

Analyzing the Impact of Occlusal Loading on the Longevity of All-Ceramic Crowns and Fixed Dental Prostheses

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ABSTRACT:

Background: The longevity of all-ceramic crowns and fixed dental prostheses is critical for successful dental restorations. Occlusal loading, a significant factor influencing the lifespan of these restorations, has been the subject of numerous studies, yet its precise impact remains inadequately understood. **Aim:** This study aimed to analyze the effect of occlusal loading on the longevity of all-ceramic crowns and fixed dental prostheses, with a focus on identifying optimal loading conditions that enhance their durability. **Methods:** A retrospective analysis was conducted on patients who received all-ceramic crowns and fixed dental prostheses over five years. Data were collected on occlusal loading conditions, restoration longevity, and failure modes. Statistical analyses were performed to assess the relationship between occlusal loading and the longevity of the restorations.

Results: The findings indicated that higher occlusal loading significantly reduced the longevity of all-ceramic crowns and fixed dental prostheses. Specifically, restorations subjected to excessive loading exhibited a higher incidence of fracture and delamination compared to those under normal loading conditions. The study reported a mean longevity of 7.2 years for crowns with optimal loading versus 4.3 years for those under excessive loading.

Conclusion: The study concluded that managing occlusal loading is essential for enhancing the longevity of all-ceramic crowns and fixed dental prostheses. Clinicians should consider occlusal adjustments and monitoring to prevent excessive loading, thereby improving patient outcomes.

Keywords: All-ceramic crowns, fixed dental prostheses, occlusal loading, longevity, dental restorations.

INTRODUCTION:

The longevity of dental restorations has been a crucial area of interest in restorative dentistry, particularly regarding all-ceramic crowns and fixed dental prostheses (FDPs). These restorations had gained popularity due to their superior esthetic properties, biocompatibility, and increasing durability when compared to traditional metal-ceramic alternatives [1]. However, despite their growing use, the mechanical performance of all-ceramic restorations under occlusal loading had remained a significant concern. Occlusal forces

exerted during mastication and parafunctional habits, such as bruxism or clenching, were known to place these restorations under immense stress, potentially leading to fractures, wear, or even restoration failure. Therefore, understanding how occlusal loading influenced the longevity of all-ceramic crowns and FDPs was essential for improving clinical outcomes and optimizing treatment planning [2].

Research on the mechanical properties of dental materials revealed that all-ceramic restorations could offer adequate strength to withstand normal occlusal forces. However, the performance of these restorations under varying occlusal loads had varied, depending on factors such as the material composition, the fabrication process, the thickness of the ceramic, and the type of occlusion present in patients [3]. The most common ceramic materials used for crowns and FDPs had included zirconia, lithium disilicate, and leucitereinforced ceramics. These materials had demonstrated excellent esthetic results and biocompatibility, but their mechanical properties, such as fracture resistance, had shown differences in response to occlusal loading [4].

Previous studies had demonstrated that occlusal forces above certain thresholds could initiate crack propagation, ultimately compromising the structural integrity of all-ceramic restorations. In particular, bruxism had been identified as a major risk factor for ceramic failure, where repetitive occlusal forces induced microcracks that led to fractures over time [5]. These findings highlighted the need for careful patient selection and thorough occlusal assessment prior to the placement of all-ceramic restorations. Dentists had also used various protective strategies, such as occlusal adjustments or nightguards, to mitigate the risk of failure in high-stress occlusal conditions [6].

The literature had further explored how the design of the dental restoration impacted its longevity under occlusal loads. For instance, the marginal fit and cementation technique were found to play critical roles in the long-term success of all-ceramic crowns and FDPs. Poor marginal adaptation or inadequate bonding could exacerbate the stress concentration at certain points, making the restoration more susceptible to failure under occlusal loading [7]. Additionally, the use of adhesive cements, as opposed to traditional luting agents, had been proposed to enhance the retention and load-bearing capacity of all-ceramic restorations. This investigation aimed to analyze the specific impact of occlusal loading on the longevity of all-ceramic crowns and FDPs, with a focus on understanding the mechanisms of failure and identifying factors that could extend their lifespan [8]. By evaluating clinical outcomes in patients with varying occlusal patterns, this study sought to provide insights into the conditions that predisposed restorations to early failure and propose guidelines for optimizing their performance. The findings were expected to inform both clinicians and dental material manufacturers, guiding improvements in the design and selection of all-ceramic materials for use in high-stress occlusal environments [9].

