Original Article
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# Osteoperiosteal Decortication and Autogenous Cancellous Bone Graft Combined with Bridge Plating for Non-hypertrophic Diaphyseal Nonunion

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**Background:** The aim of this study was to evaluate results of osteoperiosteal decortication and autogenous cancellous bone graft combined with a bridge plating technique in atrophic and oligotrophic femoral and tibial diaphyseal nonunion.

**Methods:** We retrospectively reviewed 31 patients with atrophic or oligotrophic femoral and tibial diaphyseal nonunion treated with osteoperiosteal decortication and autogenous cancellous bone graft between January 2008 and December 2018. Patients with hypertrophic nonunion, infected nonunion, and nonunion treated with autogenous cancellous bone graft alone were excluded. The nonunion site was exposed by using the Judet technique of osteoperiosteal decortication. Nonunion with a lack of stability was stabilized with a new plate using a bridge plating technique or augmented by supplemental fixation with a plate. Nonunion with malalignment was stabilized with a new plate after deformity correction. Autogenous cancellous bone graft was harvested from the posterior iliac crest and placed within the area of decortication. A basic demographic survey was conducted, and the type of existing implants, mechanical stability of the implants, the type of implants used for stabilization, the operation time, the time to bone union, and postoperative complications were investigated.

**Results:** The average follow-up period was 33.3 months (range, 8–108 months). The operation time was 207 minutes (range, 100–351 minutes). All but 1 nonunion (96.7%) were healed at an average of 4.2 months (range, 3–8 months). In 1 patient, bone union failed due to implant loosening with absorbed bone graft, and solid union was achieved by an additional surgery for stable fixation with a new plate, osteoperiosteal decortication, and autogenous cancellous bone graft. There were no other major complications such as neurovascular injuries, infection, loss of fixation, and malunion.

**Conclusions:** Osteoperiosteal decortication and autogenous cancellous bone graft combined with stable fixation by bridge plating showed reliable outcomes in atrophic and oligotrophic diaphyseal nonunion. This treatment modality can be effective for treating atrophic and oligotrophic diaphyseal nonunion because it is very helpful stimulating bone union.

**Keywords:** *Atrophic nonunion, Oligotrophic nonunion, Osteoperiosteal decortication, Autogenous cancellous bone graft, Bridge plating*

Nonunion is a common clinical complication following fracture and its treatment is a significant challenge for patients and surgeons. It causes psychological problems as well as socioeconomic burden for patients and puts a lot of stress on orthopedic surgeons. Hypertrophic nonunion, which has been associated with adequate healing responses and satisfactory vascularity, is relatively easy to treat with mechanical support alone to unite bone fragments. However, atrophic and oligotrophic nonunions are

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a bit more complicated because they usually manifest poor or minimal healing responses with mechanical problems.

Autogenous cancellous bone graft is the gold standard to enhance biological environment of atrophic or oligotrophic nonunion. The reamer-irrigator-aspirator (RIA) is a novel alternative technique to obtain a sizable amount of bone from the femur for bone grafting, and clinical results of RIA graft showed similar union rates compared with iliac bone graft and less donor-site morbidity.[1)] Judet first published the osteoperiosteal decortication technique in 1972.[2)] He reported that faster and firmer healing of pseudarthrosis could be obtained by surrounding the fracture site with bone fragments not detached from their blood supply. Guyver et al.[3)] also reported that osteoperiosteal decortication remains a highly effective surgical technique in the management of failed fracture union. In the current study, we report results of osteoperiosteal decortication and autogenous cancellous bone graft for atrophic and oligotrophic nonunion of the fracture.

## METHODS

This study was approved by the Institutional Review Board of Daegu Fatima Hospital (IRB No. DFE20ORIO077-R1), which waived informed consent.

A retrospective clinical and radiographic review was conducted on patients with atrophic or oligotrophic diaphyseal nonunion of the femur or tibia treated with osteoperiosteal decortication and autogenous cancellous bone graft between January 2008 and December 2018. All patients had pain on the fracture site when bearing weight and a radiolucent gap between main fracture fragments. Hypertrophic nonunion, infected nonunion, and nonunion treated with autogenous cancellous bone graft alone were excluded from the study.

