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Research article

Bony landmarks, distances and their correlations to each other, which can be used during periacetabular osteotomy: a CT study performed on dysplastic hips

Onur Hapa[1], Onur Gürsan [1]*, Osman Nuri Eroğlu[1], Hakan Özgül [2], Efe Kemal Akdoğan[1], Vadym Zhamilov[3], Ali Balcı[2] and Hasan Havitçioğlu[1]

[1]Department of Orthopedic Surgery, Dokuz Eylül University, 35330, Balçova, İzmir, Turkey
[2]Department of Radiology, Dokuz Eylül University, 35330, Balçova, İzmir, Turkey
[3]Department of Orthopedic Surgery, Tepecik Training Hospital, 35180, Konak, İzmir, Turkey.
*Correspondence to: O. Gürsan. E-mail: onur_84_gursan@hotmail.com
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ABSTRACT

As a surgical technique for hip dysplasia, Bernese periacetabular osteotomy (PAO) still poses technical difficulties and unclear surgical steps like the depth of the first 'ischial' cut, the start of the iliac cut and the width of the retroacetabular cut to prevent either iatrogenic joint entrance or posterior column fracture. Twenty-seven dysplastic hips (CE $< 25°$) were randomly matched with nondysplastic hips (n: 27, CE $> 25°$). 3D CT sections of the hips were evaluated and the width of the ischium, the distance from the infra-acetabular groove to the ischial spine, from the anterior superior iliac spine (ASIS) to the joint or sciatic notch or the sciatic spine, from the most medial point at the acetabulum to the posterior column, ischial spine or sciatic notch were measured for each group and correlated. The distances (mm) from the infra-acetabular groove to the ischial spine (42 ± 4, 44 ± 4, P: 0.03), the anterior superior iliac spine to the joint (52 ± 6, 60 ± 3, P: 0.03), the most medial point at the acetabulum to the posterior column (34 ± 2, 36 ± 2, P: 0.005) were shorter in the dysplastic group. The distance from the ASIS to the sciatic notch was correlated with the distance from the infra-acetabular groove to the ischial spine, from the ASIS to the joint and the most medial point at the acetabulum to the posterior column. The distance from the ASIS to the sciatic notch can be used intraoperatively to guess the X-ray guided or blindly osteotomized stages to predict the width or depth of the osteotomy to prevent intraarticular extension or posterior column fracture.

INTRODUCTION

Bernese periacetabular osteotomy (PAO) was introduced as a novel surgical technique for hip dysplasia with congruent hip by Ganz in the 1980s to reorient the acetabulum in skeletally mature patients; however, it still poses technical difficulties with a moderate to high rate of debilitating complications with a frequency of 5.9–37%; including major nerve injuries, serious infections, intraoperative posterior column fracture, intraarticular extension of the ostetomy, which may not always be associated with the level of the surgeon's experience or beyond the learning curve.[1–6]

Computer-assisted navigation systems are integrated into this demanding surgery to help reduce the learning curve, improve accuracy and safety of the procedure while potentially improving outcomes of the patients.[7,8]

Preoperative computerized tomography-based measurements with use of specific-width osteotomes are also advised to prevent complications.[9]

First of all, the cut in the ischium is done without visual contact, so the ischium base width is palpated and an incomplete ishial osteotomy towards the ishial spine is performed. However, in various research, the suggested depth of this osteotomy changes between 10 and 25 mm.[1,10–14]

The second conflicting point is the starting point of the supra-acetabular or iliac osteotomy to prevent joint entrance or to leave behind enough bridge of bone for fixation of the osteotomy site at the end of surgery and is reported as the point halfway between ASIS and AIIS or proximal to AIIS or 3 cm above the anterior acetabular rim or the ASIS or just distal to ASIS for 20 mm above the joint or at a point that will give an optimal bony bridge between osteotomy and joint to allow the firm grip of a 5 mm Schanz' screw while preventing the retroacetabular osteotomy from running into the joint or ending in a fracture of the sciatic notch.[1,10–14]

