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Does the location of the entry point affect the reduction of proximal humeral fractures? A cadaveric study

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ABSTRACT

The selection of the correct entry point for stabilisation of long bone fractures and particularly of the humerus with intramedullary nailing is of paramount importance. The insertion of a nail from the correct entry point ensures anatomical alignment of the head and the shaft fragment. However, particularly for the humerus, the literature addressing this issue is obscure. Twenty cadaveric humeri without soft tissue attachment were studied. Two groups were studied: Group A (straight nail) and Group B (angled nail). A fracture of the surgical neck of the humerus was simulated. Then intramedullary nail was inserted through the correct entry hole. Displacement at the fracture site and force to reduce the displacement were measured.

The average horizontal displacement was 2.5 ± 2.2 mm in Group A and 1.9 ± 1.1 mm in Group B. The humeral shaft tended to displace medially. The force required to reduce the produced displacement was usually less than 15 N. Anatomical reduction could not be obtained in 3/20 humeri even after applying a force of over 35 N.

Our results of an average displacement of 2 mm following nail insertion, supports the significance of the entry point as a cause of loss of reduction at the fracture site post nail insertion. In most cases, anatomical reduction can be corrected with relative small forces, whereas in the rest the correction of the displacement is not feasible even with the application of substantial forces.

Introduction

Most fractures of the proximal humerus are minimally displaced and are commonly treated non-operatively with good clinical and functional results.[1−4] The treatment of displaced and unstable humeral fractures remains controversial.[2,3,5] Various devices have been proposed for fixation, including plates and screws, multiple pins, staples, and intramedullary nails. Intramedullary nails, with their advantages of closed technique and superior nail-bone purchase for osteoporotic bone, are theoretically the ideal device for proximal humeral fractures, which are very common fractures in the elderly.[6,7] However, postoperative varus deformity of humeral neck as high as 9 to 37%, is one of the commonly reported complications.[8−10] This complication is said to be prevented by cortical apposition of the medial cortex.[11]

Young et al.[12] emphasised that the key to intramedullary nailing for proximal humeral fractures is the correct entry point. A nail insertion from the correct entry point is asserted not only to insure anatomical alignment of the head and the shaft fragment,[7,8,13] but also to avoid postoperative varus deformity.[7,10] Kitson et al.[11] reported stability against varus deformity is conferred by cortical apposition at the medial side. According to these reports therefore, a nail insertion from the correct entry point should automatically provide cortical apposition of the fracture. Nevertheless, to our knowledge, no articles are currently available to support this concept.

The purpose of this cadaveric study was to measure displacement at the proximal humeral fracture site following nail insertion from the recommended entry point. The hypothesis is that even this type of "optimal" insertion occasionally causes non cortical apposition at the fracture site, especially in patients with a wider intramedullary canal or a curved humerus.

Materials and methods

Twenty right humeri from Mongolian cadavers were obtained, which had been fixed in a formalin solution. All soft tissue attachments were removed. The mean age of the specimens was 85 years (range, 68 to 108 years). There were 10 male and 10 females. We excluded specimens which showed any evidence of moderate or severe osteoarthritis, osseous pathology, or previous fractures. Specimens selected were divided into two groups equal in numbers, same gender ratio and similar mean age. In each group, the same implant and the same entry point were used.

An unstable surgical neck fracture model (11-A3 injury according to the AO-classification) was simulated in each specimen with a technique as previously described.[14] Each humeral head was fixed

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Fig. 1. Testing apparatus to simulate an unstable humeral surgical neck fractures. Humeral head secured via an Ilizarov external fixator allowing the displacement of the proximal humerus in the horizontal plane.

