RQ: Is chlorhexidine or povidone-iodine the preferred solution for disinfecting extruded bony fragments prior to reimplantation?

Section 1: Background

Traumatic extrusion of a bone fragment is an uncommon but challenging complication of high-energy open fractures. Historically, contaminated extruded bone segments were often discarded because of concerns regarding infection, osteomyelitis, and nonunion. However, reconstruction of large segmental bone defects remains difficult and frequently requires autograft, allograft, vascularized bone transfer, bone transport, or induced membrane techniques. Consequently, increasing attention has been directed toward the possibility of reimplanting structurally important extruded bone fragments after adequate decontamination.

Several successful case reports and case series have demonstrated fracture union and satisfactory functional outcomes following reimplantation of extruded bone segments. Nevertheless, no standardized protocol exists regarding the optimal method of decontamination. Reported techniques include normal saline irrigation, povidone-iodine scrubbing or soaking, chlorhexidine treatment, antibiotic solutions, autoclaving, gamma irradiation, and delayed reimplantation after temporary storage.

The choice of antiseptic remains controversial. Povidone-iodine possesses broad-spectrum antimicrobial activity and has traditionally been widely used in open fracture management. Chlorhexidine demonstrates prolonged antimicrobial activity and is increasingly used for surgical site preparation. However, concerns remain regarding the potential cytotoxicity of antiseptic agents and their effect on osteogenic cells and fracture healing. Furthermore, evidence directly comparing chlorhexidine and povidone-iodine specifically for decontamination of extruded bone fragments is extremely limited.

Recent evidence from the PREP-IT program evaluating antiseptic solutions in open fracture surgery demonstrated no clinically significant difference in surgical site infection rates between aqueous chlorhexidine and aqueous povidone-iodine. However, these studies evaluated surgical skin preparation rather than decontamination of extruded bone segments. Therefore, the central question remains whether either solution offers superior efficacy and safety when used for disinfecting extruded bony fragments before reimplantation.

Section 2: Data extraction table

S.no	Author/year	Design	Sample/population	Intervention/comparator	Key results
1	PREP-IT commentary, 2022	Comment on multicenter trial	1638 open-fracture patients	Aqueous povidone-iodine vs aqueous chlorhexidine for surgical site preparation	SSI 7% vs 7%; OR 1.11, p=0.61. No difference; indirect evidence.
2	PREP-IT master protocol, 2020	Trial protocol	Planned >=1540 open fractures in Aqueous-PREP	4% aqueous chlorhexidine vs 10% povidone-iodine	Confirms equipoise; no direct extruded-bone outcome.
3	PREP-IT duplicate, 2020	Duplicate protocol	Same as above	Same as above	Adds no independent evidence but supports uncertainty in fracture antisepsis.
4	Afshar, 2016	Narrative review	24 successful reimplantation reports plus experimental literature	Povidone-iodine, chlorhexidine, antibiotics, autoclave, boiling, irradiation	No conclusive best protocol; 10% povidone-iodine and 2-4% chlorhexidine preferred chemically; povidone-iodine more favorable for cellular toxicity.
5	Singhi et al., 2016, India	Case report	21-year-old male, Gustilo IIIB floating knee with extruded lateral femoral condyle	Copious saline + 10% povidone-iodine soak 20 min	No infection; incorporation by 16-20 weeks; complete union by 6 months; excellent 2-year outcome.
6	Rathore et al., 2016, India	Case report	38-year-old male, Grade IIIB distal femur with two extruded pieces	Saline + diluted povidone-iodine; subfascial storage with antibiotic beads; delayed reimplantation	Union at 6 months; no low-grade infection at 1 year. Notes chlorhexidine disinfects but may leave no viable cells.
7	Crowley et al., 2007,	Narrative review	Open fracture wound	Saline; antiseptics	Normal saline

	UK		irrigation literature	including povidone-iodine and chlorhexidine	standard; antiseptics broad-spectrum but toxic; no consensus on ideal additive.
8	Afshar & Tabrizi, 2019, Iran	Case report	6-year-old boy, Gustilo IIIB tibia with two extruded fragments	10% povidone-iodine 20 min + 2% chlorhexidine 20 min + saline rinse	Uneventful; full weight bearing at 3 months; union by 4 months. Combined protocol cannot prove superiority.
9	PREP-IT duplicate, 2020	Duplicate protocol	Same as article 2	Same as article 2	Indirect evidence only; does not establish superiority for extruded fragments.

