

Characteristics and Clinical Significance of Dome Impaction in Acetabular Fractures

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Research article

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Abstract

Objective

This study aimed to explore the characteristics of acetabular dome impaction fractures (ADIF) and evaluate the clinical outcomes.

Methods

Twenty-two ADIF treated by single surgeon were analyzed. The location and size of impaction was measured through Mimics. Patients' demographic, characteristic data, surgical data and clinical outcomes were collected. The quality of reduction was assessed using criteria described by Matta. Functional outcomes were evaluated using modified Merle d'Aubigné score and SF-36.

Results

40.91% of the ADIF located at the posterosuperior quadrant, 36.36% of the ADIF located at anterosuperior quadrant, 22.73% of the ADIF involved both areas. The average impacted size was $467.24 \pm 308.25 \text{mm}^2$. The average percent of the impacted was $17.18 \pm 8.94\%$ (impaction size/ lunar surfaces). At the final follow-up, the rate of excellent and good outcome per Matta's radiographic grading was 77.27%. The modified Merle d'Aubigné score graded as excellent in 5 (22.73%), good in 10 (45.45%), fair in 5 (22.73%), and poor in 2 (9.09%). The mean score of SF-36 was 76.76 ± 20.18 . Avascular necrosis (AVN) developed in two patients. Heterotopic ossification (HO) developed in one patient. Sciatic nerve injury developed in one patient. Arthritis developed in one patient.

Conclusions

The ADIF can locate at the posterosuperior quadrant, the anterosuperior quadrant or involved both areas. Understanding the characteristics of the dome impaction can aid surgeons during reduction and fixation. Meanwhile, good to excellent outcomes and a high degree of patient satisfaction can be achieved in majority of the patients.

Introduction

Traditionally, acetabular fractures have been associated with high energy trauma in younger patients. However, with the increasing prevalence of osteoporosis amongst an ageing population, low energy acetabular fractures in the elderly are likely to become ever more predominant [8]. The ADIF which was usually called the gull-wing sign is frequently encountered in the elderly population with poor bone quality. The gull-wing sign was first described in 1965 by Berkebile et al. [1] It describes the appearance of a posterior fracture-dislocation of the hip on the lateral view. The posteriorly displaced fragment of the acetabulum combines with the rest of the acetabulum to create a double curved shadow which resembles the silhouette of a flying seagull [21]. An influential article described that the notorious gull-wing sign is a medially displaced fracture of the acetabular roof where the medially displaced fragment

of the acetabulum and the lateral part together also form a seagull outline on a plain AP radiograph[12]. Traditionally, the fracture including this characteristic represents a less reliable outcome from fixation alone.[5; 12] This fracture pattern was defined by Theodoros H. Tosounidis as an anterior column fracture without involvement of the pelvic brim according to the 2-column concept, which was contradictory to the description of the Judet-Letournel classification superomedial impaction of the anterior dome is a risk factor for poor outcome in elderly patients[12; 22].

However, all the study described the ADIF and evaluated the clinical outcomes of the gull-wing sign or ADIF only in the plain X-ray[8; 10; 24]. Thus, the exact location, the characteristics and the outcomes are controversial[10; 15; 24]. Meanwhile, the location of dome impaction determined the ability of the surgeon to access and reduce the fragment under direct visualization during surgery. To the best of our knowledge, current study is the first one to explore characteristics of the lesion based on the CT[24]. The purpose of this article is to explore the characteristics of ADIF and evaluate the clinical outcomes based on the CT scan and 3D reconstruction.