A total of 31 patients with atrophic or oligotrophic nonunion were included in the current study. Basic data of patients are shown in Table 1. There were 20 men and 11 women and the mean age of patients was 51.7 years (range, 19–79 years). The injury mechanism of the fracture was a traffic accident in 20 patients, a simple fall in 5, a fall from a height in 4, and a hit by a movable object in 2. There were 29 femoral and 2 tibial diaphyseal fractures. According to AO/Orthopaedic Trauma Association (OTA) classification of diaphyseal fractures,[4)] there were 1 case of A1 fracture, 9 cases of A2 fracture, 4 cases of A3 fracture, 13 cases of B2 fracture, and 4 cases of B3 fracture. Existing implants at the time of treatment were an intramedullary nail in 25 nonunions and a plate in 6 nonunions. The number of operations prior to the definitive treatment of nonunion was 1 in 26 patients, 2 in 3 patients, and 4 and 5 in 1 patient each.

Preoperatively, we carefully evaluated the history of surgery, the mechanical stability of implants (breakage or loosening), and routine laboratory tests including white blood cell count, erythrocyte sedimentation rate, and C-reactive protein to rule out infection.

The nonunion site was exposed by using a Judet technique of osteoperiosteal decortication in all patients.

**Table 1.** Preoperative Basic Data of the Patients

| Variable | No. of patients |
|---|---|
| Sex | |
| Male | 20 |
| Female | 11 |
| Age (yr), mean (range) | 51.7 (19–79) |
| Mechanism of injury | |
| Traffic accident | 20 |
| Fall from a height | 4 |
| Hit by a movable object | 2 |
| Simple fall | 5 |
| Site | |
| Femur | 29 |
| Tibia | 2 |
| AO/OTA classification | |
| A1 | 1 |
| A2 | 9 |
| A3 | 4 |
| B2 | 13 |
| B3 | 4 |
| Device before nonunion surgery | |
| Intramedullary nail | 25 |
| Plate and screws | 6 |
| No. of previous surgery | |
| 1 | 26 |
| 2 | 3 |
| 4 | 1 |
| 5 | 1 |

OTA: Orthopaedic Trauma Association.

Decortication was performed within 2–3 cm on each side of the nonunion site and extended well beyond the nonunion site. Thin, 3- to 4-mm bone chips were created with the use of an osteotome and the soft tissue on the bone fragments was preserved as much as possible during the surgery (Fig. 1). The interposed fibrous tissue was not removed from the nonunion site.

Seventeen nonunion cases with implant breakage or loosening and 1 nonunion case with malalignment were stabilized with 10- to 12-hole large fragment locking compression plates (LCP) (7 cases), 7- and 9-hole condylar blade plates (2 cases), or 9- to 12-hole LCP distal femur (8 cases) using a bridge plating technique after removal of the existing implants and correction of any malalignment. Twelve nonunion cases with a lack of stability without implant breakage or loosening were augmented by supplemental fixation with 6- to 10-hole small fragment or reconstruction LCP. One nonunion was fixed with a locked intramedullary nail and showed adequate stability without further support for improving stability (Table 2). Autogenous cancellous bone graft was harvested from the posterior iliac crest and placed within the area of decortication.

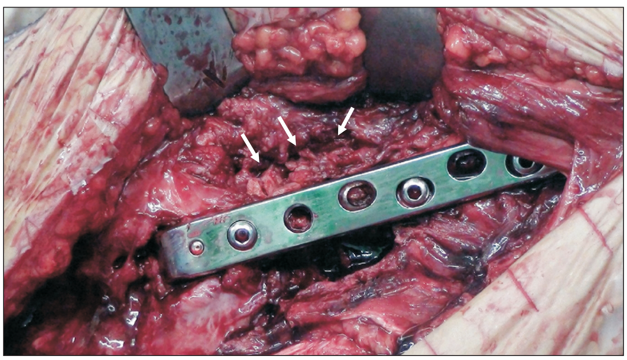

**Fig. 1.** Intraoperative photograph after decortication. White arrows indicate soft tissue preserved bone chip after decortication.

Patients were followed up every month after surgery until obtaining bone union and more than 1 year in most patients. Standard radiographs were obtained at the follow-up visit (Fig. 2).

