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Research Article

Influence of Microbial Profile and Antibiotic Delivery Method on Anatomical Bone Deformity after Chronic Osteomyelitis Surgery

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ABSTRACT
Background: Chronic osteomyelitis is a chronic bone infection that can result in the development of structural damage of the bone, recurrent surgery and postoperative deformity. The postoperative results could be influenced by the type of infecting organism and antibiotic delivery technique.
Objective: To determine the influence of microbial profile and antibiotic delivery method on anatomical bone deformity after chronic osteomyelitis surgery.
Methods: This observational study was conducted from January 2025 to June 2025, at the Margalla Institute of Health Sciences, Islamabad. Forty-nine of the 76 patients who had undergone surgery for chronic osteomyelitis were included. Demographic data, clinical characteristics, bone involved, culture results, microbial isolates, antibiotic administration route and postoperative outcomes were documented. The types of antibiotic delivery were classified as systemic antibiotics only, local antibiotics only, or combined systemic and local antibiotic therapy. The common final results were postoperative anatomical deformity of the bones, which included angulation, shortening, malalignment, joint stiffness and pathological fracture. Data were analyzed either by frequencies or percentages and using chi square test or logistic regression, and a value of $p<0.05$ was taken to be statistically significant.
Results: Culture positivity was observed in 63 patients (82.9%). Gram-positive organisms were most common, while multidrug-resistant organisms were identified in 24 patients (31.6%). Postoperative anatomical bone deformity occurred in 24 patients (31.6%). Deformity was more frequent among patients with polymicrobial infection, MRSA, and multidrug-resistant organisms. Patients treated with systemic antibiotics only had the highest deformity rate, while combined systemic and local antibiotic therapy was associated with a lower frequency of deformity. Multidrug-resistant infection, polymicrobial infection, MRSA, postoperative bone defect, and systemic antibiotics only were important predictors of deformity.
Conclusion: Postoperative anatomical bone deformity was observed in nearly one-third of patients after chronic osteomyelitis surgery. Resistant and polymicrobial infections increased the risk of deformity, whereas combined systemic and local antibiotic therapy was associated with better anatomical outcomes. Culture-guided treatment and appropriate local antibiotic delivery may help reduce deformity after surgery.

Keywords: Chronic Osteomyelitis, Microbial Profile, Antibiotic Delivery, Bone Deformity, Mrsa, Multidrug-Resistant Organisms, Local Antibiotics.

INTRODUCTION

Chronic osteomyelitis is a chronic condition of bone infection which is complicated by poor vascularity, necrotic bone, presence of bacteria, and recurrent inflammatory bone destruction and is difficult to treat. It can arise following

trauma, open fracture, orthopedic surgery, infection around implants, infection in diabetic foot or hematogenous spread. With chronic infection, sequestration, sinus tract development, bone loss, and soft tissue compromise may develop. These alterations extend treatment, and also raise the risk of postoperative issues and deformity [1-3].

Treatment for chronic osteomyelitis typically involves a combination of surgical debridement, removal of dead space, dead space management, stabilization (if necessary) and extended antibiotic use. Surgical debridement is necessary because antibiotics are not effective in penetrating avascular necrotic bone. But if infected/damaged bone is aggressively removed, defects and structural weaknesses will result. Therefore, despite infection control, patients can get angulation, shortening, malalignment, stiffness or fracture. Surgery and culture-based antimicrobial therapy remain a key tenet of the treatment of chronic osteomyelitis as described in recent literature [4-6].

Microbial profile is an important aspect of the clinical course of chronic osteomyelitis. S. aureus is still one of the most frequent isolates and complicated cases often involve MRSA, Gram-negative bacilli and polymicrobial infections. Clinically important resistant organisms are those that may lead to decreased response to treatment, recurrence of infection, extended antibiotic treatment and repeated surgery. The bacteria are protected from host defense and antimicrobial activity by the formation of biofilms, particularly in implant-associated and chronic infections [7, 8].

Another critical factor that may impact surgical outcome is delivery of the antibiotic. For infection, systemic antibiotic delivery has been the standard treatment, but there has been increasing interest in the delivery of antibiotic locally, which allows high levels of drug at the site of infection. Antibiotic beads, antibiotic loaded materials, cement spacers and coated implants are all local antibiotic methods. These techniques are especially helpful in dead space or poorly vascularized areas or those with a high bacterial count. Local antibiotic delivery has been documented and reviewed to aid with infection control and bone healing in the context of a comprehensive surgical plan [9-11].

