

Effect of Sintering Mode, Ceramic Type, and Occlusal Thickness of Endocrowns on Stress Distribution: A Finite Element Analysis

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Abstract

Endocrowns have emerged as a highly predictable, minimally invasive alternative to traditional post-and-core restorations for endodontically treated posterior teeth. These restorations rely on adhesive cementation and the internal anatomy of the pulp chamber for macro- and micro-retention. However, the long-term biomechanical behavior and survivability of the tooth-restoration complex are fundamentally governed by the interplay between the elastic properties of the chosen CAD/CAM ceramics, the geometric occlusal thickness of the preparation, and the complex multiaxial loading conditions inherent to the human masticatory system. The objective of this study was to conduct a comparative evaluation of the stress-strain state and biomechanical behavior of endocrowns fabricated from multilayer zirconia, traditional lithium disilicate, and an advanced virgilite-containing lithium silicate glass-ceramic using three-dimensional finite element analysis (FEA). A highly detailed, three-dimensional finite element model of an endodontically treated mandibular first molar was constructed. Endocrown restorations featuring varying occlusal thicknesses (1 mm, 2 mm, and 3 mm) were geometrically modeled. The investigation simulated the biomechanical response of multilayer high-translucency zirconia (a material class introduced in 2013), standard lithium disilicate (IPS e.max CAD), and a novel advanced lithium silicate (CEREC Tessera) under both standard and speed sintering protocols. Numerical modeling was performed utilizing the Ansys LS-DYNA software package, assuming linear elastic, isotropic, and homogeneous material properties. The models were subjected to both vertical (axial) and 45° oblique occlusal loads of 800 N. Maximum von Mises equivalent stresses within the restorative materials and the residual dental tissues were computed and analyzed. High-modulus ceramic materials, specifically zirconia (Young's modulus >210 GPa), exhibited a pronounced "stress-shielding" effect. At an optimal preparation thickness of 2 mm, zirconia restorations concentrated the applied occlusal forces within their own robust bulk, thereby significantly minimizing stress transfer to the underlying dentin compared to silicate materials. Silicate ceramics (Young's modulus ~105 GPa) transferred proportionally higher stresses to the structural tooth tissues due to their inherently greater flexibility and deformation under load. Under oblique loading, stresses within all evaluated systems increased exponentially. At a 1 mm thickness, oblique loading forced silicate endocrowns into critical internal stress ranges, approaching catastrophic failure thresholds, whereas zirconia maintained a significant structural safety

margin. Importantly, the stress distribution and overall biomechanical performance of the restorations were not significantly affected by the sintering mode (standard versus speed sintering). The advanced lithium silicate (CEREC Tessera) demonstrated a macroscopic stress distribution profile that was nearly identical to that of traditional lithium disilicate under all simulated conditions.

Keywords

Three-dimensional Model, Endocrown, Finite Element Stress Analysis, Multilayer Zirconia, Lithium Disilicate, Speed Sintering, CAD/CAM, Advanced Lithium Disilicate, Chairside