Use of 3D-CT for evaluating curved periacetabular osteotomy

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[Introduction]
Curved periacetabular osteotomy (CPO) is a modified Ganz procedure that we have been performing in our facility since 1995 to treat acetabular dysplasia from prearthrosis to the advanced stage in young patients. During surgery, we use an image intensifier while performing rotation of the acetabulum, with the main indices being femoral head coverage, acetabular roof obliquity (ARO), and medialization of the femoral head. Plain X-rays are used for pre- and postoperative measurement of indices such as sharp angle, center-edge (CE) angle, ARO, acetabular head index (AHI), and head lateralization index. Variations occur, however, as a result of changes in patient posture before and after surgery, as well as the technician performing radiography. The present study investigated the validity of measurements made using CT for evaluation, as well as relationships with medialization.

[Subjects and Methods]
A total of 30 patients with 30 hips capable of undergoing computed tomography (CT) measurements under the same conditions (0.5-mm slice) 1 week before and after CPO. After the hip region of interest for reconstructing 3-dimensional images had been identified, bone CT values were binarized. In the two images, positions of bones in three directions and three rotation angles were required to express the 3-dimensional state. The principle of 3-dimensional image superimposition used in the present study was a full-search method whereby all six variables for postoperative 3-dimensional images were varied independently of each other and superimposition on preoperative images was performed. Movement of the acetabulum was calculated as (x, y, z), rotation direction as (q, θ, ψ), and change in position of the femoral head as (X, Y, Z) using the least-squares method. CE angle and ARO were measured pre- and postoperatively using plain X-rays. Distance and direction of movement between the centers of femoral heads, distance moved by the acetabulum, and direction of rotation were measured on pre- and postoperative CT, and relationships were evaluated.

[Results]
Differential volume ratio was calculated using a full-search method whereby all six variables were varied independently of each other with regard to postoperative 3-dimensional images, and superimposition on preoperative images was performed. As shown in this figure, if the state of superimposition was poor, the number of voxels in the superimposed image was greater than the original number of voxels. That is, a search was performed for the position and posture in which epsilon was minimized. (Fig.3)

Table 1 shows differential volume ratios when the search pitch for position and posture was varied during superimposition. As can be seen from the table, the differential volume ratio decreased sharply from a pitch of 4 mm, 4° to 0.5 mm, 0.5°, but little change was seen from a pitch of 0.125 mm, 0.125° to 0.0625.

To demonstrate the validity of using differential volume ratio at a pitch of 0.125 mm, 0.125° for evaluation, Table 2 shows changes in differential volume ratio when images of an identical phantom were displaced at the specified pitch. As can be seen from this table, pitch when the differential volume ratio was 4% was about 0.5 mm, 0.5°. As this is almost equivalent to the size of voxels in CT images, the automatic processing used for superimposition in this study was regarded as sufficiently accurate for evaluation.

[Discussion]
In CT evaluation, factors with significant effects on medialization of the femoral head were small x, y (movement of the acetabulum) and θ, ψ ( rotational direction). In other words, medial and anterior movement of the acetabulum, increased CE, and direction of anterior rotation of the posterior part of the acetabulum made the greatest contributions to medialization. (Table 3,4) A tendency was seen for medialization to be insufficient in patients with flattening of the femoral head, deformity of the weight-bearing area of the acetabulum, or acetabular retroversion. However, sufficient femoral head coverage was possible even with severe acetabular dysplasia, confirming the utility of this surgical technique.

[References]