G56: Does the use of hydrogel-coated implants reduce the incidence of Surgical Site Infection (SSI)/Periprosthetic Joint Infection (PJI) in patients undergoing major orthopedic surgery?

Daniele De Meo; Ricardo Alzate Chacon; Seung-Hoon Baek; Pablo S. Corona; Francisco Cuadrado; Yusuf O. Hasan; Jonathan D. Stevenson; Luigi Zagra

Response/Recommendation:
Yes. Hydrogel coated implants may reduce the incidence of infection following major orthopedic surgery. Considering the limited data available, the use of antibiotic-loaded hydrogel might be considered in high-risk patients (e.g., those undergoing aseptic revision, reimplantation in revision for PJI, orthopaedic oncology, or open fracture management).

Level of Evidence: Limited

Delegate vote:

Rationale

Implant-related infections, particularly periprosthetic joint infections (PJIs), remain a major cause of failure—especially in total hip and knee arthroplasties [1,2]. Bacterial biofilm formation is widely recognized as a critical factor in the development and persistence of PJIs and other implant-related infections [3,4]. Key properties of implant surfaces, such as roughness, hydrophobicity, and electrostatic charge, facilitate bacterial adhesion and subsequent colonization [5]. To mitigate these challenges, intraoperative strategies have been developed to enhance the antibacterial properties of implants, including the application of antiseptic or antibiotic coatings. Romano et al. have outlined the ideal characteristics for such coatings: they should demonstrate broad-spectrum antibacterial efficacy *in vivo*, be easy to handle and cost-effective, and, importantly, avoid local or systemic toxicity while supporting proper bone healing and implant integration [6].

Hydrogel coatings have emerged as a promising approach that may fulfill these criteria. Various hydrogel systems are currently under preclinical investigation [7,8], and hyaluronic acid–based hydrogels already available on the market have demonstrated safety in both *in vitro* and in vivo settings [9,10]. However, the efficacy of hydrogel coatings in reducing surgical site and periprosthetic joint infections remains unclear due to the limited available literature.

To answer the question posed above, we conducted a comprehensive systematic review to evaluate the clinical outcomes of hydrogel use in orthopedic surgery compared to control cases. A comprehensive search of the Scopus and PubMed databases identified 545 studies for screening. After removing 61 duplicates, 484 studies were assessed for eligibility; 469 were excluded, leaving 15 full-text articles for review. Ultimately, 13 studies met the inclusion criteria and were included in the final analysis. Among these, two studies were classified as

level II evidence [11,12], four as level III [13–16], and the remainder were case series [17–23]. Data were extracted to compare infection rates between patients receiving hydrogel-coated implants and control groups, when available. The studies were subdivided into two groups: the first group (seven studies) involved the use of hydrogel in elective orthopedic surgery—such as joint replacement, spinal surgery, and fracture fixation (Table 1)—while the second group (six studies) examined hydrogel coatings used in patients with established infections undergoing one- or two-stage joint revision (OSE and TSE) (Table 2). The main antibiotics used were gentamicin and vancomycin.

Four studies compared hydrogel-coated implants with uncoated implants (joint replacement or internal fixation hardware) in a total of 375 patients who received hydrogel-coated implants, among whom only 1 case of infection was reported, compared with 29 infections among 371 control patients [11,12,15,16]. Follow-up periods ranged from 12.4 to 24 months. Notably, all these studies reported a significantly lower incidence of infection with the use of antibiotic-loaded hydrogel (ALH): one randomized controlled trial (RCT) investigated its use in trauma patients ($p=0.03$) [12], while the other three studies (one RCT and two retrospective matched case–control studies, with $p=0.003$, $p=0.0001$ and $p=0.02$ respectively) focused on primary, revision and mega implants total joint arthroplasty (TJA) [11,15,16]. Two additional case series in the first group evaluated high-risk fracture fixation (37 patients) and primary or revision instrumented lumbar vertebral fusion (73 patients), reporting infection rates of 2.7% and 0%, respectively, with a minimum follow-up of 12 months [20,22]. Lastly, one case series described the use of hydrogel as a coating for single-stage transcutaneous osseointegrated prostheses in above-knee amputations, with no infections reported after a median follow-up of 27 months [18].

In the second group six studies evaluated the use of hydrogel in established infections. In one study, its application during debridement, antibiotics, and implant retention (DAIR) procedures for acute PJI was compared with the application of antibiotic-loaded calcium sulfate beads, with no significant differences observed ($p=0.36$) [19]. Two studies assessing one-stage exchange (OSE) with ALH yielded promising results [13,23]; in one, Capuano et al. compared a hydrogel coated OSE with an uncoated two-stage exchange (TSE), finding no statistically significant difference in infection eradication between the groups [13]. Three additional studies reported on cementless TSE procedures applying ALH: one case series documented failure in two out of 28 cases of cementless hip TSE [21], another case series on post-traumatic septic TSE of the distal femur reported no infections [17], and a retrospective matched case–control study by Zagra et al. observed no infections in the treatment group compared to four infections in the control group ($p = 0.11$) [14].

