Shear Is What We Should Fear: A Multicenter Study of Diaphyseal Nonunions

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Purpose: Diaphyseal nonunions of the lower limb are a clinically significant and costly occurrence in orthopaedics. It is hypothesized that both mechanical and biological factors contribute to delay and failure in fracture healing. It has been proposed that mechanical factors dominate as normal fracture healing occurs in a low-strain environment and commonly high strain persists in nonunions. The senior authors have observed that many nonunions seem to occur in 1 plane and obliquely to the long axis of the bone. It is postulated that they form in the plane of greatest strain, where shear is maximized at 45° to the long axis. This study aims to define the mean angle of a series of diaphyseal nonunions based on radiographic analysis.

Methods: A retrospective analysis of prospectively collected trauma reconstruction databases was conducted. All patients requiring treatment for diaphyseal nonunion in 2 internationally separate tertiary referral trauma centers between June 2014 and May 2018 were identified. The mean nonunion angle was measured on both AP and lateral radiographs using a standardized technique. It was then estimated in a single plane by considering the greater of the 2 angles. Additional data collected included patient age, sex, nonunion site, initial fracture angle, and original fracture pattern.

Results: After exclusions, 120 cases of diaphyseal nonunions were included (63% male, average age 46 years). 52% of nonunions were femoral, 48% tibial. The mean angle of all nonunions in the coronal plane was 42° (standard deviation [SD] 17°), 42° in the sagittal plane (SD 18°), and 48° (SD 15°) in single plane. All observed nonunions had developed in a single plane; even in initially multifragmentary fractures, there were no multifocal nonunions. The single plane nonunion angle in fractures that were originally multifragmentary was steeper when compared to those occurring in originally simple fractures ($P = 0.004$) although both were close to 45°. There was no significant difference in the nonunion angles on subgroup analysis of age, sex, or anatomic location.

Conclusion: This study demonstrates the mean angle of diaphyseal nonunions of the long bones of the lower limb approaches 45°. This is the first study to try to establish the geometry of nonunions based off radiographs. This finding is noted in all types of fractures and is irrespective of age, sex, or anatomic location. This confirms the hypothesis that shear is likely to play a role in the development of a nonunion. This study provides further evidence that nonunions occur primarily due to mechanical instability.