups. Nevertheless, index values remained higher in the ceramic bracket group compared with the metallic bracket group (Figure 1, Table 1).

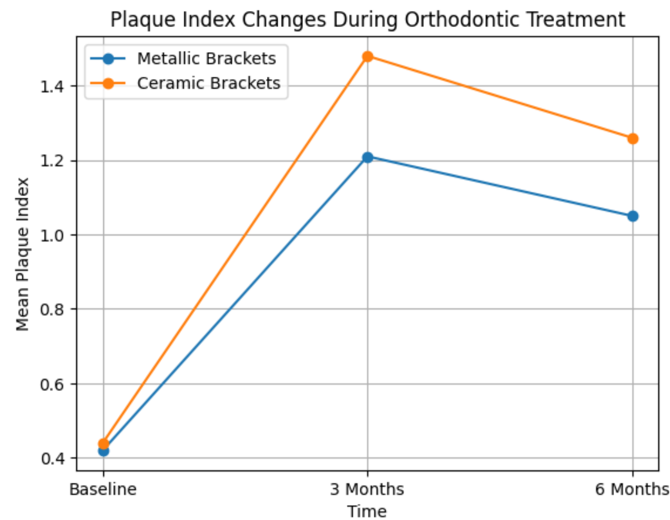

Figure 1. Changes in Plaque Index values during orthodontic treatment with metallic and ceramic brackets

Table 1. Clinical Index Values During Treatment

Time Point	Index	Metallic Brackets (n=30)	Ceramic Brackets (n=30)
Baseline	Plaque Index	0.42 ± 0.15	0.44 ± 0.17
Baseline	Gingival Index	0.36 ± 0.12	0.39 ± 0.14
3 Months	Plaque Index	1.21 ± 0.30	1.48 ± 0.35
3 Months	Gingival Index	0.92 ± 0.28	1.15 ± 0.31
6 Months	Plaque Index	1.05 ± 0.26	1.26 ± 0.29
6 Months	Gingival Index	0.78 ± 0.22	0.95 ± 0.25

Microbiological Findings

Qualitative microbiological analysis, illustrated in Table 2, showed that all patients presented non-pathogenic bacterial flora at baseline.

At three months, a shift toward pathogenic flora was observed in 6 patients (20%) in the metallic bracket group and 12 patients (40%) in the ceramic bracket group.

Following reinforcement of oral hygiene protocols, most patients showed restoration of non-pathogenic flora at six months. Pathogenic flora persisted in only two patients in the ceramic bracket group.

Table 2. Microbiological Changes During Treatment

Time Point	Flora Type	Metallic Brackets (n=30)	Ceramic Brackets (n=30)
Baseline	Non-pathogenic	30	30
Baseline	Pathogenic	0	0
3 Months	Non-pathogenic	24	18
3 Months	Pathogenic	6	12
6 Months	Non-pathogenic	30	28
6 Months	Pathogenic	0	2

Patient Satisfaction Outcomes

Patient-reported outcomes demonstrated significant differences between groups.

Aesthetic satisfaction scores were markedly higher among ceramic bracket wearers, with a mean score of 4.7 ± 0.5 compared to 3.1 ± 0.8 in the metallic group.

However, patients treated with ceramic brackets reported greater difficulty in maintaining oral hygiene and slightly higher discomfort levels during the initial treatment period.

Overall treatment satisfaction remained high in both groups, with no statistically significant differences (Table 3).

Table 3. Patient-Reported Outcomes (Likert Scale 1–5)

Parameter	Metallic Brackets	Ceramic Brackets
Aesthetic satisfaction	3.1 ± 0.8	4.7 ± 0.5
Comfort level	3.9 ± 0.6	3.4 ± 0.7
Oral hygiene difficulty	3.5 ± 0.6	2.6 ± 0.7
Speech impairment	4.2 ± 0.5	4.0 ± 0.6
Overall satisfaction	4.3 ± 0.6	4.5 ± 0.5

Orthodontic treatment resulted in increased plaque accumulation and gingival inflammation in both groups. However, ceramic brackets were associated with higher plaque index values, greater gingival inflammation, and a higher proportion of pathogenic microbiological shifts during the early stages of treatment. Despite these findings, ceramic brackets demonstrated superior aesthetic satisfaction and comparable overall treatment acceptance.

Intergroup analysis demonstrated no statistically significant differences in Plaque Index and Gingival Index at baseline ($p > 0.05$). However, at three months, both indices were significantly higher in the ceramic bracket group compared to the metallic bracket group (Plaque Index: $p = 0.002$; Gingival Index: $p = 0.01$). At six months, although improvements were observed in both groups, plaque and gingival values remained significantly higher in ceramic bracket patients (Plaque Index: $p = 0.01$; Gingival Index: $p = 0.03$).

Microbiological analysis revealed a significantly greater prevalence of pathogenic flora in the ceramic group at three months ($p = 0.04$). No statistically significant differences were observed at six months following hygiene reinforcement ($p > 0.05$).

Regarding patient-reported outcomes, aesthetic satisfaction was significantly higher in ceramic bracket wearers ($p < 0.001$), while metallic bracket patients reported significantly better oral hygiene comfort ($p = 0.02$).