Materials And Methods

We retrospectively analyzed a series of 228 consecutive patients treated by a single surgeon(ZY) from Jan 2014 and Jan 2018. Inclusion criteria were as follows: (1) age >18 years; (2) acetabular dome impaction fractures (3) complete clinical data and imaging information, including X-ray and CT data. Exclusion criteria included: (1) incomplete clinical information; (2) poor quality of X-ray and CT data. Demographic information such as gender, age, mechanism of injury, associated injuries, fracture classification, surgical related data was recorded. According to the Letournel-Judet classification, the fractures were classified into five elementary patterns and five associated patterns by the senior orthopaedic traumatologists (YZ and KZ). Meanwhile, the dome impaction was identified by them through the AP view of the pelvis. If the agreement was not achieved, the third senior surgeon (XW, 20-year experience in pelvic and acetabular surgery) was consulted. All measurements were performed by two orthopedists at intervals of two weeks. The radiographic and functional outcomes were evaluated by two orthopaedic traumatologists (XW and HW) who were not involved in the surgeries. The quality of the reduction was graded as anatomical (0-1mm displacement), imperfect (2-3mm displacement), or poor (more than 3mm displacement) based on Matta's criteria[19]. The clinical outcomes were evaluated using the modified Merle d'Aubigné score [19]. The patients were categorized as excellent (18 points), good (15–17 points), fair (13–14 points), or poor (<13 points). At final follow-up, the radiographs were utilized to evaluate the heterotopic ossification (HO) (Brooker classification[3]), osteoarthritis (Kellgren-Lawrence classification[14]) and avascular necrosis (AVN)(Ficat/Arlet classification[9])

Location and measurement

The data of computer tomography were obtained in the Digital Imaging and Communications in Medicine (DICOM) format from our radiology database and then imported into the MIMICS19.0 (Materialise, Belgium). The pelvic position was corrected to the standard lateral decubitus. The bilateral femoral head

was removed from the 3D-CT reconstruction. Acetabular abduction angle and anteversion angle were eliminated through controlling the rotation of the pelvis before measurement. The acetabulum was divided into 4 quadrants by the midperpendicular of the acetabular notch and their bisector across the acetabulum. The dome impaction fragment was located by selecting all axial and coronal computed tomography sections[2; 13]. The 3D reconstruction was converted by 3-Matic 12.0 materialise, Belgium. The area of acetabular dome impaction was located. The normal size of acetabulum, the normal size of the lunar surface, the impacted size and percent of the impaction area were measured. When measuring the normal size of acetabulum and normal size of acetabular lunar surface, a mirror of the uninjured, contralateral acetabulum was used.

Results

Demographic characteristics

Twenty-two patients were included in the study and had an average age of 58.91 ± 13.68 years (range; 30–85), with 14 males and 8 female participants. Average follow-up was 28 ± 4.5 months. Patient characteristics, fracture pattern and mechanism of injury are shown in **Table 1**. Associated injuries included 1 upper extremity, 3 lower extremities, 2 chest injuries, 1 minor head injury and 1 abdominal injury. There were no open fractures. Three combined pelvic injuries were classified according to Tile's classification (1 type B2 and 2 type C). 7 patients with femoral head cartilage injury.

Measurement of the acetabular dome impaction

45.45% ADIF are located at the posterosuperior quadrant. 40.91% ADIF are located at the anterosuperior quadrant. The remaining (13.64%) ADIF involved both areas. The details are shown in **Table 2 and Table 3**.

Clinical imagine and functional outcomes

Most involving both columns fractures (18 patients, 81.82%) were managed through single Iliioinguinal approach (11 patients) or Stoppa approach (7 patients) in our study. Additional injuries to the pelvis were treated with either plates or screws. Surgical related data are in **Table 1**. At final follow-up, according to the reduction categories described by Matta[19], we achieved anatomical reduction in 10 patients (45.45%), imperfect reduction in 7 patients (31.82%), and poor reduction in 5 patients (22.73%). According to the Merle d'Aubigné score, 5 patients (22.73%) were rated excellent, 10 patients (45.45%) were rated good, 5 patients (22.73%) were rated fair and 2 patients (9.09%) rated poor. The average score of SF-36 was 76.76 ± 20.18 . Deep venous thrombosis (DVT) was screened in 12 patients (54.55%) during hospitalization. One sciatic nerve injury was observed preoperatively. One patient developed mild heterotopic ossification (Brookers' type II). Significant AVN was seen in 2 patients and required subsequent revision surgery with a total hip arthroplasty. Two patients developed mild osteoarthritis (Kellgren-Lawrence classification I-II).