to a board with Ilizarov fixator (Fig. 1). The distal humerus was held with a thin and short intramedullary rod. An osteotomy was performed at the level of the surgical neck creating a 3 mm defect. The proximal side of the osteotomy (humeral head) was completely immobilized, whereas the distal side of the osteotomy (proximal humeral shaft) could be freely translated even with the application of small force. A guide pin was inserted at the correct entry point and drilled to accommodate nail insertion. Two intramedullary nails designed for proximal humeral fracture fixation were used in this study (Fig. 2). The entry point for each different nail was selected dependent on its curvature and according to the designers specifications. In Group A, the Targon PH nail (Aesculap, Tuttlingen, Germany) was used which is straight with a length of 150 mm. The entry point is about 8 mm medial to the cartilage-bone transitional zone at the sulcus between the head and greater tubercle[8,13] (Fig. 3). In Group B, the Stryker T2 PF nail (Stryker, Kiel, Germany) was used which is 6 degrees angled at the point 62 mm from the proximal tip and has the same length of 150 mm. The recommended entry point is 10 mm posterior to the anterior edge of the supraspinatus and at the junction of the greater tuberosity and articular cartilage.[1,4,5,12] The specimens were mounted on a testing apparatus. A nail was inserted manually through the entry point of each humeral head into the intramedullary canal. The depth of the nail insertion was 3 to 4 mm below the articular surface of the humeral head.

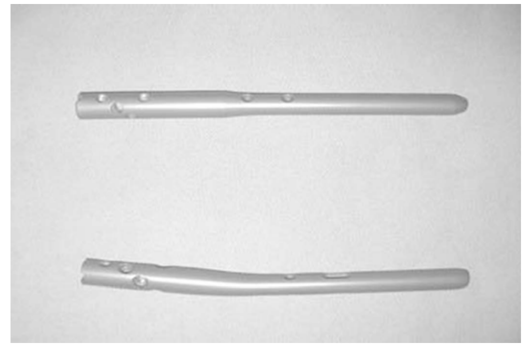

Fig. 2 Nails used in this study. Upper – Group A: straight Targon PH nail (Aesculap, Tuttlingen, Germany), and lower – group B: 6 degrees angled – Stryker T2 PF nail (Stryker, Kiel, Germany).

In the first study prior to a nail insertion, the thickest part of cortex (defined as "cortical thickness") and the largest outer diameter (defined as "outer diameter") at the osteotomy site were measured with callipers. In the second study after a nail insertion, horizontal displacement of the medial cortex at the osteotomy site was measured for antero-posterior and medial-lateral direction by callipers and defined as "displacement" at the fracture site (Fig. 4). In the third study during a nail insertion, the force required to reduce the displaced metaphysis anatomically with cortical apposition at the medial cortex was measured. This value was defined as "force to reduce the displacement". The displacement of the proximal humeral shaft after nail insertion was scaled in antero-posterior and medial-lateral planes (Fig. 5). Results were expressed as distance and direction of displacement.

All the statistical calculation was performed with use of Statcel2 (OMS Publ., Saitama, Japan). To investigate the association of the "displacement" with the average "cortical thickness" and "outer diameter" at the osteotomy site, Pearson correlation coefficients were obtained. Comparisons of values of "displacement" between Groups A and B were performed with use of paired 2-tailed Student ttest. To determine important predictors of "displacement", multiple regression analyses were performed. Results were considered significantly different at $p < 0.05$.

Results

Average "cortical thickness" was 2.0 mm (range, 1.0 to 3.5 mm) in Group A and 2.4 mm (range, 1.0 to 4.0 mm) in Group B respectively. Average "outer diameter" was 24.4 mm (range, 18 to 29 mm) in Group A and 25.1 mm (range, 21 to 36 mm) in Group B. "Cortical thickness" and "outer diameter" at the osteotomy site

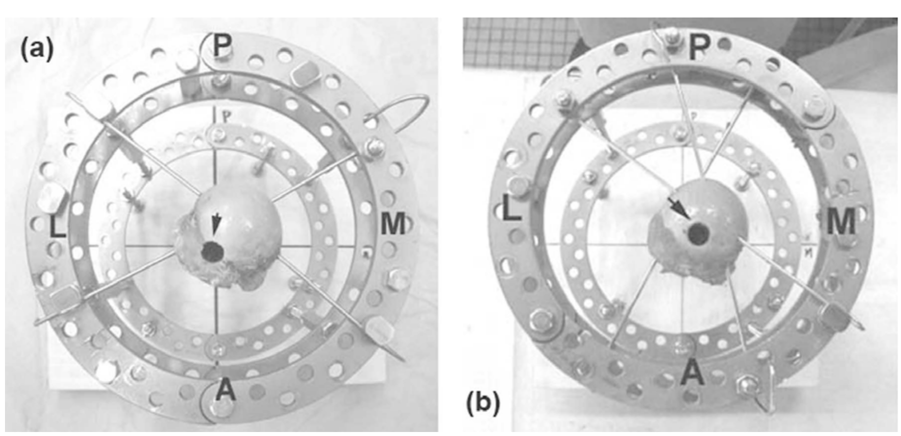

Fig. 3. Note the difference of the correct entry points (arrows), (a) about 8 mm medial to the cartilage-bone transitional zone for the straight nail (Group A), and (b) the junction of the greater tuberosity and articular cartilage for the angled nail (Group B).

