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Original article

Adult diaphyseal both-bone forearm fractures: A clinical and biomechanical comparison of four different fixations

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ABSTRACT

Background: Although there have been a small number of studies reporting single bone fixation of either radius or ulna as well as hybrid fixation, the paucity of data for the hybrid fixation method still remains.
Hypothesis: Hybrid fixation with plate and IM nailing would achieve good fixation and functional outcome, minimal damage to soft tissues and lower re-fracture risk.
Materials and methods: Forty cadavers (20 males, 20 females; mean age 68.06, SD 1.58 years) were selected in biomechanical study under axial loading, bending loading, and torsional loading. Eighty-seven patients (47 males, 40 females; mean age 38.03 ± 0.88 years) were enrolled in the clinical study and randomly received different fixation: both-bone plate fixation or both-bone intramedullary nailing, plate fixation of ulna and intramedullary nailing of radius and intramedullary nailing of ulna and plate fixation of radius.
Results: In the biomechanical study, intramedullary nailing of ulna and plate fixation of radius had similar results with that using both-bone plate method under axial, bending and torsional loading (All $P > 0.05$), suggesting the more stable fixation compared with the other two groups (All $P < 0.05$). In clinical research, both-bone intramedullary nailing was related to shortest operative time, smallest wound size and periosteal stripping area compared with other three groups ($P < 0.05$). Patients receiving intramedullary nailing of ulna and plate fixation of radius showed the lowest incidence of postoperative complications and the best functional recovery outcome comparing with other three groups of patients (Both $P < 0.05$).
Conclusion: The hybrid fixation method of intramedullary nailing of ulna and plate fixation of radius showed good stability in biomechanics, fewer complications and better functional clinical outcomes.
Level of evidence: Level II, prospective randomised study.

1. Introduction

Forearm fractures are common skeletal injury and most occur in the childhood group. There is an increasing trend in the incidence worldwide [1,2]. As one of the various types of forearm fractures, both-bone diaphyseal forearm fractures in adults are frequently met by the orthopaedic doctors in clinical practice [3]. It has been demonstrated that open reduction and plate fixation are the most traditional and commonly used techniques for the treatment of both-bone midshaft forearm fractures in adults [4,5]. The plate fixation is of good fixation, adequate reduction and satisfactory healing and functional recovery [6]. However, many reports also showed several recognized complications related to plate fixation, such as extensive soft tissue damage, periosteal damage, radioulnar synostosis, and neurovascular injury, as well as nonunion, re-fracture and infection following plate removal [7–10]. Intramedullary (IM) nailing has been proposed as an alternative technique to circumvent these above problems, with the advantages of minimal invasion, no periosteal stripping, faster healing and lower re-fracture rate [11,12]. At present, this method is widely used in clinical practice. However, the IM nailing technique is also associated with high rate of nonunion, neurovascular injuries and the need for additional immobilization [13].

It was hypothesized that hybrid fixation with plate and IM nailing would achieve good fixation and functional outcome, minimal damage to soft tissues and lower re-fracture. Although there have been a small number of studies reporting single bone fixation of either radius or ulna as well as hybrid fixation [5,14–16], the paucity of data for the hybrid fixation method still exists. In addition, these studies are deficient in relating their biomechanical characteristics.

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The aim of our study was to evaluate the differences in biomechanical stability and clinical outcomes of four different fixation methods for both-bone diaphyseal fracture: both-bone plate fixation, both-bone IM nailing fixation, plate fixation of ulna and IM nailing fixation of radius, and IM nailing of ulna and plate fixation of radius. We aim to determine which method of fixation is more feasible in the treatment of both-bone diaphyseal forearm fractures in clinical practice.

2. Materials and methods

This study included two parts: a cadaveric study to investigate biomechanical characteristics and a prospective study on patients to investigate clinical outcomes. The use of human cadaveric specimens and the clinical study were all approved by Regional Ethics Committee of our hospital and the clinical study was performed in accordance with the Helsinki Declaration. Informed consents were obtained from family members or legal guardians for inclusion of cadavers and parents for clinical research, respectively.

2.1. Cadaveric study

For the cadaveric research, 40 fresh human cadaver forearms (20 males and 20 females; mean age 68.06, SD 1.58 years) were investigated in our hospital. Exclusion criteria of the specimen included congenital anomalies, trauma, tumor, and degenerative diseases using radiographic method. All the specimens were denuded of soft tissue, left with the distal humerus, ulna, radius, elbow joint, interosseous membrane, metacarpals and wrist joints. They were sealed in double-layer plastic bags and stored in refrigerator at −30 °C. Then after the fixation of proximal and distal ulna and radius, all the specimens were made into midshaft transverse fracture of ulna and radius with AO 3.2 [17] by laterigradely sawing the distal-third diaphysis using an electric saw, with proximal and distal radioulnar joint free of dislocations, and they were treated with osteosynthesis randomly using one of four methods: both-bone plate fixation (group I), both-bone IM nailing (group II), plate fixation of ulna and IM nailing of radius (group III) and IM nailing of ulna and plate fixation of radius (group IV).

