

Bacterial Adherence to High-Tensile Strength Sutures

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Purpose: The purpose of this study was to evaluate the bacterial adherence to high-tensile strength suture materials using a bioluminescent in vitro model. **Methods:** Eleven strands each of No. 2 MaxBraid (Arthrotek [Biomet], Warsaw, IN), FiberWire (Arthrex, Naples, FL), Ethibond (Ethicon, Somerville, NJ), Orthocord (DePuy Mitek, Raynham, MA), and silk (Ethicon) sutures were immersed in a broth of bioluminescent *Staphylococcus aureus*, which is genetically engineered to emit photons. After 12 hours in the broth, the suture strands were individually irrigated with 10 mL of low-pressure normal saline solution and imaged with a photon-capturing camera system that yields a total photon count that correlates directly with residual bacterial counts. **Results:** MaxBraid had the greatest adherence, followed by FiberWire, Ethibond, Orthocord, and silk. Orthocord had only 25% of the bacterial adherence of MaxBraid ($P < .001$). Ethibond and FiberWire had 53% ($P < .001$) and 75% ($P = .003$) of the adherence of MaxBraid, respectively. Differences between each suture were also statistically significant, with Ethibond and Orthocord having 71% ($P = .007$) and 33% ($P < .001$) of the adherence of FiberWire, respectively, and Orthocord having 47% ($P < .001$) of the adherence of Ethibond. The adherence to silk was statistically lower than all of the high-tensile strength sutures. **Conclusions:** Among high-tensile strength sutures, Orthocord has significantly less bacterial adherence than MaxBraid and FiberWire. Although infections in arthroscopic shoulder surgery are rare, the physical properties of surgical implants should be known by surgeons. In addition, bacterial adherence may contribute to suture selection in a patient prone to infection or to the use of suture in other body areas at greater risk for contamination. **Clinical Relevance:** Bacterial adherence to high-tensile strength sutures may be a useful factor in implant selection in a patient with predisposition for contamination or infection.

New suture materials and designs are constantly being introduced to the surgical marketplace. The choice of suture material is a surgeon-dependent variable that is often taken for granted. Suture material in ortho-

paedic surgery is on the cutting edge of technology because fixation of soft-tissue structures to bone is among the most demanding of applications. To this end, the development of high-tensile strength sutures, often incorporating braided ultrahigh-molecular weight polyethylene (UHMWPE), is an important advance in this field. High-tensile strength suture material has gained wide acceptance in orthopaedics for fixation of soft tissues to bone, often in conjunction with suture anchors.¹ Investigation into the properties of these sutures has focused primarily on strength, knot security, handling properties, and failure mechanisms.²⁻⁵

These are clearly important because the properties of the suture must match the intended use to avoid complications. An additional complication that could be associated with this suture choice is infection. Whereas arthroscopic and open procedures for sports-related procedures have low infection rates and are considered to be “clean” surgery, infection may be a

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devastating complication. Suture material is a foreign body that potentiates infection when implanted, and the ability of the sutured tissue to resist infection varies with the kind of material implanted.⁶ This issue has clinical relevance both in the attempt to decrease the incidence of surgical-site infection and in the ability to clear a surgical infection while retaining the suture construct. This study investigates a possible difference in the infectious potential of high-tensile strength suture materials by quantifying bacterial adherence in an in vitro model. We hypothesize that different high-tensile strength suture materials will have different levels of bacterial adherence.

METHODS

Suture Selection

The suture types selected for testing represented 3 high-tensile strength suture materials that are commonly used in our surgical facility. FiberWire (Arthrex, Naples, FL) was among the first high-tensile strength sutures developed and consists of a non-braided long-chain polyethylene (UHMWPE) core with braided polyester jacket. Orthocord (DePuy Mitek, Raynham, MA) consists of a polydioxanone (PDS) core with a sleeve of UHMWPE. This configuration is designed to leave a lower-profile suture after the PDS has dissolved and to retain strength from the outer sleeve.² MaxBraid (Arthrotek [Biomet], Warsaw, IN) is a 100% UHMWPE suture manufactured from a braided Dyneema Purity material (DSM Dyneema, Heerlen, The Netherlands).¹ The fourth testing material, Ethibond (Ethicon, Somerville, NJ), is a UHMWPE suture with polyester coating to improve handling characteristics. Though made of UHMWPE, Ethibond is not generally considered a high-tensile strength suture. The fifth testing material, silk (Ethicon), was selected to compare a braided nonabsorbable suture of the same caliber with one that is known to be absorbent.

