STRESS ANALYSIS IN WRIST JOINT -- NEUTRAL POSITION AND FUNCTIONAL POSITION

Introduction: Many researches about wrist joint stress analysis including experimental and theoretical have been performed under neutral wrist position. However, the functional position is used more frequent in daily living and it is impossible to analyze this position using two dimensional computer simulation analysis. The objectives of this study is to compare the stress distribution in radio-ulna-carpal joint under two different position (neutral and functional) using three dimensional Rigid Body Spring Modeling technique (1).

Methods: Subjects were six normal healthy female adult after providing informed consent. The wrist joint was scanned by computer tomography at 1 mm interval in neutral position and the functional position which was defined by asking subject to grip a cylinder in diameter of 3 cm. Three dimensional surface models were constructed from these data using original software.

Articulating surfaces with distances less than the thickness of the cartilage (1.2 mm) were assumed to be in contact. Contact surface models were constructed as a matrix of small quadrilateral mesh elements which were equidistant from articulating bone surfaces. Compressive springs were distributed in normal direction on meshed surface at one spring per unit area. Twenty six of articulating surface models were constructed in wrist joint. The stiffness of springs were assumed to be 22.6 N/mm. The ligaments were modeled as the line segments which resist only to tensile force. The three dimensional attachment points of the ligaments were digitized using two orthogonal projections of the model on the computer screen. The fifty ligaments were digitized and each ligament was consisted 2 to 5 line segments according to its width. The location and stiffness of the ligaments were obtained from previous reports (2).

The total amount of 140N was applied on five metacarpals in vertical direction to each carpo-metacarpal joint surface. The stress distribution pattern of each joint was calculated under two different positions and the paired Student t-test was used for statistical analysis.

Results: In neutral position (Fig. 1), at radio-ulna-carpal joint, stress was concentrated at volar side of joint. Average of maximum contact pressure was 4.5±1.5 MPa at the scaphoid fossa and 3.4±1.7 MPa at the lunate fossa (Fig. 3 left). The maximum pressure ratio of the scaphoid to the lunate was 1.4. Regarding force transmission at the radio-ulna-carpal joint level, 48.2±8 % of the load was transferred through the scaphoid fossa and 45.2±6 % through the lunate fossa.

In functional position (Fig. 2), the wrist joint was slightly inclined to extension and ulnar deviation, as a result, the proximal carpal bones extended. Especially, the scaphoid rotated dorsally by 13 degrees from extension and ulnar deviation, as a result, the proximal carpal bones were equidistant from articulating bone surfaces. Compressive springs were distributed in normal direction on meshed surface at one spring per unit area. Twenty six of articulating surface models were constructed in wrist joint. The stiffness of springs were assumed to be 22.6 N/mm. The ligaments were modeled as the line segments which resist only to tensile force. The three dimensional attachment points of the ligaments were digitized using two orthogonal projections of the model on the computer screen. The fifty ligaments were digitized and each ligament was consisted 2 to 5 line segments according to its width. The location and stiffness of the ligaments were obtained from previous reports (2).

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In functional position (Fig. 2), the wrist joint was slightly inclined to extension and ulnar deviation, as a result, the proximal carpal bones extended. Especially, the scaphoid rotated dorsally by 13 degrees from neutral position (p<0.05) (Fig. 1 and Fig. 2). Average of maximum contact pressure was 4.6±1.5 MPa at the scaphoid fossa and 5.0±1.1 MPa at the lunate fossa (Fig. 3 right). The maximum pressure ratio of the scaphoid to the lunate was 1.1. The contact area at the lunate fossa was increased compared to the scaphoid fossa, as a result, 40±7 % of load was transferred through the scaphoid fossa and 53±9 % through the lunate fossa. The maximum pressure ratio of the scaphoid to the lunate decreased to 1.1.

In the mid-carpal joint, there was no significant difference between two positions.

Discussion: Our analysis of the wrist joint in neutral position was consistent with the data by the previous reports. However, in functional position, the load on the lunate fossa increased and was larger than that on the scaphoid fossa. In clinical situation, the osteonecrosis frequently occurs in the lunate and excision of the lunate easily causes collapse of the carpus. Our analysis in functional position suggests that the lunate might be the key stone in stress transmission on wrist joint.

Conclusion: Load transmission in the wrist joint should be analyzed not only in neutral position but also in functional position. The lunate is important in stress transmission on wrist joint.

References

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Fig. 1 Neutral position

Fig. 2 Functional position

Fig. 3 The stress distribution under neutral position (left) and functional position (right) at radio-carpal joint.