The available evidence highlights the potential benefits of hydrogel coating of orthopedic implants. Our findings suggest that ALH may be particularly beneficial in high-risk settings—such as open fractures or complex reoperations and revisions where it could protect the new implant, especially in cementless prostheses and in case of one stage or reimplantation after two stage procedures of infected TJA when a tailored antibiotics can be used. However, the limited number of studies, its heterogeneity, and small sample sizes underscore the need for further high-quality research to establish definitive recommendations for its use.

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Table 1 Summary of studies in which hydrogel coating was used for prevention of infection

Author (year)	LoE	Study Design	Primary Country	Multi-centre	Total N	Mean Age	Sex, F %	Mean F-U (Months)	Population ALH/control (if any)	N ALH/control	Infection rates ALH/control	Other complications ALH/control (Types)
Corona (2024)	IV	Retrospective, case series	Spain	No	11	53	36.3%	24	instrumented AKA	11	0%	1 stump necrosis of the anterior flap, 1 soft tissue infection, 1 dual cone breakage
De Meo (2020)	III	Retrospective, matched case-control study	Italy	No	34	75	64.7%	12.4	THR with/without ALH	17/17	0%/35.3%	2 prolonged wound discharge, 1 systemic / 1 dislocation, 1 prolonged wound discharge, 1 nerve deficit, 2 systemic
De Meo (2023)	IV	Retrospective, case series	Italy	No	37	63	45.9%	36	ORIF	37	2.7%	1 delay consolidation, 1 aseptic loosening
Malizos (2017)	II	RCT	Italy	Yes	256	62/59	55.9%	18.1	ORIF with/without ALH	126/127	0%/4.7%	5 delayed wound healing 2 delayed union/7 delayed wound healing 5 delayed union
Parbonetti (2021)	IV	Retrospective case series	Italy	No	73	62	49.3%	12	primary or revision LVF	73	0%	
Romano (2016)	II	RCT	Italy	Yes	373	69/71	58.4%	14.5	TJA with/without ALH	189/184	0.53%/5.9%	2 delayed wound healing, 1 TH dislocation, 1 knee stiffness, 2 DVT / 7 delayed wound healing; 1 THA dislocation, 2 knee stiffness; 2 DVT
Zoccali (2021)	III	Retrospective, matched case-control study	Italy	Yes	86	46	44.2%	24	MegaTJA with/without ALH	43/43	0%/13.9%	1 intra-operative fracture, 1 femoral diaphysis fissure, 1 Hematoma, 2 aseptic loosening, 5 Oncological disease progression. / 1 Implant dislocation, 2 Intra-operative femoral fissure,1 Transient femoral nerve palsy, 2 Aseptic loosening, 6 Oncological disease progression.

LoE, Level of Evidence; N, numbers; F-U, Follow-Up; AKA, Above Knee Amputation; THR, Total Hip Revision; ALH, Antibiotic Loaded Hydrogel, ORIF, Open Reduction Internal Fixation; LVF, Lumber Vertebral Fusion; TJA, Total Joint Arthroplasty; n.r.: not reported.

Table 2 Summary of studies in which hydrogel coating was used for already established infection

Author (year)	LoE	Study Design	Primary Country	Multi-centre	Total N	Mean Age	Sex, F %	Mean F-U (Months)	Infection site and type	Treatment with ALH	N ALH/control (if any)	% infection relapse ALH/control (if any)	Other complication ALH/control (if any)
Capuano (2018)	III	Prospective, matched case-control	Italy	Yes	44	71	59%	29.3	hip/knee PJI	OSE	22/22 TSE	9.1%/13.6%	0
Corona (2021)	IV	Retrospective, case series	Spain	No	10	52	20%	27	segmental distal femur FRI	TSE	10	0%	2 aspetic loosening (CPS fixation failure)
De Meo (2023)	IV	Retrospective, case-control	Italy	No	16	67	50%	26.1	hip/knee PJI	DACRI	7/9 DAPRI	11.1%/0	0
Franceschini (2020)	IV	Retrospective, case series	Italy	No	28	n.r.	n.r.	24	hip PJI	TSE	28	7.1%	0
Pellegrini (2021)	IV	Retrospective case series	Italy	No	10	69	50%	37.2	hip PJI	OSE	10	0%	0
Zagra (2018)	III	Retrospective, matched case-control study	Italy	No	54	64	54%	30	hip PJI	TSE	27/27 TSE	0%/14.8%	1 dislocation (open reduction)/1 dislocation (closed reduction)

LoE, Level of Evidence; N, numbers; F-U, Follow-Up; ALH, Antibiotic Loaded Hydrogel; PJI, Periprosthetic Joint Infection; OSE, One-Stage Exchange; TSE, Two-stage exchange; DACRI, Debridement, Antibiotic Coating and Retention of Implants; DAPRI, Debridement, Antibiotic Pearls and Retention of Implants; n.r., not reported.