Quantification of Doxycycline and Vancomycin Elution from 1.5mm and 2.0mm Commercial High-Strength Sutures

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INTRODUCTION: It is estimated that 13-33% of sutures used in arthroscopic rotator cuff repair may undergo contamination during the case leading to a greater chance of re-tear and need for subsequent treatment (Hong et al., 2024). Braided and tape-like sutures are widely used in these procedures, but their multifilament structure increases surface area creating microscopic spaces that can trap bacteria, fluids, and debris. Therefore, identifying a preventative method to decrease suture contamination bears significant clinical potential.

METHODS: Four different high-strength sutures, ActivBraid (Zimmer Biomet, Warsaw, IN) in 1.5mm (AB1.5) and 2.0mm (AB2) sizes, 1.5mm LabralTape (LT1.5; Arthrex, Naples, FL), and 2.0mm FiberWire (FW2.0; Arthrex, Naples, FL) were utilized. All sutures first underwent one of two dip-coating processes: either low concentration (C1) or high concentration (C2). Each dip-coat solution was composed of 8 mL gelatin solution and 4 mL of either doxycycline or vancomycin solution. The gelatin component was prepared by heating a 10% type A porcine gelatin solution to 80°C for 10 minutes, followed by incubation at 37°C for storage. For the doxycycline antibiotic solutions, either 100 mg or 200 mg of doxycycline were dissolved in 6 mL of 10 mM HCl respectively. For the vancomycin solutions, either 80 mg or 160 mg of vancomycin were dissolved in 6 mL of 10 mM HCl. The resulting concentrations of the final dip-coats were 5.56 (C1D) and 11.1 mg/mL (C2D) for doxycycline, and 4.4 (C1V) and 8.9 mg/mL (C2V) for the vancomycin dip-coats respectively. Suture strands measuring 40 cm were then inserted into each dip-coat, dried at 25°C for 4-6 hours, and stored at 4°C overnight. These suture strands were subsequently cut into 1 cm pieces, organized in a well plate, submerged in 1.5 mL of Dulbecco's phosphate-buffered saline DPBS, and stored in the incubator at 37°C. Aliquot collections of DPBS were performed every day for 7 days. During aliquot collection, the suture was removed and the DPBS was collected and stored in -80°C for later analysis. The suture was then placed back into the well and fresh DPBS was added. Doxycycline and vancomycin enzyme-linked immunosorbent assay kits were used to quantify the amount of antibiotic released from each 1-cm suture piece.

RESULTS: The total amount of doxycycline eluted from AB1.5 and LT1.5 were 151.8 and 137.6ng using C1D as well as 171.8 and 143.1ng using C2D respectively. The total amount of vancomycin eluted from AB1.5 and LT1.5 were 319.1 and 308.6ng using C1V as well as 325.5 and 305.7ng using C2V respectively. The total amount of doxycycline eluted from AB2 and LT2 FW2 were 94.4 and 83.6ng using C1D as well as 86.6 and 90.1ng using C2D respectively. The total amount of vancomycin eluted were 290.3 and 279.0ng using C1V as well as 310.1 and 261.3ng using C2V respectively. For all sutures (AB1.5, LT1.5, AB2, and FW2), the doxycycline elution profile displayed a downward trend with the highest elution seen in days 1-3 and the lowest seen in days 5-7 using C1D and C2D (Figure 1). For AB1.5 and LT1.5, the vancomycin elution profile using C1V and C2V demonstrated a constant elution with minor fluctuations across all 7 days. For the AB2 and LT2 FW2 suture groups, however, the elution profile displayed a greater degree of fluctuation with no obvious trend in both C1V and C2V (Figure 2). Regarding individual timepoints, AB1.5 in C1D demonstrated greater elution on day 2 ($p = 0.004$) and day 5 ($p = 0.014$) compared to LT1.5 (Figure 1A). AB2 in C2D displayed greater elution on day 2 ($p = 0.026$) and day 3 ($p = 0.046$) compared to FW2 (Figure 1B). AB2 in C1V yielded greater elution on day 4 ($p = 0.034$) and day 6 ($p = 0.042$) compared to FW2 (Figure 2B). AB2 in CV2 demonstrated elution on day 2 ($p = 0.034$) compared to FW2 (Figure 2B).

DISCUSSION AND CONCLUSION:

Our findings show that coating commercial high-strength sutures is feasible and that both suture types and sizes exhibit a measurable elution profile over 1 week. The doxycycline elution displayed a downward trend for all sutures while the vancomycin displayed a consistent sustained release over time in only the 1.5mm sutures. This observation may be explained by the molecular weights of vancomycin and doxycycline. The molecular weight of vancomycin (1449.3 g/mol) is approximately 3.5 times greater than the molecular weight of doxycycline (444.4 g/mol). This in combination with the wider surface area of the suture tapes may explain the more constant elution of vancomycin over time. Considering that Gram-positive skin flora are primarily responsible for postoperative infections following shoulder arthroscopy, a consistent elution of vancomycin for at least one week may provide benefit especially in high-risk patients. In addition to its antibacterial properties, doxycycline elution may inhibit matrix metalloproteinase activity, improve collagen organization, increase fibrocartilage formation, and enhance mechanical strength of a rotator cuff repair in a rat model (Bedi et al., 2010). Optimizing antibiotic-coated sutures is in its infancy; therefore, this is the first study to demonstrate feasibility in commercial high-strength sutures as well as compare elution profiles across suture type and size.

In most conditions, AB1.5 and AB2 tended to elute more antibiotics than their LT1.5 and FW2 counterparts; however, the difference was small and the resultant clinical impact is unknown. Similarly, the more concentrated dip-coat tended to yield greater elution but not at the same ratio given the starting dip-coat concentrations.