

A morphological study of age-related changes in medullary characteristics of proximal humerus

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To the Editor: Proximal humeral fracture (PHF) predominantly occurs in patients older than 60 years old with severe osteoporosis.^[1] Although a majority of PHFs can be treated non-operatively, the complicated ones require surgical fixation.^[2] In older individuals, the loss of trabecular structure and the calcar region in the proximal humeral medullary cavity makes them prone to comminuted fracture and loss of medial hinge support, leading to a high rate of implant failure and reoperation.^[3] Recent studies have shown that endosteal augments incorporated into the locking plate construct might provide better medullary support and mechanical stability.^[1] However, the endosteal augments used in PHF fixation are of different shapes, modes, and positions, which can lead to implant failure and reduction loss.^[1,4,5] This may be because of a lack of understanding of the morphological changes that take place in the proximal humerus at different ages. Therefore, in this study, we analyzed and compared the anatomical degeneration pattern of the medullary canal between older and younger patients to have a better understanding of the medullary morphology of proximal humerus anatomically and the application of endosteal support clinically.

In this retrospective study, patients with PHFs who were treated in one trauma center from January 2013 to December 2016 were reviewed. The inclusion criteria were as follows: (1) the contralateral proximal humerus was unaffected and (2) age ≥ 18 years. The exclusion criteria were as follows: (1) previous operative treatment on the contralateral upper limb; (2) history of illness affecting the shape and function of the contralateral upper limb, such as non-union, arthritis, tumors, and other diseases; (3) history of long-term use of steroids or other drugs affecting bone mineral density (BMD); and (4) combined metabolic osteopathy. All included patients were divided into a young (<60 years) and older group (≥ 60 years) based on their age, who underwent a full-length computed tomography (CT) scan of the uninjured humerus. Based on the

CT images in the Digital Imaging and Communication in Medicine format, three-dimensional (3D) models of the uninjured humerus were reconstructed using the Mimics software (version 18.0; Materialise Inc., Leuven, Belgium), described as follows. After the whole humerus mask was created, the bone and the cortical bone mask were created based on the threshold (148–3071 and 662–3071 HU, respectively). Then, the medullary mask and cancellous bone mask were created using Boolean operations. The humerus models were imported into the 3-matic (V11.0, Materialise, Belgium) for analysis [Figure 1A and 1B].

The measurement benchmarks were established for the medullary canal in both groups [Figure 1C–F]. Below the humeral head, the medullary canal in the 20 to 60 mm is approximately cylindrical, and the axis of the medullary cavity of the humeral shaft (humerus canal axis [HCA]) is generated using the axis fitting tool of 3-matic. The humeral head is selected and fitted to a sphere using the sphere fitting tool of the 3-matic. The center of the sphere was the center of the humeral head (Os) and the semidiameter of the sphere was Rs [Figure 1C]. The coronal datum plane (CP₀) was established based on HCA and Os. Thereafter, the axial datum plane (AP₀) was established with HCA as the normal line, crossing the lowest point of the humeral head on CP₀. The intersection point of HCA and AP₀ was taken as O. On the view of CP₀, the most medial and lateral intersection points of medullary canal and AP₀ are marked as medial point (M) and lateral point (L). The highest point of the medullary cavity model was defined as the apex point (V) [Figure 1D]. The interface between the medullary cavity and the humeral head and its subcapital region was defined as the support plane (SP). Then, the SP was established through the point of V and M and perpendicular to CP₀. The supporting angle (SA) was defined as the angle between AP₀ and SP [Figure 1E]. Finally, the section of the medullary canal at the level of the SP was calibrated, the best fitting circle of the section was obtained using the

