



OPEN Results of percutaneous needle culture sampling and synchronous irrigation with Dakins' solution in Wagner Grade 3 diabetic foot osteomyelitis

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Wagner Grade 3 diabetic foot osteomyelitis is a severe infection involving bone, often requiring a multidisciplinary approach for effective management. While percutaneous bone biopsy is widely recognized as the gold standard for pathogen identification, the addition of percutaneous bactericidal irrigation has not been extensively explored in the literature. This study evaluates a minimally invasive approach combining percutaneous needle culture sampling with Dakins' solution irrigation in a single session. A retrospective analysis of 31 patients was conducted to assess its feasibility, effectiveness in pathogen identification, and impact on infection control. The most frequently isolated bacterium was *Staphylococcus aureus*, with no significant correlation between bacterial type and infected bone. Four patients required re-intervention due to persistent symptoms, revealing different bacterial isolates upon re-culture. Significant reductions in CRP levels were observed post-intervention, while WBC changes were not statistically significant. These findings suggest that this combined percutaneous approach may be an effective and minimally invasive strategy for both diagnostic and therapeutic purposes in Wagner Grade 3 osteomyelitis. Further studies with larger sample sizes and extended follow-up are warranted to confirm its long-term benefits.

Keywords Patients with diabetes foot, Osteomyelitis, Percutaneous culture sampling, Percutaneous irrigation, Dakins' solution, Sodium hypochlorite

Diabetic foot (DF) infections is a common complication of diabetes mellitus which may lead to ulcers with an incidence of 19 to 34% in lifetime and give rise to non-traumatic amputations¹. Patients with DF infections, particularly those that lead to osteomyelitis, present a significant clinical challenge. Besides the preventive methods, treatment modalities of diabetic foot osteomyelitis are widely searched and needs multidisciplinary approach including effective infection control, timely diagnosis, and appropriate therapeutic interventions^{1,2}. Diabetic foot osteomyelitis is commonly caused by a range of microorganisms, reflecting a polymicrobial etiology³.

The Wagner classification is a widely used system to assess the patients with DF in which the patients are classified into five grades. While the infection is limited to the skin in grades 1 and 2, the presence of osteomyelitis is classified as at least grade 3 according to the Wagner classification. Skin necrosis involvement upgrades the classification category to grade 4 or 5, depending on the extent of necrosis⁴. Wagner Grade 3 cases can recover without amputation with appropriate treatment, hence early detection and revascularization is mandatory to prevent unfavourable process^{5,6}. However, even diabetic foot osteomyelitis diagnosis may not be easy because of the higher possibility of deficiency of local and/or systematic signs of the infection^{2,5}.

In the management of osteomyelitis, identifying the causative pathogen is crucial⁷. While the ideal antibiotic treatment is guided by culture results, wound swab samples often fail to accurately reflect the causative

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organisms^{8,9}. Hence, percutaneous bone biopsy culture sampling is considered as the gold standard^{10,11}, however obtaining an appropriate specimen from the affected bone can be technically challenging⁹.

Enhanced Recovery After Surgery is a patient-centered, evidence-based perioperative care model designed to reduce complications, shorten hospital length of stay, and promote faster functional recovery, in which minimally invasive approaches play a key role¹². From this perspective, although the aetiology of vertebral osteomyelitis and diabetic foot osteomyelitis differs, the use of percutaneous irrigation in the management of osteomyelitis has long been applied and has been shown to be minimally invasive with low complication rates^{13,14}. Additionally, suction–irrigation is commonly performed following open surgical debridement in cases of chronic osteomyelitis of long bones^{15–18}. By this point, to determine the effects of combining percutaneous needle culture sampling with Dakins' solution irrigation in a single session in different osteomyelitis cases would be valuable for obtaining a new therapeutic approach.

Various irrigation solutions including Castile soap, chlorhexidine, antibiotic serum, silver nitrate, acetic acid and Dakins' solution are used in orthopaedic practice^{15–20}. The use of Dakins' solution (0.5% sodium hypochlorite) for percutaneous irrigation of infected bone tissue has been shown to be promising as an adjunctive treatment^{19,20}. Dakins' solution is bactericidal and may reduce bacterial load, and thereby facilitate wound healing. Additionally, irrigation with Dakins' solution may aid in the debridement of infected tissue and enhance the efficacy of antibiotic therapy without damaging the bone tissue^{21,22}.

