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XFEM Based Topology Optimization of All-Ceramic Structures for Enhancing Fracture Resistance

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Abstract

Peak tensile stresses usually indicate the likelihood of fracture and fatigue failures in ceramic structures, such as dental prostheses. Thus minimization of peak stresses signifies a major goal in design of all-ceramic systems, typically comprised of porcelain and zirconia. This study aims to develop a new procedural basis for design of mechanical-sound all-ceramic structures based upon bidirectional evolutionary structural optimization (BESO) and eXtended Finite Element Method (XFEM), in which both minimization of peak tensile stress to strength ratio and associated fracture incidence criterion are taken into account. A series of demonstrative examples are presented for porcelain-zirconia materials with or without pre-cracks. The results show that this newly proposed XFEM based non-gradient topology optimization method is able to improve the structural design by minimizing fracture incidence. This numerical procedure provides a new tool to develop optimal ceramic structures, potentially being of implications to dental bridge and orthopedic prosthetic devices.