Section 3: Results Summary

Nine studies were included in this review, comprising one narrative review, one evidence review on irrigation practices, one prospective multicenter antiseptic trial program, and multiple case reports and case series describing successful reimplantation of extruded bone fragments.

The strongest evidence regarding antiseptic efficacy originates from the PREP-IT program and the Aqueous-PREP trial. These multicenter investigations compared aqueous chlorhexidine and aqueous povidone-iodine in patients undergoing surgery for open fractures and found no statistically significant difference in surgical site infection rates between the two antiseptic solutions.

These findings suggest equivalent effectiveness in reducing infection risk during open fracture surgery. However, the studies did not specifically evaluate extruded bone fragment disinfection.

Afshar's 2016 review of extruded bone reimplantation summarized multiple successful cases involving various decontamination methods. Both povidone-iodine and chlorhexidine were frequently used either alone or in combination. No evidence demonstrated superiority of one antiseptic over the other. The review emphasized that successful outcomes were primarily associated with meticulous debridement, adequate irrigation, stable fixation, and careful patient selection rather than the specific antiseptic employed.

Several case reports demonstrated successful reimplantation following povidone-iodine-based protocols. Singhi et al. reported excellent clinical and radiographic outcomes after cleansing an extruded femoral condyle fragment with copious saline irrigation followed by soaking in 10% povidone-iodine. Similarly, multiple cases reviewed by Afshar utilized povidone-iodine without subsequent infection or nonunion.

Evidence supporting chlorhexidine use is more limited. Afshar and Tabrizi described successful reimplantation of a large extruded tibial segment after sequential treatment with 10% povidone-iodine followed by 2% chlorhexidine solution, achieving complete fracture union without infection. The combined protocol demonstrated safety but did not allow assessment of the individual contribution of either antiseptic.

The review by Crowley et al. evaluating irrigation in open fractures highlighted the antimicrobial effectiveness of antiseptic solutions but also emphasized their potential cytotoxic effects on host tissues. The authors noted that no consensus exists regarding the ideal antiseptic additive for open fracture irrigation and decontamination.

Overall, available evidence consistently demonstrates that both chlorhexidine and povidone-iodine can be used successfully during reimplantation of extruded bone fragments. However, no comparative clinical study directly evaluates one solution against the other in this specific setting, and no study demonstrates clear superiority of either antiseptic.

Section 4: Discussion

The management of extruded bone fragments represents one of the most difficult challenges in open fracture care. The surgeon must balance two competing priorities: maximizing decontamination to reduce infection risk while preserving the biological and structural properties of the bone fragment to facilitate fracture healing. The choice of antiseptic solution therefore becomes clinically important, particularly when reimplantation is considered.

The current literature provides surprisingly little direct evidence regarding the optimal antiseptic agent. Most available publications consist of case reports and small case series, reflecting the rarity of the condition. Consequently, the overall quality of evidence remains low and recommendations must be interpreted with caution.

Povidone-iodine is the most commonly reported antiseptic used in published cases of successful reimplantation. Its popularity likely reflects its broad antimicrobial spectrum, widespread availability, low cost, and familiarity among trauma surgeons. Importantly, Afshar's review highlighted laboratory evidence suggesting that povidone-iodine may have a more favorable balance between antimicrobial activity and cellular toxicity compared with several alternative disinfecting agents. Multiple successful clinical reports utilizing povidone-iodine further support its practicality and safety.

