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**Authors:** Kevin Tetsworth, Peter Giannoudis, Rajendra Shetty, G. Kleftouris

## QUESTION 9: What is the optimum waiting time for bone grafting in staged management of septic nonunion?

**RECOMMENDATION:** The interval between the first and second stages should be dependent upon infection control and the status of the local soft tissue of the individual patient, rather than any specific time. Therefore, the precise time is unknown. The current recommendations are that if conditions are favorable, the second stage can be performed between 6 and 12 weeks after the first stage. This recommendation may not apply to the Masquelet technique.

**LEVEL OF EVIDENCE:** Limited

**DELEGATE VOTE:** Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

### RATIONALE

Successful treatment of infected long bone nonunions remains a great challenge for the orthopaedic trauma and limb reconstruction surgeon. They are frequently associated with bone and soft tissue loss, failed internal fixation, broken implants, poor vascularity, drainage from sinuses, osteopenia, osteomyelitis, adjacent joint stiffness, deformities, length discrepancies, prior surgery and polymicrobial infection with resistant organisms [1–4]. Available evidence on the operative management of infected long bone nonunions indicates that staged reconstruction (incorporating debridement, antibiotic beads, soft tissue coverage and provisional stabilization, followed by delayed osseous reconstruction and definitive stabilization [3–6]) can achieve union in 93–100% of cases. With expert care under staged protocols by surgeons specializing in musculoskeletal sepsis, persistence of infection is present in only 2-9% of cases [5,6],

**TABLE 1. Studies before 2000**

| Author | Year | Type of Study | Number of Patients | N Septic Nonunion | Mean Follow-up, Months (Range) | Location | Timing of Bone Grafting (Weeks) | Recurrence of Infection | Union |
|---|---|---|---|---|---|---|---|---|---|
| Green [10] | 1983 | Case series, retrospective | 15 | 15 | 42 (24-78) | Tibia, femur, ulna | **4** | 0% | 87% |
| Esterhai [11] | 1990 | Case series, retrospective | 42 | 36 | Not specified | Tibia | **1** | 31% | 72% |
| Ueng [12] | 1994 | Case series, retrospective | 13 | 8 | 37 (24-54) | Tibia | **2-4** | 0% | 100% |
| Patzakis [13] | 1995 | Case series, retrospective | 32 | 32 | 28 (12-49) | Tibia | **8** | 0% | 91% |
| Emani [14] | 1995 | Case series, retrospective | 37 | 37 | 24 | Tibia | **2.1** | 0% | 100% |
| Cove [15] | 1997 | Case series, retrospective | 44 | 12 | 28 (24-108) | Femur | **Min 2** | 0% | 92% |
| Chen [16] | 1997 | Case series, retrospective | 14 | 14 | 73 (29-108) | Humerus | **6** | 0% | 93% |
| Ueng [17] | 1999 | Case series, retrospective | 15 | 11 | 58 (40-76) | Femur | **2-6** | 18% | 100% |

which is significantly better that one-stage strategies or two-stage strategies without local antibiotic depots using polymethyl methacrylate (PMMA) beads [2–4].

Although bone grafting is widely used for the treatment of infected nonunions, there is little evidence on the optimum timing of its use in the staged management of septic nonunion. A search in the Ovid Database (including Embase and Medline) did not identify any studies focusing on the optimum timing of bone grafting. The current evidence is based on studies that report outcomes on the management of infected nonunions. The most commonly reported prerequisite for bone grafting is complete eradication of infection. This is confirmed either clinically (absence of systemic signs such as fever or local signs such as dry healed wounds), by laboratory tests (normalization of inflammatory markers) [7,8] or by biopsies [9].

There has been only one randomized control study on the management of infected nonunion [8]. This study compared the use of antibiotic-impregnated autologous cancellous bone graft with pure autologous cancellous bone graft in the management of infected nonunions. The timing of bone grafting depended on whether muscle transfer was required. Bone grafting was performed after five weeks on average (range two to seven weeks) from the last debridement and application of PMMA if muscle transfer was not required and on an average 10 weeks (range 8 to 12 weeks) if muscle transfer was required. There were no results reported specifically for the two groups with different timing of bone grafting. This study showed that antibiotic-impregnated bone graft was associated with lower rates of recurrent infections than pure bone graft. The rest of the published studies were case-series reporting outcomes on the staged management of infected nonunions.

Interestingly, there has been a change in the timing of bone grafting for the staged management of infected nonunions over the course of the past several decades. Prior to 2000, the mean time of bone grafting was four weeks following the first-stage procedure [10–17] (Table 1). Furthermore, in only two [13,16] out of the eight published studies, bone grafting was carried out later than four weeks from the first-stage procedure. On the contrary, after 2000 the mean time between the first and second stages was 7.9 weeks and in no study was bone graft implanted earlier than four weeks from the first stage [7–9,18–35] (Table 2). This could be partially explained by increasing popularity of the induced membrane technique. The most recent case series use the principles of this technique for the effective eradication of infection and reconstruction of bone defects. The time interval between the two stages of the procedure is essential not only for the eradication of the infection but also for the maturation of the induced membrane. This may be another reason towards the shift of longer waiting times between the two stages.

