

ICM 2025 Question B16: “Are ultrasonic debridement devices useful for removal of biofilm in orthopedic infections?”

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RESPONSE/RECOMMENDATION: Ultrasonic debridement devices show promise for managing chronic wound infection and biofilm-associated infections. While preclinical evidence in dentistry is robust, clinical data is less conclusive specially for orthopedic implant these evidence are very limited but suggest potential benefits.

LEVEL OF EVIDENCE: Weak

DELEGATE VOTE: Agree: [% vote], Disagree: [%], Abstain: [%]

RATIONALE: Orthopedic infections, particularly those associated with implants, present significant challenges due to biofilm formation^{1,2}. Biofilms are complex microbial communities that adhere to surfaces, exhibiting resistance to antibiotics and host immune responses³⁻⁵. Ultrasonic debridement devices have emerged as a potential solution for disrupting biofilms, but their efficacy remains a subject of debate^{6,7}. This systematic review synthesizes evidence from enrolled screened studies to evaluate the utility of ultrasonic debridement devices in removing biofilm in orthopedic infections.

Methods:

A comprehensive literature search was conducted using MeSH terms relevant to ultrasonic debridement, biofilm, and orthopedic infections. On PubMed/MedLine and Science Direct. Of the initial 192 studies identified, 45 met inclusion criteria after abstract screening. Full text had been reviewed, and 13 studies were selected for systematic review and one study was found in references. Fourteen Studies⁸⁻²¹ included in this review evaluated the efficacy of ultrasonic debridement devices for biofilm removal in preclinical and clinical settings. Data was extracted from study design, outcomes, and limitations.

Results:

We have summarized the extracted results on table below:

Title	Year	Region	Journal	Level of Evidence	Intervention	Sample	Results
1.Effectiveness of biofilm-based wound care system on wound healing in chronic wounds	2019	Japan	Wound Repair Regen	III	Ultrasonic Vs.Biofilm based wound care Vs. standard of care in chronic ulcers		The median of biofilm removal proportion was 38.9% (interquartile range, 12.9–68.0%) for pressure ulcers treated with standard care and 65.2% (41.1–78.8%) for those treated with ultrasonic debridement (p = 0.009).
2. Multispecies biofilm removal by XP-endo Finisher and passive ultrasonic irrigation: A scanning electron microscopy study.	2022	US	Aust Endod J	In Vitro	XP-endo Finisher (XPF) Vs. passive ultrasonic irrigation (PUI) and conventional syringe irrigation (CSI), on biofilm removal by scanning electron microscope (SEM).	50	There were no differences between PUI and XPF (P > 0.05), and both groups promoted higher biofilm removal than CSI+4%NaOCl and

							CSI+water groups (P < 0.05). It can be concluded the multispecies biofilm removal was significantly improved using XPF and PUI when compared to CSI.
3. Reduction of dual-species biofilm after sonic- or ultrasonic-activated irrigation protocols: A laboratory study.	2021	Germany	Int Endod J	In Vitro	Normal Saline Vs. Ultrasonic irrigation of teeth after root canal procedure	240	High-frequency sonic activation resulted in a greater bacterial reduction compared to ultrasonic activation in groups receiving solely irrigation/activation protocols; however, irrigation using NaOCl and ultrasonic activation also contributed significantly to bacterial reduction compared to the control groups.
4.Efficacy of laser and ultrasonic-activated irrigation on eradicating a mixed-species biofilm in human mesial roots.	2019	Australia	Aust Endod J	In Vitro	Laser (Er,Cr:YSGG) Vs ultrasonic activated irrigation on eradicating a mixed-species biofilm grown in root canals with complex anatomy		chemomechanical irrigation with laser and ultrasonic activated irrigation significantly reduced the bacterial load from complex root canal systems; however, there were no significant differences found between the experimental groups.
5.Multispecies biofilm removal by a multisonic irrigation system in mandibular molars.	2022	US	Int Endod J	In Vitro	GentleWave System and passive ultrasonic irrigation (PUI) of the mandibular teeth.	22	Bacterial reduction in mesial roots of mandibular molars prepared to 35.04 with PUI was similar to those prepared to 20.06 with a multisonic irrigant activation system.
6.Bacterial Biofilm Removal Using Static and Passive Ultrasonic Irrigation.	2015	India	J Int Irat Health	In Vitro	Static irrigation and passive ultrasonic irrigation (PUI) of the maxilar extracted teeth	24	Biofilm could not be removed completely either by passive ultrasonic instrumentation or static irrigation. The PUI was found to be more effective in the removal of collagen, especially in the apical part of the root canal.
7.Comparative Analysis of Irrigation Techniques for Cleaning Efficiency in Isthmus Structures.	2024	Germany	J Endod	In Vitro	Conventional needle irrigation; SAI-E Endo ActivatorUltrasonically-activated irrigation and LAI (Er:YAG-laser) in biofilm removal of the 3D root canal model	20	Laser-activated irrigation (LAI) was associated with the greatest removal of hydrogel from the entire root canal system (P < .05), followed by SAI-E.