By this perspective, we performed a technique in which percutaneous sampling and percutaneous irrigation with a bactericidal solution were carried out in the same session in the management of Wagner Grade 3 diabetic foot osteomyelitis management. In this study, we share our experience with a cohort of patients with Wagner Grade 3 diabetic foot osteomyelitis who were treated with percutaneous needle culture sampling, local irrigation with Dakins' solution, and culture-guided antibiotic therapy. Our aim is to evaluate the feasibility of this approach, assess patient outcomes, and identify the common pathogens involved in these infections.

Methods

This retrospective study was conducted at the Giresun University Training and Research Hospital, following approval by the local ethics committee (Giresun University Clinical Research Ethics Committee, Decision no: 21.02.2023/16). This study was conducted in accordance with the principles of the Declaration of Helsinki, the Good Clinical Practice guidelines, and other applicable laws and regulations and written informed consent was obtained from all patients or their legally acceptable representatives. Diabetic foot osteomyelitis diagnosed patients via MRI with Wagner classification grade 3 and treated with percutaneous culture sampling and percutaneous irrigation of Dakins' solution were included in the investigation⁴.

The inclusion criteria were as follows:

- (1) Diagnosis of diabetes mellitus,
- (2) DF patients classified as Wagner's classification grade 3,
- (3) Patients who underwent percutaneous culture sampling and irrigation with Dakins' solution.

The exclusion criteria were:

- (1) Patients whose data were inaccessible,
- (2) Patients who had treatment previously for the same complaint,
- (3) Patients with chronic osteomyelitis,
- (4) Patients with less than six months of follow-up,
- (5) Patients who completed their treatment at other centers.

The following data were collected: sex, age, duration of diabetes mellitus diagnosis, affected side (right or left), whether presence of the skin ulcer or not, affected bone(s), location of the percutaneous intervention (outpatient clinic or operating theatre), pre-intervention and final follow-up values for WBC and CRP, culture results, number of interventions (if more than one culture sampling and irrigation was performed), follow-up duration.

Pre-interventional plan: determining the needle entry points

We paid attention to two key issues when determining the entry points of the needles into the bone.

The first was based on the ethical principle of “Primum non nocere” (“First, do no harm”). To avoid causing iatrogenic septic arthritis, care was taken to ensure that the insertion site was located outside the joint capsule. Specifically, the needle insertion site was selected to be distant from the joint and outside the joint capsule surrounding the phalanges, as well as the head and base of the metatarsal.

For interventions performed under fluoroscopy, the entry point for needles inserted into the metatarsal or phalangeal head was determined just beyond the level of the epicondyle, while for the base, it was identified at the metaphysis. For interventions performed in the outpatient clinic, the epicondyles and bases were palpated, and the entry points were determined manually.

The second issue concerned positioning the needle tips as far apart as possible. This approach ensured that the fluid injected into the medullary or spongy bone would flow through a wider area and exit the bone more effectively. We anticipated that saline injected into the bone for culture purposes would thus sweep through a larger region, increasing the likelihood of bacterial growth in the blood culture bottle. Similarly, we expected that the Dakins' solution would exert a bactericidal effect over a broader area.

Interventional procedure

The culture sampling and irrigation were performed following the diagnosis of osteomyelitis via MRI. Our goal was to intervene as soon as possible. The patient's comfort was prioritized to ensure a successful intervention. To this end, if the affected bone could be palpated, we tried to perform the intervention in the outpatient clinic under local anaesthesia. If the affected bone could not be palpated or if the patient preferred not to undergo the procedure in the outpatient clinic, the procedure was performed in the operating theatre under local anaesthesia under fluoroscopy.

