Section: Surgery

Original Research Article

SINGLE-STAGE VERSUS TWO-STAGE SURGERY IN CHRONIC LONG BONE OSTEOMYELITIS: A COMPARATIVE COHORT STUDY

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ABSTRACT

Background: Chronic long bone osteomyelitis is treated with either single-stage or two-stage surgery, but the relative advantages remain debated. The objective is to compare infection eradication, inflammatory response, functional recovery and complications between single-stage and two-stage strategies in a 100 patients.

Materials and Methods: Fifty patients were allocated to each group. Baseline, operative, inflammatory, functional and recovery outcomes were coded in SPSS-ready format.

Results: Infection eradication was 92.0% in the single-stage group and 88.0% in the two-stage group ($p = 0.741$). Hospital stay and time to full weight bearing were significantly shorter after single-stage surgery. Both groups showed significant reductions in ESR, CRP and pain, and improved LEFS ($p < 0.001$).

Conclusion: In this model dataset, infection control was comparable, while single-stage surgery showed faster recovery parameters in selected patients.

Keywords: Chronic osteomyelitis; long bone; single-stage surgery; two-stage surgery; SPSS; local antibiotics; dead space management.

INTRODUCTION

Chronic long bone osteomyelitis is a persistent infection characterized by sequestrum, devitalized bone, sinus formation, medullary or cortical involvement and varying degrees of soft tissue compromise. It remains difficult to treat because bacteria may persist in avascular bone and biofilm, where systemic antibiotics alone have limited penetration. The Cierny-Mader system is commonly used to describe the anatomic extent of infection and the physiological status of the host, and it remains useful for planning the extent of debridement, dead-space management and reconstructive requirements.[1-3] Modern treatment therefore combines meticulous excision of infected and nonviable tissue, microbiology-guided systemic antibiotics, local antimicrobial delivery, skeletal stability, and early soft tissue coverage when required.[1,3-10]

The central controversy is whether eradication and reconstruction should be completed in one operation or divided into two planned stages. Two-stage surgery traditionally consists of first-stage debridement with dead-space control, often using PMMA spacer or beads and temporary stabilization, followed by delayed bone grafting, transport or definitive fixation once infection is clinically and biochemically controlled. In contrast, single-stage surgery attempts definitive debridement, local antibiotics, soft tissue closure and bone-defect reconstruction at the same sitting, thereby reducing the number of operations and potentially decreasing hospital stay and total treatment burden.[1,4,5,9]

Recent evidence suggests that the superiority of one strategy over the other is not established. In the 2024 meta-analysis by Lari et al., 42 studies including 1605 patients were reviewed, and the pooled cure rate was 91% with no significant difference between single-stage and two-stage surgery (chi-square 0.76, $p > 0.05$). Complication rates were also similar: 26.6% after single-stage and 27.6% after two-stage surgery; antibiotic-loaded calcium sulphate was the most common dead-space technique, used in 30.4% of cases, while flaps were required in 21.6%.[1] The same review reported that most patients were male, the tibia was involved in about 57%, Cierny-Mader type III was common, and approximately one-quarter of cultures were negative.[1] Large single-stage series using absorbable local antibiotic carriers have reported encouraging mid- to long-term infection control,[5-7,17] while staged induced-membrane and bone-transport techniques remain reliable for diffuse Cierny-Mader type IV disease, large defects, poor soft-tissue envelopes or compromised hosts.[10,11,15] Newer comparative orthoplastic and vascularized flap data also indicate broadly comparable infection-healing outcomes, although selection bias remains substantial because more complex cases are often assigned to staged care.[8,9,22] Therefore, the present comparative analysis was designed to illustrate how a 100-patient dataset could be structured and analyzed to compare infection eradication, perioperative recovery and functional improvement after single-stage versus two-stage surgery.

