Effect of periacetabular osteotomy on stress distribution of the knee joint

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INTRODUCTION: Developmental dysplasia of the hip (DDH) is a common cause of secondary osteoarthritis of the hip. Acetabular dysplasia causes high loading stress concentration in the joint, associated with femoral head instability and subluxation. A recent study showed that the prevalence of knee osteoarthritis (OA) and lower-limb malalignment on the ipsilateral side of hip OA varies between primary hip OA and DDH-OA [1]. Eccentric rotational acetabular osteotomy (ERAO), one of the peri-acetabular osteotomies for DDH, has reported good results and may reduce articular cartilage contact stress in the hip through distal and medialization of the bone head [2]. We have recently reported that loading was altered by ERAO to be more similar to physiological loading [3], using computed tomography osteoabsorptiometry (CT-OAM). This method was developed to measure subchondral bone density as a surrogate for cumulative stress and loading abnormalities [4]. Hence, we hypothesize that 1) DDH has different loading environments in both the knee and hip joints and 2) ERAO could alter these loading environments to resemble physiological loading. The purpose of this study is to investigate the effect of ERAO on knee joints by evaluating changes in bone mineral density distribution in the subchondral bone before and after ERAO using the CT-OAM method.

METHODS: This study was approved by an Ethics Committee.The study included 28 patients (mean age 31.6 ± 12.2 years) who underwent ERAO at our hospital between 2015 and 2021, excluding bilateral cases, in the ERAO group, and 25 patients (mean age 44.6 ± 15.0 years) who underwent surgery for unilateral idiopathic osteonecrosis of the femoral head (ONFH) in the same period in the control group. We retrospectively collected radiological and computed tomography data from the knee ipsilateral to the surgical side in the ERAO group and the knee unaffected side of ONFH. Data from the ERAO group were collected before and approximately one year postoperatively. Measurements included the distance of femoral head displacement, acetabular roof obliquity (ARO), and mechanical axis (MA%); the latter defined as the point where the line crosses the tibial plateau, with the medial side of the tibial plateau set at 0%. Subchondral bone density of the articular surface of the proximal tibia was measured by CT-OAM to calculate the high bone density area (HDA), defined as the area where the HU values are in the top 20% of Hounsfield units from the total area of the medial and lateral articular surface. The ratio of HDA of the medial articular surface to the total medial and lateral articular surfaces (Medial ratio), and the percentage of HDA in each region divided into six equal parts from the articular surface from medial to lateral (MM, MC, ML, LM, LC, and LL from the medial to the lateral) were calculated (Figure 1, 2).

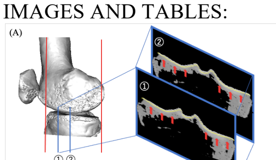
RESULTS SECTION: ERAO resulted in distal and medial displacement of the femoral head (distalization 1.9±2.5mm, medialization 2.0±3.1mm, p<0.01) and improved coverage (ARO pre-operation 20.3±7.3°, post-operation -3.4±7.8°, p<0.01). MA% did not change significantly before and after surgery (45.8±10.5% pre-operation, 43.6±16.2% post-operation, p=0.83), and there was no significant change between the pre-operation and control groups (42.2±12.7%, p=0.93). In CT-OAM, the Medial ratio was significantly lower in the ERAO group pre-operation than in the control group (50.6±20.5% pre-operation, 61.5±18.2% control, p=0.04), and significantly increased to 56.0±19.5% after ERAO surgery (p<0.01). The change in Medial ratio was significantly correlated with the change in ARO (r=0.39, p=0.03). Additionally, HDA in the LC region decreased significantly before and after surgery (31.1±16% pre-operation, 26.5±13.6% post-operation, p=0.02) (Table 1).

DISCUSSION: This study has found that ERAO can alter the loading stress distribution of the knee joint, even though ERAO does not change the lower extremity load axis since it involves only acetabulum osteotomy. Untreated DDH has been reported to contribute to external knee deformity, as the lateral deviation of the femoral head results in a lateral deviation of the load axis [1][5]. The relationship between the degree of correction and the change in stress distribution suggests that appropriate correction may not only normalize the loading stress distribution at the hip joint but may also prevent future deformity of the knee joint and lateral-type osteoarthritis of the knee joint.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): The loading stress distribution of the knee joint was significantly changed by ERAO for DDH.

REFERENCES: [1] Sato R et al. Mod Rheumatol 2021 [2] Yukiharu Hasegawa et al. J Bone Joint Surg 2014 [3] Shimizu et al. JOR 2022 [4] Muller-Gerbl M et al. Skeletal Radiol 1989 [5] Qiwei Li et al. Knee 2014

IMAGES AND TABLES:



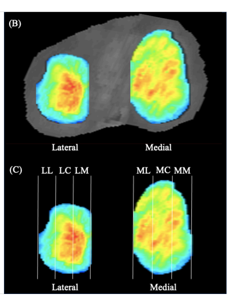


Figure1. (A,B) The image shows identification of the subchondral bone regions of the proximal tibia using a customized software. In each coronal slice, we measured the Hounsfield units of radiograph absorption in the subchondral bone at each coordinate point in 1 mm intervals.
(C) The image shows segments used for quantitative analysis of the bone density mapping data for the proximal tibia. Both the medial and lateral compartments of the tibial articular surface were divided into three subregions each from medial to lateral. LL: lateral lateral, LC: lateral central, LM: lateral medial, ML: medial lateral, MC: medial central, MM: medial medial.

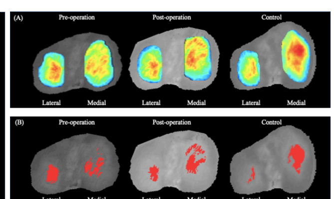


Figure2. (A)The images show the distribution of bone density values across the proximal tibia surface at pre-operation and approximately 1 year after periacetabular osteotomy.
(B) The images show distribution of high-density area (HDA) of proximal tibia articular surface. HDA was defined as the area where the HU values are in the top 20% of Housefield units out of the total area of the medial and lateral articular surface.

Table1. Subregional analysis of percentage HDA (%)

		ERAO group		P value	
Subregion	Control	Pre-operation	Post-operation	Pre-operation vs Control	Pre to post-operation change
MM	10.2 (7.3)	11.0 (8.1)	10.1 (8.6)	.730	.603
MC	38.0 (12.3)	31.9 (15.9)	33.6 (13.3)	.131	.399
ML	21.0 (10.5)	18.4 (12.8)	21.5 (15.8)	.419	.206
LM	23.3 (11.0)	21.2 (10.5)	17.2 (11.2)	.493	.068
LC	17.4 (11.0)	31.1 (16.0)	26.5 (13.6)	**<.001**	**.024**
LL	2.3 (7.6)	7.3 (11.1)	5.4 (7.5)	.060	.289
Medial ratio	61.5 (18.2)	50.6 (20.5)	56.0 (19.5)	**.047**	**.005**

※Data are reported as mean (standard deviation). HDA, high-density area (i.e., 20% highest area in Hounsfield units out of the sum of the medial and lateral articular surface). ERAO, eccentric rotational acetabular osteotomy. Medial ratio: the ratio of HDA of the medial articular surface to the total medial and lateral articular surfaces .

Pre-operation (before ERAO) and post-operation (approximal 1 year after ERAO).

Subregion: regions divided into six equal parts from the articular surface from medial to lateral (MM: medial medial, MC: medial central, ML: medial lateral, LM: lateral medial, LC: lateral central, LL: lateral lateral)