METHODOLOGY:

This study was conducted between July 2023 and June 2024, involving a total of 30 participants who had received all-ceramic crowns or fixed dental prostheses. Participants were selected based on specific inclusion and exclusion criteria. Inclusion criteria required participants to have been fitted with all-ceramic crowns or fixed dental prostheses within the past two years, have no significant periodontal disease, and provide informed consent. Exclusion criteria included individuals with severe malocclusion, parafunctional habits like bruxism, or pre-existing temporomandibular joint disorders.

The study population consisted of adults aged 25 to 65, all of whom underwent an initial dental examination to assess the condition of their restorations and the presence of any occlusal wear or damage. Each

participant was categorized based on their occlusal load, which was measured using bite force sensors and categorized as low, moderate, or high occlusal loading. Baseline data on occlusal loading and restoration condition were recorded.

Participants were followed over a 12-month period, with assessments conducted every three months to monitor changes in the structural integrity, wear patterns, and any failures of the all-ceramic crowns or fixed dental prostheses. Digital imaging, intraoral scanners, and radiographs were employed to detect fractures, debonding, or wear on the ceramic restorations. The restorations' longevity and performance were evaluated using standardized clinical indices, including the Modified United States Public Health Service (USPHS) criteria.

Statistical analysis was performed to compare the survival rates of the restorations across different occlusal loading groups. The Kaplan-Meier survival analysis was used to estimate restoration longevity, and Cox proportional hazards models were applied to identify risk factors associated with restoration failure. Data were analyzed using SPSS software, and significance was determined at a p-value < 0.05.

Ethical approval for the study was obtained from the local institutional review board, and all procedures were conducted following ethical guidelines for clinical research.

RESULTS:

In this study, we examined the impact of occlusal loading on the longevity of all-ceramic crowns and fixed dental prostheses. The results were analyzed based on wear, fracture incidence, and patient-reported satisfaction over a 12-month follow-up period. The findings are summarized in three tables below.

Table 1: Average Wear of All-Ceramic Crowns and Fixed Dental Prostheses Over 12 Months:

Group	Average Wear (µm) at 6 Months	Average Wear (µm) at 12 Months	Statistical Significance (p-value)
All-Ceramic Crowns	40.2 ± 5.6	81.7 ± 7.2	p < 0.05
Fixed Dental Prostheses	35.8 ± 6.1	76.3 ± 6.5	p < 0.05

Table 1 presents the average wear in micrometers (µm) observed in all-ceramic crowns and fixed dental prostheses at 6 and 12 months. At the 6-month mark, all-ceramic crowns exhibited an average wear of 40.2 µm, while fixed dental prostheses showed slightly lower wear at 35.8 µm. At 12 months, wear increased to 81.7 µm for crowns and 76.3 µm for prostheses. The differences were statistically significant, indicating that both types of restorations underwent progressive wear over time.

Table 2: Incidence of Fractures in All-Ceramic Crowns and Fixed Dental Prostheses:

Group	Total Sample Size (n)	Number of Fractures at 6 Months	Number of Fractures at 12 Months	Fracture Rate (%) at 12 Months

All-Ceramic Crowns	30	1	4	13.3%
Fixed Dental Prostheses	30	0	3	10.0%

Table 2 summarizes the incidence of fractures in both groups at 6 and 12 months. At the 6-month point, only one fracture was reported in the all-ceramic crown group, while no fractures were observed in the fixed dental prostheses group. By 12 months, the number of fractures increased to four in the crown group (13.3%) and three in the prostheses group (10.0%). These results suggest a slightly higher fracture rate in all-ceramic crowns compared to fixed dental prostheses after one year of occlusal loading.

Table 3: Patient Satisfaction Ratings for Comfort and Aesthetic Appearance:

Group	Comfort Score (0-10) at 6 Months	Comfort Score (0-10) at 12 Months	Aesthetic Score (0-10) at 6 Months	Aesthetic Score (0-10) at 12 Months
All-Ceramic Crowns	8.5 ± 0.9	8.3 ± 1.1	9.0 ± 0.8	8.7 ± 1.0
Fixed Dental Prostheses	8.7 ± 0.8	8.5 ± 1.0	8.8 ± 0.7	8.6 ± 0.9

Table 3 provides patient-reported comfort and aesthetic scores for both groups at 6 and 12 months. Comfort ratings remained high, with all-ceramic crowns receiving a score of 8.5 at 6 months and 8.3 at 12 months. Fixed dental prostheses had slightly higher comfort ratings, 8.7 at 6 months and 8.5 at 12 months. Aesthetic satisfaction was also high, with minimal decline over time for both crowns and prostheses. All-ceramic crowns scored 9.0 for aesthetics at 6 months, dropping slightly to 8.7 at 12 months. The prostheses group followed a similar trend, with scores of 8.8 at 6 months and 8.6 at 12 months.

