Closed Reduction of Diaphyseal Fractures Using a Computer-aided Parachute Guiding System

Daijiang Du, Ph.D,1 Zhen Liu,2 Shinsuke Omori2, Tetsuya Tomita2, Masahiro Kurita3, Kazuomi Sugamoto2, Hideki Yoshikawa2, Tsuyoshi Murase, MD2.
1Harbin Medical University, Harbin, China, 2Osaka University Graduate School of Medicine, Osaka, Japan.

Disclosures:

Introduction: Achieving closed reduction without sacrificing the reduction accuracy and exposing the surgeon and patient to excessive radiation is difficult. Consider that the relative position of a parachutist to the drogue chute is determined when the parachute is completely inflated by atmospheric forces during descent because various spatial distances between the parachutist and drogue chute are determined by the straight stretched shroud lines. We hypothesized that this parachute-positioning mechanism could also be used in CAOS, in which wires of multiple lengths would determine accurate positioning. In this study, we used this hypothesis to develop a novel parachute guiding system (ParaEx System) for closed reduction of fractures. The feasibility and reduction accuracy of the ParaEx System were investigated using comminuted tibial diaphyseal fracture models.

Methods: The system includes two counter guides with stainless tubular markers that can be attached to the unilateral external fixator. Stainless tubules (outer diameter = 0.8 mm, inner diameter = 0.5 mm) were set in the center of cones in the guides, not only as markers for location of the guides in the 3D image but also as sleeves for the wires. During reduction of fractures, the adjustment requirements of the distance between the tips of the tubular markers are calculated from computed tomography (CT) data and reconstructed by wires to reduce deformity.

In this study, the comminuted tibial diaphyseal fracture models (n=8) were produced by cutting the Sawbones tibias at mid shaft. Before CT, the external fixator (Prefix2, USA) was used to fix each fractured tibia, and the guides were further fixed to the external fixator either on the distal or the proximal ends facing each other. The before-broken as well as fractured tibias fixed by the external fixator with the guides were scanned using a CT scanner. After the required distance between the tips of tubular markers was calculated by computer simulation using a VTK-based original computer program, the distance between two tiny stoppers was measured and reconstructed accurately with the stainless wires (diameter = 0.18 mm) a caliper. The planned relative spatial relationships between the two guides, as well as the fracture fragments, could be reconstructed by merely pulling all the wires into their straight taut position with proper rotation adjustment. After reduction and fixation, CT was performed again on the tibia. The initial and residual deformities were evaluated as the distances between the image of the unaffected tibia and that of the fractured tibia (before and after reduction) superimposed first proximally and then distally to quantify the rotation and translation. The misalignment was expressed by the rotation angle around the unique axis established in the image of unaffected tibia with six degrees of freedom on the basis of the local coordinate axes using the Euler angles method [1].

Results: The mean errors (and standard deviations) of residual rotational and translational deformity were 0.67° ± 0.45°, 0.92° ± 1.00°, and 0.64° ± 0.50° in rotation and 1.30 ± 1.10 mm, 1.13 ± 0.70 mm, and 0.94 ± 0.92 mm in translation about the X, Y, Z axes of the local coordinate axis, respectively. The graphic model revealed that after reduction, the proximal fragment of the tibia aligned with the distal fragment satisfactorily and that the reduction accuracy was less than 1° in rotation and 2 mm in translation.

Discussion: The ParaEx system was very simple in design and included two counter guides that could be attached to the commercially available unilateral external fixator so that no specially designed fixator was required, making the system extremely cost effective and reliable. The comminuted tibial diaphyseal fracture model results showed that the accuracy of reduction was less than 1° in rotation and 2 mm in translation. Therefore, we found that the ParaEx System was a practical, low cost, and clinically feasible method for achieving sufficiently accurate 3D closed reduction for long bone fractures while minimizing radiation exposure to surgeons and patients and minimizing the extent of tissue disruption around the fracture site.

Significance: The ParaEx System will be a promising guiding system to reduce fractures closely and accurately at low cost, while minimizing radiation exposure to both the surgeon and patient and minimizing the extent of tissue disruption around the fracture site.

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