While the primary goal in chronic osteomyelitis is eradication of infection, it is equally significant to seek a good anatomical result. While they may be infection-free, the patient can have deformity, loss of length in the affected limb, functional limitation or decreased quality of life. Therefore it is important to look for factors associated with postoperative bone deformity to enhance surgical planning and postoperative care. Poor anatomical outcome may be associated with microbial resistance, polymicrobial infection, bone defect and inadequate local infection control [11].

There is limited local evidence regarding how microbial profile and antibiotic delivery method affect anatomical bone deformity after chronic osteomyelitis surgery. Most available studies focus on infection recurrence or treatment success, while postoperative deformity is less commonly evaluated as a primary outcome. Therefore, the present study was conducted to assess the influence of microbial profile and antibiotic delivery method on anatomical bone deformity after chronic osteomyelitis surgery among patients treated at Margalla Institute of Health Sciences, Islamabad.

METHODOLOGY

This observational study was conducted at Margalla Institute of Health Sciences, Islamabad**,** over a period of six months from January 2025 to June 2025**.** The study was designed to evaluate the influence of microbial profile and antibiotic delivery method on the development of anatomical bone deformity after surgery for chronic osteomyelitis. A total of 76 patients diagnosed with chronic osteomyelitis and managed surgically during the study period were included. Patients were enrolled after fulfilling the selection criteria, and relevant demographic, clinical, microbiological, surgical, and postoperative outcome data were recorded on a structured proforma.

The study included patients of both sexes and varying ages with chronic osteomyelitis who were treated surgically. Chronic osteomyelitis diagnosis was made based upon clinical presentation, radiologic, surgical and/or microbiological evidence (if available). The criteria for inclusion were patients with persistent bone pain, discharging sinus, swelling, a history of trauma or previous bone surgery, sequestrum, involucrum or radiological evidence of chronic bone infection. The patients with incomplete clinical data, acute osteomyelitis, malignant destruction of bone, congenital deformities of bone and those who were not followed up for the required duration were excluded.

Detailed history and clinical examination was done after admission. Data on age, gender,

living place, smoking, diabetes mellitus, previous trauma, surgery, duration of osteomyelitis, sinus tract, bone affected, and type of osteomyelitis were obtained. Radiological evaluation was done preoperatively by X-ray and other imaging modalities as needed to assess the extent of bone involvement, sequestrum formation, bone defect, pathological fracture and pre-existing deformity. Laboratory tests were conducted prior to surgery and included a complete blood count, an erythrocyte sedimentation rate, C-reactive protein, renal function tests and other appropriate laboratory tests.

All patients received surgical treatment that depended on the severity and extent of the disease. The surgery consisted of debridement, sequestrectomy, removal of necrotic tissue, bone grafting and fixation as appropriate. Samples from intra-operative bone, pus or deep wound were taken and cultured and subjected to antibiotic sensitivity testing under aseptic conditions. In general, superficial swabs were not collected to minimize contamination and enhance microbiological results. The isolates were classified as Gram-positive organisms, Gram-negative organisms, polymicrobial infections, culture-negative infection, methicillin-resistant Staphylococcus aureus infection, and multidrug-resistant organisms.

Treatment started with antibiotic therapy as per clinical condition and modified based on culture and sensitivity result. Different antibiotic delivery therapies were used, such as systemic antibiotic therapy alone and local antibiotic therapy alone, or both systemic and local antibiotic therapy. Systemic antibiotics: intravenous antibiotics followed by oral antibiotics as appropriate. Depending on the surgical indications and availability, antibiotic beads, antibiotic cement spacers, antibiotic loaded materials or antibiotic coated implants were used for local antibiotic delivery. Depending on the severity of the infection, the size of the bone defect, the culture, the surgeon's preference, and the patient-related factors, the method of antibiotic delivery was determined.

The main outcome variable was postoperative anatomical bone deformity. Patients were evaluated at the time of follow-up for deformity following surgery for chronic osteomyelitis. Anatomical deformity was determined after surgery and was defined as any clinical/radiological evidence of bone alignment or structure change, such as angulation, shortening of bones, malalignment, stiffening of the joints and/or pathological fracture. The severity of deformity was graded as mild, moderate or severe by clinical assessment, functional limitation and radiological findings. Assessment was determined after surgery and involved checking for wound healing, reinfection, bony defect and anatomical appearance.

