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Accurate Implant Placement in THA Using Three-dimensional Printed Custom-made Acetabular Component for Massive Defects

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Abstract

The development of 3D printing technology has had a significant impact on the medical field. This technology has made it possible to create custom-made implants that can be flexibly adapted to the bone defects of individual patients. In this study, total hip arthroplasty (THA) using the custom-made implant developed in Japan, was reviewed in patients with severe acetabular bone defects. The accuracy of each implant placement was examined.

We retrospectively studied 10 patients who underwent THA with T-REX® (Teijin Nakashima Medical) at our institution between 2020 and 2022. A 3D pelvic model of each patient was created based on preoperative computed tomography (CT) data. The 3D CAD system was used to preoperatively plan the construction of an augmentation and a flange, where necessary. A pelvic model and an implant copy made to the same shape as the custom-made implant were used as a patient-specific guide. Postoperative CT data confirmed implant placement and determined alignment errors.

The absolute errors of implant alignment were 3.92 degrees for inclination, 1.81 degrees for anteversion, and 5.48 degrees for rotation. Absolute errors of 1.87 mm in the internal/external direction, 1.55 mm in the anteroposterior direction, and 1.10 mm in the vertical direction were also observed.

In conclusion, T-REX® implants can be accurately placed during THA in cases with severe acetabular bone defects. These implants can be expected to provide firm initial fixation by taking advantage of the flexibility in their design, making them a useful treatment option for patients.

1 Introduction

In total hip arthroplasty (THA), whether primary or revision surgery, significant bone defects in the acetabulum make the placement of the acetabular component challenging. Such cases have been resolved by reinforcing the defect with bone grafts or a support ring, or high placement of the acetabular component 1)-3). However, these treatments have their own limitations, including mechanical failure of the grafted bone, bony impingement and biomechanical problems from high placement of acetabular component 1)-2), and complicated support ring procedures and breakage problems 3). Sturdy spacing with metal augmentation was developed to replace bone grafts and the advent of 3D printing has made it possible to create custom-made implants that can be flexibly adapted to the bone defects of individual patients. The development of these custom-made implants has taken place all over the world, including in Japan. In this study, the accuracy of implant placement was examined in patients with severe acetabular bone defects who underwent THA using the T-REX® (Teijin Nakashima Medical Ltd. Japan), a custom-made implant developed in Japan.

2 Study Design & Methods

We performed a retrospective study involving 10 patients (4 males and 6 females; mean age at surgery, 73.8 [57-87] years) who underwent primary and revision THA with T-REX® at our institution between October 2020 and July 2022. The diagnoses of the patients included three hips with high dislocation, three hips with periprosthetic infection, and four hips with aseptic loosening. Acetabular defects were Paprosky type IIB in three hips, IIIA in five hips, and IIIB in two hips [4). Primary THA was performed on three patients and revision THA on seven patients. A 3D pelvic model of each patient was created by segmentation using Mimics (Materialise, Belgium) based on preoperative computed tomography (CT) data. Preoperative detailed planning was performed using the 3D CAD system SolidWorks (Dassault Systèmes SolidWorks Corporation, France) to construct an augmentation to fill the acetabular defect, as well as a flange if necessary. A custom-made implant was designed and fabricated using 3D additive manufacturing technology. A pelvic model and an implant copy made to the same shape as the custom-made implant were prepared for use as a patient-specific guide and used intraoperatively to confirm the implant alignment and position (Figure 1). To be sure, the position of the placement was also checked using CT-based navigation. A 3D model of each pelvis and implant was constructed using CT data acquired postoperatively. The bilateral superior anterior iliac spine, pubic tuberosity, and superior posterior iliac spine were superimposed on the preoperative 3D model to verify the accuracy of the implant alignment (inclination, anteversion, rotation) and placement position (internal and external, anteroposterior, and perspective directions) errors [5).