Discussion

Characteristics of Acetabular Dome Impaction Fractures

Treatment of an ADIF poses a difficult challenge for the orthopaedic traumatologist. Several authors have recently reported clinical outcomes involve the acetabular dome impaction[4; 6; 10; 16; 23; 25]. Jeffrey O. Anglen[12] found the ADIF which was called the 'gull sign', was 100% predictive of failure of reduction and/or fixation. In their study, they considered that it was difficult to reduce and fix the gull sign because of the superoanterior location of the fragment and its displacement into the cancellous^[12]. It is difficult or impossible to get any bone graft or hardware applied in a manner to reliably support the fragment. The previous study was controversial on the location of the dome impaction. Most of the study identified the location was in the anteromedial area of the acetabulum[24]. Some authors identified that the impaction part involved the posteromedial portion of the roof[8; 17; 20]. But none of the previous study explored the morphological characteristics[24]. In the current study, based on the CT scan, we founded that the 45.45% of the ADIF was located more posterosuperior which was different from the previous study. The location of the ADIF might influence the approach and then manipulate and the implant placement. From current morphological study, most of the dome impaction located at the posterosuperior quadrant. The average impaction size was 467.24 ± 308.25 , almost occupied 17% of the normal size of the lunar surface, which needs more widely debrided toward to the posterior and lateral. Usually, anterior based approach is used in all cases and the location/configuration of the fracture dictate the exact reduction maneuvers and fixation techniques. Previous study reported that the dome impaction is important to success and can generally be accomplished through use of the lateral two windows of the ilioinguinal approach[25]. This circumstance might lead to it difficult to maneuver get the perfect reduction and stable fixation.

Clinical significance of Acetabular Dome Impaction Fractures

Several study had reported that the clinical outcomes and imagine results of ADIF were poor[11; 12]. The best predictor of success for acetabular fractures is the quality of the reduction according to Matta^[19]. However, the perfection of the reduction was difficult to achieved especially in associated acetabular fracture in elderly patients. We recommend that the indirect reduction techniques are generally not ideal for ADIF. 45.45% of the ADIF located in the posteromedial, the area was covered up by the anterior cortex, which may influence the direct reduction. The accesses to the dome impaction were usually through opening the anterior wall fracture segment, the true pelvic fracture line or making a cortical window in the anterior wall^[25]. When reduction was performed, the surgeon should pay more attention to debride the ADIF fragments more posteriorly and exposure the periphery. Fracture fragments and hematoma are then subsequently cleaned from fracture lines, frequently by use of long pituitary rongeurs and elevators. Usually, a small curved elevator or mosquito forceps was used for the reduction. The femoral head was used as the template. The reduction maneuvers should be more anterior/posterior which depended on the location of the ADIF Then, the bone defect was filled through the anterior column /wall fracture window with allograft or shaped autograft which was harvested from the iliac spine^[25]. We prefer to address

dome impaction and then proceed with the definitive reduction of the infrapectineal buttress plate^[26]. Screws may be placed independently or through the buttress plate.

After investigated in 15 Level-1 trauma centers, Manson TT reported that the fractures with dome impaction were significantly more likely to be treated initially with THA^[18]. However, in a larger study, Carroll et al. found no association between the gull sign and the need for subsequent arthroplasty, stating that the failure rate was largely related to the overall quality of the reduction and fixation^[7]. Based on our previous study, the primary ORIF can receive good clinical and imagine outcomes^[25]. In this study, the quality of reduction within 3mm was achieved in 77.27% patients which were similar to the previous study^[10; 25]. The excellent and good rate per modified Merle d'Aubigne score was 68.18%, which was lower than previous study^[25]. We infer that might attribute to the younger patients in Zhuang's previous study^[25]. In addition, THA is more expensive than ORIF, according to our medical insurance system, many patients cannot afford it. 2 patients were performed revision surgery with THA due to avascular necrosis. One patient (4.55%) had grade II arthritic changes as described by Brookers^[3] and was complaining of intermittent moderate pain requiring occasional oral non-steroidal anti-inflammatory medication.

Limitations

This study has several limitations due to its retrospective single-center design and non-comparative study. The number of patients in the study is not high but this is secondary to the relatively low incidence of complex acetabular fractures. Although this is the first study mentioned the ADIF morphological characteristics in CT, the relatively limited number of patients with this procedure further limits this study's generalizability. This study also had relatively short length of follow-up to evaluate progression of arthritis.

Conclusion

The ADIF can locate at the posterosuperior quadrant, the anteriorsuperior quadrant or both of these two areas. Understanding the characteristics of the dome impaction can aid surgeons during reduction and fixation. Meanwhile, good to excellent outcomes and a high degree of patient satisfaction can be achieved in majority of the patients.

