Clinical and Radiological Results Five Years After Non-Union Surgery: Ongoing Remodelling and Functional Improvement

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INTRODUCTION: Non-unions constitute a significant complication in the field of trauma surgery, leading to prolonged morbidity and compromised functional capacity. Although bone possesses a remarkable ability for regeneration and remodelling, the long-term healing process following surgical intervention for non-union remains inadequately characterized, particularly beyond the two years postoperative interval. The majority of existing studies predominantly address short- and mid-term outcomes, thereby leaving a gap concerning sustained bone remodelling and functional recovery. The present study evaluates clinical, functional, and radiological outcomes five years postoperatively, with particular focus on ongoing bone remodelling processes and patient-reported outcomes. Additionally, a representative clinical case is included to exemplify typical healing.

METHODS:
This prospective study included all patients aged 18 years or over who underwent surgical treatment for non-union between June 2018 and December 2020, provided they gave informed consent. Exclusion criteria encompassed cases involving permanent cement spacer implantation or conversion to total joint arthroplasty. Surgical management adhered to the diamond concept, using either one- or two-stage procedures alongside various bone substitute materials. Clinical evaluation at the five-year follow-up included the assessment of health-related quality of life via the Short-Form-12 (SF-12), pain quantification using the visual analogue scale (VAS), and measurement of active range of motion (ROM). Radiological analysis was conducted using standardized radiographs, graded by the modified Lane-Sandhu-Score (LSS; union defined as LSS ≥3). Complications and relevant risk factors such as infection and smoking history exceeding 6.1 pack-years were analysed. Statistical analysis included paired/unpaired t-tests and Wilcoxon signed-rank test and Mann-Whitney-U-Test ($p<0.05$).
RESULTS:
Out of 154 patients screened, 45 met inclusion criteria and completed five-year follow-up (median age 55 years, 60% male). Non-unions sites were distributed as follows: lower extremity (53%), upper extremity (24%), and foot (22%); with 38% classified as infectious non-unions. The median follow-up was 63 months. The union rate (LSS ≥3) was 90.5%. Median LSS at five years was 4 (IQR: 4–4), representing a statistically significant improvement from the two-year follow-up ($Z=-4.334$, $p<0.0001$; see Table 1). Pain levels (VAS) decreased significantly from 3 (IQR: 0.5; 4.5) at one year to 0 (IQR: 0; 4) at five years ($p=0.008$), with 55% of patients reporting complete absence of pain at final follow-up. SF-12 scores showed improvement in both the mental component (from 54.05 (IQR: 47.4; 57.05) to 56.2 (IQR: 50.7; 57.6), $p = 0.08$) and the physical component (from 42.77 ± 9.15 to 45.4 ± 9.91, $p = 0.0468$), with the latter being significant. Thirty-one percent of patients demonstrated improved range of motion. Patient satisfaction was notably high with 95.6% reporting being satisfied or very satisfied. Six patients (13.3%) required reintervention. A history of smoking over 6.1 pack-years was linked to higher pain scores (3.5 [IQR: 0; 6.75] vs. 0 [IQR: 0; 3]; $p=0.098$), though not significantly. Infectious non-unions showed marginally poorer SF-12 scores; however, these differences did not reach statistically significance. No late-onset infections or implant failures were observed beyond the two-year postoperative period.
DISCUSSION AND CONCLUSION:
Significant clinical and radiological improvements are sustained beyond the second postoperative year following surgical treatment of non-unions. The high union rates, marked pain reduction, enhanced quality of life, and restored function highlight the critical role of long-term follow-up within specialized clinics. Identified risk factors, including smoking and infection, may adversely affect pain levels and functional outcomes. The illustrated case exemplifies ongoing bone remodelling and continued recovery over time. These findings support the necessity for extended postoperative surveillance and comprehensive rehabilitation protocols to optimize patient outcomes.

Figure 1: Serial radiographs of the case example at 6 weeks, 12 weeks, 6 months, 1 year, 2 years, and 5 years postoperatively, demonstrating progressive healing and remodelling.

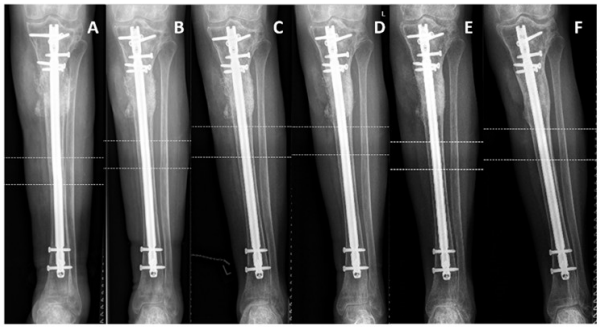

Table 1: Lane-Sandhu-Score (LSS) Distribution at 2 and 5 Years

LSS	2 years, N (%)	5 years, N (%)
0	1 (2.8)	0 (0)
1	2 (5.6)	1 (2.4)
2	4 (11.1)	3 (7.1)
3	14 (38.9)	2 (4.8)
4	15 (41.7)	36 (85.7)