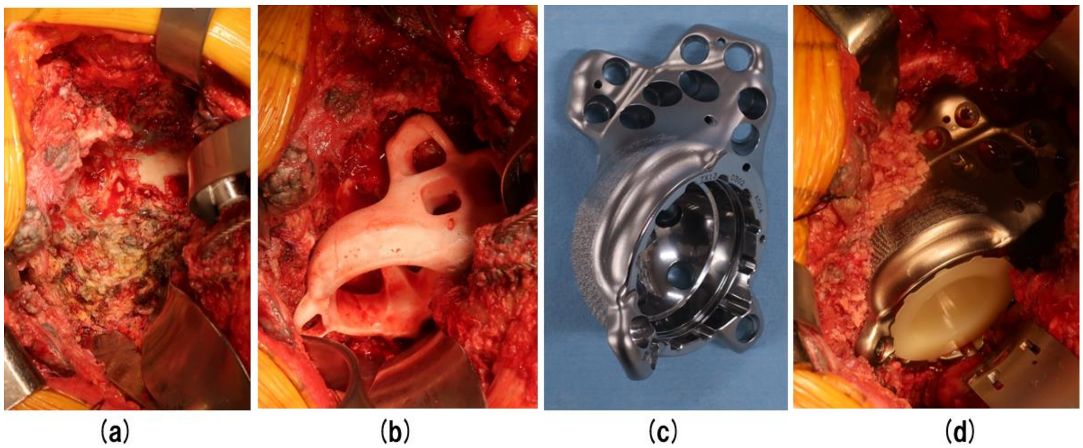

Figure 1: a: Severe bone defect. b: Implant trial (used as a patient-specific guide). C: T-REX.d: After replacement.

3 Results

Evaluation of each installation alignment compared to its preoperative plan showed an average of 42.1 (34.9-48.4) degrees for inclination, with a mean absolute error of 3.92 ± 2.40 degrees, and an average of 20.1 degrees for anteversion, with a mean absolute error of 1.81 ± 1.34 degrees. Inclination and anteversion were within 3 degrees in three cases (30%) and within 5 degrees in six cases (60%) of the intended alignment. Rotation error was larger than 18 degrees in one case; in the remaining nine cases the error was within 7 degrees. The overall absolute error in rotation was relatively large at 5.48 ± 4.89 degrees from the preoperative plan.

In the evaluation of placement position error, it was possible to place the implants within 5 mm of the planned position in all cases and within 3 mm in six cases (60%). Absolute errors of 1.87 ± 0.94 mm in the internal/external direction, 1.55 ± 0.98 mm in the anteroposterior direction, and 1.10 ± 0.77 mm in the vertical direction were observed (Figure 2).

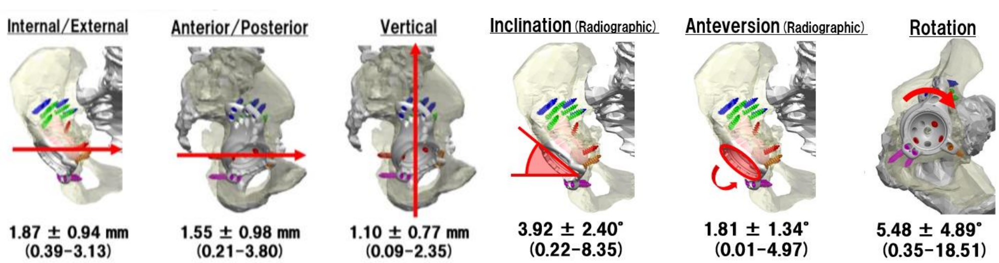

Figure 2: Absolute errors of implant position and alignment.

4 Discussion and Conclusions

Consensus on the treatment method for reconstruction of high acetabular bone defects has not been reached. Custom-made implants, such as the T-REX®, allow for implant design that is personalized to the individual bone defect that would otherwise be difficult to reconstruct with conventional implants. Thus, these implants can be expected to provide strong initial fixation. There are some reports that it is difficult to accurately place an acetabular component without using a navigation system for patients with significant bone loss, such as Paprosky IIIB [6)]. In this study, accurate placement and alignment were achieved by using an implant copy with a flange as a patient-specific guide. This accuracy was comparable to previous reports of accuracy verification with various navigation and patient-specific guides [7)-9)]. However, the shape of the acetabulum defect, implant design, and CT artifacts may cause errors in placement accuracy and further study is needed. In addition, inadequate fitting throughout the shell and augmentation area can lead to errors in both position and alignment, so it is important to ensure adequate visualization of the entire acetabulum. The clinical significance of the rotation of acetabular implants has not been evaluated, yet because of their specific shape, rotation errors can lead to augment maladjustment. However, there are some reports that indicate that custom-made implants with a rotation error of more than 10 degrees are not clinically problematic. In the present study, one case had a large error, but the other cases showed errors of less than 7 degrees. No clinical problems were observed in any of the cases. Evidently the clinical impact of rotation error must still be evaluated.

This study showed that the T-REX®, a custom-made implant, is a viable treatment option for individuals with significant acetabular bone defects given that it can be accurately placed during THA and can provide firm initial fixation by taking advantage of its flexibility in design. However, further study is required for the long-term evaluation of bone reaction and fixation around implants and clinical results, as well as for the evaluation of production duration and cost. We believe that these issues will be resolved as data from more cases accumulates.

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