an inexpensive femoral stem with a new acetabular liner [9]. They published excellent results in 31 of the 32 patients; however, information on the number of patients receiving a resterilized stem and details of the autoclaving protocol were lacking.

There are questions about the ultimate sterility of autoclaved components because of the few studies directly examining the technique. Lyons et al. cultured swabs from six explanted femoral components both before and after a 45-minute autoclave cycle at 121°C [10]. Autoclaving was able to kill the majority of multiple bacterial species of both the planktonic and biofilm phenotypes on the surface of smooth cobalt and chromium (CoCr) material. The six sterile components were then inoculated with various organisms and the tests were repeated; again, no organisms grew after autoclaving. Additionally, electron microscopic analysis of the inoculated specimens demonstrated a dramatic decrease in biofilm after autoclaving. However, the study used relatively immature biofilms (only 24 hours of growth), whereas biofilm formation in vivo likely occurs over multiple days, if not months, on an implant surface. Leary et al. reported that autoclaving at 121°C for 30 minutes was not able to remove biofilms of *Staphylococcus aureus* or *Staphylococcus epidermidis* from the surface of CoCr discs, but that pre-treatment with a 4% chlorhexidine gluconate scrub brush did successfully remove all biofilm [11]. Additionally, in a more recent study, Williams et al. evaluated different flash autoclave temperatures and durations to remove monomicrobial and polymicrobial biofilms of eight days of maturation [12]. Although ten minutes of autoclaving at 132°C rendered all biofilm nonviable by culture, residual biofilm did remain on the titanium materials studied. The clinical importance of remaining nonviable biofilm is unclear, especially when translating these results from titanium material to the CoCr implants used with AC-FC. The use of 4% chlorhexidine gluconate scrub, as shown by Leary et al., may solve this potential problem [11].

All series in this area are small and subject to Type II error; however, the clinical literature taken as a whole consistently suggests equivalent infection eradication between the different strategies, including use of an AC-FC. Additionally, the laboratory study by Lyons et al. demonstrates the effectiveness of autoclaving at a microbiological and microscopic level [10] and the addition of a chlorhexidine scrub prior to autoclaving may further eliminate the potential for nonviable biofilm remnants [11]. While the available clinical evidence and cost-effectiveness of AC-FC make it an intriguing treatment option, many hospitals are restricting the reimplantation of hip and knee components after autoclave resterilization. The Centers for Disease Control and Prevention (CDC), Association of perioperative Registered Nurses (AORN), health care institutions, implant companies and medical consultation teams are understandably hesitant to temporarily reuse implants for medical, legal and financial reasons [10]. In 2016, a directive released by the Department of Veterans Affairs stated that nonbiological implantable devices are not to be sterilized by flash autoclave and should be used primarily in cases of emergency [13]. Given these restrictions, the AC-FC technique may be most appropriately utilized when proper dynamic spacer components are unavailable or when economic circumstances make it necessary. Future studies to standardize sterilization protocol and spacer techniques with larger patient series should be performed.

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QUESTION 8: Is it necessary to revise or reduce dislocated articulating antibiotic spacers?

RECOMMENDATION: Unless the spacer is pressing against the skin with imminent necrosis/ulceration, resulting in severe, progressive loss of essential soft tissue or bone, neurovascular compromise or notable pain and disability for the patient, a dislocated or fractured antibiotic-impregnated cement spacer is safe to leave in place until definitive second-stage surgery.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 89%, Disagree: 8%, Abstain: 3% (Super Majority, Strong Consensus)

TABLE 1. Summary of studies reporting complications of hip and knee antibiotic cement spacers in the literature

Lead Author	Year	N	Age (Y)	M/F	BMI (Kg/m2)	[1° -2° T] (D)	Follow-up (M)	Complications	Treatment
Lau	2016	72 knees	70,2 ± 1,8	45/26	32,4 ± 6,4	128,2 ± 80,8	44,9 ± 29,8		If subluxation of the articulating spacer is present, constrained revision knee systems as well as augments should be available at time of re-implantation.
Faschingbauer	2015	133 knees	70,1 ± 9,9	69/64				Fracture/fissure of the tibia (n9 - 6,8%); fracture/fissure of the femur (n3 - 2.3%); spacer fracture (n1 - 0,8%); subluxation of the patella (n1 - 0, 8%)	Not clear in the article.
Faschingbauer	2014	138 hips	69,3 ± 10, 5	Spacer fracture (n12 - 8,7%) 50% with a spacer fracture showed a stable condition. The other half underwent spacer revision. Periprosthetic femoral fracture (n1 - 0,7%) Managed Operatively Dislocation with a simultaneous spacer fracture (n1 - 0,7%) Not clear in the article				Dislocation (n12 - 8,7%)	Close reduction and stable retention in 4/12 dislocations. All other underwent spacer revision.
Jung	2009	88 hips	70	43/39		90	54	Dislocations (n15 - 17%)	12 patients >> conservatively by reduction and immobilization in a hip orthesis. The others: in one case (combined spacer dislocation and fracture) >> spacer exchange, two cases (recurrent spacer dislocations and unsuccessful conservative treatment) >> resection arthroplasty.
								Spacer fracture (n9 - 10,2%)	7 (in the distal part of the spacer stem) >> asymptomatic. The other two cases (spacer-neck fractures) >> spacer exchange.
								Periprosthetic femoral fracture (n12 - 13,6%)	4 with femoral scissure >> conservatively; 5 at 1st stage >> implantation of antibiotic-coated femoral nail and spacer implantation on top; 1 (avulsion of the minor trochanter) >> cerclage refixation; 1 fracture beneath the spacer stem >> implantation of an antibiotic-coated prosthesis stem and placement of a spacer head onto the stem.