For plate fixation, a 6-hole compression plate (Smith & Nephew Inc., London, UK) was placed after the reduction of fracture model. Then three screws (Smith & Nephew Inc., London, UK) were fixed at each end of the fracture line to obtain stability. For ulnar intramedullary nail fixation, a guide pin (Smith & Nephew Inc., London, UK) was inserted into the medullary cavity through olecroanon and the position was assured at the center of medullary cavity. Once the guide pin position had been accepted, a 6-mm hollowness reamer was introduced to expand the medullary cavity. Intramedullary reaming was then performed 1.0 mm beyond the chosen nail diameter. After that, a straight guide pin at the diameter of 2.4 mm was inserted into the medullary cavity to maintain the relative position of bone blocks. Then the intramedullary nail was preliminary curved according to physiological curvature. The nail was inserted into medullary cavity and mergenced the cortical bone after taking out the guide pin. Finally, locking screws were placed at both the proximal and distal ends. Similar method was performed for radial IM nailing. The difference was that the guide pin was inserted into the medullary cavity with 30° at the distal end of radialis Lister's tubercle, at 5 mm distance from articular facet.

All the biochemical experiments were conducted in a lab of Shanghai Biomechanical Engineering Institute. Testing was carried out using a universal testing device (HT-9102, Hung Ta Instrument Co., Ltd, China), whereby axial compression loads as well as bending and torsion loads were applied. Firstly, the prepared specimen of ulna and radius was placed on the device. Then the transducer, loading plate (HT-9102, Hung Ta Instrument Co., Ltd, China) and roller were fixed. The distal part of bone was also embedded in a tailor-made mold for fixation in the testing device. Following the adjustment for all the instruments, pre-experiment was conducted to eliminate the temporal effects of bone creeping and chalasis. Then formal test was carried out. The specimens were loaded (at a rate of 1.4 mm/min) to a force of 0–1000 N for axial compression loads and to a force of 1 N·m/degree for bending and torsion loads. Data were collected within 30 s after loading, and each loading cycle was repeated at least three times to ensure repeatability of the measurements. The displacement was measured by high-precision displacement transducer and twisting data by torsion angle meter.

2.2. Clinical study

For the prospective study, a total of 87 consecutive patients (47 males and 40 females; mean age 38.03, SD 0.88 years) with both-bone midshaft forearm fractures by radiograph were scheduled to receive operations at our hospital from September, 2004 to March, 2008. Those who had specific history of trauma and were treated by open reduction and internal fixation (IM nailing, plate fixation or both) were eligible for inclusion. Exclusion criteria were open midshaft fractures, pathological fractures, associated injuries of adjacent blood vessels and nerves, osteoporosis and associated humeral condyle fracture or wrist fracture. All the patients were randomly divided into four groups using lottery method: group A (both-bone plate fixation, 21 cases), group B (both-bone IM nailing, 22 cases), group C (plate fixation of ulna and IM nailing of radius, 21 cases) and group D (IM nailing of ulna and plate fixation of radius, 23 cases). The demographic data including age, gender, fracture types and surgery time after fracture were collected.

All the surgery procedures were performed by the same group of surgeons with at least 5 years' experiences under brachial plexus anesthesia. Preoperatively, X-ray radiography was routinely taken to determine the size of implant. Patient was in supine position, with the affected forearm placed under a C-arm X-ray diagnostic machine. The injured forearm was in neutral position and the elbow was at 90° of flexion. All the operations were conducted according to the following principle: one tended to fix fracture of ulna first usually and then fracture of radius. For plate fixation (Smith & Nephew Inc., London, UK), Henry incision was made for radial fixation while the incision of ulnar fixation was along the ulnar crest. The ramus profundus nervi radialis was separated and muscles, blood vessels and nerve bundles were avoidant. Then the broken ends of fractured bone were annealed followed by common compression plating.

For IM nailing (Smith & Nephew Inc., London, UK), preoperative radiographs taken on the uninjured forearm confirmed the moulding of IM nail trial mode. For ulna, the incision was chosen at the top of olecroanon. For radius, the incision was chosen at the Lister's tubercle. The forearm was drafted and performed with closed reduction or limited open reduction under the C-arm fluoroscopy device. Then a guide pin was inserted into the medullary cavity and a 6 mm entry reamer (Smith & Nephew Inc., London, UK) was introduced to expand the medullary cavity adequately. Intramedullary reaming was then performed 1.5 mm beyond the chosen nail diameter and the preliminary curved IM nail was inserted. Finally, lock pin (Smith & Nephew Inc., London, UK) were screwed at both the proximal and distal ends.

All patients received a routine postoperative regime using our integrated forearm fracture care pathway. The main difference was that patients in group A were allowed to take the flexion and abduction exercises as well as wrist and elbow range of motion exercises 24 h postoperatively (3 times/day, 1 h/time). The rotation function exercise of forearm was begun 4 weeks after surgery. Patients in