Deciding the placement of the needles

First, the foot was disinfected with povidone-iodine solution and covered with sterile drapes. An 18-gauge syringe needle was then used to access the bone. The procedure consisted of two main steps: (1) Irrigation with saline for culture sampling and (2) Irrigation with 0.5% NaOCl (sodium hypochlorite- Dakins' solution) to leverage its bactericidal effect^{22,23}. To perform this procedure, at least two needles were used (Fig. 1A and B). The first needle was used to inject saline into the affected bone, while the second needle served as a passive tap, allowing the fluid to drain out for sampling. The initial samples retrieved from the bone were collected in a blood culture flask (Video 1), and this completed the first step.

In the second step, 0.5% NaOCl saline solution was used for further irrigations. The irrigation continued until the solution exiting the bone appeared transparent (Video 2). If osteomyelitis affected more than one bone, separate needles were used for each bone.

Follow up

The patients were administered broad-spectrum antibiotic therapy until the culture sampling results were obtained²⁴. The antibiotic regimen was subsequently adjusted in accordance with the antibiogram results. Patients were instructed to bear as much load as tolerated while walking.

Statistics

In this study, statistical analyses were conducted to evaluate the follow-up data. Parametric tests were used for normally distributed variables, while non-parametric tests were applied for variables without normal distribution. Chi-Square tests were utilized for categorical data to examine associations between variables. Correlation analyses were performed to explore relationships between continuous variables, and comparative



Fig. 1. shows a patient diagnosed with osteomyelitis in the proximal and distal phalanges of the great toe. (A) Two needles were inserted into each phalanx: the first for culture sampling and the second for irrigation with 0.5% NaOCl. (B) The fluoroscopic view depicts the needles inside the phalanges of the same patient.

Number of patients (n)	Age (years old) ± SD	Sex (n)	The duration of diabetes mellitus (month) ± SD	The follow-up time (month) ± SD	Pre-interventional WBC ($10^3/\mu\text{L}$) ± SD	Final control WBC ($10^3/\mu\text{L}$) ± SD	Pre-interventional CRP (mg/L) ± SD	Final control CRP (mg/L) ± SD
31	60,0 ± 10,62	Male:24 Female: 7	15,42 ± 5,51	18,61 ± 6,65	8,64 ± 1,76	9,38 ± 3,1	35,33 ± 65,75	8,34 ± 9,75

Table 1. The demographic data and laboratory findings of the patients.

	Operating theater (n)	Outpatient clinic (n)
Place of intervention	26	5
The number of bacterial growths on culture	25	5
The number of non-bacterial growths on culture	1	-
The number of patients only one intervention is adequate	24	3
The number of patients re-intervention is required	2	2

Table 2. The results of bacterial growth on culture and re-intervention number are compared according to the interventional place.

tests assessed changes in pre-intervention and post-intervention values. All statistical analyses were performed using Python and R programming languages, ensuring a robust and reproducible analysis process. In all analyses, the p-value threshold for significance was set at 0.05.

Results

The demographic data with the pre-interventional and final control WBC and CRP values of the study group are given at Table 1. Of the patients 24 were male and 7 were female. While 16 patients had right feet osteomyelitis, 15 had left feet osteomyelitis, and 21 patients had skin ulcers at the diagnosis time. The data of the intervention place, the number of bacterial growth or non-bacterial growth on culture, the number of patients of whom only one intervention was adequate or a second intervention was required are given at Table 2. One patient diagnosed with osteomyelitis of the great toe distal phalanx, who underwent surgical intervention in the operating theater, showed no bacterial growth in culture. Due to clinical remission following broad-spectrum antibiotic therapy, re-sampling was not performed. Due to the worsening of clinical symptoms in 4 patients, despite appropriate antibiotic treatment based on the antibiogram of the isolated bacteria, re-intervention was required. All re-interventions were conducted in the operating theatre under fluoroscopy.

The location of the intervention, whether in the operating theatre or outpatient clinic, did not affect the need for a second intervention

While 5 patients had been treated in the outpatient clinic in the first intervention, all four patients who required a re-intervention were treated in the theatre under fluoroscopy. The Chi-Square test results indicate no statistically significant association between the place of intervention and the need for re-intervention ($p=0.213$). The analysis, with a Chi-Square statistic of 1.55 and 1 degree of freedom, suggests that the observed differences in intervention locations are likely attributable to random variation rather than a meaningful relationship.