8. Influence of ultrasonic tip distance and orientation on biofilm removal.	2017	Switzerland	Clin Oral Investig	In Vitro	Mechanical biofilm removal Vs. Ultrasonic removal in different orientation and distance of the tip	6	Bacterial detachment depended on tip orientation and distance, especially when the tip was applied sideways similar to the clinical setting.
9. Piezoelectric ultrasonic debridement as new tool for biofilm removal from orthopedic implants: A study in vitro.	2023	Italy	J Orthop Res	In Vitro	Piezoelectric ultrasonic debridement Vs. Pulse lavage for biofilm removal from orthopedic stainless steel and poly implant		The comparison between the two lavage/debridement displayed a two-log reduction of CFU/mL ($p < 0.001$ for each material) of PUS compared with PL.
10. In vitro efficacy of Er:YAG laser-activated irrigation versus passive ultrasonic irrigation and sonic-powered irrigation for treating multispecies biofilms in artificial grooves and dentinal tubules: an SEM and CLSM study.	2024	China	BMC Oral Health	In vitro	YAG laser-activated irrigation Vs. passive ultrasonic irrigation and sonic-powered irrigation for treating multispecies biofilms	90	YAG laser-activated irrigation techniques, along with EDDY, demonstrated significant antibiofilm efficacy in apical artificial grooves of the teeth
11. Healing following ultrasonic debridement and PVP-iodine in individuals with severe chronic periodontal disease: a randomized, controlled clinical study.	2006	Sweden	Acta Odontol Scand	I	Ultrasonic Vs. PVP-iodine Vs. Saline	20	Ultrasonic debridement using Odontogain is effective in controlling infection in patients with severe chronic periodontitis. PVP-iodine does not add any clinical benefit
12. Microbiological effect of the use of an ultrasonic device and iodine irrigation in patients with severe chronic periodontal disease: a randomized controlled clinical study.	2007	Sweden	Acta Odontol Scand	I	Ultrasonic Vs. PVP-iodine Vs. Saline	20	Utilization of an ultrasonic device was effective in reducing the analyzed putative periodontal bacteria. No statistically significant difference between ultrasonic+saline and ultrasonic+PVP-iodine was found.
13. Early experience using low-frequency ultrasound in chronic wounds.	2005	US	Ann Plast Surg	II	Low-frequency ultrasonic debridement (LFUD) performed on 17 patients over 8 months, with a minimum follow-up of 3 months	17	88% of the wound healed (primarily or with the aid of a skin graft) or experienced a wound-size reduction of at least 50%.
14. Ultrasonic debridement management of lower extremity wounds: retrospective analysis of clinical outcomes and cost	2019	US	Journal of Wound Care	III	A retrospective review was conducted for patients undergoing lower extremity wound treatment with direct, low-frequency (22.5 kHz), high-intensity (~60 W/cm ²) ultrasonic debridement	51	The use of direct, low-frequency, high-intensity, ultrasonic debridement is a safe and reliable adjunctive therapy for the management of these wounds

Five out of fourteen studies (35.7%) were clinical studies, and the rest were *in vitro*. Most studies were in the field of Endodontics and plastic surgery and chronic wound management.