In summary, even though there are no studies assessing the optimum timing of bone grafting in the management of septic nonunion, current case series recommend an interval of 7-8 weeks while most studies range between 6-12 weeks following debridement.

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**TABLE 2. Studies after 2000**

| Author | Year | Type of Study | Number of Patients | N Septic Nonunion | Follow-up | Location | Timing of Bone Grafting (Weeks) | Recurrence of Infection | Union |
|---|---|---|---|---|---|---|---|---|---|
| Chan [8] | 2000 | Randomized, prospective | 96 | 96 | 57 (48-72) | Tibia | **5 or 10** | 11% | 99% |
| Tulner [18] | 2004 | Case series, retrospective | 47 | 22 | 94 (24-163) | Tibia | **4-7** | 18% | 95% |
| Chen [19] | 2005 | Case series, retrospective | 18 | 18 | 48 (24-74) | Tibia | **6 or 11** | 0% | 72% |
| Jain [20] | 2005 | Case series, retrospective | 42 | 18 | Not specified | Femur, tibia, humerus, forearm | **6** | 6% | 100% |
| Babhulkar [21] | 2005 | Case series, retrospective | 113 | 14 | 40 (24-180) | Tibia, femur, humerus, forearm | **6-8** | 0% | 100% |
| Schöttle [22] | 2005 | Case series, retrospective | 6 | 6 | 36 (18-60) | Tibia | **15** | 0% | 83% |
| Chiang [23] | 2006 | Case series, retrospective | 12 | 7 | 31 (24-37) | Tibia | **Min 13.5** | 14% | 86% |
| Ryzewicz [36] | 2009 | Comparative, retrospective | 44 | 14 | Not specified | Tibia | **6** | 21% | 93% |
| Stafford [24] | 2010 | Case series, retrospective | 27 | 7 | 12 | Tibia, femur | **6-8** | 14% | 57% |
| Allende [7] | 2010 | Comparative, retrospective | 20 | 13 | 18 (10-96) | umerus, forearm | **8.5** | 0% | 100% |
| Schröter [25] | 2015 | Case series, retrospective | 18 | 18 | 70 (24-96) | Femur | **Min 6** | 0% | 83% |
| Scholz [26] | 2015 | Case series, retrospective | 13 | 13 | 13 (9-24) | Tibia, femur, fibula, radius, metatarsal | **9.8** | 0% | 100% |
| Olesen [27] | 2015 | Case series, retrospective | 8 | 2 | Min 9 | Tibia, femur | **7** | 0% | 50% |
| El-Alfy [28] | 2015 | Case series, prospective | 17 | 12 | 23 (14-38) | Tibia, femur | **11.3** | 8% | 92% |
| Mauffrey [9] | 2016 | Case series, retrospective | 12 | 12 | 14-23 | Tibia | **6-8** | 0% | unknown |
| Canavese [29] | 2016 | Case series, retrospective | 5 | 4 | 39 (24-60) | Femur, humerus | **4** | 0% | 100% |
| Davis [30] | 2016 | Case series, retrospective | 9 | 7 | 42 (18-137) | Forearm | **6-12** | 0% | 100% |
| Giannoudis [31] | 2016 | Case series, retrospective | 43 | 21 | Min 12 | Tibia, femur, humerus, metatarsal, forearm | **6-8** | 5% | 95% |
| Pollon [32] | 2016 | Case series, retrospective | 16 | 3 | 78 (12-160) | Humerus | **8.6** | 0% | 67% |
| Gupta [33] | 2016 | Case series, retrospective | 9 | 8 | 21.5 | Tibia | **4-6** | 25% | 75% |
| Wang [34] | 2016 | Case series, retrospective | 32 | 32 | 27 (24-32) | Tibia, femur | **8.9** | 0% | 100% |
| Mühlhäusser [35] | 2017 | Case series, retrospective | 8 | 3 | Min 12 | Tibia | **8.7** | 0% | 100% |

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## 3.5. TREATMENT: MANAGEMENT OF HARDWARE

**Author:** J. Tracy Watson

### QUESTION 1: When should hardware be removed when treating surgical site infection (SSI) in orthopaedic trauma?

**RECOMMENDATION:** The decision to retain or remove hardware differs by clinical scenario and must take into account extent of the infection and stability of the hardware and fracture.

A methodical approach that addresses the pathogen, host factors and bony and soft tissue deficiencies is required, and includes thorough debridement, dead-space management and soft tissue and bony reconstruction using the established principles of the reconstruction ladder.

**LEVEL OF EVIDENCE:** Moderate

**DELEGATE VOTE:** Agree: 95%, Disagree: 0%, Abstain: 5% (Unanimous, Strongest Consensus)

### RATIONALE

#### Acute or Subacute Infection with Stable Hardware and Fixation

When dealing with orthopaedic implant-related infections, the most common recommendation of nonsurgical consultants is to remove all hardware, obtain deep cultures and administer antibiotics. This is unfortunately only partially correct. Cultures are helpful, and antibiotics are essential, but the removal of stable, functioning hardware in the setting of an acutely infected fracture