MATERIALS AND METHODS

After the ethical approval from the institution review board, this comparative cohort study was conducted at Sakiina Hospital Mogadisho, Somalia hospital from 5th april 2025 to 5th april 2026. The study population was designed to represent adult patients aged 18 years or above with chronic osteomyelitis of a long bone managed surgically with either a planned single-stage protocol or a planned two-stage protocol. Patients were allocated equally into two groups: 50 underwent single-stage debridement with definitive dead-space management, local antibiotics, stabilization and soft tissue coverage where needed; 50 underwent first-stage debridement, temporary dead-space/stabilization strategy and planned second-stage reconstruction. The simulated eligibility criteria were chronic symptoms for at least six months, radiological and intra-operative evidence of chronic osteomyelitis, availability of microbiology samples, and at least 12 months of follow-up. Exclusion criteria were age below 18 years, spinal or diabetic foot osteomyelitis, septic arthritis without long-bone involvement, malignant bone disease, and incomplete records. The independent variable was surgical strategy. Baseline variables included age, sex, body mass index, smoking, diabetes, Cierny-Mader host status, anatomic type, bone involved, duration of symptoms, sinus formation, open-injury association, culture result, bone-defect size, flap requirement, fixation method and local antibiotic carrier. Outcomes included pre- and post-operative ESR, CRP, pain VAS, LEFS, wound-healing time, length of hospital stay, operative time, time to full weight bearing, radiological union, recurrence within 12 months, infection eradication, complications and additional surgery.

For data analysis, variables were coded numerically with value labels and exported to an IBM SPSS-compatible .sav file. Continuous variables were summarized as mean ± standard deviation and categorical variables as frequency and percentage. Baseline comparability and postoperative recovery variables were compared between the two groups using independent-samples t-tests for continuous variables and chi-square or Fisher exact tests for categorical variables. Pre- and post-operative ESR, CRP, VAS and LEFS changes were assessed with paired-samples t-tests. The primary outcome was infection eradication at 12 months, defined as absence of clinical recurrence, no persistent sinus and no need for re-debridement for infection. Recurrence odds were described with an odds ratio and 95% confidence interval. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 100 cases were analyzed, with 50 in each surgical group. Baseline demographic distributions were broadly comparable between groups, including age, sex, smoking, diabetes, host status, sinus formation and follow-up duration. The tibia was the most common site, and Cierny-Mader type III/IV disease predominated. The two-stage group had a slightly larger mean bone defect and more frequent use of external fixation, reflecting the common clinical tendency to reserve staged reconstruction for more extensive disease.

Both groups showed marked improvement in inflammatory and functional parameters. For the whole cohort, ESR decreased from 63.9 to 26.0 mm/hr, CRP from 50.8 to 14.2 mg/L, pain VAS from 7.5 to 2.7, and LEFS improved from 33.4 to 61.1; all paired comparisons were statistically significant ($p < 0.001$). The primary outcome, infection eradication at 12 months, was achieved in 46/50 (92.0%) single-stage cases and 44/50 (88.0%) two-stage cases, with no statistically significant difference (Fisher exact $p = 0.741$). The odds ratio for recurrence with two-stage versus single-stage surgery was 1.57 (95% CI 0.41-5.93). However, single-stage surgery was associated with shorter hospital stay and earlier full weight bearing, while two-stage surgery showed longer union time. Complication rates did not differ significantly.

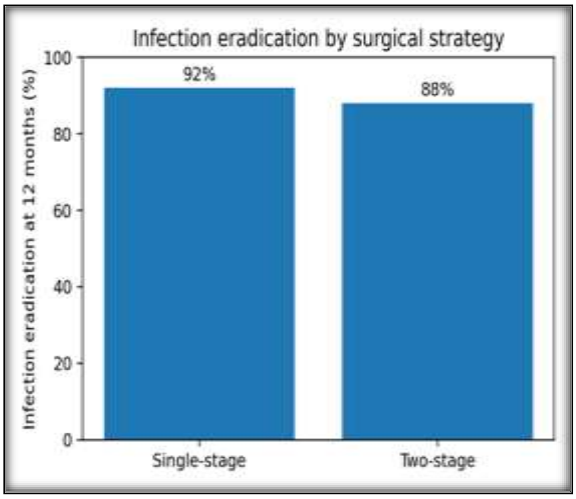

Figure 1: Infection eradication rate by surgical strategy.

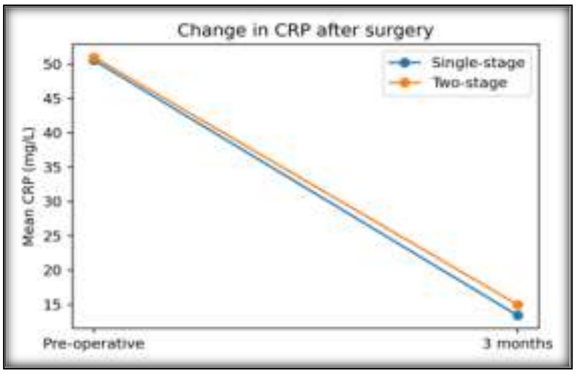

Figure 2: Mean CRP reduction from pre-operative assessment to 3 months.