The age of the patients and the duration of diabetes mellitus did not have an effect on the re-intervention need

While the mean age for men was 59.71 ± 11.53 years and 61.14 ± 7.27 years for women, it was 60.03 ± 10.62 years for all patients. The mean duration of diabetes mellitus diagnosis was 15.42 ± 5.51 years. Among the 27 patients who underwent only one intervention, the mean age was 60.70 ± 10.83 years, and the mean duration of diabetes mellitus was 15.52 ± 5.71 years. The 4 patients who required re-intervention had a mean age of 55.60 ± 8.96 years, and the mean duration of diabetes mellitus was 14.75 ± 4.57 years. These differences were statistically insignificant ($p=0.347$ for age and $p=0.775$ for duration of diabetes mellitus).

In the comparison of pre-intervention and post-intervention data, a statistically significant decrease in CRP levels was observed in all patients, while changes in WBC were not statistically significant

For all patients, the mean pre-intervention WBC value of 8.55 ± 1.67 changed to 9.00 ± 2.59 in post-intervention period, and this finding was statistically insignificant ($p=0.682$). The mean pre-intervention CRP value of 34.54 ± 47.01 mg/L decreased to 9.10 ± 9.54 mg/L at the final follow-up, which was statistically significant ($p=0.003$). When comparing the pre-intervention mean CRP values, the patients who underwent only one intervention had a mean of 35.18 ± 50.45 mg/L, while the patients who required re-intervention had a mean of 32.81 ± 30.36 mg/L, which was statistically insignificant ($p=0.902$).

The distribution of infected bones demonstrated a statistically significant anatomic pattern

The infected bone(s) in each patient are shown in Fig. 2. The distribution of bone involvement was examined to describe anatomical patterns of infection. The frequencies of involvement for each bone and their co-occurrence with other bones were tabulated to illustrate how osteomyelitis was distributed across the foot. The findings showed a recognizable anatomical pattern, with infection more frequently affecting bones in weightbearing areas.

The frequency of each infected bone showed that the bones in the first ray were the most frequently involved

The total number of infected bones in all patients' feet is presented in Fig. 3A and B. According to the frequencies, the most commonly involved bones are the load-bearing areas of the foot, such as those in the first row, the fifth row, and the calcaneus.

The most frequently isolated bacterium was *Staphylococcus aureus*

The most frequently isolated bacterium was *Staphylococcus aureus*, and the most common bacterial group was *Staphylococcus* spp. However, there was no statistical correlation between the infected bone and the bacteria isolated. Figure 4 illustrate the distribution of isolated bacteria and bacterial groups across different bone types, highlighting a higher frequency and diversity of bacterial isolates in D1 bones (distal and proximal phalanges) compared to others. Notably, bacteria such as *Staphylococcus aureus* are more prominent in these bones. While other bones, such as the cuboid and calcaneus, show fewer bacterial isolates, the overall pattern reveals a broad spectrum of pathogens involved in patients with diabetes foot infections, with certain bacteria being dominant. This emphasizes the importance of targeted treatment strategies based on the specific bone type and bacterial profile.

Chi-Square test was performed to evaluate the relationship between the isolated bacteria after the first intervention and the bones where the growth occurred. The test resulted in a Chi-Square statistic of 353.40 with a p-value of 0.8033. Since the p-value is significantly greater than the typical significance level of 0.05, it indicates no statistically significant association between the type of isolated bacteria and the bones where growth occurred. This suggests that bacterial growth is independent of the specific bone involved.

Figure 5 show that isolated bacteria and bacterial groups during the re-intervention were distributed across various bone types. This distribution indicates a diverse range of bacterial infections occurring in different bones following the re-intervention, emphasizing the need for targeted treatment strategies based on the bacterial profile and bone type.

Discussion

The results of this study suggest that percutaneous intramedullary needle sampling, followed by irrigation with Dakins' solution and appropriate antibiotic therapy guided by culture and sensitivity results, is an effective approach for managing patients with diabetes foot osteomyelitis. Additionally, our results indicate that the culture results in patients requiring re-intervention differed from those of the first intervention, highlighting the necessity of re-culturing in cases with persistent symptoms.