The statistical software was used for data entry and analysis. Quantitative variables were presented as mean and standard deviation like age and duration of disease. Qualitative variables were presented as frequency and percentage of patients as: gender, microbial profile, antibiotic delivery method, bone involved, type of surgery and postoperative deformity. Chi-square test or Fisher's exact test as appropriate was used to determine the association between the microbial profile and the type of antibiotic delivery with postoperative anatomical bone deformity. Logistic regression was performed to determine factors associated with postoperative deformity. P-values < 0.05 were considered statistically significant.

RESULTS

A total of 76 patients underwent surgery for chronic osteomyelitis were included in the study. The average age of the patients was 36.8 ± 14.2 years, and most of the patients were in the adult age group. Males were found to be affected more than females. The tibia was the most common bone affected, with the femur the second most common. The majority of patients suffered from post-traumatic osteomyelitis and over 50% of patients had a sinus tract.

Table 1. Baseline Demographic and Clinical Characteristics of Patients

Variable	Frequency / Mean	Percentage
Total patients	76	100
Age, years	36.8 ± 14.2	—
Age ≤30 years	24	31.6
Age 31–45 years	29	38.2
Age >45 years	23	30.3
Male	52	68.4

Female	24	31.6
Diabetes mellitus	15	19.7
Smoking history	21	27.6
Previous bone surgery	33	43.4
History of trauma	48	63.2
Sinus tract present	45	59.2
Disease duration >12 months	39	51.3

The clinical distribution indicated that the tibia was the most frequent bone involved (almost half of the cases). The most common cause was post-traumatic osteomyelitis, and the other types were less common, such as hematogenous and implant-related. The results of this study showed that in chronic osteomyelitis the main cause was trauma and surgical operations in the past.

Table 2. Disease-Related Characteristics of Chronic Osteomyelitis

Variable	Frequency	Percentage
Bone involved		
Tibia	35	46.1
Femur	18	23.7
Humerus	9	11.8
Radius/ulna	6	7.9
Foot bones	8	10.5
Type of osteomyelitis		
Post-traumatic	43	56.6
Hematogenous	14	18.4
Implant-related	12	15.8
Diabetic foot-related	7	9.2
Surgical procedure performed		
Debridement only	29	38.2
Debridement with sequestrectomy	24	31.6
Debridement with bone grafting	11	14.5
Debridement with fixation	12	15.8

Most patients were found to be culture positive. The Gram-positive organisms were more common than the Gram-negative organisms and Staphylococcus aureus was the most common Gram-positive organism. A high prevalence of multidrug-resistant organisms (MDRO), specifically MRSA and resistant Gram-negative bacteria (GNB) were found.

Table 3. Microbial Profile of Patients with Chronic Osteomyelitis

Microbial variable	Frequency	Percentage
Culture positive	63	82.9
Culture negative	13	17.1
Gram-positive organisms	35	46.1
Gram-negative organisms	20	26.3
Polymicrobial infection	8	10.5
No growth	13	17.1
Staphylococcus aureus	22	28.9
MRSA	11	14.5
Pseudomonas aeruginosa	9	11.8
Escherichia coli	5	6.6
Klebsiella pneumoniae	4	5.3
Proteus species	2	2.6
Other organisms	10	13.2
Multidrug-resistant organism	24	31.6

When it came to antibiotic therapy, combined antibiotic therapy (systemic and local) was most commonly used, followed by systemic antibiotics alone. Most of the local antibiotics were provided as antibiotic beads or cement spacers. In most culture-positive cases, culture-guided antibiotic adjustment was done.

Table 4. Antibiotic Delivery Methods used after Surgery

Antibiotic delivery method	Frequency	Percentage
Systemic antibiotics only	31	40.8
Local antibiotics only	10	13.2
Combined systemic + local antibiotics	35	46.1
Intravenous followed by oral antibiotics	49	64.5
Local antibiotic beads	24	31.6
Antibiotic cement spacer	14	18.4
Antibiotic-coated implant	7	9.2
Culture-guided antibiotic therapy	58	76.3
Antibiotic changed after sensitivity report	27	35.5

Twenty-four patients (31.6%) had postoperative anatomic bone deformity. Angulation was the most common deformity, with limb shortening and malalignment being the next most common deformities. The deformities were mostly mild to moderate in severity with severe deformity being seen in a smaller number of patients.