Preclinical Studies

Ultrasonic debridement devices have been shown in numerous *In vitro* and few *In vivo* investigations to efficiently break up biofilms produced by common pathogens, such as *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Among the main conclusions are that high-frequency ultrasound altered the structure of biofilms, making bacteria more vulnerable to antibiotics. According to certain research, biofilms can be removed from metal and bone surfaces by >90% without seriously harming the host tissues.^{22,23} Low-frequency devices and other advanced ultrasonic technologies demonstrated improved penetration into irregular surfaces, which is crucial for orthopedic applications. Although the results of clinical studies were limited, they showed that ultrasound debridement, when used in conjunction with conventional surgical techniques, increased the rates of infection clearance in chronic wounds and infections surrounding implants.^{8,20-22} There is a gap between experimental and clinical studies; despite promising experimental results, clinical studies remain limited. Ultrasonic debridement has been shown in some studies to reduce surgical morbidity and preserve healthy tissue. Ultrasonic debridement demonstrated superior biofilm removal efficacy and shorter treatment durations in preclinical models. In clinical settings, outcomes were comparable but favored ultrasonic methods in specific cases of resistant biofilms.^{21,22}

Conclusion:

Ultrasonic debridement devices show promise for managing chronic wound infection and biofilm-associated infections. While preclinical evidence in dentistry is robust, clinical data is less conclusive specially for orthopedic implant this evidence is very limited but suggest potential benefits.

References:

1. Goh GS, Parvizi J. Diagnosis and treatment of culture-negative periprosthetic joint infection. The Journal of Arthroplasty. 2022 Aug 1;37(8):1488-93.
2. Hameister R, Lim CT, Lohmann CH, Wang W, Singh G. What is the role of diagnostic and therapeutic sonication in periprosthetic joint infections?. The Journal of Arthroplasty. 2018 Aug 1;33(8):2575-81.
3. Seta JF, Pawlitz PR, Aboona F, Weaver MJ, Bou-Akl T, Ren W, Markel DC. Efficacy of Commercially Available Irrigation Solutions on Removal of *Staphylococcus Aureus* and Biofilm From Porous Titanium Implants: An In Vitro Study. The Journal of Arthroplasty. 2024 Sep 1;39(9):S292-8.
4. Amanatullah D, Dennis D, Oltra EG, Gomes LS, Goodman SB, Hamlin B, Hansen E, Hashemi-Nejad A, Holst DC, Komnos G, Koutalos A. Hip and knee section, diagnosis, definitions: proceedings of international consensus on orthopedic infections. The Journal of arthroplasty. 2019 Feb 1;34(2):S329-37.
5. Fillingham Y, Greenwald AS, Greiner J, Oshkukov S, Parsa A, Porteous A, Squire MW. Hip and knee section, prevention, local antimicrobials: proceedings of international consensus on orthopedic infections. The Journal of Arthroplasty. 2019 Feb 1;34(2):S289-92.
6. Cooper AM, Shope AJ, Javid M, Parsa A, Chinoy MA, Parvizi J. Musculoskeletal infection in pediatrics: assessment of the 2018 International Consensus Meeting on Musculoskeletal Infection. JBJS. 2019 Dec 18;101(24):e133.
7. Urish KL, DeMuth PW, Craft DW, Haider H, Davis III CM. Pulse lavage is inadequate at removal of biofilm from the surface of total knee arthroplasty materials. The Journal of arthroplasty. 2014 Jun 1;29(6):1128-32.