All sutures tested were of No. 2 size. They were obtained from commercially available, unexpired, sterilized packets. The No. 2 suture size was selected for testing because of its wide clinical use for fixation in the musculoskeletal system. In addition, suture anchors are typically preloaded with No. 2 sutures.

Bioluminescent Bacteria

The bacterial broth prepared for this investigation consisted of 10^8 colony-forming units per milliliter of *Staphylococcus aureus* (lux) (Xenogen 29; Caliper Life Science, Hopkinton, MA). The lux bacteria strain

are genetically engineered to emit photons, allowing for quantification with a photon-counting camera system. Bioluminescent bacteria emit light in proportion to their number. This allows us to correlate photon counts with bacterial counts.⁷⁻⁹

Incubation

Eleven strands each of No. 2 MaxBraid, FiberWire, Ethibond, Orthocord, and silk sutures were taken from sterile, unopened, unexpired packages and cut into 10-cm strands. This was the width of our custom suture frame and also represented the image field for our camera system. The strands were immersed together in the broth of bioluminescent *S. aureus*. The immersion was performed in a single beaker for all strands to ensure uniform bacterial concentration exposure, and all suture types spontaneously submerged in the broth, ensuring circumferential surface area exposure. There was no apparent difference in the behavior of each suture type in the broth. The beaker was placed in an incubator agitator at 37°C and 100 rpm for the duration to prevent the sutures from clumping or settling to the bottom of the container. An appropriate uniform temperature ensured bacteria viability.

After 12 hours in the broth, sufficient time to allow biofilm formation,¹⁰ the suture strands were individually removed from the broth and irrigated with 10 mL of normal saline solution, expressed at low pressure from a syringe. This irrigation protocol was established because in the model development phase, it was found to sufficiently remove any bacterial broth that remained on the suture strands that was not adherent to the suture. The wash was not intended to debride the suture.

Quantification

Once removed from the broth and irrigated, the suture was suspended in a custom frame and placed within our dark box for imaging. The IVIS100 imaging system (Xenogen, Alameda, CA), uses an optical charge-coupled device camera to count photon emissions. Imaging software (LIVINGIMAGE [version 2.12; Xenogen] and IGOR [version 4.02A; WaveMetrics, Lake Oswego, OR]) was used to superimpose the photon count onto a grayscale background image, yielding the location and photon intensity. A standard-size region of interest was placed around the suture on the image, and from this region of interest, the total photon count was taken. This photon count is directly

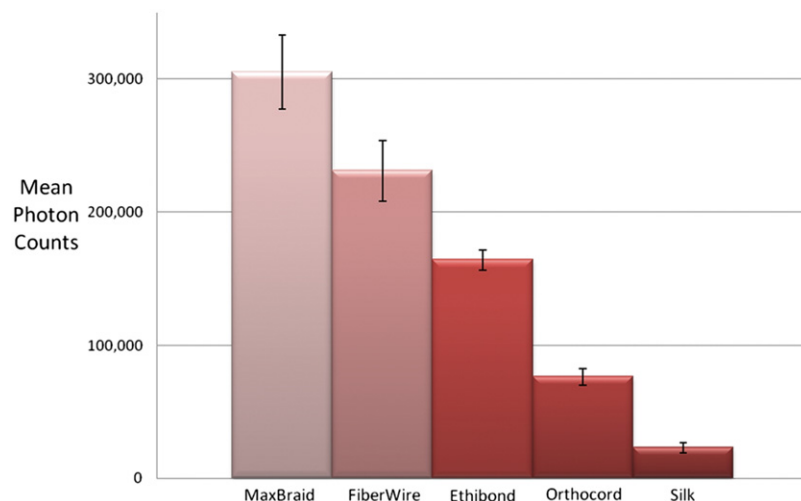


FIGURE 1. Mean bacterial photon counts.

proportional to the bacteria number adherent to the suture material.