A basic demographic survey was conducted and the type of existing implants, the mechanical stability of implants, the type of implants used for stabilization, the operation time, the time to bone union, and postoperative complications were investigated. Bone union itself and the time to bone union were the primary outcome measures. Corrales et al.[5] described bone union as follows: clinical absence of pain at the fracture site on both palpation and weight bearing and radiological evidence of bridging of 3 or more cortices on two different views. We believed this is a reasonable description for united bone and used this definition for the current study.

## RESULTS

There were 24 atrophic nonunions (23 femurs and 1 tibia) and 7 oligotrophic nonunions (6 femurs and 1 tibia). The average follow-up period was 33.3 months (range, 8–108 months). The operation time was 207 minutes (range, 100–351 minutes). The overall union rate after a single operation was 30/31 (96.7%) with failed union in 1 patient.

**Table 2.** Mechanical Support during Nonunion Surgery

| Method | Cause | No. of patients |
|---|---|---|
| New plate and screws | Implant breakage | 11 |
| | Implant loosening | 6 |
| | Malalignment | 1 |
| Augmentation plate | Insufficient stability | 12 |
| No further support | Stable implant | 1 |

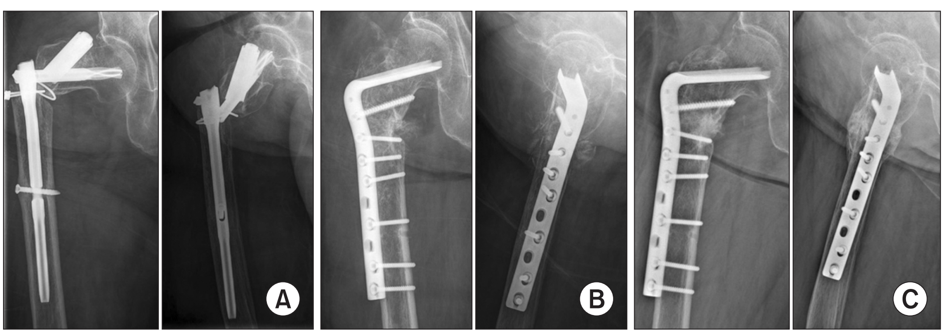


**Fig. 2.** Anteroposterior and lateral plain radiographs of a 79-year-old woman. (A) Preoperative radiographs show breakage of intramedullary nail without any callus. (B) Immediate postoperative radiographs show decorticated bone chip on the outer surface of femoral cortex. (C) Ten-month follow-up radiographs show complete connection of nonunion site with smoothening of decortication surface.

The average time to bone union was 4.2 months (range, 3–8 months) after surgery. In 1 patient, union failed due to implant loosening with absorbed bone graft, and solid union was achieved by an additional surgery for stable fixation with a new plate, osteoperiosteal decortication, and autogenous cancellous bone graft. There were no other major complications, such as neurovascular injuries, infection, loss of fixation, and malunion.

## DISCUSSION

Nonunion is one of the most disastrous complications after fracture treatment for the patients and their family. It causes not only physical and psychological problems for patients, but also economic hardship by delaying their return to work.[6] It also contributes to increased stress on orthopedic surgeons who need to treat nonunion, as well as primary care physicians who need to do fracture management.

Fracture healing is a complex physiological process. Although most of the injured tissues in human body are healed by a fibrous scar tissue, the bone is restored by its original tissue without scar formation. A successful fracture healing depends on the biological environment at the fracture site and the mechanical environment that provides adequate stability to the fracture site. The classic triangular concept emphasized the biological environment of fracture healing, involving the potent osteogenic cell population, the osteoinductive stimulus, and the osteoconductive matrix scaffold. Giannoudis et al.[7] described the diamond concept of fracture healing, which added the mechanical environment to the triangular concept of fracture healing. According to this diamond concept, the mechanical environment of the fracture site gives equal importance to the biological environment as a conceptual framework for successful fracture healing.[8]

There are two mechanisms of bone healing to be influenced by the local mechanical environment. Primary or direct bone healing is a biological process of osteonal bone remodeling and occurs only with absolute stability achieved by close contact of fracture surfaces and rigid fixation, whereas secondary or indirect bone healing is a natural healing process and occurs with relative stability that is achieved by nonsurgical methods or flexible fixation methods. Most contemporary operations for diaphyseal fractures of the lower extremity aim at secondary bone healing with callus formation.[9-12]

