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Three-Dimensional Printing of Bioactive Dental Materials: Current Evidence and Clinical Applications

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Three-dimensional (3D) printing has revolutionized dentistry by the ability for fabrication of patient-specific restorations consistent with individual anatomical shapes. Unlike the conventional subtractive approach, 3D printing additive manufacturing creates objects layer by layer with minimum material loss, while allowing the building of complex inner architecture, which is impossible by milling.

3D printed bioactive restorative dental materials would promote biologic restorations by the controlled release of therapeutic ions. They have been shown to release calcium and phosphate ions at a concentration sufficient to remineralize the demineralized enamel and dentin[1]. In addition, the use of quaternary ammonium compounds in 3D-printed items has shown considerable antimicrobial effect by preventing Streptococcus mutans biofilm formation by up to 60%, potentially decreasing secondary caries incidence[2].

In periodontal treatments, β-tricalcium phosphate scaffolds made by 3D printing with pore diameters of between 300 and 500 µm have demonstrated remarkable bone form ability in preclinical studies, allowing tissue integration and vascularization at rates comparative to autografts. The scaffolds are able to perform bone formation at autograft-comparable rates, with clinical findings reporting alveolar ridge preservation and histologic evidence of vascularization and tissue integration[3].

3D printing is economically a material-saving method (saving by 35–45%), with no reduction in mechanical function. Dental composites based on this method meet ISO 10477 standards for permanent crowns and bridges, with flexural strength testing as support. Fatigue resistance data in the long term are not yet based on facts, and additional clinical trials must be performed[4]. Employment of artificial intelligence (AI) in 3D printing has increased accuracy to decrease marginal discrepancies by approximately 25% compared with traditional CAD/CAM systems. Although before bringing these enhancements into practice, extensive trials and standardized clinical protocols need to demonstrate the efficacy and dependability of such enhancements[5].

Lastly, the use of 3D printing technology with antimicrobial and bioactive dental composites is potentially a paradigm-shift approach for individualized, biologically active therapies. Evidence favors both economic benefits and clinical effectiveness with additive manufacturing for periodontal treatments and restorations. Additional research needs to be done to ensure biocompatibility and long-term stability. With advancing digital dentistry and AI, there will be a requirement for systematic clinical recommendations in order to integrate them smoothly into the routine practice[6, 7].

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