The third blind spot is the distance between the most medial point of the acetabulum and the posterior edge of the posterior column where the retroacetabular cut is performed without seeing the joint. Different reported widths for the distance between the retroacetabular cut and the posterior column rim without breaking the posterior column or entering the joint have been described. These can change between 0.5 and 2 cm or at an equal distance between posterior column and posterior acetabula, which is detected in scopy images.[1,10–15]

The purpose of the present study was to report first time, the various above mentioned ill-defined distances, in the CT sections of dysplastic patients and compare them with those of nondysplastic patients. The hypothesis was those uncertain distances in dysplastic patients would still be different than the range of values reported in the literature also different when compared to nondyplastic patients that moreover, measurable and/or predictable intraoperative distances in dysplastic patients (e.g. the distance between the sciatic notch and the ASIS or width of ischium) would correlate to nonmeasurable or unseen distances (e.g. the distance from the infraacetabular Groove to the sciatic spine or from the ASIS to the joint or posterior column to the most medial point of the joint).

METHODS AND PATIENTS

The study group was comprised of 20 people having lateral CE angle $< 25^\circ$ (27 hips having >2 mm joint space) and the control group consisted of 20 age and gender matched people having lateral CE $> 25^\circ$ and having no hip related symptoms. Patients with any history of hip disease and/or osteoarthritis were excluded from both groups.

Computed tomography protocol

All computed tomography (CT) images were obtained using the Aquilion Prime 160-channel instrument (Toshiba Medical Systems, Otawara, Japan) or the Brilliance (16- or 64-channel) instrument (Phillips Healthcare, Best, The Netherlands). Slice thickness varied from 1.5 to 2 mm. No contrast agent was used in the CT examinations. Source images were obtained in the axial section. All lesions were evaluated at the optimal bone window adjustments.

Assessment of CT images and three-dimensional measurements

CT images in Digital Imaging and Communications in Medicine (DICOM) format were evaluated with the Picture Archiving and Communication Systems (PACS)-Sectra IDS7 (Sectra AB, Linköping, Sweden) program by two radiologists with 5 and 20 years of radiology experience. Images of patients who were eligible for the study were transformed into three-dimensional (3D) form by running the 3D trauma pelvic tool on the same program. The femoral bone on the side to be measured was marked and removed from the image.

In the 3D CT sections of the hip, the measured parameters were: medial to lateral width of the ischium (Isc_w) (Fig. 1), distances from the infraacetabular Groove to the ischial spine tip (Ace_{Gr}-Isc_{sp}) (Fig. 2), the tip of the anterior superior iliac spine to the highest point of the joint (A_{SIS}-J_{oint}) (Fig. 3), the anterior superior iliac spine to deepest point of the sciatic notch (A_{SIS}-Sci_{notch}) (Fig. 4), the sciatic notch to the ischial spine (Sci_{notch}-Isc_{sp}), the width of the acetabulum at the most medial point (D_{eepw}) (Fig. 5), from the most medial point to the edge of the posterior column ($D_{eep\text{-}post}$) or to the ishial spine (D_{eep}-Isc_{sp}) or the sciatic notch ($D_{eep\text{-}}$ Sci_{notch}) (Fig. 6). Last, femoral head diameters were measured to exclude the effect of pelvis size differences between compared groups.

Statistical analysis

All analyses were carried out with SPSS® v.25.0 (Statistical Packages for the Social Sciences, Version 25.0. Armonk, NY: IBM Corp, 2016). Descriptive statistics were given as mean ± standard deviation ($-x \pm sd$) or median (range). The Mann–Whitney test was used to compare normal hips to dysplastic hips. Correlations between the measured parameters were assessed using the Spearman correlation analysis test. Correlations between the intraoperatively measurable or predictable distances (e.g. Isc_w, A_{SIS}-Sci_{notch},

Fig. 1. Medial to lateral width of the ischium (Isc_w) (37 mm in this case).

