

Bacterial Growth on Articulating Spacers: An In Vitro Study

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abstract

We fashioned cement disk-shaped spacer models using antibiotic-loaded Palacos and embedded polyethylene and titanium into the surface of half of the models and inoculated the models with methicillin-sensitive *Staphylococcus aureus* (MSSA), methicillin-resistant *S aureus* (MRSA), or *Staphylococcus epidermidis*, and placed them in nutrient broth. Vancomycin was loaded into the cement of the MRSA spacer models and tobramycin into the MSSA and *Staphylococcus epidermidis* models. In the MSSA and MRSA models, no organisms survived beyond 48 hours in the antibiotic bath regardless of the presence of additional materials. At 96 hours, 86.6% of models with only antibiotic cement had viable *Staphylococcus epidermidis*, while 80% of models with antibiotic cement, polyethylene, and titanium had viable *Staphylococcus epidermidis*. Adding polyethylene and titanium to antibiotic-loaded cement does not promote bacterial survival.

The standard of care for treating late infection in total knee arthroplasty (TKA) is a staged revision. Two-stage treatment of infected TKA has been shown to successfully eradicate infection in >90% of cases.^{1,2} Many surgeons use an antibiotic-impregnated cement spacer as a local adjunct to systemic antibiotic therapy. Difficulty at reimplantation secondary to formation of dense scar tissue and extensor mechanism shortening led surgeons to fashion articulating spacers.^{3,4} Articulating spacers have the theoretic advantage of minimizing arthrofibrosis and maintaining the joint space and extensor mechanism length over simple block spacers. Frequently, metal components are used in fashioning temporary spacers

and polyethylene tibial inserts are used occasionally, as well.⁴

We hypothesized that titanium and polyethylene added to the cement would promote bacterial survival. We conducted this in vitro study to determine if additional materials such as metal alloys and polyethylene used commonly in articulating spacers would promote bacterial survival compared with traditional methods using only antibiotic-laden cement.

MATERIALS AND METHODS

We used an in vitro model to simulate bacterial survival on static block spacer models and articulating dynamic composite material spacer models to test the hypothesis. We fashioned disk-shaped

spacer models from Palacos acrylic cement (Biomet, Warsaw, Indiana). The disk-shaped spacer models were 1 cm in diameter and 0.75-cm thick, with an average weight of 2.3 g, a size similar to the experimental conditions described in a study by Kendall et al.⁵ We loaded 65 spacer models with 2.4 g of tobramycin per 40 g of cement, and loaded 35 with 1.0 g of vancomycin per 40 g of cement.⁶ Ten spacer models without antibiotics served as the control group. We added additional materials to the disks prior to the cement curing; 45 articulating spacer models had a 0.75 cm diameter, 0.25-cm thick titanium disk embedded into one surface and 10 high-density polyethylene spheres embedded into the opposite surface. We fashioned all spacer models under sterile conditions and sterilized all materials prior to embedding. Each spacer model was placed into a sterile specimen container with 20 mL of sterile tryptic soy broth prior to inoculation.

Using bacterial specimens obtained at

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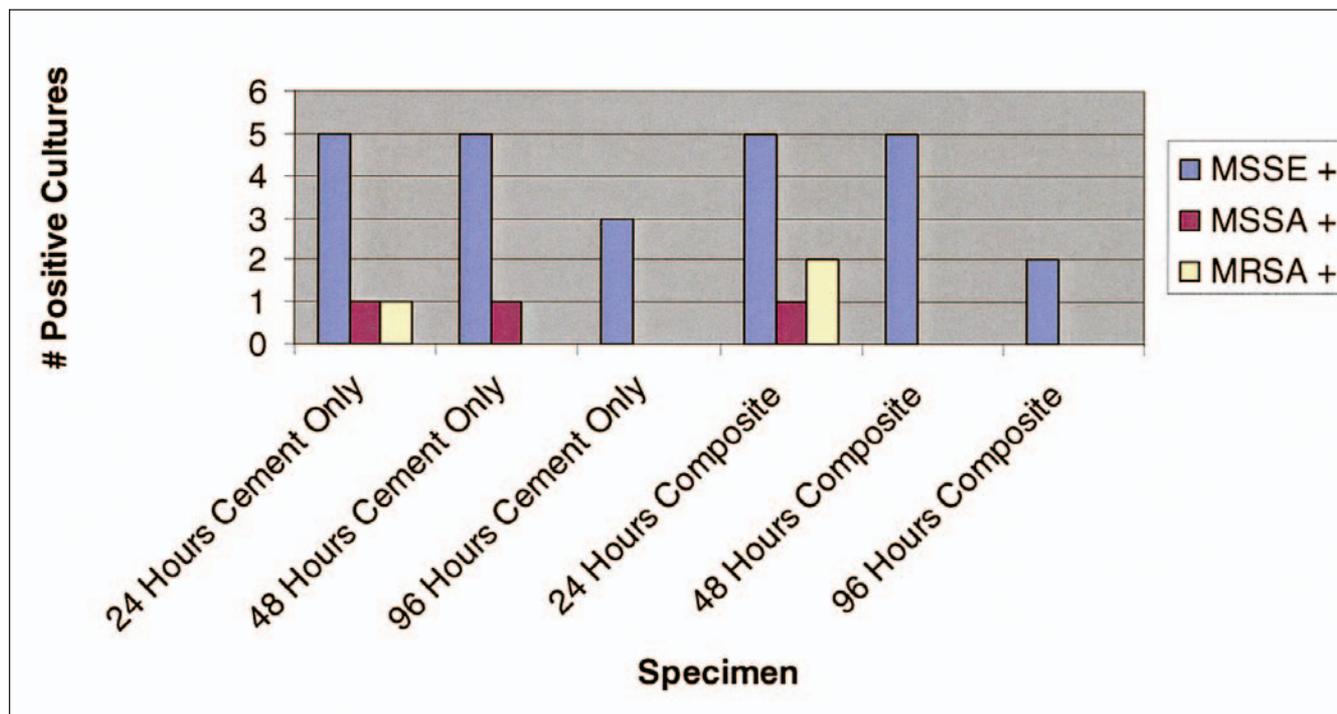


