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Radiographic analysis of the restoration of hip joint following open reduction and internal fixation of acetabular fractures: A retrospective cohort study

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ABSTRACT

Background: Acetabular fracture remains as a major challenge to orthopaedic surgeons despite of decades of improvement in its operative management. Unfavorable reduction is considered one of the key factors leading to joint degeneration and compromised clinical outcome in acetabular fracture patients. Besides the columns, walls, and superior dome, the postoperative position of hip joint center (HJC), which is reported to affect hip biomechanics, should be considered during the assessment of quality of reduction. Objectives: In this study, we aimed to quantify the postoperative shift of HJC radiographically, and to evaluate the relationship between the shift of HJC and the quality of fracture reduction following ORIF of acetabular fractures. Material and Methods: Patients with a displaced acetabular fracture that received open reduction and internal fixation in the authors' institution during the past three years were identified from the trauma database. The horizontal and vertical shifts of HJC were measured in the standard anteroposterior view radiographs taken postoperatively. The radiographic quality of fracture reduction was graded according to Matta's criteria. The relationships between the shift of HJC and the other variables were evaluated. Results: Totally 95 patients with 36 elementary and 59 associated-type acetabular fractures were included, wherein the majority showed a medial (92.0%) and proximal (94.0%) shift of HJC postoperatively. An average of 2.9 mm horizontal and 2.3 mm vertical shift of HJC were observed, which correlated significantly with the quality of fracture reduction ($P < 0.001$ for both). The horizontal shift of HJC correlated with the fracture type ($P = 0.022$). Conclusion: The restoration of HJC correlates with the quality of reduction in acetabular fractures following open reduction and internal fixation. Further studies are required to address the effects of HJC shift on the biomechanical changes and clinical outcomes of hip joint, especially in poorly reduced acetabular fractures.

KEYWORDS	Acetabular fracture, Open reduction and internal fixation, Hip joint center, Radiography

Introduction:

Acetabular fractures are becoming more common in older patients and a recent study reported a 2.4-fold increase in their incidence.[1] The mean age of patients being treated for an acetabular fracture also seems to be rising.[2] In younger patients, long-term results for the treatment of acetabular fractures are available[3,4] and factors associated with a favourable outcome and the indications for treatment are now well accepted.[5-7]

Acetabular fracture remains as a major challenge to orthopaedic surgeons despite of decades of improvement in its operative management. Following well-planned open reduction and internal fixation (ORIF), a good to excellent result can be estimated in a large part of the patients with acetabular fractures. Meanwhile, the complication rate is still high, which leads to poor long-term outcomes in approximately 20% of the patients.[8,9]

Post-traumatic osteoarthritis, usually accompanied with loss of hip motion and increase of pain, has been considered one of the most common complications associated with compromised outcomes in acetabular fractures.[10] It's generally accepted that biomechanical alterations in hip joint, caused by an unfavorable fracture reduction, play undoubtable roles in the development of arthritis. In previous studies, special emphases were placed to analyze the changes of intraarticular contact characteristics and the loss of stability after acetabular fractures.[11,12]

The hip joint center (HJC), also known as the rotation center of hip joint, is considered crucial for the biomechanical reconstruction of the hip joint during total hip arthroplasty (THA) and revision surgeries.[13,14] When an acetabular fracture occurs, it's not rare that the position of HJC will change following the destruction of acetabulum and innominate bone. Since an unfavorable position of HJC was reported to cause increased hip load, compromised soft tissue balancing, and even gait changes[15,16], it might contribute to the development of post-traumatic arthritis in patients with acetabular fractures as well. Currently, the postoperative assessment of fracture reduction focuses on the residual displacement of columns, walls, and the superior dome.[17,18] A clearer understanding of the restoration of postoperative HJC in acetabular fractures, which was merely addressed previously, might shed lights on further optimization of the surgical management.

Aims and objectives:
In this study, we aimed to quantify the postoperative shift of HJC radiographically, and to evaluate the relationship between the shift of HJC and the quality of fracture reduction following ORIF of acetabular fractures.