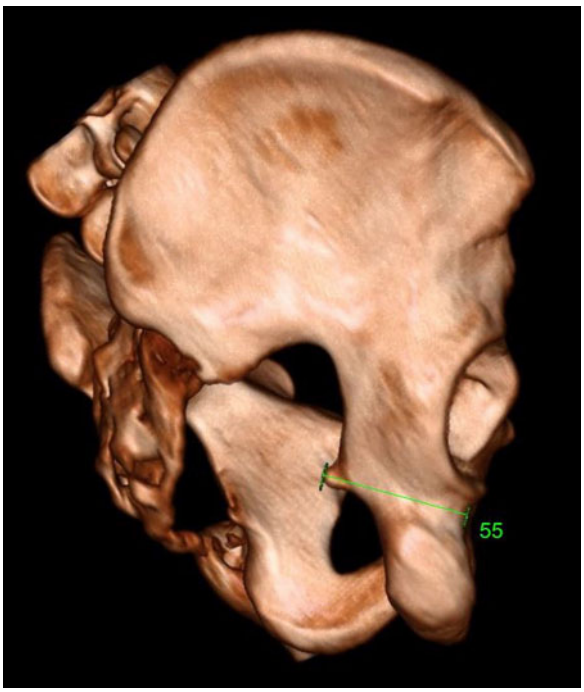

Fig. 2. Distance from the infraacetabular Groove to the ischial spine tip (Ace_{Gr}-Isc_{sp}). (55 mm measured).

Sci_{notch}-Isc_{sp}) and the nonmeasurable or unpredictable distances during the surgery (Ace_{Gr}-Isc_{sp}, A_{SIS}-J_{oint}, D_{eep}-$_{post}$)

Fig. 3. Distance from the tip of the anterior superior iliac spine to the highest point of the joint (A_{SIS}-J_{oint}). (52 mm measured).

Fig. 4. Distance from the anterior superior iliac spine to the deepest point of the sciatic notch (A_{SIS}-Sci_{notch}). (96 mm measured).

of those in the dysplastic group have been reported. Significance was set as $P < 0.05$.

Results

The mean age of both groups was 27 (20–37) years. There were 9 women, 11 men in both groups. The study group had a mean CE angle of $18 \pm 4^\circ$ (20°), while that of the

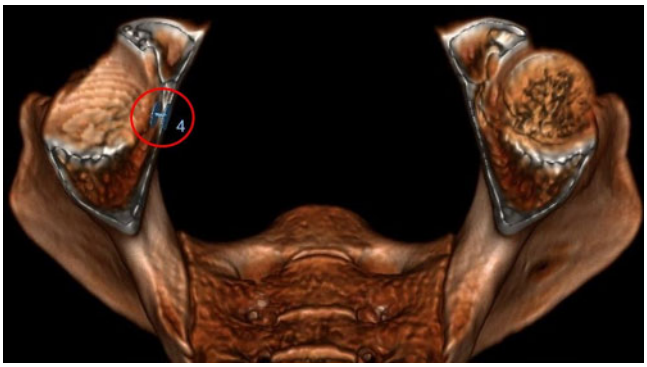

Fig. 5. The width of the acetabulum at the most medial point (D_{eepw}) (4 mm measured 'red circle').

