Development and Characterization of Seleno-Compound Incorporated Mesoporous Bioactive Glass with Antibacterial Activity Against MRSA for Osteomyelitis Treatment

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INTRODUCTION: Osteomyelitis is a frequent complication following orthopedic surgery, primarily caused by Staphylococcus aureus. Standard treatment involves surgical debridement and antibiotic therapy; however, increasing antibiotic resistance, particularly methicillin-resistant S. aureus (MRSA), complicates effective management. This study aims to develop and evaluate a novel mesoporous bioactive glass (MBG) incorporated with a seleno-compound to enhance antibacterial efficacy against MRSA infections associated with osteomyelitis.

METHODS: MBG was synthesized via evaporation-induced self-assembly with a molar ratio of Si:Ca:P = 80:15:5. The seleno-compound was incorporated into MBG using vacuum concentration, yielding seleno-MBG. Characterization included Brunauer-Emmett-Teller (BET) surface area analysis, scanning electron microscopy (SEM), transmission electron microscopy (TEM) with elemental mapping. Antibacterial activity against 10 MRSA clinical isolates (collected 2008–2010 at Kaohsiung Medical University Hospital) was assessed in vitro. Biocompatibility was evaluated via 24-hour cell viability assays at concentrations up to 75 mg/ml. No human or animal subjects were involved; therefore, institutional review board approval was not applicable.

RESULTS SECTION: Elemental mapping of MBG showed O (72.4%), Si (26.7%), Ca (0.8%), and P (0.2%). SEM revealed smooth, spherical particles with uniform distribution, maintained after seleno-compound incorporation. TEM confirmed highly ordered mesoporous structures with pore sizes ~10 nm. BET analysis indicated MBG had a specific surface area of 141 m^2/g, pore volume ~0.40 cm^3/g, and average pore size 11.36 nm; seleno-MBG had increased surface area (207 m^2/g), pore volume (~0.44 cm^3/g), and slightly decreased pore size (9.14 nm), demonstrating successful loading. MBG alone showed no antibacterial effect against MRSA isolates, whereas seleno-MBG exhibited significant inhibition across all isolates ($p < 0.05$). Both materials maintained >90% cell viability after 24 hours at tested concentrations, confirming biocompatibility.

DISCUSSION: The results confirm successful synthesis of a seleno-compound incorporated MBG with preserved mesoporous structure and enhanced antibacterial properties against clinically relevant MRSA strains. The increased surface area and pore characteristics likely facilitated selenium loading and release. Limitations include lack of in vivo evaluation and mechanistic elucidation of antibacterial action, which require further study. These findings support the potential role of seleno-MBG as an alternative or adjunctive biomaterial for osteomyelitis treatment amid rising antibiotic resistance.

SIGNIFICANCE/CLINICAL RELEVANCE: This study introduces a novel seleno-functionalized bioactive glass demonstrating strong anti-MRSA activity and biocompatibility, potentially addressing the clinical challenge of antibiotic-resistant bone infections. The material holds promise for improving outcomes in osteomyelitis management and reducing reliance on systemic antibiotics.

IMAGES AND TABLES:

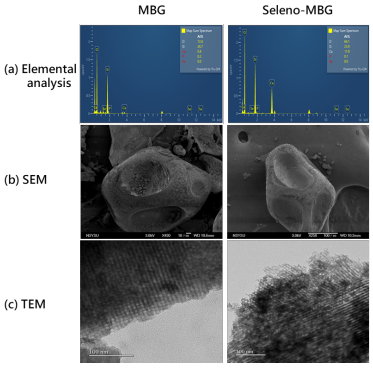

Figure 1. Comprehensive microstructural analysis of with or without seleno-compound by electron microscopy and elemental mapping. (a) elemental mapping by TEM (b) SEM and (c) TEM.

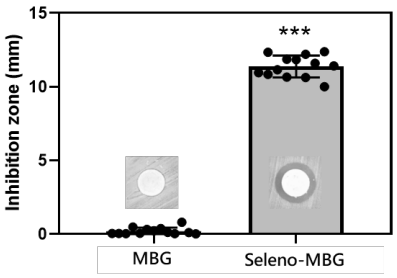

Figure 2. Antibacterial properties against MRSA clinical isolates.

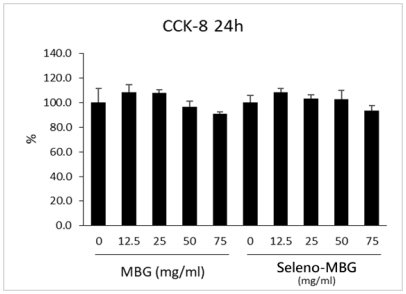

Figure 3. Cell viability of MBG and seleno-MBG in osteogenic cell.