Abbreviations

ADIF :acetabular dome impaction fractures; AVN :Avascular necrosis; HO :Heterotopic ossification; AP: anterior-posterior; CT: computed tomography; DICOM:Digital Imaging and Communications in Medicine; DVT:deep venous thrombosis; THA: total hip arthroplasty.

Declarations

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Availability of data and materials The datasets generated and/or analyzed during the current study are not publicly available due to personal reasons, but are available from the corresponding author on reasonable request.

Authors contributions Pengfei Wang carried out the study, and drafted the manuscript. Chen Fei measured the data. Zhi Li, Hu Wang, Xing Wei, Yahui Fu, collected the data. Binfei Zhang and Yuxuan Cong helped to finish the statistics. Kun Zhang and Yan Zhuang designed the study. All authors read and approved the final manuscript.

Ethical review committee statement

This study was approved by the Ethics Committee and Institutional Review Board of Honghui hospital. The informed consent forms were obtained from the patients prior to study participation.

Consent for publication Written informed consent was obtained from individual participants.

Competing interests The authors declare that they have no competing interests

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Tables

Table 1 Patient demographics data, characteristics and surgical related data

Variable	N=22
Mean age (years)	58.91±13.68
Sex (n, %)	
M	14(63.63%)
F	8(36.37%)
Mechanism of injury	
MVA	5(22.7%)
fall from standing height	6(27.3%)
fall from height (<3m)	7(31.8%)
fall from height (>=3m)	4(18.2%)
acetabular fracture type (Letournel)	
anterior column+anterior wall	1(4.55%)
posterior column+posterior wall	1(4.55%)
transverse	1(4.55%)
anterior column+posterior hemitransvers	13(59.09%)
both column	2(9.10%)
T-type	1(4.55%)
indeterminate fracture	3(13.64%)
transverse+posterior wall	2(9.10%)
isolate quadrilateral surface	1(4.55%)
associated injury	
pelvic injury	3(13.64%)
upper extremity	1(4.55%)
lower extremity	3(13.64%)
chest injury	2(9.10%)
head injury	1(4.55%)
abdominal injury	1(4.55%)
multi-injury	3(13.64%)
femoral head injury	7(31.81%)

approach	
IL	11(50%)
Stoppa	7(31.82%)
KL	4(18.18%)
operation time(minutes)	226.59±48.34
blood loss(ml)	1122.73±482.98
bone graft	
autograft	15(68.2%)
allograft	7(31.8%)
follow-up(months)	28±4.5
Tornetta and Matta Radiographic grades	
anatomical (0–1 mm displacement)	10(45.45%)
imperfect (2–3 mm displacement)	7(31.82%)
poor (more than 3 mm displacement)	5(22.73%)
modified Merle d’Aubigné score excellent (18 points)	
good (15–17 points)	5(22.73%)
fair (13–14 points)	10(45.45%)
poor (<13 points)	5(22.73%)
	2(9.09%)
SF-36	76.76±20.18
Complication	
None	10(45.45%)
DVT	12(54.54%)
sciatic nerve injury	1(4.55%)
HO	1(4.55%)
arthritis	2(9.09%)
AVN	2(9.09%)

Note: MVA: motor vehicle accident, IL: Iliioinguinal, KL: Kocher–Langenbeck, DVT: deep venous thrombosis, HO: heterotopic ossification, AVN: avascular necrosis

Table 2 Location of the acetabular dome impaction

Location	N=22
9-12 o'clock	10(45.45%)
12-3 o'clock	9(40.91%)
9-3 o'clock	3(13.64%)

Table 3 Characteristics of the acetabular dome impaction

Characteristics	N	Minimum	Maximum	Mean	S.D
normal size of acetabulum (contralateral)	22	3300.00	4662.00	4010.86	449.74
normal size of lunar surface	22	2124.00	3637.00	2749.46	371.73
impaction size	22	80.00	1100.00	467.24	308.25
percent of the impaction area (%)	22	3.13	36.94	17.18	8.94

