Comparison Between Hand Rasping and Robotic Milling for Stem Implantation in Cementless Total Hip Arthroplasty

Shunsaku Nishihara, MD,* Nobuhiko Sugano, MD,† Takashi Nishii, MD,* Hidenobu Miki, MD,* Nobuo Nakamura, MD,† and Hideki Yoshikawa, MD*

Abstract: We evaluated the effects of conventional hand rasping and robotic milling on the clinical and radiographic results of cementless total hip arthroplasty, with the same computed tomography (CT)–based 3-dimensional preoperative planning using a ROBODOC workstation (Integrated Surgical Systems, Davis, Calif). The robotic milling group consisted of 78 hips, and the hand-rasping group 78 hips. The radiographic findings from the preoperative planning and postoperative CT data were evaluated using the most accurate CT images reconstructed by the ROBODOC workstation. The robotic milling group showed significant superior Merle D'Aubigne hip score at 2 years. In the robotic milling group, there were no intraoperative femoral fractures, and a radiographically superior implant fit was obtained. Hand rasping had the potential to cause intraoperative femoral fractures, undersizing of the stem, unexpectedly higher vertical seating, and unexpected femoral anteversion causing inferior implant fit. **Key words:** ROBODOC, ORTHODOC, femoral canal preparation, comparison between hand rasping and robotic milling, cementless total hip arthroplasty.

Fit and fill of cementless femoral stems in the femoral canal are important factors for stable fixation and good clinical results in many types of cementless total hip arthroplasty (THA) [1-6]. As one of the options to obtain optimal fit and fill of cementless femoral stems, the ROBODOC system (Integrated Surgical Systems, Davis, Calif) was developed [7,8]. This system consists of a preoperative planning computer workstation (ORTHODOC, Integrated Surgical Systems, Davis, Calif) and a robotic arm equipped with a high-speed milling device to prepare the femoral canal. This system is an active robot that moves a milling device automatically, independent of an operator, according to preoperative planning [7]. ORTHODOC provides precise 3-dimensional information on fit and fill of the femoral stem in the femoral canal using computed tomography (CT) images and helps the surgeon to decide the optimal position and size of a femoral stem. Computed tomography–based planning is more accurate than conventional x-ray template preoperative planning because magnification and shape of the femoral canal on x-rays are highly variable depending on the x-ray technique [9-11]. Based on CT-based planning, the milling path for preparation of the femoral canal can be visualized using ORTHODOC, so that the surgeon can ensure that the path avoids interference with important structures such as the greater trochanter. After approval of the plan by the surgeon, ROBODOC precisely executes femoral canal milling according to the plan, using robotic machining intraoperatively [7,8].

*From the *Department of Orthopaedic Surgery, Osaka University Medical School, Suita, Osaka, Japan; and †Center of Arthroplasty, Kyowakai Hospital, Suita, Osaka, Japan.*
Submitted October 30, 2004; accepted January 1, 2006.
No benefits or funds were received in support of the study.
Reprint requests: Shunsaku Nishihara, MD, Department of Orthopaedic Surgery, Osaka University Medical School, 2-2 Yamadaoka, Suita, Osaka 565-0871, Japan.

0883-5403/06/1906-0004$32.00/0
doi:10.1016/j.arth.2006.01.001

In previous studies comparing robotic implantation of a femoral stem with conventional manual implantation [7,12], differences in outcome could be attributed to 2 factors. The first factor is the difference in preoperative planning between the conventional x-ray template method and the CT-based 3-dimensional preoperative planning. The second factor is the difference in surgical procedure between conventional hand rasping and robotic milling. There have been no previous reports of a pure comparison between conventional hand rasping and robotic milling using the same CT-based 3-dimensional preoperative planning.

The purpose of the present study was to compare clinical and radiographic results between hand rasping and robotic milling, based on the same 3-dimensional preoperative planning using ORTHODOC.

Materials and Methods

From September 2000 to September 2002, a total of 156 primary cementless THAs were performed on 140 patients at our 2 institutions. The indications were good bone quality (Dorr type A or B) [13] and Crowe class I, II, or III (0%-100% subluxation of the hip) [14]. Patients with poor bone quality (Dorr type C) were excluded because of the need for use of cement. Patients with Crowe class IV (>100% subluxation of the hip) were excluded because of the need for subtrochanteric osteotomy to be included in the surgery. Each patient was randomly assigned into the hand-rasping or robotic milling group. The patients' demographics are given in Table 1. The robotic milling group comprised 73 patients who underwent 78 primary THAs using the 2-pin–based procedure of the ROBODOC system. The diagnoses of the robotic milling group were as follows: degenerative arthritis secondary to hip dysplasia in 74 hips, osteonecrosis in 3 hips, and rheumatoid arthritis in 1 hip. The hand-rasping group comprised 67 patients who underwent 78 primary THAs. The diagnoses of the hand-rasping group were as follows: degenerative arthritis secondary to hip dysplasia in 73 hips, osteonecrosis in 4 hips, and rheumatoid arthritis in 2 hips. There was no significant difference in age (Mann-Whitney *U* test) or sex ratio (χ^2 test) between the 2 groups. This study was approved by the Institutional Internal Clinical Research Committees of our 2 institutions. Informed consent was obtained from all patients after the nature of the procedure had been fully explained.

Table 1. Demographics of Patients Used for Comparison

	No. of Patients (Femora)	Sex (Male/Female)	Age (y)*
Robotic milling group	73 (78)	14: 64†	58 (27-81)‡
Hand-rasping group	67 (78)	14: 64†	58 (29-77)‡

*Values represent average (range).
†Difference was not statistically significant (χ^2 test).
‡Difference was not statistically significant (Mann-Whitney *U* test).

All THAs were performed via the posterolateral approach, with the patient in the lateral decubitus position. VerSys fiber metal taper hydroxyapatite-coated femoral stems (Zimmer, Warsaw, Ind) were used in all THAs. The VerSys fiber metal taper femoral stem is a straight stem, with a symmetry plane that contains the femoral stem axis and the neck axis. The femoral stem has 2 variations in the proximal metaphysis: standard and large metaphysis.

In the robotic milling group, CT images of the femur were taken after 1 locator pin was inserted into the greater trochanter of the affected femur and the other locator pin was inserted into the lateral condyle. Three-dimensional preoperative planning (described hereinafter) was performed based on the CT data on the ORTHODOC, and the milling path was transferred to the robot controller. Intraoperatively, the 2 groups had the same length of skin incision for the hip (12-15 cm), except for the extra skin incision for the knee pin. After the leg was secured in the leg holder and the femur was rigidly attached to the robot base with the femoral external fixator, intraoperative pin-based registration using the 2 locator pins was performed. The robot milled the inside of the femoral canal according to the preoperative plan. Surgeons inserted and impacted the femoral stem manually.

In the hand-rasping group, CT images of the femur were taken preoperatively. The CT data were transferred to the ORTHODOC, which was used for the 3-dimensional preoperative planning described below. After surgeons obtained information about the position and size of the femoral stem, the femur was prepared using a handheld rasp. Surgeons inserted and impacted the femoral stem manually.

Three-dimensional preoperative planning in the 2 groups was performed as follows [15,16]. Because 3 arbitrarily selected orthogonal planner reconstructed images of the CT data could be displayed on ORTHODOC, the center of the femoral head was at first located using a circle drawing tool to encompass the femoral head contour. The femur was reoriented on the workstation to obtain the