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Improving the Biomechanical Resistance of a Treated Tooth via Composite Restorations Using Optimised Cavity Geometries

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Abstract : The objective of this study is to assess the hypotheses that a restored tooth with a class II occlusal-distal (OD) cavity can be strengthened by designing an optimized cavity geometry, as well as selecting the composite restoration with optimized elastic moduli when there is a sharp de-bonded edge at the interface of the tooth and restoration. Methods: A scanned human maxillary molar tooth was segmented into dentine and enamel parts. The dentine and enamel profiles were extracted and imported into a finite element (FE) software. The enamel rod orientations were estimated virtually. Fifteen models for the restored tooth with different cavity occlusal depths (1.5, 2, and 2.5 mm) and internal cavity angles were generated. By using a semi-circular stone part, a 400 N load was applied to two contact points of the restored tooth model. The junctions between the enamel, dentine, and restoration were considered perfectly bonded. All parts in the model were considered homogeneous, isotropic, and elastic. The quadrilateral and triangular elements were employed in the models. A mesh convergence analysis was conducted to verify that the element numbers did not influence the simulation results. According to the criteria of a 5% error in the stress, we found that a total element number of over 14,000 elements resulted in the convergence of the stress. A Python script was employed to automatically assign 2-22 GPa moduli (with increments of 4 GPa) for the composite restorations, 18.6 GPa to the dentine, and two different elastic moduli to the enamel (72 GPa in the enamel rods’ direction and 63 GPa in perpendicular one). The linear, homogeneous, and elastic material models were considered for the dentine, enamel, and composite restorations. 108 FEA simulations were successively conducted. Results: The internal cavity angles (α) significantly altered the peak maximum principal stress at the interface of the enamel and restoration. The strongest structures against the contact loads were observed in the models with α = 100° and 105. Even when the enamel rods’ directional mechanical properties were disregarded, interestingly, the models with α = 100° and 105° exhibited the highest resistance against the mechanical loads. Regarding the effect of occlusal cavity depth, the models with 1.5 mm depth showed higher resistance to contact loads than the model with thicker cavities (2.0 and 2.5 mm). Moreover, the composite moduli in the range of 10-18 GPa alleviated the stress levels in the enamel. Significance: For the class II OD cavity models in this study, the optimal geometries, composite properties, and occlusal cavity depths were determined. Designing the cavities with α ≥100˚ was significantly effective in minimizing peak stress levels. The composite restoration with optimized properties reduced the stress concentrations on critical points of the models. Additionally, when more enamel was preserved, the sturdier enamel-restoration interface against the mechanical loads was observed.

Keywords : dental composite restoration, cavity geometry, finite element approach, maximum principal stress
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