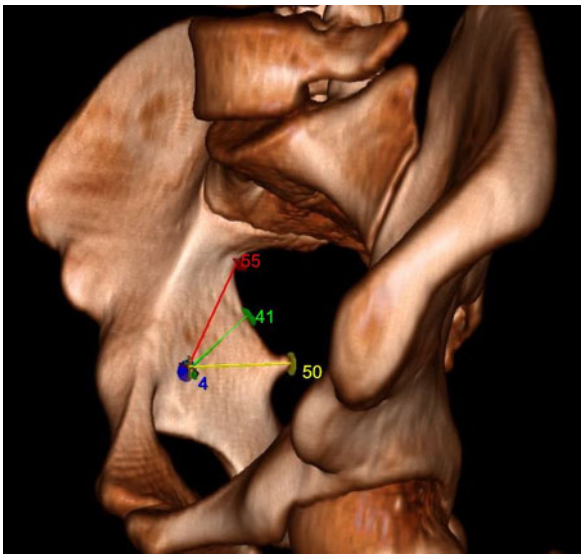

Fig. 6. Distance from the most medial point to the edge of the posterior column ($D_{eep\text{-}post}$) (green line) (41 mm) or to the ishial spine (D_{eep}-Isc_{sp}) (yellow line) (50 mm) or the sciatic notch (D_{eep}-Sci_{notch}) (red line) (55 mm).

control group was $32 \pm 4°$ ($31°$). These are given in Table I.

The distances from infra-acetabular groove to ischial spine (42 ± 4 versus 44 ± 4 mm), anterior superior iliac spine to joint (52 ± 6 versus 60 ± 3 mm), and the most medial point from acetabulum to posterior column (34 ± 2 versus 36 ± 2 mm) or ischial spine (42 ± 3 versus 45 ± 3 mm) were shorter, while the width of the most medial point was greater in the study group (6 versus 5 mm) ($P < 0.05$).

A_{SIS}-Sci_{notch} was positively correlated with Ace_{Gr}-Isc_{sp} (r: 0.459, P: 0.01), A_{SIS}-J_{oint} (r: 0.431, P: 0.02), D_{eep}-$_{post}$ (r: 0.451, P: 0.018). Only first correlation was detected at severely dysplastic group ($CE° < 20°$, n: 12) (A_{SIS}-Sci_{notch} versus Ace_{Gr}-Isc_{sp} r: 0.63, P: 0.02).

Sci_{notch}-Isc_{sp} was positively correlated with Ace_{Gr}-Isc_{sp} (r: 0.433, P: 0.024), Isc_{w} (r: 0.496, P: 0.009), D_{eep}-$_{post}$ (r: 0.422, P: 0.028). Mean diameter of femoral head did not differ between groups [normal: $45 \pm 2(44)$ mm versus dysplastic: 46 ± 3 (46) mm, P: 0.7].

Discussion

The main findings of this study were that the three intraoperative distances that surgeons usually use fluoroscopy during these stages or try to understand by depth of osteotome penetration and tactile feedback of the bone (infraacetabular groove to ischial spine, anterior superior iliac spine to joint and most medial point to posterior column) with Ganz osteotomy were shorter for the dysplastic group compared to the normal group, while the width of the ischium did not differ between groups. Nor did it correlate to these intraoperative distances. However, the distance between the sciatic notch and the ASIS correlated to all these three distances.

For the first 'ischial' cut, different osteotomy lengths were advised, changing between 1 and 2.5 cm.[1,10–14] In this study, 34 mm was the shortest distance found, which suggests that an osteotomy up to 2.5 cm would be safe to prevent iatrogenic posterior column fracture.

For the second 'iliac' cut, there are studies only advising the starting point of the iliac osteotomy to prevent joint entrance or suggesting it be 2–3 cm above the acetabular rim, which is usually difficult or impossible to detect during surgery.[1,10–14] In the present study, we measured the distance between the highest point of the acetabulum (12 o'clock) and the ASIS to see what would be the shortest distance possible. The median value was 52 mm (the shortest being 44 mm), but could actually be a little bit longer due to the lower position of the anterior acetabulum. These values may assist surgeon to choose the appropriate length of screw for fixation later and possibly decreasing fluoroscopy time.

Table I. Comparison of study and control groups.

