The Infected Mesh: Which Antiseptic Solution Most Effectively Removes Biofilm?

Suenghwan Jo[1], Christina A Chao, Tyler Kim Khilnani, Aarti A Shenoy[2], Mathias P G Bostrom[2], Alberto V Carli[2]
[1]Hospital for Speical Surgery, [2]Hospital For Special Surgery

INTRODUCTION:

Polypropylene (PPE) synthetic mesh has gained popularity to treat a disrupted extensor mechanism in knee arthroplasty surgery. Use of a knitted monofilament PPE mesh has yielded successful clinical results for extensor mechanism reconstruction and is preferred due to its exceptional tensile strength and properties which promote fibroblast ingrowth. Despite this success, revision surgery involving PPE mesh is associated with a high rate of periprosthetic joint infection (PJI), a catastrophic complication that requires additional surgical treatment. It is hypothesized that bacterial biofilm formation on the surface of knitted PPE mesh is a leading cause of infection following mesh procedures, but little is known regarding how biofilm formation occurs nor if it can be eradicated. The purpose of the current study is to describe the progression of PPE-based biofilm formation over time and to determine if intraoperative antiseptic solutions can effectively remove biofilm thus permitting retention of the mesh graft.

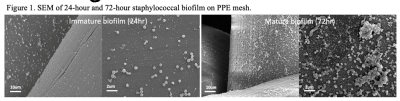
METHODS: Knitted monofilament PPE mesh samples were cultured with methicillin-sensitive staphylococcus au individually in 48-well plates. Biofilm grown on mesh over time was quantified by counting colony-forming units (CFUs) after sonication at every 24 hours, up to 7 days. Biofilm formation on the mesh was also validated using scanning electron microscopy (SEM) at different time points. The effect of saline and five antiseptic solutions were tested: Irrisept (0.05% chlorohexidine gluconate), Bactisure (ethanol, acetic acid, sodium acetate, benzalkonium chloride and water), diluted povidone-iodine (dPI, 0.35%), undiluted povidone-iodine (10%PI), and a 1:1 combination of 10% povidone-iodine and 3% hydrogen peroxide (PI+HP). Immature and mature biofilms were created through culturing bacteria for 24 hours and 72 hours respectively, then immersed in one of the antiseptic solutions or saline for 3 minutes, then sonicated to quantify the number of CFUs. Antiseptic treatments that produced a three-log reduction in CFU counts compared to controls were considered clinically effective.

RESULTS: Biofilm grew on knitted PPE-mesh at 24 hours which reached a plateau at 72 hours. Biofilm was visualized on SEM (figure 1). For 24-hour PPE-based biofilm, all formulations of povidone-iodine and Bactisure produced effective reductions (>99.9%) in CFU counts. Although not meeting the established threshold, saline irrigation and Irrisept removed 86.5% and 99.2% respectively (Figure2). For 72-hour PPE-based biofilm, all povidone-iodine formulations and Bactisure again produced effect reductions in CFU counts, but not Irrisept (Figure 3). Non-diluted (10%) povidone-iodine consistently produced the greatest reduction in CFUs (10,000x-fold reduction) in both immature and mature biofilms.

DISCUSSION AND CONCLUSION:

The current study is the first to investigate and treat staphylococcal biofilms forming on PPE mesh in an orthopaedic context. We identified several antiseptic solutions commonly utilized in revision arthroplasty that are capable of reducing viable bacterial counts by over 90% from both immature and mature biofilm. Povidone-iodine formulations and Bactisure were consistently clinically effective with undiluted povidone-iodine being the most effective antiseptic solution. Given the rapidity by which bacterial biofilm can form on PPE, we recommend that surgeons routinely use antiseptic solutions when inserting PPE mesh and when dealing with PPE mesh in the setting of PJI.

Figure 1. SEM of 24-hour and 72-hour staphylococcal biofilm on PPE mesh.



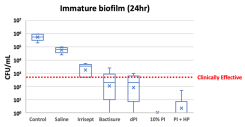


Figure 2. Boxplot demonstrating effect of antiseptic solutions on immature biofilm. The red dotted line represents a 3-log (1,000x-fold) reduction.

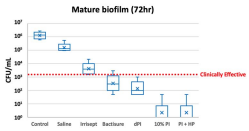


Figure 3. Boxplot demonstrating effect of antiseptic solutions on mature biofilm. The red dotted line represents a 3-log (1,000x-fold) reduction.