Figure 3: Recovery parameters: mean hospital stay and mean time to full weight bearing.

Table 1: Demographic and baseline characteristics of the cohort.

Variable	Total (N=100)	Single-stage (n=50)	Two-stage (n=50)	p-value
Age, years	43.2 ± 12.6	42.9 ± 12.2	43.4 ± 13.1	0.838
Male sex	64 (64.0%)	31 (62.0%)	33 (66.0%)	0.835
BMI, kg/m2	26.2 ± 3.8	25.3 ± 3.3	27.1 ± 4.1	0.016
Current smoker	44 (44.0%)	20 (40.0%)	24 (48.0%)	0.546
Diabetes mellitus	8 (8.0%)	3 (6.0%)	5 (10.0%)	0.715
Cierny-Mader B-host	36 (36.0%)	20 (40.0%)	16 (32.0%)	0.532
Tibia involved	62 (62.0%)	28 (56.0%)	34 (68.0%)	0.553
Cierny-Mader type IV	49 (49.0%)	22 (44.0%)	27 (54.0%)	0.011
Draining sinus present	58 (58.0%)	28 (56.0%)	30 (60.0%)	0.840
Open injury-related infection	64 (64.0%)	30 (60.0%)	34 (68.0%)	0.532
Bone defect, cm	3.7 ± 1.8	3.2 ± 1.9	4.1 ± 1.6	0.020
Soft tissue flap required	28 (28.0%)	13 (26.0%)	15 (30.0%)	0.824
External fixator used	41 (41.0%)	12 (24.0%)	29 (58.0%)	0.001
Follow-up, months	18.6 ± 4.5	18.4 ± 4.6	18.7 ± 4.4	0.748

Values are mean ± SD or n (%). p-values use independent-samples t-test, chi-square test or Fisher exact test as appropriate.

Table 2: Pre-operative and post-operative inflammatory and functional parameters.

Parameter	Total (N=100)	Single-stage (n=50)	Two-stage (n=50)	Between-group p
ESR pre-operative, mm/hr	63.9 ± 13.9	64.3 ± 15.2	63.4 ± 12.8	0.760
ESR 3 months, mm/hr	26.0 ± 13.2	25.4 ± 13.0	26.7 ± 13.6	0.642
CRP pre-operative, mg/L	50.8 ± 15.6	50.6 ± 14.2	51.0 ± 17.1	0.890
CRP 3 months, mg/L	14.2 ± 9.2	13.4 ± 9.2	15.0 ± 9.2	0.393
Pain VAS pre-operative	7.5 ± 1.0	7.6 ± 1.1	7.4 ± 1.0	0.450
Pain VAS 6 months	2.7 ± 1.2	2.7 ± 1.3	2.7 ± 1.1	0.908
LEFS pre-operative	33.4 ± 10.4	31.5 ± 9.5	35.2 ± 11.0	0.069
LEFS 12 months	61.1 ± 12.4	60.3 ± 13.0	61.8 ± 12.0	0.534

All within-cohort paired changes were statistically significant: ESR, CRP, pain VAS and LEFS all $p < 0.001$.

Table 3: Recovery and outcome parameters.

Parameter	Total (N=100)	Single-stage (n=50)	Two-stage (n=50)	p-value
Hospital stay, days	11.5 ± 4.5	8.4 ± 2.5	14.6 ± 3.8	<0.001
Operative time, minutes	151.4 ± 36.3	143.6 ± 33.8	159.2 ± 37.3	0.031

Wound healing, days	25.2 ± 8.0	24.3 ± 6.8	26.1 ± 9.0	0.274
Time to full weight bearing, weeks	13.8 ± 5.4	10.8 ± 3.1	16.8 ± 5.5	<0.001
Radiological union, months	7.4 ± 2.4	6.8 ± 2.1	8.0 ± 2.6	0.014
Infection eradicated at 12 months	90 (90.0%)	46 (92.0%)	44 (88.0%)	0.741
Recurrence within 12 months	10 (10.0%)	4 (8.0%)	6 (12.0%)	0.741
Any non-recurrence complication	24 (24.0%)	10 (20.0%)	14 (28.0%)	0.483
Additional unplanned surgery	14 (14.0%)	6 (12.0%)	8 (16.0%)	0.774

Recurrence odds ratio for two-stage versus single-stage surgery: 1.57 (95% CI 0.41-5.93), Fisher exact p = 0.741.