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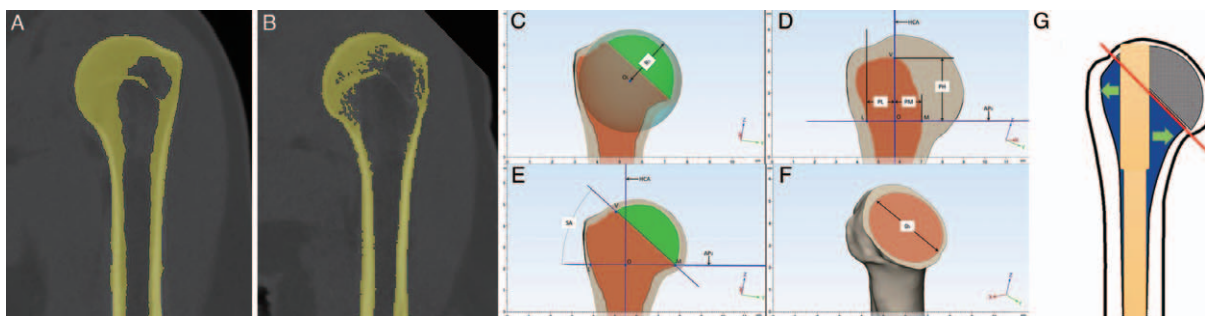


Figure 1: (A) The young group of patients with proximal humeral fracture. (B) The older group of patients with proximal humeral fracture. (C) The humeral head is selected and fitted to a sphere using the sphere fitting tool of the 3-matic, the semidiameter of the sphere was radius (Rs). (D) The measurement benchmarks and corresponding parameters were established for the proximal humeral medullary canal. (E) Establishment of the measurement benchmarks of the support plane and angle. The green area showed the residual dense cancellous bone in the proximal humeral head of older patients. (F) The best fitting circle of the support plane (SP) was obtained and the diameter (Ds) of the circle was measured. (G) The existing medullary system is columnar structure, which cannot achieve an anatomical matching with the medullary cavity and an effective endosteal support for older patients with proximal humeral fracture (PHF). HCA: Humerus canal axis; PH: The distance between V and AP₀; PL: The distance between L and HCA; PM: The distance between M and HCA; PV: The medullary volume above the AP₀; SA: Supporting angle.

automatic fitting arc function of 3-matic software, and the diameter (Ds) of the circle was measured [Figure 1F].

Statistical analysis was performed using SPSS (version 21.0; SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to test whether the metric data conformed to the normal distribution. The independent sample *t*-test was used to compare and analyze the differences of metric data between groups conforming to the normal distribution, which was reported as arithmetic mean \pm standard deviation. Count data were tested using the Chi-square test. For the outcomes of interests, such as proximal volume (PV), proximal height (PH), proximal medial distance (PM), and proximal lateral distance (PL), we used multiple regression analysis adjusting gender and humerus radius. We reported the mean value for each outcome with the predicted marginal mean from the linear regression model. Statistical significance was set at $P < 0.050$.

Sixty patients were included in our study. Demographics characteristics in both groups showed that: (1) there was no statistical difference in terms of gender (*n*) (female: 22 *vs.* 21, $P = 1.000$), dominant side (*n*) (26 *vs.* 25, $P = 1.000$), height (1.63 ± 0.05 *vs.* 1.64 ± 0.07 m, $P = 0.427$), and weight (51.67 ± 8.72 *vs.* 53.02 ± 10.14 kg, $P = 0.627$) and (2) there was significant statistical difference ($P < 0.001$) in terms of age (45.8 ± 8.61 *vs.* 76.33 ± 6.85 years), BMD (0.96 ± 0.11 *vs.* 0.60 ± 0.15 g/cm²), and Neer classification of injured side (*n*) (2/3/4 parts: 7/13/10 *vs.* 2/13/15).

The values of Rs (mm) were 22.31 ± 1.72 and 22.06 ± 2.06 in the young and older groups, respectively, and there was no significant statistical difference ($P = 0.613$). Compared with the young group, the PV (cm³) in the older group increased significantly (21.60 ± 3.03 *vs.* 29.40 ± 1.98 mm, $P < 0.001$), with significant expansion in the proximal (PH: 25.36 ± 1.08 *vs.* 27.38 ± 0.67 mm, $P < 0.001$), medial (PM: 13.14 ± 1.16 *vs.* 21.60 ± 3.03 mm, $P < 0.001$), and lateral (PL: 17.90 ± 0.95 *vs.* 26.02 ± 0.76 mm, $P < 0.001$) directions, respectively. Compared with young patients, the SA was also decreased in older ones ($65.28^\circ \pm 9.89^\circ$ *vs.* $45.02^\circ \pm 2.10^\circ$, $P < 0.001$). However, the SA did not show significant variation among the older patients (ranging from

41.04° to 49.24°). Multiple regression analysis results were consistent with results from the unadjusted analysis, showing a significant difference in medullary cavity morphology. Besides, there was the cancellous bone in the humeral head in the older group. Its junction with the medullary cavity was a quasi-circular facial structure with a diameter of 11.67 ± 1.50 mm.