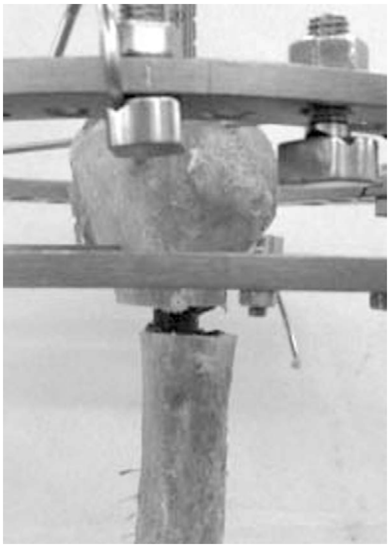

Fig. 4. Showing the displacement following nail insertion.

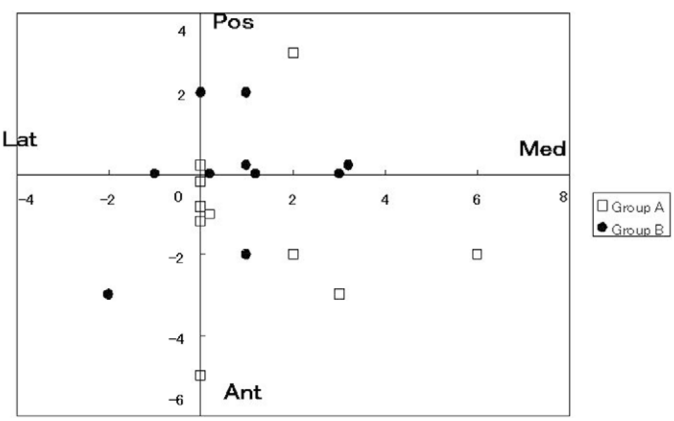

Fig. 5. Scatter plot showing values and direction of displacement at the proximal humeral shaft after nail insertion. In Group A, the humeral shaft tended to displace medially and posteriorly, while in Group B medially.

were analysed to find the relation with distance of displacement at the fracture site. Comparative analysis demonstrated a significant positive Pearson correlation between “cortical thickness” and “outer diameter” ($r = 0.52$, $p = 0.02$).

Repeated measurements of the “displacement” showed an average horizontal displacement (and standard deviation) of 2.5 ± 2.2 mm (range, 0 to 6.3 mm) in Group A, and 1.9 ± 1.1 mm (range, 0 to 3.6 mm) in Group B, a difference that failed to reach statistical significance ($p = 0.45$).

In Group A, the “displacement” tended to be medially and posteriorly. Three specimens out of ten revealed more than 4 mm displacement. While in Group B, the displacement tended to be medially. No patients displaced more than 4 mm.

Multiple regression analysis showed that “cortical thickness” and “outer diameter” were predictors of “displacement”, though statistically not significant ($r^2 = 0.27$; $p = 0.068$).

In both groups, “reduction force” was mostly under 15 N (Fig. 6). Anatomical reduction was not completed in 3 /20 humeri even after applying forces over 35 N. The two humeri among these three had a thick cortex (3.5 mm in both) with a wide “outer diameter” (26 mm, 29 mm, respectively). The third un-reducible humerus revealed a narrow inner diameter (“cortical thickness” of 2.0 mm and “outer diameter” of 21 mm).