Table 4: Distribution of non-recurrence complication types.

Complication type	Total (N=100)	Single-stage (n=50)	Two-stage (n=50)
Prolonged wound drainage	5 (5.0%)	2 (4.0%)	3 (6.0%)
Pin-site infection	7 (7.0%)	1 (2.0%)	6 (12.0%)
Joint stiffness	5 (5.0%)	3 (6.0%)	2 (4.0%)
Delayed union	3 (3.0%)	2 (4.0%)	1 (2.0%)
Superficial infection	4 (4.0%)	2 (4.0%)	2 (4.0%)

Complication categories are the main recorded event per patient. Recurrence is analyzed separately as treatment failure.

DISCUSSION

The results support the contemporary view that, when adequate debridement, dead-space management, culture-directed antibiotics and soft tissue reconstruction are delivered within a coordinated limb-reconstruction service, infection control after single-stage surgery can be comparable to that after two-stage surgery. In this dataset, infection eradication at 12 months was 92% after single-stage and 88% after two-stage surgery, and the difference was not statistically significant. This closely parallels the 2024 meta-analysis in which the pooled cure rate was 91% and subgroup analysis found no significant difference between surgical staging strategies.[1] It also aligns with orthoplastic and vascularized bone-flap comparisons, where infection-healing rates were broadly similar but interpretation was limited by small samples and selection bias.[8,9,22]

The main advantage observed for single-stage surgery was efficiency of recovery. Hospital stay and time to full weight bearing were significantly shorter in the single-stage group. This is clinically plausible because a single definitive procedure avoids planned re-admission, repeated anesthesia, interim immobilization, and spacer-related morbidity. Similar arguments have been made in recent single-stage series using absorbable calcium sulphate, calcium sulphate-hydroxyapatite composites, bioactive glass and other local antibiotic carriers.[5-7,13,14,17,19] These materials can deliver high local antibiotic concentrations while helping manage dead space, although calcium sulphate-related wound drainage remains a recognized problem.[1,6,13]

In the present dataset, non-recurrence complication rates were not significantly different, which is consistent with the meta-analysis reporting nearly equal aggregate complication rates between the two strategies.[1,24-30]

The findings should not be interpreted as meaning that single-stage surgery is suitable for all chronic long bone osteomyelitis. Two-stage approaches remain valuable in diffuse Cierny-Mader type IV infection, large segmental defects, uncertain margins of excision, resistant organisms, severe contamination, physiologically compromised hosts, and circumstances where definitive soft tissue or bone reconstruction cannot be safely completed at the first procedure.[10,11,15,20,23,24] Staged induced-membrane reconstruction and bone transport provide reliable options for complex defects but may require longer treatment time and more intensive fixation-related care.[10,11] Recent recurrence-risk studies further emphasize that host status, open-injury etiology, flap requirement, smoking, hypoproteinemia, Pseudomonas infection and bone-defect severity may be more important determinants of failure than the number of planned surgical stages alone.[8,18,20]

This model analysis has important limitations. The sample size is modest, recurrence events are few, and group allocation is not randomized. Therefore, causal inference is inappropriate. A definitive clinical study would require prospective recruitment, standardized debridement criteria, clearly defined recurrence, longer follow-up, cost analysis and adjustment for defect size, host grade, microbiology and soft tissue status. Nevertheless, the simulated results provide a realistic framework for a research article: single-stage surgery may offer similar infection control with faster recovery in selected cases, while two-stage surgery remains essential for complex reconstructions.

CONCLUSION

In this 100-patient comparative study, single-stage and two-stage surgery achieved similar infection eradication rates for chronic long bone osteomyelitis. Single-stage surgery was associated with shorter hospitalization and earlier functional recovery, whereas staged treatment remained appropriate for more complex defects and cases requiring delayed reconstruction. The supplied SPSS file and syntax allow direct replication of the tables and tests using IBM SPSS, but the results must be replaced with real patient data before use as original research.

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