Note \square percent of the impaction= impaction size/ lunar surface

Figures

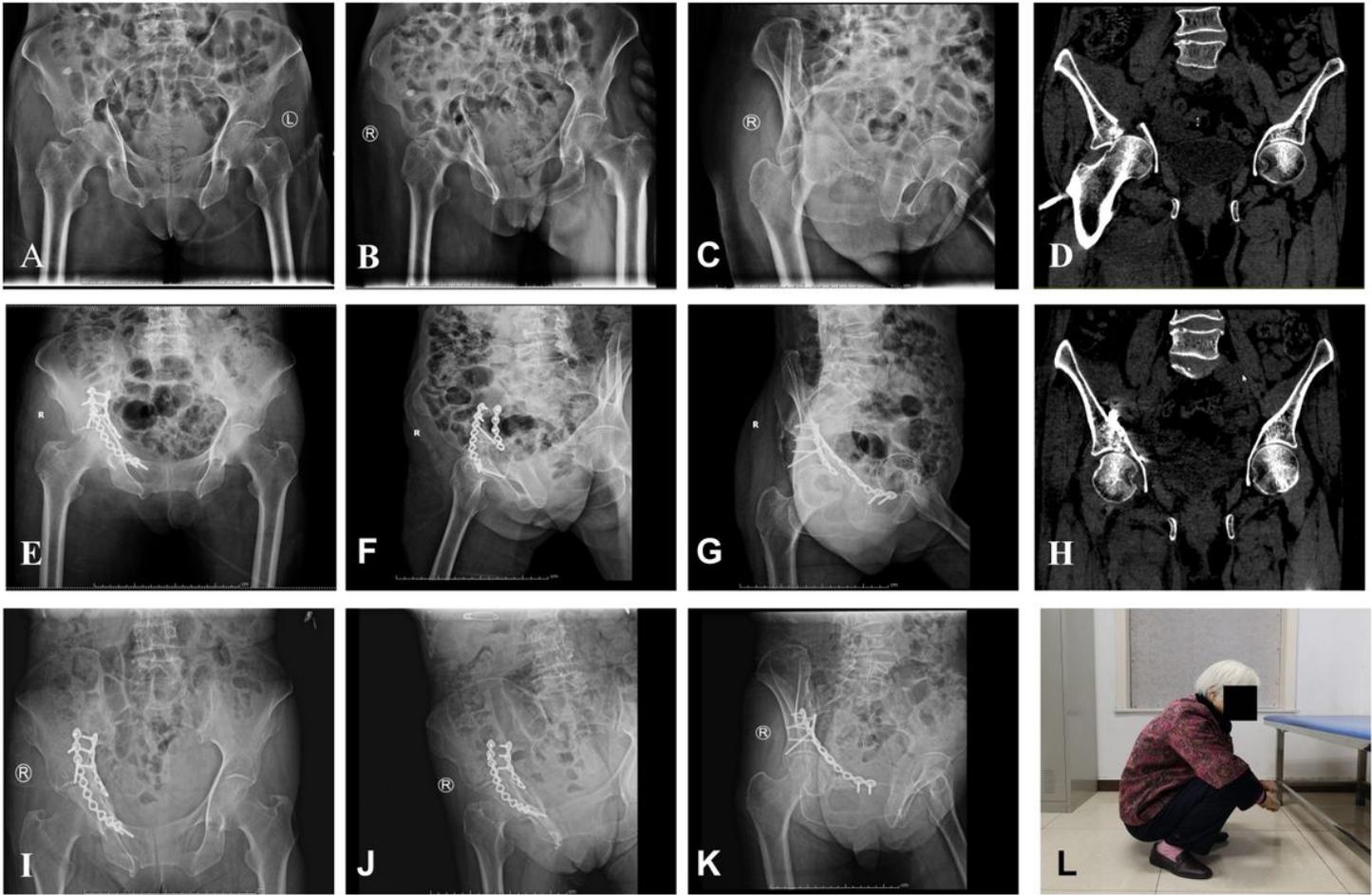


Figure 1

A 74-year-old female presented with acetabular fractures. Preoperative radiographs [AP view and Judet views pictured] showed right anterior column +hemi-transverse fractures (A-C). Gull wing sign can be clearly seen from the AP view. (D) Acetabular dome impaction can be found from the coronal view of CT scan. (E-H) Postoperative radiographs, CT scan showed the reduction was well. (I-K) Post-operative radiographs at 30 months after surgery. (L) The range of motion at 22 months follow up.

