CT-based navigation for curved periacetabular osteotomy

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Rotational acetabular osteotomy (RAO), in which the acetabulum was exposed and osteotomized through the lateral approach by dissecting the hip abductor muscles, was a gold standard of the bone cartilage preserving surgery for Japanese patients suffering from developing dysplasia of hip joints (DDH). This RAO requires long term (over 6 months) rehabilitation to return to the daily activities because the hip abductor muscles are partially injured by detaching from the outer table of the pelvis. Patients who undergo curved periacetabular osteotomy (CPO) can return to their social activities within two months because the acetabulum is osteotomized from the inside of the pelvis without dissecting the hip abductor muscles. However, it is not easy to osteotomize the pelvis from the inner table of the pelvis without direct view of the hip joint. The OrthoMAP 3D® (Stryker, US) is a universal CT-based navigation system for orthopedic surgeries such as osteotomies, tumor extirpations, and anterior cruciate ligament reconstructions. We can use conventional surgical tools by attaching the active reference trackers by using of the universal attachments. Here, we introduced the CT-based navigation assisted CPO using the OrthoMAP 3D®.

In the pre-operative planning, we placed a spherical computer aided design (CAD) model of 85 to 90 mm in diameter on the pelvis to cross the landmarks (just above the anterior inferior iliac spine, just beneath the infra-cotyloid notch, and the base of the pubic bone) for the pelvic osteotomy line. We placed the osteotomy line at over 15 mm anterior to the sciatic notch to avoid sciatic nerve injuries. In our preoperative planning, the center of the spherical CAD was eventually set at anterior and lateral position from the center of the femoral head.

We used the surface matching procedure or the 3D-3D matching method for registration in this navigation system. For the surface matching registration, we palpated the inner table of the pelvis around the pelvic brim including the superior part of the quadri-lateral space. Our basic study using a pelvic plastic model indicated that the error of distance in our surface matching registration for CPO was less than 1.5 mm. For the 3D-3D registration, we used a flat panel C-arm, Vision2 Vario 3D (Ziehm, Germany). We took intraoperative 3D images around the osteotomy site. Using the OrthoMAP 3D®, these 3D images were semi-automatically matched to the patients' 3D pelvic models created based on the preoperative pelvic CT images. We checked the distance errors between the actual bone surfaces and the 3D pelvic models in the verification view of the OrthoMAP 3D® by palpating the inner pelvic surfaces. The accuracy of this registration was revealed to be clinically acceptable.

The tips of the curved chisels, on which active reference trackers were attached, were shown as crossing points of lines in the monitor of the OrthoMAP 3D®. We could control the position of chisel during osteotomy by tracking these tips of the chisels. Using a special trocar with the active references, we could insert guide wires for the absorbable screws to fix the rotated osteomized acetabular fragments. By this procedure, we could not only shorten the time of screw insertion, but also insert the screws in an optimum position to firmly fix the osteotomized acetabulum.

We compared operative time and intraoperative blood loss between the CPO cases with navigation using the OrthoMAP 3D® (7 joints, 7 female, average age: 32.7 y.o.) and the CPO cases without navigation (7 joints, 1 male, 6 female, average age: 36.3 y.o). Since we could control the insertion positions of chisels and screws, both the operative time and the intra-operative blood loss decreased in the CPO with CT-based navigation (with navigation: operative time; 98.0±17.5 min, intra-operative blood loss; 872.9±424.1 mL, without navigation: operative time; 104.3±9.5 min, intra-operative blood loss; 1520.7±1063.8 mL). From these results, the OrthoMAP 3D® is a powerful tool to achieve safe and successful CPO for the Japanese patients with DDH.

In this navigation system, we cannot measure rotation angles or acetabular coverage in the pre-, intra- and post-operative images. To track the actual position of the rotated acetabular fragment is the most important issue to improve the navigation system for CPO. We need some modifications in this OrthoMAP 3D® to add quantitative applications in the pre, intra-, and post-operative images.