Quaternary-Ammonium Urethane Dimethacrylate Dental Composite for Long-Lasting Restorations

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Failures at the tooth-restoration interface remain the dominant reason for replacement of resin-based composite restorations, with recurrent caries accounting for a significant portion of clinical failures. Each replacement cycle generates particulate waste derived from crosslinked polymer matrices and inorganic fillers, which is released into the environment and accumulates as persistent microplastic waste. Extending the service life of composite restorations therefore has implications that extend beyond clinical performance, directly contributing to material sustainability and waste-reduction strategies in modern dentistry.

Recent efforts have introduced antimicrobial agents into resin matrices to suppress biofilm formation at restoration interfaces. Among the explored efforts, covalently bonded quaternary ammonium dimethacrylate monomers (QADMs) have provided sustained antimicrobial action [1][2]. Regardless of these encouraging findings at the monomer level, relatively few investigations have reported on fully formulated antimicrobial resin composites, limiting insights into material design and clinical translation.

In this work, the gap is addressed through the development of a novel QAUDMA-based composite containing an antimicrobial monomer synthesized via a modified Menshutkin reaction and incorporated into a conventional resin matrix at 40 wt.%, followed by the addition of mineral-based inorganic fillers according to a typical formulation design. Initial mechanical performance was assessed using Vickers microhardness testing under a load of 1 N and a dwell time of 15 s. The experimental composite exhibited microhardness similar to the control composite without the antimicrobial monomer, which suggest that the incorporation of the antimicrobial monomer did not affect the composite's initial surface characteristics.

Future investigations are focused on a comprehensive assessment of mechanical, physicochemical, and antimicrobial performance to determine whether QAUDMA-based composites can be a clinically durable approach to extending the longevity of dental restorations while contributing to sustainability goals in dentistry.

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