Experimental Study on Antibiotic Coating of Titanium-Based Orthopedic Implants

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INTRODUCTION:

Implant-related infections remain one of the most devastating complications in orthopedic trauma surgery. Infections following fracture fixation can lead to severe morbidity, including prolonged hospitalization, revision surgeries, or even amputations. While several strategies have been explored to prevent biofilm formation on implant surfaces, direct antibiotic coating of titanium-based implants is not yet widely established. This study aimed to investigate the feasibility and efficacy of direct antibiotic coating on titanium alloy implants using the micro-arc oxidation (MAO) method.

METHODS: Titanium alloy screws (ISO 5832/3 Ti6Al4V-ELI; 5 mm diameter, 75 mm length) were used. MAO treatment was performed using a plasma electrolytic oxidation process at high voltage, generating a porous titanium dioxide (TiO□) layer with micro- and nano-scale pores on the implant surface. Implants were divided into four groups: untreated-conventionel titanium screws - control group (Group 1, n=65), MAO-treated titanium screws (Group 2, n=65), antibiotic-coated untreated titanium screws (Group 3, n=65), and antibiotic-coated MAO-treated titanium screws (Group 4, n=65). For Groups 3 and 4, five different antibiotics were tested (vancomycin, teicoplanin, gentamicin, meropenem, colistin, with n=13 screws per antibiotic.). Screws were sterilized, immersed in antibiotic solutions for 1 hour, and dried under sterile conditions where applicable. Surface morphology and antibiotic presence were confirmed via scanning electron microscopy (SEM) at magnifications ranging from 50x, 100x, 200x, 2000x, 5000x, 15000x and 35000x. All screws in all groups were then inoculated with *Staphylococcus aureus* ATCC(American Type Culture Collection) 29213 or *Pseudomonas aeruginosa* ATCC 27853 , and incubated on CHROMagar plates. Cultures were monitored bi-daily, and the day of first observable bacterial growth was recorded as the endpoint of infection resistance and all groups statistically compared each other.

RESULTS:

Following bacterial inoculation, both untreated - conventionel titanium screws (Group 1) and MAO-treated screws (Group 2) exhibited bacterial growth on the first culture check, with no significant difference in time to growth between the two groups.

Compared to untreated - conventionel screws(Gruop 1), antibiotic-coated titanium screws (Group 3) demonstrated significantly prolonged bacterial inhibition when coated with vancomycin, gentamicin, or meropenem (**$p < 0.05$**). Although teicoplanin-coated screws showed a trend toward prolonged inhibition, this did not reach statistical significance(**$p < 0.071$**). No significant difference was observed with colistin-coated screws.

Similarly, MAO-treated antibiotic-coated screws (Group 4) exhibited significantly longer bacterial inhibition compared to uncoated MAO screws when coated with vancomycin, teicoplanin, gentamicin, or meropenem (**$p < 0.05$**), while colistin showed no significant effect.

Finally, when comparing antibiotic-coated MAO screws (Group 4) to antibiotic-coated untreated screws (Group 3), MAO-coated implants demonstrated significantly prolonged bacterial inhibition with vancomycin, teicoplanin, gentamicin, and meropenem (**$p < 0.05$**), whereas no significant difference was observed with colistin.

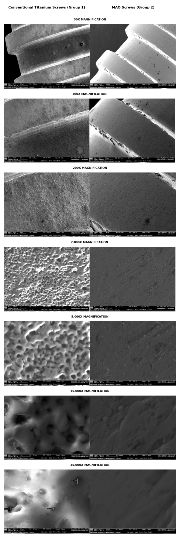
Antibiotic-coated untreated screws remained sterile **1.33 to 1.92 times longer** than uncoated screws, while MAO-treated antibiotic-coated screws remained sterile **2.07 to 5.35 times longer**, may indicating enhanced antibiotic retention and controlled release.

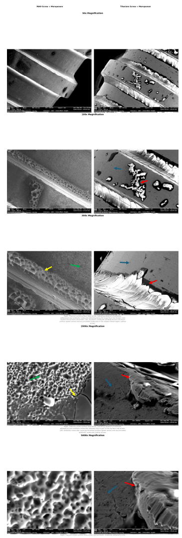
Comparison of all groups with different antibiotics is shown in the table*.

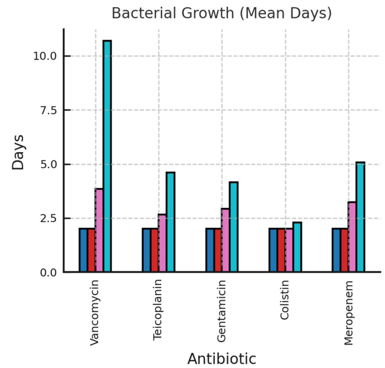
SEM analysis (50× to 35,000×) revealed increased surface roughness and the formation of heterogeneously distributed pores of varying sizes on MAO-treated screws, compared to untreated screws.

DISCUSSION AND CONCLUSION:

Although various surface modification techniques and experimental strategies have been investigated to prevent initial bacterial adhesion and implant-related infections, our approach of direct antibiotic coating on titanium implants offers a promising avenue for future research. To our knowledge, this is the first method demonstrating that modifying the inherent surface properties of titanium implants can enable controlled antibiotic release. Further development of this technique and validation through advanced experimental animal studies and randomized controlled trials are warranted to support clinical translation.


Conventional Titanium Screws (Group 1)
MAO Screws (Group 2)




Bacterial Growth (Mean Days)
Days
0.0
2.5
5.0
7.5
10.0
Vancomycin
Teicoplanin
Gentamicin
Colistin
Meropenem
Antibiotic