

# PERCUTANEOUS AUTOLOGOUS BONE-MARROW GRAFTING FOR NONUNIONS

INFLUENCE OF THE NUMBER AND CONCENTRATION OF PROGENITOR CELLS

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**Background:** Bone marrow aspirated from the iliac crest contains progenitor cells that can be used to obtain bone-healing of nonunions. However, there is little available information regarding the number and concentration of these cells that are necessary to obtain bone repair. The purpose of this study was to evaluate the number and concentration of progenitor cells that were transplanted for the treatment of nonunion, the callus volume obtained after the transplantation, and the clinical healing rate.

**Methods:** Marrow was aspirated from both anterior iliac crests, concentrated on a cell separator, and then injected into sixty noninfected atrophic nonunions of the tibia. Each nonunion received a relatively constant volume of 20 cm<sup>3</sup> of concentrated bone marrow. The number of progenitor cells that was transplanted was estimated by counting the fibroblast colony-forming units. The volume of mineralized bone formation was determined by comparing preoperative computerized tomography scans with scans performed four months following the injection.

**Results:** The aspirates contained an average (and standard deviation) of 612 ± 134 progenitors/cm<sup>3</sup> (range, 12 to 1224 progenitors/cm<sup>3</sup>) before concentration and an average of 2579 ± 1121 progenitors/cm<sup>3</sup> (range, 60 to 6120 progenitors/cm<sup>3</sup>) after concentration. An average total of 51 × 10<sup>3</sup> fibroblast colony-forming units was injected into each nonunion. Bone union was obtained in fifty-three patients, and the bone marrow that had been injected into the nonunions of those patients contained >1500 progenitors/cm<sup>3</sup> and an average total of 54,962 ± 17,431 progenitors. The concentration (634 ± 187 progenitors/cm<sup>3</sup>) and the total number (19,324 ± 6843) of progenitors injected into the nonunion sites of the seven patients in whom bone union was not obtained were both significantly lower ( $p = 0.001$  and  $p < 0.01$ , respectively) than those in the patients who obtained bone union. The volume of the mineralized callus measured at four months on the computerized tomography scans of the patients who had union ranged from 0.8 to 5.3 cm<sup>3</sup> (mean, 3.1 cm<sup>3</sup>). There was a positive correlation between the volume of mineralized callus at four months and the number ( $p = 0.04$ ) and concentration ( $p = 0.01$ ) of fibroblast colony-forming units in the graft. There was a negative correlation between the time needed to obtain union and the concentration of fibroblast colony-forming units in the graft ( $p = 0.04$ ).

**Conclusions:** Percutaneous autologous bone-marrow grafting is an effective and safe method for the treatment of an atrophic tibial diaphyseal nonunion. However, its efficacy appears to be related to the number of progenitors in the graft, and the number of progenitors available in bone marrow aspirated from the iliac crest appears to be less than optimal in the absence of concentration.

**Level of Evidence:** Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.