RATIONALE

Antibiotic-impregnated cement spacers are used after resection arthroplasty, as part of a two-stage exchange procedure. The rationale for the use of spacers is to allow for delivery of local antibiotics, while managing the dead space that is left behind after resection of the components. Spacers also may facilitate subsequent joint exposure during second-stage reimplantation and, depending on their configuration, may improve function during the resection interval. Spacers can be classified as either static or articulating. There are numerous problems that can occur with the use of spacers and relative to the type of spacer used (Table 1).

Knee

In a study by Struelens et al. [1], 57% of patients experienced issues related to the use of articulating spacers in the knee. Of these, 45% were minor problems such as spacer tilting and medio-lateral translation. In their cohort, 12% of spacers had dislocated, fractured or subluxed. Possible reasons for subluxation or dislocation of spacers are inadequate soft-tissue tension and/or incorrect positioning of the spacer. In addition, pre-fabricated articulating spacers typically come in a limited number of sizes and have inadequate morphology offering minimal inherent stability. Articulating spacers rely mainly on soft-tissue tension around the joint for stability and function and soft tissues often have some compromise in this setting.

Soft tissues are not always to blame for instability associated with spacers. Even when proper tension is restored during surgery, later bone loss may cause further motion and subsidence of the spacer, leading to instability and dislocation. A study by Lau et al. [2] reported that sagittal subluxation was associated with bone defects on the tibial side. The same study found that coronal subluxation tended to be correlated with larger bone defects on the femoral side although this finding did not reach statistical significance. Lanting et al. [3] found that subluxed knees, more than one standard deviation from the mean in the sagittal plane, had lower early- to mid-term Knee Society Function Scores, but did not show any significance in other patient-reported scores like Medical Outcomes Study Short Form-12 (SF-12), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Coronal subluxation did not affect any of these scores.

Hip

There are fewer reports related to complications of spacers in the hip. A study by Jung et al. [4] reported a total complication rate with hip spacers of 40.8% (i.e., 17% dislocations, 10.2% fractures of the spacer, 13.6% femoral fractures). These numbers were not confirmed by Faschingbauer et al. [5] who had an overall mechanical complication rate of 19.6 % (i.e., fracture of the spacer 8.7 %, dislocation 8.7 %, femoral fracture 0.7 %, protrusion into the pelvis 0.7 %, dislocation and spacer fracture 0.7 %). According to Faschingbauer et al., 50% of the patients with a spacer fracture remained asymptomatic (the spacer fracture occurred at the stem area of the spacer) and showed a stable condition, while the other half underwent spacer revision. A fracture of the proximal femur occurred in one of the study patients (0.7 %), which was managed operatively. Closed reduction and stable retention was possible in only 4 of 12 dislocations. All other patients with a spacer dislocation underwent a subsequent operation with spacer revision. There was no comparison in these studies between the functional and morbidity outcomes between the revised and the nonrevised spacers with respect to associated complications.

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5.5. TREATMENT: TWO-STAGE EXCHANGE

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QUESTION 1: What is the optimal timing for reimplantation of a two-stage exchange arthroplasty of the hip and knee?

RECOMMENDATION: The optimal timing for reimplantation of a two-stage exchange arthroplasty of the hip or knee has not been established. Reimplantation may be performed when the treating medical team feels that the infection is under control.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 93%, Disagree: 4%, Abstain: 3% (Super Majority, Strong Consensus)

RATIONALE

There is no conclusive evidence for defining the optimal timing between resection arthroplasty and reimplantation in a two-stage revision arthroplasty for periprosthetic joint infections (PJIs). Multiple studies have reported time to reimplantation ranging from a few weeks to several months or even years [1–11]. Literature has utilized various definitions for PJI two-stage treatment success or failure as well as different variables influencing the timing of reimplantation. Due to this heterogeneity, they have failed to answer this