Figure : The duration of positive cultures for the specimen.

our institution, we prepared 3 inoculation solutions: methicillin-sensitive *Staphylococcus aureus* (MSSA), methicillin-resistant *S aureus* (MRSA), or *Staphylococcus epidermidis*. We chose these organisms as they are common pathogens in infected prostheses.^{7,8} The organisms were plated onto 5% sheep blood agar and a bacterial suspension with 10³-10⁵ organisms/mL was prepared using a spectrophotometer and log dilution techniques.^{9,10}

Each of the 3 groups contained 30 specimens, 15 with cement-only spacer models and 15 with a cement, titanium, and high-density polyethylene composite. In the MSSA and MSSE groups the cement was loaded with tobramycin, and the MRSA group's cement was loaded with vancomycin. To ensure our model would support bacterial survival, an infected control group of 10 spacer models was prepared using cement without antibiotics. In this group, we infected 4 spacer models with MSSA, 3 with MSSE, and 3 with MRSA and placed them in 20 mL of tryptic soy broth. We used an uninfected

control group of 10 specimens to assure appropriate elution of antibiotics in the tryptic soy broth bath; 5 of these specimens contained a cement spacer model loaded with tobramycin and 5 loaded with vancomycin. Two milliliters of the bath were used for antibiotic concentration level analysis from each specimen at 24, 48, and 96 hours. With the exception of the uninfected control group, each specimen in the tryptic soy broth bath was inoculated with 1 mL of the appropriate bacterial suspension. All specimens were placed in an incubator at 37°C.

We sampled spacer models in the MSSA, MSSE, and MRSA groups at 24, 48, and 96 hours to determine the presence of viable bacteria. In these three groups 5 articulating and 5 static spacer models were tested at each time point. In the infected control group, all specimens were tested at 96 hours. Each specimen was sampled by agitating the spacer model within its container and filtering the bath through a bacterial filter (Millipore Microfil S 0.45 µm). Each filter was

plated directly onto 5% sheep blood agar and incubated at 37°C. A spacer model was considered positive for bacterial survival if bacterial growth was present after 48 hours of incubation. If there was no growth at 48 hours, the spacer model was considered to have no viable bacteria and the specimen was discarded.¹¹

RESULTS

In both the MSSA and MRSA groups, no organisms survived beyond 48 hours in the antibiotic bath. However, 83% of the spacer models inoculated with *S epidermidis* had viable bacteria at 96 hours (Figure). Thirteen of the 15 spacer models with only antibiotic cement had viable *S epidermidis*, while the 12 of 15 with polyethylene and titanium had viable *S epidermidis*. All 10 spacer models in the infected control group (without antibiotics in the cement) had viable bacteria cultured. Antibiotic concentrations in the uninfected control group indicated that all spacer models had an antibiotic level exceeding the minimum inhibitory concentration at all time points.

DISCUSSION

We hypothesized that adding additional prosthetic materials to antibiotic-impregnated cement might increase the likelihood of bacterial survival. However, our in vitro model showed that adding high-density polyethylene and titanium to antibiotic-loaded cement does not promote bacterial survival.

In general, the addition of foreign materials to an infected wound is not a common practice and has the potential to harbor pathogens.¹² Although there are no published studies indicating an increase in the recurrence of infection when adding metal or polyethylene to the temporary cement spacer, Kendall et al⁵ showed that bacteria can survive on antibiotic-laden cement in solution. Although several authors have reported their results using articulating or dynamic spacers, they based outcome measures on knee function rather than recurrence of infection. Meek et al⁴ published a retrospective review in 2003 of 47 patients treated with an articulating spacer and reported a 4% infection recurrence rate at an average of 41 months follow-up using antibiotic-laden cement and a metal femoral component. Others have reported their functional outcomes but did not report recurrence of infection.

While this experimental model produced definitive results, several weaknesses are notable. The ratio of cement mass to polyethylene and titanium was approximately 60% cement, 30% titanium, and 10% high-density polyethylene. Changing these proportions could alter the effect

of adding prosthetic materials and affect antibiotic elution characteristics. Cement spacer size and shape vary considerably in clinical practice and we resorted to a common-sense approach to determine the size and proportion of materials. Also, this experimental model does not account for the potential effect of antibiotics administered intravenously in the clinical setting; however, the high antibiotic levels found in the tryptic soy broth are likely to make the effect of intravenous antibiotics negligible.

Our in vitro simulation of the environment of an infected TKA did not indicate that the addition of high-density polyethylene and titanium to conventional antibiotic-laden spacers facilitates bacterial survival. All specimens in both the MSSA and MRSA groups were sterile within 48 hours of incubation. *Staphylococcus epidermidis* was viable in an antibiotic bath far exceeding the minimum inhibitory concentration at 96 hours regardless of the presence of high-density polyethylene and titanium. In the clinical setting, randomized trials are needed to determine the safety and efficacy of composite articulating spacers in vivo in patients with infected TKA. 

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