Judet first described his technique of osteoperiosteal decortication in 1962 and published his results in 1972.[2] This method increases the surface area for bone healing and enhances the healing of fracture nonunion when surrounded by vascularized bone chips from each fragment itself. We can usually identify radiolucent lines that persist in one or two planes in radiographs of patients with nonunion. According to Perren's strain theory,[13] a higher strain is applied where there is such a simple fracture line compared to a multifragmented fracture site. So, osteoperiosteal decortication is not a simple approaching technique. This technique promotes bone union biomechanically because it reduces strain by creating a lot of bone fragments in the nonunion sites and also promotes bone union biologically because it makes a living bone fragment attached to the periosteum.

Several studies already demonstrated that osteoperiosteal decortication was effective in treating atrophic and oligotrophic nonunion of various long bones and their union rates varied from 92.3% to 100%.[3,14-16] Ramoutar et al.[14] treated 96 cases of nonunion with Judet decortication and compression plating with or without bone graft and the union rate was 95% with bone graft and 94.6% without bone graft. They suggested that the routine use of autologous bone graft may not be necessary. However, autogenous cancellous bone graft is often used in combination with decortication to add a biological stimulus to bone healing. It contains all three essential components of osteogenic, osteoinductive, and osteoconductive properties for fracture healing.[17] Judet and Patel[2] applied bone graft in several cases that the chips adherent to the soft tissues could not be raised because of the absence of peripherally adhering soft tissue or the ivory brittleness of the bone.

Wiss et al.[18] reported a union rate of 96% with the use of autogenous bone graft in a series of 50 tibial nonunions treated with compression plating. In nonunion surgery, compression plating to apply a compression force at the nonunion site is a well-known surgical technique and provides absolute stability and the mechanical environment for fracture healing.[4,14] However, compression plating may cause limb shortening, which results in leg length discrepancy in the lower limbs. In our series, new plates were fixed using a bridge plating technique to provide the adequate mechanical stability with load sharing and to avoid limb shortening.

Our study showed that the overall union rate after a single operation was 30/31 (96.7%) and the average time to bone union was 4.2 months (range, 3–8 months). The union rate in our study is comparable to the union rates of 92.3%–100% in several studies using decortication[3,14-16] and the union rate of 38/40 (95%) in a study using decortication and bone graft.[14]

Previous studies reported that the average time to bone union was 5.9 to 8.3 months.[14-16] The average time to bone union in our study was 4.2 months after surgery. The time to bone union in our study was shorter than that in other studies, but we could not demonstrate statistical significance of this result because there were no control groups treated by osteoperiosteal decortication and compression plating without autogenous cancellous bone graft. It may have been influenced by autogenous cancellous bone graft, but it should be proved through further research.

Autogenous bone grafting is still used to enhance fracture healing in most atrophic nonunions and many oligotrophic nonunions,[19] but bone grafting has disadvantages of donor site morbidity such as hematoma, infection, fracture, and neurovascular injury.[20] In our series, some patients complained of acute pain in the donor site of the posterior iliac crest immediately after surgery, but there were no major complications.

Our study has several limitations. This is a retrospective study, so there is a possibility of selection bias. The number of patients is small, but it should be considered that modern advances in surgical techniques have led to reduced incidences of nonunions. Compared to other studies, it was difficult to assess whether bone graft was essential. However, we think all possible resources including bone graft must be considered to achieve bone union in management of atrophic or oligotrophic nonunion because of the relative paucity of healing potential.

Osteoperiosteal decortication creates living bone chips attached to the periosteum and soft tissues and enhances the healing of fracture nonunion. This technique is effective for the treatment of atrophic or oligotrophic nonunion of the long bone diaphysis in the aspect of biology. In addition, autogenous cancellous bone graft promotes bone union and may shorten the time to bone union. Bridge plating provides the adequate mechanical stability with load sharing and prevents limb shortening. Our study suggests that osteoperiosteal decortication and autogenous cancellous bone graft combined with stable fixation by bridge plating is effective for treating atrophic and oligotrophic diaphyseal nonunion because it is very helpful in stimulating bone union.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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