Discussion

The present study provides a comprehensive comparison of clinical periodontal parameters, microbiological findings, and patient-reported outcomes between ceramic and metallic orthodontic brackets. The results demonstrate that bracket material significantly influences plaque accumulation patterns, gingival inflammation, and microbial shifts during orthodontic treatment [9,16].

Quantitative analysis revealed that the Plaque Index increased in both groups after appliance placement, reflecting the well-established impact of fixed orthodontic appliances on oral hygiene. However, patients treated with ceramic brackets exhibited consistently higher plaque accumulation at three months (1.48 vs. 1.21) and six months (1.26 vs. 1.05). A similar trend was observed for Gingival Index values, indicating greater gingival inflammation in ceramic bracket wearers. These findings are consistent with microbiological and material science research demonstrating that ceramic brackets have rougher surface characteristics than stainless steel brackets [17]. Anhoury et al. reported significantly higher adhesion of *Streptococcus mutans* on ceramic bracket surfaces due to increased surface porosity and micro-irregularities [9]. Similarly, Barcellos Fernandes et al. confirmed that surface roughness and bracket design play a crucial role in bacterial colonization and biofilm formation [8].

Microbiological evaluation in the present study showed that pathogenic bacterial flora developed more frequently in ceramic bracket patients at three months (40%) compared to metallic bracket patients (20%). This finding aligns with the observations of Caccianiga et al. [13] who demonstrated that fixed orthodontic appliances can induce a rapid shift toward pathogenic oral microbiota due to increased plaque retention and impaired hygiene accessibility. However, not all studies support

a strong material-dependent effect. Freitas et al. [18], in a systematic review, concluded that while orthodontic appliances increase microbial load, patient compliance with oral hygiene protocols remains the most critical determinant of periodontal outcomes. Klaus et al. also emphasised that behavioral factors, including brushing technique and motivation, may outweigh the influence of bracket material alone [19].

Interestingly, despite higher plaque accumulation, clinical periodontal deterioration remained mild in both groups, suggesting that reinforced oral hygiene instructions effectively prevented severe inflammatory changes. This observation supports previous studies demonstrating that early preventive interventions can significantly reduce orthodontic-associated periodontal risks [20].

From a mechanical perspective, metallic brackets demonstrated slightly better treatment efficiency, likely due to reduced friction between bracket slots and archwires. This finding is consistent with orthodontic biomechanics literature, indicating that ceramic brackets typically exhibit higher frictional resistance, potentially prolonging tooth movement [21].

In contrast, patient-reported outcomes strongly favored ceramic brackets, particularly regarding aesthetic satisfaction (mean score 4.7 vs. 3.1). This confirms previous research showing that aesthetic concerns represent a major determinant of treatment acceptance, especially among adult orthodontic patients [20].

Overall, the findings suggest that ceramic brackets provide superior cosmetic benefits but may pose slightly greater risks for plaque retention and microbial imbalance. Importantly, these risks can be effectively minimised through strict oral hygiene protocols, regular monitoring, and patient education.

Despite providing valuable clinical and microbiological insights, this study presents several limitations that should be considered when interpreting the results.

First, the sample size was relatively moderate, which may limit the generalisability of the findings to broader orthodontic populations. Larger multicenter studies would provide stronger statistical power and more representative outcomes.

Second, microbiological evaluation was performed using qualitative phase-contrast microscopy rather than quantitative molecular methods such as PCR analysis. While microscopy allows identification of pathogenic flora patterns, it does not provide precise bacterial counts or species-level identification.

Third, the follow-up period of six months reflects early treatment changes, but does not capture long-term periodontal and microbiological effects throughout the entire duration of orthodontic therapy.

Another limitation relates to patient-dependent variables. Despite standardised oral hygiene instructions, individual compliance levels could not be fully controlled, and behavioral differences may have influenced plaque accumulation outcomes. Additionally, only conventional ceramic and stainless-steel bracket systems were evaluated. Newer bracket materials, such as self-ligating or coated brackets, may demonstrate different biological behavior.

Finally, patient satisfaction assessment relied on subjective self-reported measures, which may introduce response bias. Future research should incorporate larger sample sizes, longer observation periods, and advanced microbiological techniques to provide a more comprehensive understanding of bracket material effects on oral health.

Conclusions

This study confirms that both ceramic and metallic orthodontic brackets are effective treatment options; however, they differ significantly in their clinical and microbiological implications.

Ceramic brackets demonstrated superior aesthetic satisfaction, but were associated with higher plaque accumulation, increased gingival inflammation, and a greater prevalence of pathogenic microbial flora during early treatment stages. Metallic brackets showed better mechanical efficiency and slightly more favorable periodontal outcomes.

These findings highlight the importance of individualised treatment planning that considers not only aesthetic preferences but also patient hygiene capability and compliance.

Continuous monitoring, reinforcement of oral hygiene protocols, and preventive strategies remain essential for maintaining periodontal health throughout orthodontic therapy.

Author Contributions (CRediT Taxonomy)

Conceptualisation: V.A.; B.S.M., Data curation: E.B., Formal analysis- E.B., Investigation: B.S.M; A.V., Methodology: E.B.; B.S.M., Software: A.V.; E.B., Writing original draft: B.S.M; Writing review and editing: A.V.; Supervision- E.B. Validation: B.S.M.; A.V.; E.B.

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Conflict of interest

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