The suture testing pattern was A, B, C, D, E and then reversed—E, D, C, B, A—to minimize differences in bacterial broth exposure between groups. With this small number of samples, randomly selecting the testing order may have introduced a more unbalanced exposure time between groups. In addition, the testing time for a group of sutures was short (minutes) in comparison to the overall incubation time, minimizing this source of systemic error.

Statistics

Pretest power analysis was performed. A sample size of 10 has a power of 80% to detect a difference of 40,000 photon counts (20% of the anticipated mean photon count) between suture groups with a standard deviation of 50,000 photon counts and a significance level of 0.05. An additional suture was added to each group in case of loss during testing.

One-way analysis of variance was performed to compare means. When the analysis of variance's null hypothesis of equal means was rejected, the Fisher "least significant difference" method was performed for pair-wise comparisons of the groups. SAS statistical software (SAS, Cary, NC) was used for all statistical calculations. The *P* value or α level was set at .05.

RESULTS

The mean photon counts are shown in Fig 1. Orthocord had the lowest mean counts among the high-tensile strength sutures, though not as low as the silk

suture. The MaxBraid suture had the greatest counts, followed by FiberWire. Ethibond had adherence greater than Orthocord but less than FiberWire. The *P* value results shown in Table 1 reveal statistically significant differences between all groups, allowing rank ordering by bacterial adherence, with Orthocord being significantly less bacterially adherent than all groups other than silk. Figure 2 is a composite photo of the luminescent bacteria.

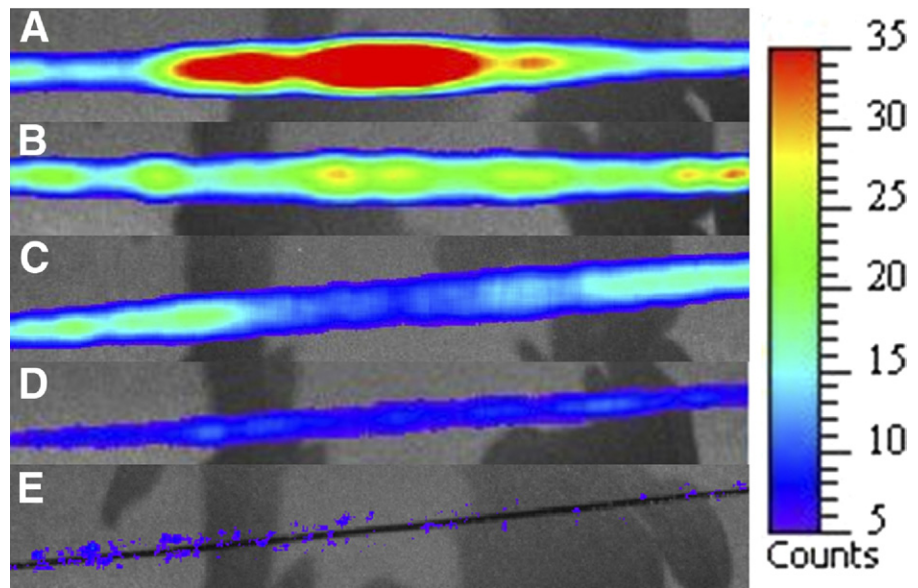
DISCUSSION

Although all of the high-tensile strength sutures have UHMWPE as a key structural component, they have widely different degrees of bacterial adherence. This is likely because of the different materials that complete the design of these sutures. Orthocord has a monofilament PDS core that may not contribute significantly to adherence of bacteria, thus yielding lower counts. The polyester coating or braided jackets of the other sutures likely

TABLE 1. *P* Values

Structure	<i>P</i> Value
MaxBraid v FiberWire	.003
MaxBraid v Ethibond	< .001
MaxBraid v Orthocord	< .001
MaxBraid v silk	< .001
FiberWire v Ethibond	.007
FiberWire v Orthocord	< .001
FiberWire v silk	< .001
Ethibond v Orthocord	< .001
Ethibond v silk	< .001
Orthocord v silk	.029

FIGURE 2. Bioluminescent suture images: (A) MaxBraid, (B) FiberWire, (C) Ethibond, (D) Orthocord, and (E) silk. Color-scale images of relative photon densities have been overlaid on grayscale image of sutures.