When we review the literature regarding the role of percutaneous biopsy in the diagnosis of musculoskeletal system infections, we observe that it has been found useful in identifying infections with different aetiologies, such as diabetic foot, vertebral osteomyelitis, or intervertebral disc infections^{9,11,25–28}. Likewise, when the literature is reviewed in terms of the irrigation of diagnosed musculoskeletal infections using minimally invasive methods, it can be seen that these techniques have been proven to be effective even in infections occurring in different anatomical regions and arising from various aetiologies^{19,29,30}. However, in the performed researches and reviews including systematic and meta-analysis we could not find data about the percutaneous culture sampling and bactericidal irrigation for debridement in the same session for diabetic foot osteomyelitis, which is the key distinction in the current work^{19,31}. The combination of percutaneous intramedullary needle sampling

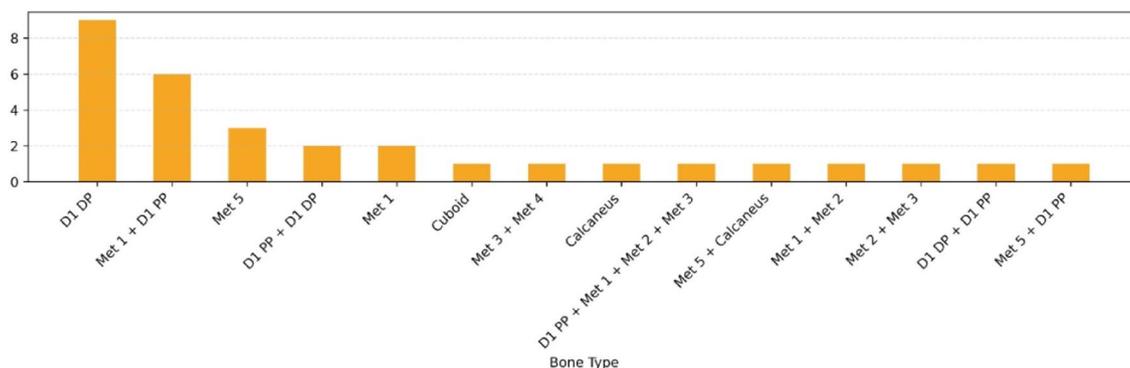


Fig. 2. The bar chart illustrates the distribution of diagnoses for infected bones among patients, indicating the bone types involved and the number of patients corresponding to each diagnosis. D1–D5, digits 1–5; MET, metatarsal; PP, proximal phalanx; DP, distal phalanx.