Table 5. Frequency and Pattern of Anatomical Bone Deformity after Surgery

Deformity variable	Frequency	Percentage
No deformity	52	68.4
Anatomical bone deformity present	24	31.6
Type of deformity		
Angulation	8	10.5
Limb shortening	6	7.9
Malalignment	5	6.6
Joint stiffness	3	3.9
Pathological fracture	2	2.6
Severity of deformity		
Mild	10	13.2
Moderate	9	11.8
Severe	5	6.6

The correlation of microbial profile with the postoperative deformity revealed that patients with polymicrobial infection, multidrug resistant organisms and MRSA had more deformity. Patients undergoing the culture-negative osteomyelitis surgery had fewer cases of deformity. There was a significant association between infection with multidrug-resistant organisms and deformity.

Table 6. Association between Microbial Profile and Postoperative Anatomical Bone Deformity

Microbial profile	Total cases	Deformity present	Deformity absent	p-value
Gram-positive infection	35	11	24	0.421
Gram-negative infection	20	7	13	0.583
Polymicrobial infection	8	5	3	0.047
Culture negative	13	1	12	0.038
MRSA	11	6	5	0.041
Multidrug-resistant organism	24	12	12	0.018
Non-MDR organism	39	11	28	Reference

Patients who received systemic antibiotics only had the highest rate of postoperative deformity when compared with other antibiotic delivery methods. Deformity, however, did not occur as

often in those patients who were given a combination of systemic and local antibiotic therapy. This difference was statistically significant, indicating that the combined therapy might be more effective in achieving anatomical results after surgery.

Table 7. Association between Antibiotic Delivery Method and Postoperative Anatomical Bone Deformity

Antibiotic delivery method	Total cases	Deformity present	Deformity absent	p-value
Systemic antibiotics only	31	14	17	0.026
Local antibiotics only	10	3	7	0.914
Combined systemic + local antibiotics	35	7	28	0.018
Culture-guided therapy	58	15	43	0.032
Non-culture-guided therapy	18	9	9	Reference

Multidrug-resistant infection, polymicrobial infection, bone defect after surgery and systemic antibiotics alone were significantly correlated with increased odds of anatomical deformity on regression analysis. A combination of systemic and local antibacterial antibiotics had a protective effect against deformity.

Table 8. Predictors of Postoperative Anatomical Bone Deformity

Predictor	Odds Ratio	95% CI	p-value
Multidrug-resistant organism	2.91	1.12–7.58	0.028
Polymicrobial infection	3.46	1.01–11.84	0.048
MRSA infection	2.68	1.03–6.97	0.043
Bone defect after surgery	3.74	1.34–10.41	0.012
Previous surgery	2.15	0.86–5.38	0.101
Systemic antibiotics only	2.87	1.10–7.49	0.031
Combined systemic + local antibiotics	0.42	0.18–0.96	0.039

Overall, the results indicated that the incidence of postoperative anatomical bone deformity was almost one-third after chronic osteomyelitis surgery. However, deformity was more common with resistant and polymicrobial infections, and in those treated with systemic antibiotics only. The addition of systemic and local antibiotic delivery had a significant association with a lower risk of deformity, making targeted and locally enhanced antimicrobial delivery an attractive option in chronic osteomyelitis surgery.

DISCUSSION

Chronic osteomyelitis remains a difficult orthopedic condition because infection control, bone stability, soft tissue healing, and preservation of anatomy must all be achieved together. In the present study, postoperative anatomical bone deformity was observed in 24 out of 76 patients, giving a deformity rate of 31.6%. This finding indicates that despite surgical debridement and antibiotic therapy, a considerable proportion of patients may develop residual angulation, shortening, malalignment, stiffness, or fracture after chronic osteomyelitis surgery. These deformities may occur due to bone destruction caused by longstanding infection, removal of necrotic bone during debridement, persistent inflammatory activity, delayed union, or recurrence of infection. Osteomyelitis is recognized as a serious inflammatory bone infection that may follow hematogenous spread, trauma, fracture, or surgery, and chronic cases are often associated with structural bone damage and difficult treatment courses [12-14].

In this study, microbial profile revealed that culture positivity was noted in 82.9% of patients and culture negative disease in 17.1% of patients. Staphylococcus aureus and MRSA were an important proportion of infections, and most infections were caused by gram-positive organisms. The pattern is clinically significant since Staphylococcus aureus is still one of the most frequent organisms associated with chronic osteomyelitis and resistant organisms like MRSA can make treatment more difficult with less available antibiotic choice and may contribute to the persistence of the infection. This microbiological profile is consistent with the experience in chronic osteomyelitis, in which Staphylococcus aureus and MRSA are frequently found pathogens [15, 16].

