Validation of the Femoral Component Placement during Hip Resurfacing between the Conventional Jigs, Custom-made Template, and CT-based Navigation

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Introduction:

Hip resurfacing has been reevaluated by its resistibility for dislocation and durability for wear. [1] However, malpositioning of the femoral component may result in femoral neck fracture which is one of the typical complications of this procedure. [2]

Conventionally, manual mechanical alignment jigs have been used to insert the initial guidewire into the femoral head. [3] Recently, image-free navigation systems [4, 5] or custom-made templates [6, 7] has been used with good accuracy in order to avoid the malpositioning. On the other hand, there are little literature about computer tomography (CT)-based navigation, or direct comparison in the accuracy between mechanical jig, custom-made template, and CT-based navigation.

In this study, using synthetic femoral bone models, we elucidated and compared the accuracy of the alignment and insertion point using conventional jigs, custom-made templates, and CT-based navigation.

Materials and Methods:

Based on CT data of 4 cases that underwent hip resurfacing with CT-based navigation, 9 synthetic femoral bone models per one case were made of zp 150 powder (Z Corporation, MA). Total of 36 femoral bone models were equally divided into the following three groups: the jig group, the template group, and the navigation group. Among three bones of each case with each method, two were operated by the same author (MK) and one was operated by another author (TS) used for intraobserver and interobserver estimation.

Alignment of the femoral component was planned with our original 3D-templating system. First, the stem of the femoral component was planned to pass through the center of the femoral neck with parallel to the medial calcar, and then moved parallel without making any notch on the femoral neck. This planning was adapted for producing custom-made templates (Fig.1) and planning of CT-based navigation. The size of neck centering jig was decided to fit most around a neck and the guidewire was inserted to be parallel to the medial calcar as possible.

Radiographic evaluation was based on postoperative CT. Anteversion, stem-shaft angle, and the three-dimensional insertion points of the guidewire were measured. The deviation between the preoperative planning and the postoperative CT was calculated at absolute value.

Statistically, ANOVA was adopted to compare deviations between devices. An intraclass correlation coefficient (ICC) was calculated to determine the level of repeatability between the two observers.

Results:

The mean deviation of the anteversion was 4.1±3.2° in the jig group, 2.6±2.5° in the template group, and 2.2±1.6° in the navigation group. The mean deviation of the stem-shaft angle was 9.0±7.4°, 2.4±1.5° and 2.7±2.1°, respectively. The mean deviation of the insertion point was 8.2±5.4 mm, 3.2±1.7 mm, and 4.0±2.0 mm, respectively. There were no statistical differences in deviation of anteversion among three groups. Deviation of stem-shaft angle was statistically different between the jig group and the template or navigation group. (p<0.01). There were statistical differences in the insertion point between the jig and the template group (p<0.05), but not between the navigation and the jig or template group (Fig.2).

The ICC in the same observer was 0.97 of anteversion, 0.98 of stem-shaft angle, and 0.64 of the insertion point in the jig group, 0.95, 0.98, and 0.43 in the template group, and 0.98, 0.99, and 0.48 in the navigation group. The ICC between two observers was 0.70, 0.18, and 0.39 in the jig group, 0.98, 0.99, and 0.93 in the template group, and 0.98, 0.96, and 0.86 in the navigation group, respectively.

Discussion:

There were some literature that compared the accuracy of the femoral implantation between with conventional jig and imageless navigation. [3, 4, 5] In these studies, the accuracy of the mechanical jigs was influenced by observer or their type. There were also some researches about the accuracy of the custom template for the femoral guidewire in

sent. [6, 7] They proved its high reliability both in laboratory and clinical situation. However there was no report which compared the accuracy of mechanical jigs, custom template and computer navigation at the same time.

In the present study, the accuracy of the mechanical jig was inferior to that of other devices, especially about the stem-shaft angle and the insertion point. The high intraobserver but low interobserver correlation coefficient showed its poor repeatability. On the other hand, the accuracy of custom-made templates and CT-based navigation was good and their repeatability was quite high.

In the clinical situation, different from the experimental situation, the accuracy of these devices may get poorer, because some factors, including the interference of the soft tissue or position of the limb during surgery, may spoil the congruency of the mechanical jig and custom template, or make it difficult to perform surface matching of the CT-based navigation.

Significance:

In the experimental situation with synthetic femoral bone, custom template and CT-based navigation could insert the femoral component guidewire with good accuracy and high repeatability. Mechanical jig was inferior about stem shaft angle and insertion point than other devices.

Fig.1: (A) Custom-made template and attachment for verification. (B) After setting the template, verification was performed by touching both greater and smaller trochanter through attachment. (C) Guidewire was inserted.

Fig. 2: Box-and-whisker plots of guidewire alignment and insertion point error. Boxes show the deviation of the anteversion, stem-shaft angle and insertion point. Box length represents the interquartile range (first to third quartiles). The line in the center of the boxes represents the median value. Data represented by “o” is outlier (greater than 1.5 to 3.0 times the interquartile range over the third quartile).

References