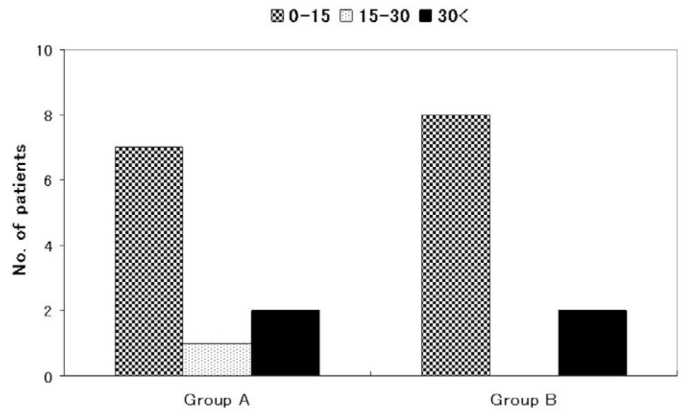

Fig. 6. Bar graph demonstrating the distribution of necessary “forces to reduce” displacement in each group. In the majority of specimens anatomical reduction was obtainable with forces less than 15 N. In 3 cases, reduction was impossible even after applying forces over 35 N.

Discussion

Many authors have advocated for the importance of a correct entry point during intramedullary nail insertion.[7,8,10,12,13] The insertion of the nail from the correct entry point is reported to provide firstly a good approximation of varus/valgus alignment of the shaft, secondly an anatomical alignment of the head and shaft fragment, and thirdly no occurrence of the postoperative varus deformity of the humeral neck that is thought to be prevented by cortical apposition of the medial fracture site.[7,11,12]

However, this manoeuvre does not always result in cortical apposition of fracture at the medial side despite the insertion of the nail via an optimal entry point. The rationale of the present study is based on the hypothesis that the diameter of the nail is too small to control the transverse displacement of the proximal humeral metaphysis, especially in the presence of osteoporosis whereas a wider diameter is combined with thin cortex.

Another cadaveric study[15] on the three-dimensional geometry of the proximal humerus, demonstrated that in almost 20% of the patients the extension of the intramedullary axis of the proximal humerus exits the humeral head more than 2 mm from the top of the articular surface. Our results of an average “displacement” of 2 mm after nail insertion support the view that even this insertion occasionally causes non cortical apposition at the fracture site. To our knowledge, this is a first report to measure transverse displacement after nail insertion.

The presented results on the necessary “force to reduce” displacement and the characteristics of the 3 cases whereas post nail insertion reduction was not feasible suggests that increased cortical thickness with a wider “outer diameter” or a “narrow intramedullary space” may hinder reduction of fractures on nail insertion. This finding may influence decision making on the use of a blocking screw or transmedullary support screw that can facilitate reduction of the displaced fragment.[16] Our study showed the nail insertion from the correct entry point resulted in 2–3 mm displacement on average at the fracture site. Assuming an average cortical thickness of 3 mm in the proximal humerus, a number of patients would lose cortical apposition after nailing.

Caution should be used when extrapolating these experimental laboratory findings to the clinical situation, since thoroughly removed periosteum or soft tissue at fracture site can not hinder displacement between the fragments.[17,18] Therefore, significantly less displacement would be expected in clinical practice in which retained periosteal structures may provide support for reduction and stabilisation by ligamentaxis.

The apparent limitations of this study include the presence of a certain selection bias in the two groups. Although the mean age, the number of the patients, and sex distribution is similar in each group, specimens in Group A using the Targon PH nail tended to be more osteoporotic, according to the "cortical thickness" or "outer diameter" parameters in each group, although not to a statistically significant level. Thus, we cannot advise on which of the two implants or entry point is superior in controlling displacement. Moreover, almost all the specimens were elderly patients, making our results less representative of the clinical scenario in younger patients. However, these type of fractures have a high incidence among the elderly with osteopenia or osteoporosis.[7] Third, the interpretation of this study is not universal because of the small number of patients, although the findings may be unique. Finally, we examined a small number of specimens thus making any generalisation of our suggestions to be interpreted with caution. Further anatomical and clinical studies of higher numbers are desirable based on the highlighted suggestions of our research to provide definite conclusions to this clinical problem.

Conclusion

Many articles stress the importance of a correct entry point in order to obtain anatomical alignment of a fractured long bone. Following the testing of our hypothesis, surgeons should be aware that even with a correct entry point cortical apposition may be lost following the insertion of the nail as a result of the specific humeral pathology and anatomic characteristics and not the poor entry point technique. Transverse displacement following nailing cannot be reduced in some patients. In such a patient, blocking screws may not succeed in obtaining cortical apposition.

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Conflict of interest

The authors have no conflict of interest to declare.

Role of the funding source

No funding has been provided.

Approval by ethics

This work has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to the work.

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