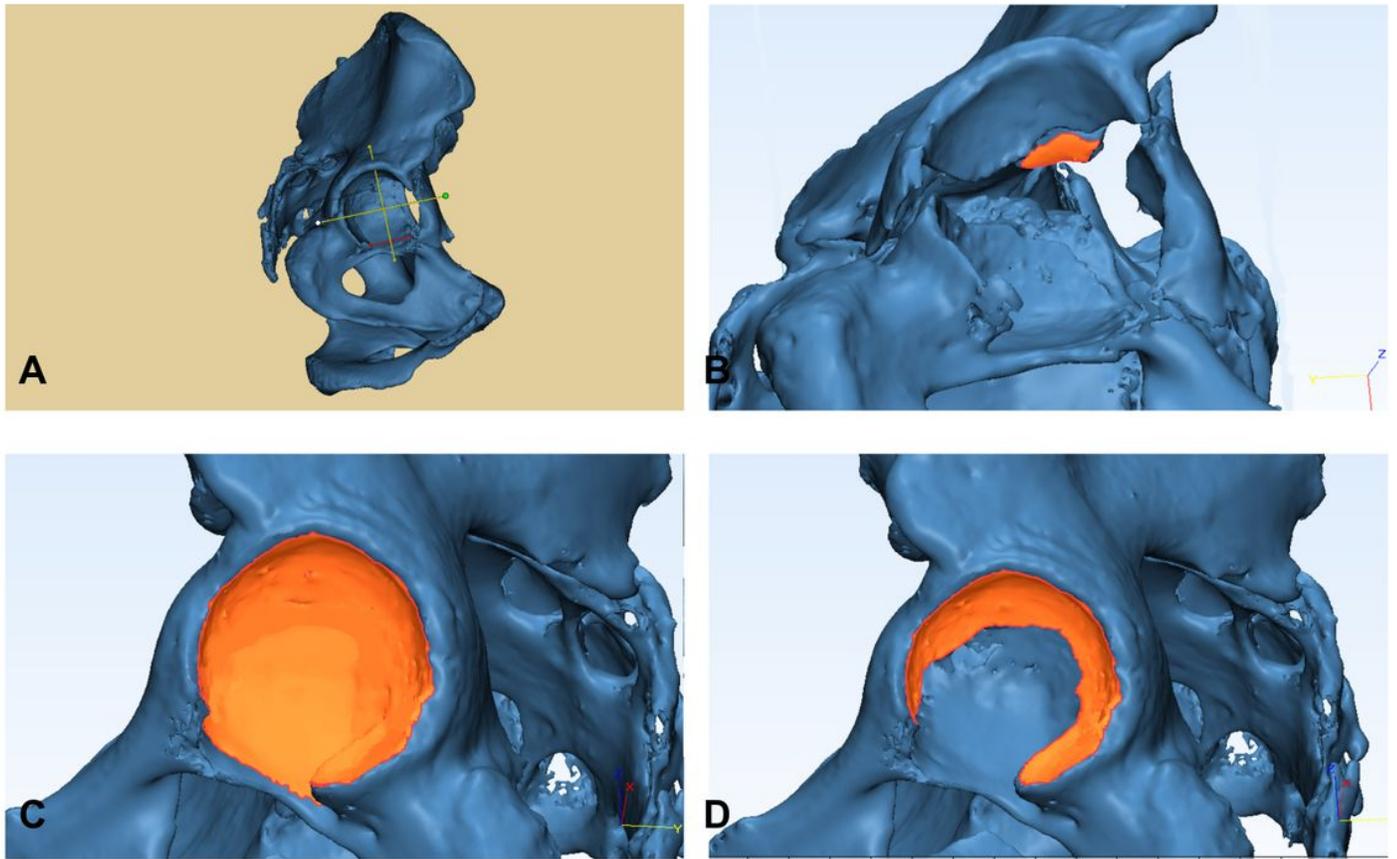


Figure 2

(A) Location of the acetabular dome impaction. (B) the area of the impaction fragment (orange) was 146.95mm^2 . (C) normal size of acetabulum (contralateral side) was 4575.62mm^2 (D) normal size of lunar surface (contralateral side) was 2684.14mm^2 .