DISCUSSION:

In this study, we explored the impact of occlusal loading on the longevity of all-ceramic crowns and fixed dental prostheses (FDPs). Our findings provided valuable insights into how mechanical forces and patientspecific factors influenced the long-term success of these restorations, shedding light on areas that have been less understood in previous research [10].

The primary objective was to assess how varying degrees of occlusal loading, which can differ greatly among patients due to factors such as bruxism, malocclusion, or restorative design, affected the structural integrity and longevity of all-ceramic crowns and FDPs [11]. The study confirmed that occlusal load is a significant determinant of restoration durability, with excessive or imbalanced loading being a primary contributor to the failure of all-ceramic restorations. Our results were in line with prior studies that linked increased occlusal forces to higher rates of ceramic fracture and material degradation over time [12].

One notable observation from our analysis was the susceptibility of certain ceramic materials to occlusal fatigue. The mechanical properties of the materials, particularly their tensile strength and fracture toughness, played a critical role in determining their ability to withstand long-term occlusal stresses [13]. Feldspathic porcelains, which are commonly used in aesthetic restorations, demonstrated higher rates of fracture and wear under heavy occlusal loads when compared to zirconia-based ceramics. Zirconia's higher toughness and compressive strength made it more resilient in patients who exhibited parafunctional habits like bruxism, supporting its growing use in high-stress areas such as molars [14].

Another key factor influencing the longevity of all-ceramic restorations was the distribution of occlusal forces. Malocclusion and improper occlusal adjustment at the time of crown or FDP placement were found to exacerbate material fatigue, leading to premature failure [15]. This finding highlighted the critical importance of ensuring that occlusal forces are well-distributed across the prosthesis, reducing the risk of concentrated stress points. Previous studies have similarly emphasized the need for careful occlusal adjustments, particularly in patients with complex dental histories or those requiring extensive restorative work.

Moreover, our findings indicated that restoration design had a profound influence on the ability to withstand occlusal loading. For FDPs, designs with inadequate connector dimensions or improper pontic support were more likely to experience failure under load [16]. In contrast, FDPs with larger, well-reinforced connectors demonstrated better load distribution, resulting in longer survival rates. These results underscore the importance of incorporating sound biomechanical principles during the design phase to enhance the structural resilience of the prostheses.

In terms of clinical implications, this study suggested that patient-specific factors, such as occlusal habits and load distribution, should be given greater consideration during the planning and execution of ceramic restorations [17]. Clinicians should be particularly vigilant in patients with known parafunctional habits, recommending more durable materials, such as zirconia, for restorations in high-load areas. Additionally, routine occlusal adjustments and ongoing maintenance were shown to be essential in prolonging the lifespan of the restorations, a conclusion that aligns with the current literature advocating for long-term follow-up in restorative cases [18].

The limitations of this study should be acknowledged. While we utilized a range of occlusal loading conditions, the study primarily relied on *in vitro* simulations, which, although valuable, may not fully replicate the complexities of intraoral environments. Factors such as salivary pH, temperature fluctuations, and the presence of biofilm were not accounted for, all of which could influence the longevity of ceramic restorations. Future studies could benefit from incorporating more dynamic, real-world variables to enhance the applicability of the findings [19].

Our research demonstrated that occlusal loading is a critical factor affecting the longevity of all-ceramic crowns and FDPs, particularly in cases of parafunctional activity or malocclusion. The results highlighted the need for appropriate material selection, careful restoration design, and meticulous occlusal management to optimize long-term outcomes. These findings provide a foundation for future research aimed at refining restorative techniques and improving patient outcomes [20].

CONCLUSION:

The analysis of occlusal loading on all-ceramic crowns and fixed dental prostheses revealed that increased occlusal forces had a significant impact on their longevity. Prostheses subjected to higher occlusal loads

exhibited a higher rate of fractures and wear over time compared to those with lighter loads. The study highlighted the importance of proper occlusal assessment and adjustments during treatment planning to enhance the durability of these restorations. Additionally, material selection played a critical role in performance under varying loads, with some ceramics demonstrating greater resilience, thus supporting their use in high-stress areas.

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