There are a few studies on the morphology of the proximal humeral medullary cavity.^[6] Sprecher *et al*^[6] reported that in osteoporotic patients, the loss of trabecular bone in the greater tubercle and the medial metaphysis was more significant compared with the loss in the subchondral region. However, these studies are based on the analysis of the two-dimensional plane of the cadaveric bone. Through the 3D reconstruction of the medullary structure, our study showed that the cylindrical-shaped medullary cavity in the younger group becomes irregular “bellbottom” shaped with bone loss in the older group. This may be the reason why a single implant fails to provide effective medullary support in older patients. Furthermore, older patients showed a significant medial offset of the medullary cavity. This characteristic change was noted, and accordingly, the endosteal support was placed as close to the medial cortex and humeral head as possible.

The age-related differences in the morphology of the medullary cavity should be associated with the clinical prognosis of PHF. Clinical studies have shown that with nails- or plate-based medullary augmentation, younger patients have better clinical outcomes than older ones.^[7] This is because the existing nail or augments are mostly columnar structures, which are well-matched with the medullary cavity of young patients [Figure 1G]. But in older patients, expansion of the proximal humeral medullary cavity renders the medullary cavity irregular, which does not anatomically match with the shape of the existing nails or struts [Figure 1G]. Therefore, a more effective anatomical supporting augment is needed for the treatment of older patients.

In conclusion, compared with younger patients, the medullary canal of the proximal humerus expanded

significantly, especially the medial offset, showing an “eggshell”-like cavity structure in older patients. Further, the residual dense cancellous bone in the humeral head could serve as an endosteal support structure with a relatively fixed support angle. It may provide anatomical references for reasonable endosteal augmentation for older patients.

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Conflicts of interest

None.

References

1. Biermann N, Prall WC, Böcker W, Mayr HO, Haasters F. Augmentation of plate osteosynthesis for proximal humeral fractures: a systematic review of current biomechanical and clinical studies. *Arch Orthop Trauma Surg* 2019;139:1075–1099. doi: 10.1007/s00402-019-03162-2.
2. Lang-Qing Z, Lu-Lu Z, Yu-Wen J, Hai-Feng W, Wen Z, Yun-Feng C. Influence of medial support screws on the maintenance of fracture reduction after locked plating of proximal humerus fractures. *Chin Med J* 2018;131:1827–1833. doi: 10.4103/0366-6999.237396.
3. Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG. The importance of medial support in locked plating of proximal humerus fractures. *J Orthop Trauma* 2007;21:185–191. doi: 10.1097/BOT.0b013e3180333094.
4. Panchal K, Jeong JJ, Park SE, Kim WY, Min HK, Kim JY, *et al.* Clinical and radiological outcomes of unstable proximal humeral fractures treated with a locking plate and fibular strut allograft. *Int Orthop* 2016;40:569–577. doi: 10.1007/s00264-015-2950-0.
5. Chen H, Zhu ZG, Li JT, Chang ZH, Tang PF. Finite element analysis of an intramedullary anatomical strut for proximal humeral fractures with disrupted medial column instability: a cohort study. *Int J Surg* 2020;73:50–56. doi: 10.1016/j.ijsu.2019.11.026.
6. Sprecher CM, Schmidutz F, Helfen T, Richards RG, Blauth M, Milz S. Histomorphometric assessment of cancellous and cortical bone material distribution in the proximal humerus of normal and osteoporotic individuals: significantly reduced bone stock in the metaphyseal and subcapital regions of osteoporotic individuals. *Medicine* 2015;94:e2043. doi: 10.1097/MD.0000000000002043.
7. Robinson CM, Stirling PHC, Goudie EB, MacDonald DJ, Strelzow JA. Complications and long-term outcomes of open reduction and plate fixation of proximal humeral fractures. *J Bone Joint Surg Am* 2019;101:2129–2139. doi: 10.2106/JBJS.19.00595.

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