Measured variables mean ± SD (median) mm	*Study group (n: 27) (CE < 25°)*	*Control group (n: 27) (CE > 25°)*	P-*value*
Isc_w	34 ± 3 (35)	35 ± 2 (35)	0.1
Ace_{Gr}-Isc_{sp}	42 ± 4 (41)	44 ± 4 (44)	0.03**
A_{SIS}-J_{oint}	52 ± 6 (52)	60 ± 3 (60)	0.00**
A_{SIS}-Sci_{notch}	97 ± 5 (100)	100 ± 4 (100)	0.2
Sci_{notch}- Isc_{sp}	47 ± 3 (49)	48 ± 3 (48)	0.7
D_{eepw}	5 ± 1 (6)	5 ± 1 (5)	0.04**
$D_{eep\text{-}post}$	34 ± 2 (34)	36 ± 2 (37)	0.005**
D_{eep}- Isc_{sp}	42 ± 3 (43)	45 ± 3 (47)	0.001**
$D_{eep\text{-}}$ Sci_{notch}	44 ± 5 (45)	46 ± 4 (47)	0.07

Width of ischium (Isc_w), infra-acetabular Groove tip (Ace_{Gr}), tip of ischial spine (Isc_{sp}), tip of anterior superior iliac spine (A_{SIS}), deepest point of sciatic notch (Sci_{notch}) width of acetabulum at most medial point (D_{eepw}), from most medial point to edge of posterior column ($D_{eep\text{-}post}$) (*$P < 0.05$).

The third conflicting point is the medial to lateral width of the posterior column cut while preventing joint entrance and posterior column fracture. Numerical values have been reported to be 0.5–2 cm.[1,10–15] The present study reported a median value of 34 mm (lowest value 30 mm), which was still higher than the highest value reported in the literature (2 cm).[14]

Most importantly, these three important distances were found to be positively correlated with the distance between the ASIS and the top of sciatic notch, which could be predictable during surgery. This prediction would depend on preoperative CT imagings or intraoperative fluoro guidance and/or from direct measurement by palpation from deepest point of sciatic notch to ASIS, however last measurement would probably give higher value than first two due to convex surface of ilium instead of vertical closest distance measured at imaging modalities. A median value of 100 mm was found and this distance from ASIS to joint would probably predict distances of 40 mm from ischium spine to infra-acetabular groove, 50 mm from ASIS to joint level, and 30 mm posterior from column to acetabulum. However, this would need to be clarified in future studies. The second point is that the width of the ischium did not differ between the two groups and did not correlate to any of these parameters.

The main contribution of this article is that three blindly intraoperatively osteotomized distances (infra-acetabular groove to ischial spine, anterior superior iliac spine to joint and most medial point to posterior column) with Ganz osteotomy were found to be shorter than the nondysplastic group while all correlated regarding the width of the ASIS to the sciatic notch. At severely dysplastic group (*n*: 12 CE° < 20°), only but stronger correlation (r value bigger) was found between width of the ASIS to the sciatic notch to distance between infraacetabular groove to ischial spine.

There are some limitations since the present study only included a study group having lateral CE lower than 25° and did not further sub-classify the dysplasia into borderline or severe dysplasia. However, PAO is still the main treatment modality for borderline dysplasia.[16]

Moreover, the number of cases in each group was low (*n*: 27) (especially at severely dysplastic group *n*: 12) to detect stronger correlations. Second, female to male ratio was 9/11 at the present study that one may argue that hip dysplasia is more prevalent among females. However, this issue is questionable that adolescent diagnosed/adult diagnosed dyplasia and infantile-diagnosed dysplasia are separate diseases and there are also reports that adolescent diagnosed had a higher male incidence or total higher prevalence among males compared to females (%4.3 versus %3.6).[17–20] There is no clear evidence in the literature for difference for pelvic dimension between two that one recent cadaveric plus CT-based anatomy study reported no difference between two for pelvic height and width.[21]

It is also necessary to point out that the distances were measured with CT sections, which may decrease the reliability of the measurements. A cadaver study would be more accurate; however, cadavers with dysplasia are very hard to come by. Nevertheless, this is the first study in the literature concerning this issue. Future studies performed on cadavers and/or with a larger number of cases with subclassification of the severity of the dysplasia would certainly ensure better results.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest relevant to this article.

DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable request to the corresponding author.

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