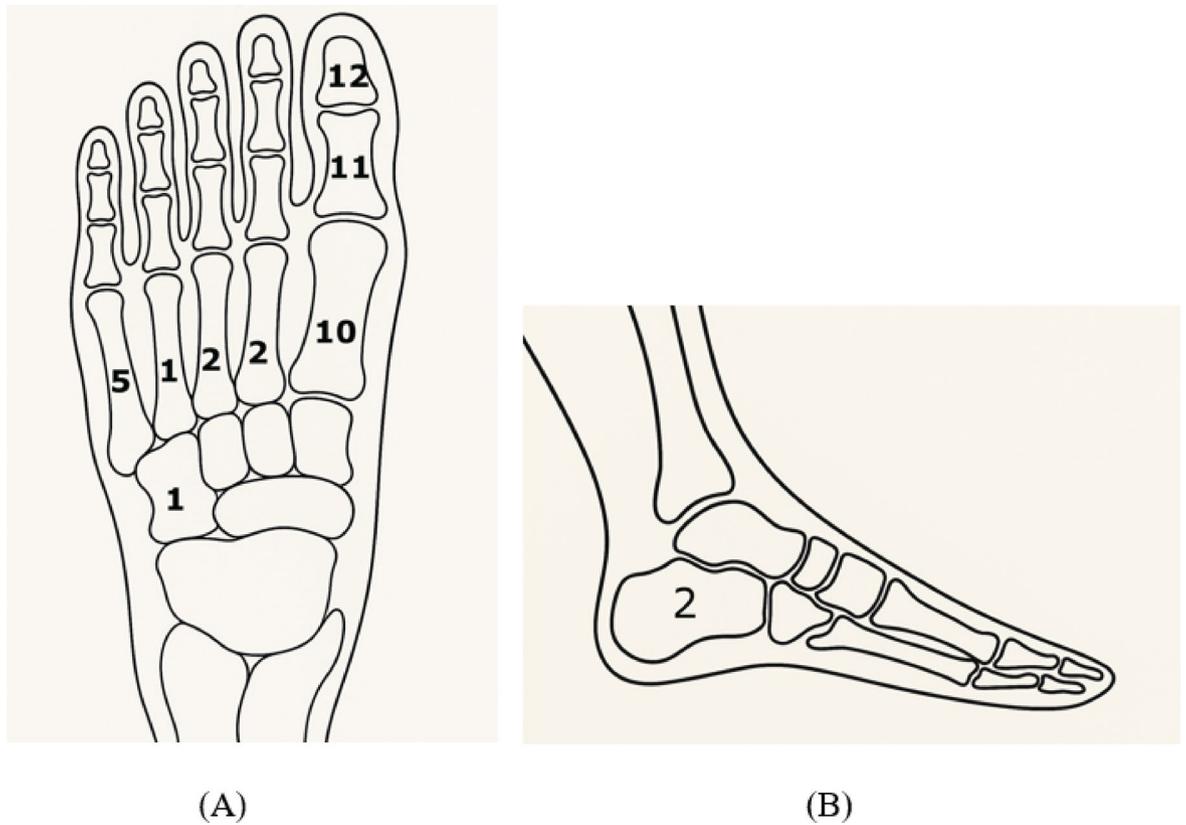


Fig. 3. The figures show the frequencies of infected bones calculated individually for each bone type. Even when multiple bones were infected in a single patient, each bone was analysed and counted separately to provide a detailed distribution of infection frequency. (A) illustrates the anteroposterior view of the foot, (B) illustrates the lateral view of the foot.

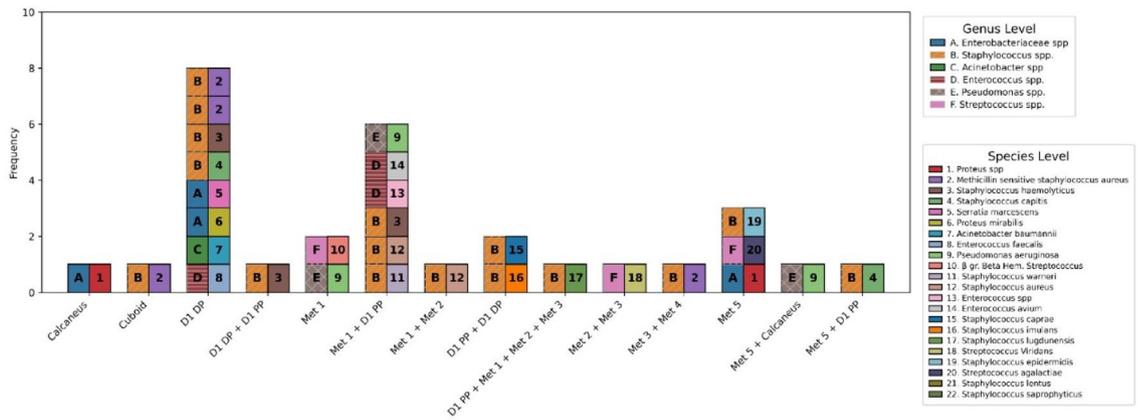


Fig. 4. Bacterial distribution in diabetic foot osteomyelitis by bone location frequency distribution of isolated bacteria at genus (left bars, hatched patterns with letter) and species (right bars, solid colors with numbers) levels across different bone locations in Wagner Grade 3 diabetic foot osteomyelitis. Numbers within bars correspond to legend entries. The D1 bones (first digit) show the highest bacterial diversity, with *Staphylococcus* spp. being the most prevalent genus. D1-D5, digits 1–5; MET, metatarsal; PP, proximal phalanx; DP, distal phalanx.

and irrigation with a bactericidal solution, such as Dakins’ solution, represents a novel approach with the potential for enhanced microbial load reduction and improved treatment outcomes.