Material and methods:
We retrospectively reviewed the patients with acetabular fractures that were recorded in the trauma database in the orthopaedics department of *Shri Guru Ram Rai Institute of Medical and Health Sciences (SGRRIM &HS), Dehradun*. The patients were admitted through emergency department or referred from other hospitals. Totally 101 displaced fractures (95 patients) were considered not fitted for Matta's criteria of nonoperative treatment[19], and then received ORIF between January 2014 and December 2014. Of these reviewed cases, we included those with a full series of standard radiographs, including pre- and postoperative anteroposterior (AP), iliac oblique and obturator oblique Judet views, as well as preoperative computed tomography (CT) scan of the pelvis. Patients with bilateral acetabular fracture, associated fractures of ipsilateral femoral head, fracture of pelvic ring, or those operated on more than two weeks after injury were excluded. The study protocol was approved by the Medical Ethics Committee of *Shri Guru Ram Rai Institute of Medical and Health Sciences (SGRRIM &HS), Dehradun.*

Surgical approaches including Kocher-Langenbeck, ilioinguinal, combined or extensile approaches were determined by the fracture pattern to facilitate reduction and fixation of the innominate bone and the articular surface of acetabulum. Definitive fixation was applied with reconstructive plates and screws to stabilize the fracture according to the standard techniques recommended by Letournel[20].

Radiographic examination was performed right after the removal of drainage (usually 48 to 72 hours) postoperatively. Standard AP radiograph of the pelvis were taken with the patients placed supine and their feet in a standard position to minimize the effect of rotation of the hip joint. To evaluate the restoration of the HJC following ORIF, we measured the vertical and horizontal shifts of the postoperative center of femoral head from the estimated center of femoral head referring to the contralateral intact hip joint

Analysis of the data was performed using proportions and frequencies for categorical variables and means along with CIs and ranges for continuous variables. Means were weighted for sample size, and statistical comparisons between the different treatment modalities were performed where appropriate using Students *t*-test. Odds ratios (OR) with 95% confidence intervals for binary outcomes were calculated and compared with Fisher's exact test. Analysis was conducted with SPSS version 17.0, and a p-value of < 0.05 was considered statistically significant.

Results:
Totally 95 patients (101 fractures) with an average age of 42.5 years (range 18 to 75 years) were included in this investigation, consisted of 62 male and 33 female patients. According to the Letournel and Judet's classification, there were 46 elementary and 55 associated-type fractures identified in preoperative radiographs and CT images. According to our surgical records, the mean length of surgery for all the patients was 220.8 minutes (range 90 to 440 minutes), while significant difference was detected among different fracture types (one-way ANOVA, $P < 0.001$). Comparing the use of different surgical approaches, the length of surgery also varied significantly (one-way ANOVA, $P < 0.001$).

The mean horizontal and vertical shifts (X and Y) of the postoperative HJC were 2.9 mm (range 0.9 to 10.6 mm) and 2.3 mm (range 0.9 to 7.8 mm) respectively, while X showed statistically significant correlation with the fracture type ($P = 0.022$). Besides, no correlation was found between the shift of HJC and the surgical approaches. A high inter observer reliability was testified with the ICC of X and Y was 0.88 and 0.81 respectively. Considering the direction of the shift, 93 cases (92.0%) showed a medial shift of postoperative HJC, while 95 (94.0%) of the vertical shift was proximal.

The quality of fracture reduction was graded radiographically as anatomical in 70 cases, imperfect in 21 cases, and poor in 10 cases, which correlated with the type of fracture classified as elementary or associated-type (chi square = 6.689, $P = 0.035$).

Discussion:
To recover a functional and pain-free hip is the main goal in the treatment of acetabular fracture. Among the identified poor prognostic factors, unfavorable fracture reduction is considered the most important one leading to biomechanical alteration and accelerated degenerative changes in hip joint[21,22]. Previously, the restoration of HJC was merely investigated during the postoperative assessments of the quality of reduction in acetabular fractures. In this study, prior to further biomechanical investigation and clinical follow-up studies, we examined the radiographic restoration of HJC following ORIF of acetabular fracture. The results showed a 2.9 mm horizontal shift and a 2.3 mm vertical shift of postoperative HJC in average, which correlated with the radiographically graded quality of fracture reduction.

