A validation study of automated 3D planning system for total hip arthroplasty

TAKAO M¹, YOKOTA F², KAGIYAMA Y³, NAKAMOTO M⁴, TOMIYAMA N⁴, TADA Y⁵, SATO Y⁴, SUGANO N⁶

¹Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, Suita, Japan
²Department of Computer Science and Systems Engineering, Graduate School of Engineering, Kobe University, Japan
³Interdisciplinary Graduate School of Medicine and Engineering, Yamanashi University, Japan
⁴Department of Radiology, Osaka University Graduate School of Medicine, Suita, Japan
⁵Department of Systems Science, Graduate School of System Informatics, Kobe University, Japan
⁶Department of Orthopaedic Medical Engineering, Osaka University Graduate School of Medicine, Suita, Japan

masaki-tko@umin.ac.jp

Introduction: Preoperative planning is an essential procedure for successful total hip arthroplasty (THA). Three-dimensional (3D) templating of THA is valuable to optimize the bone coverage of an acetabular component, fit and fill of a femoral component in the femoral canal, postoperative range of motion and leg length and offset. It is, however, time-consuming task for surgeons to make a 3D plan adjusting these parameters for all cases. We have developed automated preoperative planning system using statistical atlas-based method. The purpose of the present study was to validate the automated 3D planning system for THA.

Patients and Methods: We used 55 sets of 3D-CT data of 55 patients who underwent consecutive cementless THA using an anatomical stem (CentPillar TMZF, Stryker) and a rim-enlarged cup (TriAD PSL, Stryker). There were all female with a mean age of 60 years. The diagnosis was developmental dysplasia in 39 hips and osteonecrosis in 11 hips and primary osteoarthritis in 5 hips. Out of the 39
Dysplastic hips, 30 hips were categorized in Crowe group I, 7 hips in Crowe group II and 2 hips in Crowe group III. The operating surgeon performed 3D templating prior surgery using a planning workstation of CT-based navigation system. One surgeon blinded to surgery performed 3D templating. He had sufficient experience of 3D templating for THA. The automated system output 3D plans of every stem size with quantitative data of postoperative leg length discrepancy and range of motion (Figure).

Finally, another surgeon blinded to surgery selected the final plan. Statistical shape models of the pelvis, the femur and the femoral canal was used for automated segmentation of each structure. For automated separation of the diseased hip joint, a hierarchical multi-object statistical shape model representing shape variations as well as pose variations of the femur against the pelvis was used. For stem planning, a statistical atlas of distance map between the stem surface and the inner surface of femoral cortex was used. For cup planning a statistical shape model which encodes global spatial relationships between the individual pelvic anatomy and the acetabular component was used. Statistical atlases for cups and stems were constructed from 40 sets of preoperative 3D plans prepared by an experienced surgeon. Planned- versus-achieved accuracy was compared among the automated system, the operator and the surgeon blinded to surgery. The templating results were categorized as either exact size or within one size of implanted size.

**Results:** The exact cup size was predicted using the automated system in 36% of the cases, 73 % by the operating surgeon and 45 % by the blinded surgeon. The accuracy of exact cup size of the automated system was inferior to that of the operating surgeon (p=0.0001), while comparable to that of the blinded surgeon (p=0.33). If accuracy was expanded to include all cups within one size of the implanted size, the automated system was correct in 87 % of the cases, as compared to 96 % by the operating surgeon and 96% by the blinded surgeon. The exact stem size was predicted using the automated system in 42 % of the cases, 76 % by the operating surgeon, and 51 % by the blinded surgeon. The accuracy of templating for stem sizes of the automated system was inferior to that of the operating surgeon (p=0.0005), while was comparable to that of the blinded surgeon (p=0.33). If accuracy was expanded to include all stems within one size of the implanted size, the automated system was correct in 91 % of the cases, as compared to 98 % by the operating surgeon and 96% by the blinded surgeon.

**Conclusion:** The ability of the automated 3D planning system to predict the component size within one size was comparable to that of experienced surgeons. We concluded that the accuracy of the automated 3D planning system for THA was acceptable for clinical application.

**References**