Irrigation with bactericidal solutions, such as iodine, Castile soap, chlorhexidine, antibiotic serum, hydrogen peroxide and sodium hypochlorite (Dakins’ solution), has been explored in open surgical settings^{22,32,33}. These studies highlight the benefits of using bactericidal irrigation to reduce infection and enhance healing. Among

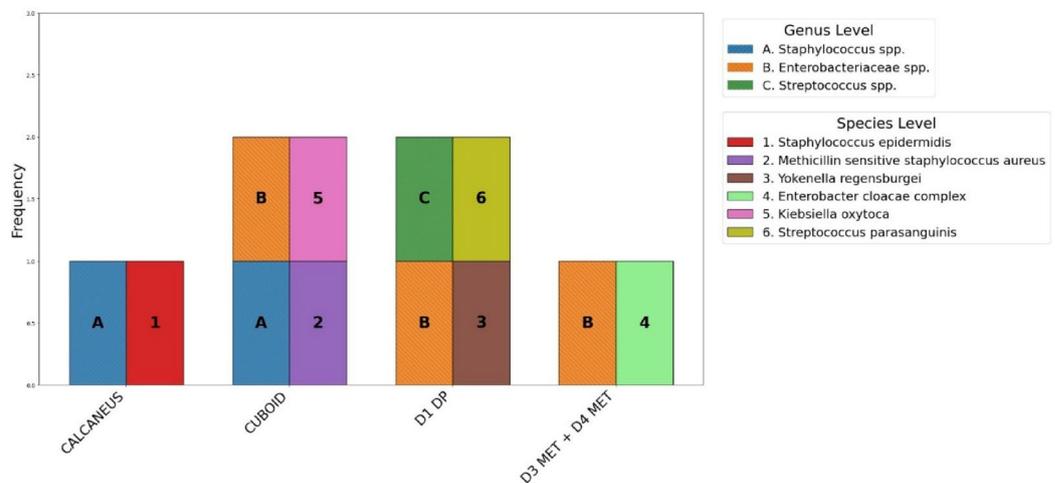


Fig. 5. Bacterial Distribution in Re-intervention Cases Frequency distribution of bacteria isolated during re-interventions ($n = 8$ isolates from 4 patients) at genus (left bars, hatched patterns with letter) and species (right bars, solid colors with numbers) levels. Numbers within bars correspond to legend entries. Re-intervention cases showed altered bacterial profiles compared to initial sampling, with emergence of Enterobacteriaceae spp. alongside *Staphylococcus* spp., indicating bacterial persistence or secondary colonization. MET, metatarsal; DP, distal phalanx.

the mentioned researches, Jaber et al. in 2022 have reported Dakins' solution to be the first time evaluated in diabetic foot ulcers and to give successful results³³. However, to our knowledge, no studies have combined both percutaneous culture sampling and bactericidal irrigation in the management of osteomyelitis in the same session. The use of Dakins' solution in our study demonstrated both mechanical debridement and direct bactericidal activity, which likely contributed to the reduction in bacterial load, as evidenced by the positive culture results. This approach could be advantageous in clinical practice by allowing for minimally invasive tissue sampling while also providing effective microbial control within the infected bone.

Percutaneous techniques have been increasingly reported in the literature as minimally invasive alternatives to open surgical biopsy, particularly in the diagnostic evaluation of musculoskeletal infections and bone pathology. Previous studies employing Jamshidi-style or image-guided percutaneous biopsy approaches have highlighted advantages such as reduced invasiveness, lower procedural burden, and potentially favorable cost profiles when compared with open biopsy techniques^{34–36}. In contrast to these diagnostic-focused methods, the approach described in the present study integrates intramedullary needle aspiration for culture with synchronous bactericidal irrigation, thereby extending the role of percutaneous access beyond sampling alone.