The biomechanical importance of an anatomically restored HJC has been widely investigated in THA and revision surgeries. Superior or lateral displacement of HJC, causing a decreased moment arm of abductor muscles, was testified to generate increased hip load during gait cycles and lead to higher rate of implant wear and loosening in THA[23-25]. Using mathematical models, Bicanic reported a 0.7% or 0.1% increase of hip load respectively, following every millimeter of lateral or proximal shift of HJC[16]. Similar in the opposite way, the hip load would decrease when the HJC shifted medially or distally. Considering an acetabular fracture, the alteration of the loading pattern was believed to be more complicated[11]. In our study, the majority of the cases presented varying degrees of medial and proximal shifts of HJC. It's hard, therefore, to clarify the changes of hip load caused by the shifted position of HJC in our study, unless further biomechanical studies could be conducted.

Besides the hip load, a shifted HJC may also lead to the changes of surrounding muscle forces in order to balance the moment of body weight. Delp observed a 44% decrease of abduction force and a 27% decrease of flexion force following 2 cm proximal shift of HJC[26]. A 2 cm medial shift of HJC, in the same study, was testified to reduce 26% of the adduction force. In our study, again, the mean values of postoperative HJC shifts were relatively small compared to a 2 cm scale. Therefore the potential contribution of the shifted HJC to the subsequent muscle imbalance and gait changes might be trivial.

However, future studies using experimental or computer models would be needed to provide direct evidence for this hypothesis. Radiographic criteria suggested by Matta are generally used to evaluate the quality of fracture reduction[18]. In our study, an anatomical reduction was achieved in 80.0% of the elementary fractures and in 55.5% of the associated fractures, while the rate of poor reduction was 3.6% and 11.3% respectively. These were comparable with the results of the other studies[27]. An important finding of our study was that the postoperative shifts of HJC were correlated with the quality of fracture reduction. This was reasonable since anatomical reduction would theoretically lead to an ideal restoration of HJC, while a poorly reduced fracture might leave residual displacements of columns and/or walls to hinder the restoration of HJC. Based on this finding, the quality of fracture reduction graded using Matta' criteria might imply the status of HJC restoration. An anatomical fracture reduction, therefore, should be aimed and checked intraoperatively to restore an optimal HJC. In this study, the horizontal shift of HJC was found to be correlated with the fracture types. This reflected the clinical reality that an associated-type or so-called complex acetabular fracture would lead to an increased duration of surgery, a decreased quality of fracture reduction, and a higher value of horizontal shift of HJC. Specifically, patients with a both-column or T-shape type of fracture presented highest value of horizontal shift of HJC. Meanwhile, the highest rate of poor functional outcome, as reported by Briffa's, was observed in the patients with a posterior column, posterior column and posterior wall, or posterior wall type of fracture[4]. This inconsistency between the radiographic and functional evaluations was also reported by Magill previously[28]. As a potential influencing factor for the horizontal shift of HJC, the displacement of the quadrilateral plate was not analyzed in this study because it's not specifically considered in the Matta's grading system.

Various methods have been reported to determine the anatomical HJC on two-dimensional pelvic radiographs. Anatomical landmarks like teardrops, Shenton's line, Köhler's line, and inter-sacroiliac line were used by different investigators, while the HJC was testified to be most precisely determined referring to the teardrops[29]. However, in our pilot study, the ipsilateral teardrop could only be precisely identified in less than 20% of the postoperative pelvic radiographs due to fracture disruption or implant obstruction. Therefore we used the contralateral intact acetabulum and femoral head as mirrored template to determine the estimated HJC. Similar methods were reported previously in other studies, showing acceptable accuracy and repeatability[30].

Conclusion:

In conclusion, varying degrees of medial and proximal shifts of HJC were observed in the majority of the acetabular fractures following ORIF. The postoperative restoration of HJC showed significant correlation with the quality of fracture reduction. A perfect fracture reduction should be aimed to achieve appropriate HJC restoration. Further studies are required to address the effects of HJC shift on the biomechanical changes and clinical outcomes of hip joint, especially in poorly reduced acetabular fractures.

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