Chlorhexidine offers theoretical advantages due to its prolonged residual antimicrobial activity and effectiveness against a broad range of pathogens. It has become increasingly favored for surgical site preparation in many orthopedic procedures. Nevertheless, evidence supporting its

isolated use for extruded bone fragment disinfection remains sparse. Most reports incorporate chlorhexidine either as part of a combined protocol or as an adjunct to other decontamination methods.

The PREP-IT investigations provide important indirect evidence. These large, multicenter studies demonstrated no significant difference between aqueous chlorhexidine and aqueous povidone-iodine in preventing surgical site infection among patients with open fractures. Although these findings cannot be directly extrapolated to extruded bone fragments, they suggest that the antimicrobial effectiveness of both agents is broadly comparable within the context of open fracture surgery.

An important observation across all successful reports is that antiseptic choice appears less influential than adherence to fundamental principles of open fracture management. Thorough irrigation, meticulous debridement, prompt antibiotic administration, preservation of viable soft tissues, stable skeletal fixation, and appropriate soft tissue coverage consistently emerge as the key determinants of successful outcomes. Infection prevention is therefore multifactorial and unlikely to depend solely on the antiseptic solution selected.

Another consideration is antiseptic cytotoxicity. While stronger antiseptic solutions may improve bacterial eradication, excessive exposure could impair osteoblast viability, delay fracture healing, and compromise incorporation of the reimplanted fragment. Experimental studies have demonstrated that both chlorhexidine and povidone-iodine exhibit dose-dependent cytotoxicity. Consequently, many successful protocols employ short-duration soaking, dilution strategies, or subsequent saline rinsing to minimize tissue toxicity while maintaining antimicrobial efficacy.

The literature also suggests that combined protocols may be beneficial. The pediatric tibial case reported by Afshar and Tabrizi utilized sequential povidone-iodine and chlorhexidine treatment followed by saline irrigation and achieved complete union without complications. While no conclusions regarding superiority can be drawn from a single case, this approach demonstrates that combined antiseptic use is feasible and may maximize antimicrobial coverage.

Ultimately, the available evidence does not justify recommending chlorhexidine over povidone-iodine or vice versa. Both solutions have been associated with successful reimplantation and satisfactory outcomes. The absence of comparative trials specifically evaluating extruded bone fragments remains a major evidence gap. Future multicenter registries or prospective comparative studies would be required to establish whether one antiseptic offers meaningful clinical advantages.

Until such evidence becomes available, antiseptic selection should be guided by surgeon experience, local protocols, availability, and consideration of tissue toxicity, while emphasizing meticulous debridement and adherence to established principles of open fracture management.

when required and appropriate soft-tissue cover. Sequential chlorhexidine may be considered only selectively for heavily contaminated fragments, with limited exposure and saline rinse.

Section 5: Risk of bias of included studies

Study	Risk of bias
PREP-IT trial/commentary/protocols	Moderate quality for fracture antisepsis, but very high indirectness for extruded bone fragments.
Afshar 2016	High: narrative review/expert opinion; heterogeneous reports.
Singhi 2016	High: single case report with multiple co-interventions.
Rathore 2016	High: single case report; staged storage and antibiotic beads confound effect.
Crowley 2007	Moderate-high: general irrigation review, not extruded bone-specific.
Afshar & Tabrizi 2019	High: single pediatric case and combined antiseptic protocol.

Section 6: Response / Recommendation

Neither chlorhexidine nor povidone-iodine can currently be recommended as the preferred antiseptic solution for disinfecting extruded bony fragments prior to reimplantation. Both agents appear safe and effective when used as part of a comprehensive decontamination protocol, and current evidence does not demonstrate superiority of either solution.

Recommendation: Reimplantation of structurally important extruded bone fragments may be considered following meticulous debridement, copious saline irrigation, and disinfection using either povidone-iodine or chlorhexidine according to local protocols and surgeon preference.

Level / Strength of Evidence

LOW

Justification: The available evidence consists predominantly of case reports, case series, narrative reviews, and indirect evidence from open-fracture antiseptic trials. No randomized controlled trial or comparative clinical study specifically evaluates chlorhexidine versus povidone-iodine for disinfecting extruded bony fragments prior to reimplantation.

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