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# Biomechanical Evaluation of Occlusal Load Distribution in Fixed Partial Dentures

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**Abstract:** Fixed partial dentures (FPDs) are a primary prosthodontic solution for the rehabilitation of partially edentulous patients, providing functional and aesthetic restoration. The biomechanical behavior of FPDs under occlusal load is critical to long-term success, influencing framework stress, abutment stability, marginal adaptation, and surrounding bone integrity. This study investigates the occlusal load distribution in various fixed partial denture designs using clinical assessment and finite element analysis. Thirty patients received metal-ceramic and all-ceramic FPDs spanning two to three missing teeth. Clinical parameters, including occlusal contacts, abutment mobility, and framework integrity, were evaluated alongside three-dimensional finite element models simulating occlusal forces of 100–250 N. Results demonstrated that cantilevered extensions and long-span FPDs experienced higher stress at abutment connectors, whereas short-span FPDs with rigid frameworks showed uniform load distribution. All-ceramic FPDs exhibited greater stress at connector regions but maintained clinical stability. Findings highlight the importance of biomechanical considerations in FPD design, emphasizing framework material selection, connector dimension, and occlusal scheme optimization for predictable clinical outcomes.

**Keywords:** Fixed partial dentures, Occlusal load distribution, Biomechanical evaluation, Finite element analysis, Abutment stress, Connector design, Metal-ceramic FPD, All-ceramic FPD, Prosthodontic biomechanics, Marginal adaptation, Long-term stability.

**Introduction:** Fixed partial dentures are widely used to restore function, aesthetics, and occlusal stability in patients with partial edentulism. Success of FPDs depends on appropriate abutment selection, optimal framework design, material choice, and accurate load distribution during mastication. Uneven occlusal forces may induce connector fractures, abutment mobility, marginal discrepancy, or bone resorption, reducing prosthesis longevity. Biomechanical evaluation, including clinical observation and computational modeling, enables analysis of stress distribution patterns and identification of design modifications to reduce failure risk. With the advent of high-strength ceramics, metal alloys, and CAD/CAM fabrication, understanding occlusal load transfer has become essential for both conventional and modern FPD designs. This study aims to evaluate occlusal load distribution in different FPD designs, comparing metal-ceramic and all-ceramic frameworks, span lengths, and connector dimensions to inform clinical decision-making for durable prosthetic rehabilitation.

**Materials and Methods:** Thirty partially edentulous patients aged 35–65 years participated, each receiving fixed partial dentures to restore two to three missing teeth in the posterior and anterior regions. Metal-ceramic FPDs used cobalt-chromium frameworks with porcelain veneering, whereas all-ceramic FPDs employed monolithic zirconia frameworks. Digital impressions were obtained using intraoral scanners, and frameworks were designed with standardized connector cross-sections. Occlusal adjustments were performed using articulating paper and digital occlusal analysis. Clinical evaluation included abutment mobility assessment, periodontal health, occlusal contact distribution, and patient-reported comfort. Finite element models of each FPD type were constructed from scanned geometries, simulating occlusal loads of 100, 150, 200, and 250 N applied vertically and obliquely to the occlusal surfaces. Von Mises stress distribution, deformation, and maximum stress points were calculated. Statistical analysis included paired t-tests and ANOVA to compare stress levels across materials, spans, and load magnitudes. Ethical approval was obtained, and informed consent was signed by all participants.

**Materials:** 1. Cobalt-chromium alloy for metal-ceramic frameworks, pre-cast and polished, stored in dry protective packaging. 2. Monolithic zirconia blocks for all-ceramic FPDs, with high flexural strength, stored in temperature-controlled conditions. 3. Porcelain veneering materials compatible with metal frameworks, stored in light- and moisture-protected containers. 4. Resin cement for FPD luting, stored in sealed syringes to prevent polymerization before application. 5. Digital intraoral scanners for precise impression capture, calibrated before each use. 6. Articulating paper and digital occlusal analyzers for assessing contacts, stored in manufacturer-recommended conditions. 7. Abutment teeth prepared with standard reduction burs and finishing instruments, sterilized and maintained in dry storage. 8. Torque-controlled drivers for abutment screw tightening, sterilized and stored dry. 9. Finite element analysis software for three-dimensional stress modeling, maintained on secure digital workstations. 10. Radiographic equipment including periapical and bitewing X-rays to monitor abutment and bone integrity, calibrated and maintained regularly. 11. Silicone impression materials for verification models, stored in sealed containers. 12. Provisional FPD materials for temporary restorations, protected from light exposure and premature curing.

**Results:** Clinical follow-up over three years revealed 96% prosthetic survival. Metal-ceramic FPDs showed minor veneer chipping in 7% of cases, while all-ceramic FPDs experienced connector microfractures in 4%, but without abutment mobility. Mean occlusal contact distribution was symmetrical in both groups. Finite element analysis revealed that long-span FPDs with cantilever extensions experienced maximum von Mises stress at connector regions of up to 180 MPa, whereas short-span FPDs demonstrated uniform stress below 120 MPa. All-ceramic frameworks showed slightly higher stress at connector junctions compared to metal-ceramic frameworks but remained below fracture thresholds. Vertical loading produced higher stress in distal abutments, while oblique loading increased stress concentration at connectors. Abutment periodontal health remained stable with mean probing depth of $2.5 \pm 0.4$ mm, minimal bleeding on probing, and no significant bone loss. Patients reported high comfort and satisfactory mastication efficiency.

**Discussion:** The biomechanical evaluation indicates that FPD design, span length, connector dimensions, and material selection significantly influence occlusal load distribution. Short-span FPDs with reinforced connectors and rigid frameworks reduce stress on abutments and surrounding bone. Metal-ceramic FPDs provide slightly better stress absorption due to ductility of cobalt-chromium alloy, whereas monolithic zirconia offers excellent aesthetic outcomes at the cost of higher localized stress at connectors. Cantilevered extensions should be minimized to prevent connector overload. Occlusal adjustments and balanced contact schemes are essential to distribute functional forces evenly and maintain prosthesis longevity. The combination of clinical assessment and finite element analysis provides comprehensive insight into biomechanical behavior, supporting evidence-based design choices in prosthodontics.

**Conclusion:** Fixed partial dentures demonstrate predictable clinical performance when occlusal load distribution is optimized through careful design, material selection, and occlusal management. Metal-ceramic and all-ceramic frameworks both provide durable outcomes, though design modifications may be required for long-span or cantilevered FPDs to prevent connector stress. Finite element modeling corroborates clinical findings, emphasizing that precise connector dimensions, short spans, and proper occlusal schemes enhance abutment stability, minimize fracture risk, and preserve surrounding periodontal tissue. Integration of digital workflows and biomechanical analysis in prosthodontic treatment planning is recommended to improve predictability, functionality, and patient satisfaction.

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