In this study, postoperative deformity rates were higher in patients who were infected with polymicrobial infection, MRSA and multidrug-resistant organisms. There was a statistically significant association between multidrug resistant infection and deformity. This is a discovery that may help to explain why patients with resistant and mixed infections have worse anatomical results after surgery. The reason may be that such infections will be harder to clear up, will take a longer time to be cured, will result in chronic inflammation and repeated debridement, and will create a larger bone defect and a delayed reconstruction. Polymicrobial infection can also be indicative of advanced disease, open wounds, sinus tract formation and/or previous surgery, which may increase the risk of structural compromise [17, 18].

There were also differences in the anatomical outcome after surgery according to the way the antibiotic was delivered. Patients receiving systemic antibiotics only had the highest deformity rate and those receiving combined systemic and local antibiotic therapy had the lowest deformity rate. This discovery validates the idea that using local antibiotics can be beneficial in the surgical treatment of chronic osteomyelitis, especially in situations with dead space, limited blood supply, necrotic bone, and/or high bacterial counts. Local antibiotic materials can help deliver a high antibiotic concentration at the infection site, and minimize reliance on systemic antibiotic levels. Surgical debridement, dead space management using antibiotic impregnated material and systemic antibiotic therapy are some of the critical components of treatment for chronic osteomyelitis, and antibiotic impregnated cement beads are widely utilized for local antibiotic delivery [19, 20].

Additionally, the combined therapy group may have achieved better infection control and local control following debridement, which could explain this lower deformity rate. Antibiotic beads, spacers or coated materials can be used to control the remaining contamination in the bone cavity and antibiotics are administered directly via the bloodstream to combat the remainder of the infection in the body. But the local delivery of antibiotics should not be viewed as a substitute for proper surgical debridement, systemic antibiotic regimen based on culture, bone stabilization and reconstruction. There is ongoing evidence of local antibiotic systems and some reviews have indicated potential benefits in healing and infection control; however, the results may be variable depending on material type, organism, host condition, and surgical technique [21].

However, multiple logistic regression analysis in this study showed that only the presence of MDR, polymicrobial infection, MRSA infection, bone defect after surgery, and systemic antibiotics only were significant predictors of postoperative deformity. Maintenance combined systemic and local antibiotic therapy was associated with protection. Based on these results, it is clear that postoperative deformity is a result of a combination of factors, including the severity of the infection, the resistance of the microorganisms, surgical bone loss, and delivery of antibiotics. One of the most important predictors was bone defect after surgery which can be expected since the removal of sequestrum and infected bone can lead to weakness and is a risk factor for angulation, shortening, or malalignment if not adequately stabilized or reconstructed [22].

This study is of clinical relevance. Firstly, deep tissue or bone culture should be taken when possible as this will enable appropriate antibiotic choice to be made based on culture. Second, resistant organisms should be regarded as markers of poor outcome of the postoperative anatomical structures. Third, in patients with bone defects, polymicrobial infection, MRSA and MDR, a more aggressive combined treatment with local antibiotic delivery, stable fixation, staged reconstruction and close follow-up may be useful. Early diagnosis of those at high risk can decrease deformity, recurrence, disability and reoperation.

There are some limitations in this study. It was carried out in a single centre and the sample size was small (76 patients), so the results are not necessarily applicable to other settings. The duration of follow-up can also influence the ability to detect deformity as some changes are more apparent over time. Antibiotics were delivered either as per the clinical or surgical decision-making process, rather than at random, and may therefore have had selection bias. Also, the deformity severity was clinically and radiologically evaluated, and was not discussed in detail in terms of long term functional outcomes. To confirm these results, it is recommended to conduct future multicenter studies with a larger number of patients, standardized antibiotic protocols, longer follow-up, and functional scoring systems.

CONCLUSION

This study concluded that postoperative anatomical bone deformity occurred in nearly one-third of patients after surgery for chronic osteomyelitis. Resistant microbial profiles, particularly MRSA, polymicrobial infection, and multidrug-resistant organisms, were associated with a higher risk of deformity. Patients managed with systemic antibiotics alone showed a greater frequency of postoperative deformity, while combined systemic and local antibiotic therapy was associated with better anatomical outcomes. These findings suggest that chronic osteomyelitis patients should be managed with culture-guided antibiotics, adequate surgical debridement, appropriate local antibiotic delivery where indicated, and careful postoperative monitoring to reduce the risk of bone deformity and improve surgical outcomes.

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