contribute to greater bacterial adherence. Differences in adherence properties between these sutures should not be unexpected despite similar component materials, given that differences in other material properties such as strength and handling have been previously demonstrated.⁵ In addition, it must be emphasized that this study evaluates only new sutures and does not account for degradation products from absorbable suture components that may affect chronic infection scenarios. It is interesting to note that the greatest bacterial adherence found in this study correlates with the greatest-strength suture (Table 2). MaxBraid has the greatest reported strength and the greatest bacterial adherence. FiberWire and Orthocord have similar reported strengths, whereas Ethibond and silk have lower reported strengths. The design enhancements that increase the other desirable properties of the suture including strength may contribute to increased bacterial adherence. The surgeon should rightly assess strength when determining the suture to use; however, it should be remembered that mean load-

to-failure values of all sutures tested far exceed the requirements for secure fixation in a tendon-to-bone repair.¹

Bacterial adherence is not among the characteristics typically considered by surgeons when choosing an implant; however, it could be one of great consequence in this product group where there are relatively few differences between the products to help guide selection. Previous investigations have shown differences in adherence to different suture materials, including one of adherence to antimicrobial sutures that demonstrated this difference using scanning electron microscopy.¹¹ Another rarely considered characteristic of suture, foreign-body reaction, was recently reported as a result of FiberWire use in the residual limbs of patients who had undergone amputations.¹² In addition to this clinical report, an animal study was performed assessing the foreign-body reaction to various types of high-tensile strength suture materials.¹³ The authors found an increased inflammatory response in 2 suture types that were not tested in the current study. Among MaxBraid, FiberWire, and Orthocord, they found no significant differences. Bacterial adherence and stimulation of inflammation may both play a role in the development or propagation of infection; however, among the 3 suture types we tested, bacterial adherence was the property that had a measurable difference and may have a greater clinical impact.

With reports of operating room contamination common, including the presence of contamination on anterior cruciate ligament grafts before implantation,¹⁴

TABLE 2. *Strength to Failure of Suture Materials*

Suture	Mean Force	
	N	lb
MaxBraid	256.1	59.6
Orthocord	197.9	46
FiberWire	187.9	43.7
Ethibond	91.7	21.3

NOTE. Data are from reference 1.

suture used either in graft preparation or for reconstruction may also be contaminated while exposed on the back table of an operating room. Although the contamination events in that study did not result in clinical infections, suture selection may be more important for surgical cases with greater infection risk or consequences, such as open trauma cases, tumor cases, or joint reconstruction cases. In addition, future study on the potential for suture to become contaminated while exposed on the back table of an operating room may be warranted.

It is important to recognize that although many arthroscopic and sports procedures have low infection rates, some procedures where use of high-tensile strength sutures is common have higher rates. Achilles tendon repairs, for example, have a reported deep infection rate of 2% to 4%.¹⁵ These procedures may call for a different suture choice than arthroscopic procedures.

Limitations of this study include the single bacteria strain tested. Additional testing with a gram-negative organism may improve our understanding of bacterial adherence to these suture materials. In addition, this study was not performed in vivo, so our results may not mimic suture behavior in the clinical setting. Our limited irrigation of the suture strands with 10 mL of normal saline solution was designed only to remove excess bacterial broth that remained beaded on the suture surface after removal from the inoculation bath. The purpose of this study was to assess the material property of adherence to the suture and not the ability of the surgeon to clear adherent bacteria with vigorous irrigation. For that reason, we chose a low-pressure irrigation protocol rather than pulsatile lavage or high-volume irrigation. The reproducibility of the focused flow of fluid from syringe to suture was noted in the model development and evidenced by the low variance in our test results in each group. The low variance allowed the finding of statistical significance between all groups and suggests that we indeed were evaluating the material property of the suture and not variations in the irrigation procedure. We do not believe that the irrigation procedure affects the internal or external validity of the study. The ability to clear adherent bacteria from suture using different irrigation techniques may be a direction for future study.

CONCLUSIONS

Our in vitro data show that the high-tensile strength sutures tested have statistically different levels of bac-

terial adherence, with Orthocord having the least adherence. Although infections in arthroscopic shoulder surgery are rare, the physical properties of surgical implants should be known by surgeons. In addition, bacterial adherence may contribute to suture selection in a patient prone to infection or to the use of suture in other body areas at greater risk for contamination.

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