Bone-defect in scaphoid nonunion: a 3-dimensional and quantitative analysis

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Purpose: We’ve made a hypothesis of the fracture location of the scaphoid relates to deformity of carpal bone and characteristic features of the subsequent bone-defect, and tested this by quantitating the fracture displacement and bone-defect in scaphoid nonunion. The purpose of this study is to obtain accurate information regarding to fracture displacement and the shape of the bone-defect in the scaphoid nonunion in order to help surgeons to achieve accurate correction of the scaphoid deformity and to illuminate mechanism of carpal collapse in scaphoid nonunion.

Methods: Twenty-five patients with scaphoid nonunions were examined with three-dimensional computed tomography and originally developed image analysis tool. We categorized them into two groups based on fracture location, distal type and proximal type. The former has fracture line distal to the dorsal apex of ridge of the scaphoid where the dorsal intercarpal ligament (DIC) and dorsal scapholunate interosseous ligament (DSLL) were attached, and the latter is proximal. Surface models of the scaphoid were constructed on the computer using CT data of the bilateral wrists. Scaphoid nonunion was matched to the mirror image of the contralateral normal scaphoid on the basis of proximal fragment using the three dimensional positional information which was obtained by Surface-based registration. In this way the displacement of the distal fragment relative to the proximal fragment was calculated from each positional information and expressed using screw displacement axis system. In screw displacement axis system, 3-dimensional transfer of the object is presented by rotation and parallel translation to the unique axis.

The shape of bone defect was shown by subtracting the reduced nonunion model from the mirror image of the contralateral normal scaphoid by means of Boolean operation of the commercially available computer software (Magics RP®, Materialise, Belgium). The shape of bone defect was visualized and the amount of bone defect was calculated. The ratio of volume between the bone defect and the contralateral scaphoid was calculated.

Result: Characteristic features of the deformity and the bone-defect were clearly separated into 2 types according to the fracture location.

1. Quantification of deformity of scaphoid nonunion
In distal type (21 cases), distal fragment rotated to the volar direction and pronation around the screw axis which ran from radioproximal to ulniodistal direction and penetrated the head of capitate (Fig.1). The average of the rotating angle around the screw axis was 39.9° (±22.1SD). In proximal type (4cases), distal fragment rotated slightly volar around the screw axis which ran from radial to ulnar direction and penetrated the head of capitate (Fig.2). The average of rotating angle around the screw axis was 9.1° (±16.5SD) (Table 1).

2. Evaluation of the shape and amount of bone defect
In distal type, all of the 21 patients had a same pattern of bone defect which shape was in wedge with its base facing to the volar side (Fig3-a). The average volume of the bone defect was 225mm³ (±143SD) and of the ratio to the contralateral normal scaphoid was 7.40% on average (range,0.53% to 16.5%). In proximal type, all of 4 patients had a little bone defect around the fracture site (Fig3-b). The average volume of the bone defect was 25.8mm³ (±22.8SD) and the ratio to the contralateral normal scaphoid was 0.85% on average (range,0.20% to 1.74%) (Table 1). The relationship between the duration of nonunion and the amount of bone defect is shown in Fig4. In distal type, bone resorption had occurred in relatively early stage.

Conclusion: To classify the patterns of deformity into two types help us to know the pathomechanism. The best operative procedure for each type might be selected considering each characteristic (Fig5). In distal type, volar approach is recommended and large wedge type bone graft and correction of distal fragment to the direction of extension and supination is needed. In proximal type, dorsal approach is recommended and certain degree of rejection of osteophyte around the fracture site and the cancellous bone graft is adequate. To insert the screw from the proximal to the distal direction is easier than the reverse way.

Table 1) Result of the displacement of distal fragment and the volume of bone defect.

- Number: Age(y) period(m) rotation° ± SD Defect(mm³) ± SD Defect(%) P-value
  - Proximal type: 4 40.5 59.6 9.1±16.5 25.8±22.8 0.85 0.05
  - Distal type: 21 35.4 80.1 79.6±22.1 220±143 7.4 P>0.05

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