In the diabetic foot osteomyelitis, rarely one pathogen but commonly more than one pathogens, being; *S. aureus* (up to 50%), Enterobacteriaceae (up to 40%), Streptococci (about 30%) and Coagulase Negative *Staphylococcus* (*S. epidermidis* about 25%) and Gram- negative bacilli are determined^{2,5}. In this research microbial growth was observed in 30 of the 31 patients, with *Enterococcus* and *Staphylococcus* species being the most commonly isolated pathogens similar with the performed researches. The high rate of positive cultures in percutaneous biopsy method in osteomyelitis diagnosis is valuable in the success of the treatment, and this study further supports the efficacy of percutaneous biopsy for pathogen identification³⁷. The ability to identify the causative organism and tailor antibiotic therapy accordingly is crucial for effective management and the prevention of antibiotic resistance^{14,27}. The only patient with no microbial growth showed clinical improvement with continued broad-spectrum antibiotic therapy, suggesting that the absence of microbial growth could be attributed to incorrect sampling rather than an inherent limitation of the method. This finding reinforces the importance of accurate needle placement during percutaneous biopsy.

The current study's findings also emphasize that the choice of intervention site (hospital setting with fluoroscopy guidance versus outpatient clinic) did not significantly impact the outcomes, suggesting that the method is versatile and can be performed in both settings without compromising effectiveness. Likewise, Kosmopoulou & Dumont and, Feron et al. have reported the outpatient and/or bedside management of diabetic foot osteomyelitis and have emphasized the importance of the non-hospitalization^{27,38}. However, four patients required a second intervention due to persistent symptoms, indicating that some cases may necessitate additional measures. Different bacteria grew in these four patients after the second intervention. Possible reasons for repeating the intervention include improper application of the technique, failure to grow all pathogens in the culture obtained during the first intervention, or secondary infection.

This study has several limitations that should be considered when interpreting the results. First, the sample size was relatively small, which may limit the generalizability of the findings. A larger cohort would provide a more robust analysis and help confirm the applicability of the results across different populations. Second, the study was retrospective in nature, which may introduce biases related to data collection and patient selection. For example; though the patients included in the study did not have chronic osteomyelitis, the distinction between acute osteomyelitis and subacute osteomyelitis could not be made completely due to the retrospective nature of

the study. Prospective studies would help mitigate these biases and provide stronger evidence. Third, the inability to standardize the irrigation duration and irrigation volume may be another shortcoming. Fourth, the follow-up duration was limited, and longer-term outcomes, such as recurrence rates and sustained healing, were not assessed. Fifth, the healing time of the skin ulcers could not be mentioned, due to the nature of the retrospective design of the current study. Future studies with longer follow-up periods and including the healing time of skin ulcers are required to evaluate the long-term effectiveness of percutaneous biopsy with bactericidal irrigation. Sixth, this technique requires a lot of force to irrigate such a small area. Seventh, the inability to compare the volumes of fluid injected from the first needle with those released from the needle acting like a passive tap can be considered a limitation of this study. Finally, the study did not account for all potential confounding factors, such as HbA1C level, doppler USG results, which could influence the clinical outcomes. These limitations should be addressed in future research to further validate the findings and refine the treatment approach.

In conclusion, percutaneous biopsy with bactericidal irrigation offers a promising, minimally invasive method for diagnosing and treating patients with diabetic foot osteomyelitis. This technique provides advantages in terms of diagnostic accuracy, infection control, cost-effectiveness, and clinical outcomes, particularly when combined with culture-guided antibiotic therapy. Moreover, a tool which will help to reduce the excessive force required during irrigation, and standardize the irrigation duration and irrigation volume may be planned in future. Future studies with larger sample sizes are needed to validate these findings and explore the potential long-term benefits of this approach.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Conceptualisation; FYA, ST, KA, Data curation; KA, Formal analysis; FYA, ST, PG, MA, KA, Funding acquisition; FYA, ST, Investigation; FYA, ST, MA, KA, Methodology; FYA, ST, MA, KA, Project administration; FYA, ST, PG, MA, KA, Resources; FYA, ST, PG, MA, KA, Software; FYA, MA, Supervision; FYA, ST, PG, MA, KA, Validation; FYA, ST, PG, MA, KA, Visualisation; FYA, ST, PG, MA, KA, Writing - original draft; FYA, ST, PG, MA, KA, Writing—review & editing. FYA, ST, PG, MA, KA.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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