8. Mori Y, Nakagami G, Kitamura A, Minematsu T, Kinoshita M, Suga H, Kurita M, Hayashi C, Kawasaki A, Sanada H. Effectiveness of biofilm-based wound care system on wound healing in chronic wounds. *Wound Repair and Regeneration*. 2019 Sep;27(5):540-7.
9. Teves A, Blanco D, Casaretto M, Torres J, Alvarado DE, Coaguila-Llerena H, Faria G, Jaramillo DE. Multispecies biofilm removal by XP-endo Finisher and passive ultrasonic irrigation: a scanning electron microscopy study. *Australian Endodontic Journal*. 2022 Apr;48(1):91-7.
10. Hoedke D, Kaulika N, Dommisch H, Schlafer S, Shemesh H, Bitter K. Reduction of dual-species biofilm after sonic-or ultrasonic-activated irrigation protocols: A laboratory study. *International endodontic journal*. 2021 Dec;54(12):2219-28.
11. Aust Endod J. 2019 Dec;45(3):317-324. doi: 10.1111/aej.12334. Epub 2019 Jan 8. Efficacy of laser and ultrasonic-activated irrigation on eradicating a mixed-species biofilm in human mesial roots.
12. Coaguila-Llerena H, Ordinola-Zapata R, Staley C, Dietz M, Chen R, Faria G. Multispecies biofilm removal by a multisonic irrigation system in mandibular molars. *International endodontic journal*. 2022 Nov;55(11):1252-61.
13. Joy J, Mathias J, Sagir VM, Babu BP, Chirayath KJ, Hameed H. Bacterial biofilm removal using static and passive ultrasonic irrigation. *Journal of international oral health: JIOH*. 2015 Jul;7(7):42.
14. Joy J, Mathias J, Sagir VM, Babu BP, Chirayath KJ, Hameed H. Bacterial biofilm removal using static and passive ultrasonic irrigation. *Journal of international oral health: JIOH*. 2015 Jul;7(7):42.
15. Donnermeyer D, Dust PC, Schäfer E, Bürklein S. Comparative analysis of irrigation techniques for cleaning efficiency in isthmus structures. *Journal of Endodontics*. 2024 May 1;50(5):644-50.
16. Gartenmann SJ, Thurnheer T, Attin T, Schmidlin PR. Influence of ultrasonic tip distance and orientation on biofilm removal. *Clinical oral investigations*. 2017 May;21:1029-36.
17. Russo A, Gatti A, Felici S, Gambardella A, Fini M, Neri MP, Zaffagnini S, Lazzarotto T. Piezoelectric ultrasonic debridement as new tool for biofilm removal from orthopedic implants: A study in vitro. *Journal of Orthopaedic Research®*. 2023 Dec;41(12):2749-55.
18. Bao P, Liu H, Yang L, Zhang L, Yang L, Xiao N, Shen J, Deng J, Shen Y. In vitro efficacy of Er: YAG laser-activated irrigation versus passive ultrasonic irrigation and sonic-powered irrigation for treating multispecies biofilms in artificial grooves and dentinal tubules: an SEM and CLSM study. *BMC Oral Health*. 2024 Feb 22;24(1):261.
19. Leonhardt Å, Bergström C, Krok L, Cardaropoli G. Healing following ultrasonic debridement and PVP-iodine in individuals with severe chronic periodontal disease: a randomized, controlled clinical study. *Acta Odontologica Scandinavica*. 2006 Jan 1;64(5):262-6.
20. Leonhardt Å, Bergström C, Krok L, Cardaropoli G. Microbiological effect of the use of an ultrasonic device and iodine irrigation in patients with severe chronic periodontal disease: a randomized controlled clinical study. *Acta Odontologica Scandinavica*. 2007 Jan 1;65(1):52-9.
21. Breuing KH, Bayer L, Neuwalder J, Orgill DP. Early experience using low-frequency ultrasound in chronic wounds. *Annals of plastic surgery*. 2005 Aug 1;55(2):183-7.

22. Messa IV CA, Chatman BC, Rhemtulla IA, Broach RB, Mauch JT, D'Angelantonio III AM, Fischer JP. Ultrasonic debridement management of lower extremity wounds: retrospective analysis of clinical outcomes and cost. *Journal of Wound Care*. 2019 May 1;28(Sup5):S30-40.
23. Saeed K, McLaren AC, Schwarz EM, Antoci V, Arnold WV, Chen AF, Clauss M, Esteban J, Gant V, Hendershot E, Hickok N. 2018 international consensus meeting on musculoskeletal infection: Summary from the biofilm workgroup and consensus on biofilm related musculoskeletal infections. *Journal of Orthopaedic Research®*. 2019 May;37(5):1007-17.