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SYMPOSIUM: FEMOROACETABULAR IMPINGEMENT: CURRENT STATUS OF DIAGNOSIS AND TREATMENT

Acetabular Morphology

Implications for Joint-preserving Surgery

**Werner Köhnlein MD, Reinhold Ganz MD,
Franco M. Impellizzeri PhD, Michael Leunig MD**

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Abstract Appropriate anatomic concepts for surgery to treat femoroacetabular impingement require a precise appreciation of the native acetabular anatomy. We therefore determined (1) the spatial acetabular rim profile, (2) the topography of the articular lunate surface, and (3) the 3-D relationships of the acetabular opening plane comparing 66 bony acetabula from 33 pelves in female and male pelves. The acetabular rim profile had a constant and regular wave-like outline without gender differences. Three prominences anterosuperiorly, anteroinferiorly and posteroinferiorly extended just above hemispheric level. Two depressions were below hemispheric level, of 9° at the anterior wall and of 21° along the posterosuperior wall. In 94% of all acetabula, the deepest extent of the articular surface was within 30° of the anterosuperior acetabular sector. In 99% of men and in 91% of women, the depth of the articular surface was at least 55° along almost half of the upper acetabular cup. The articular surface was smaller in women than in men. The acetabular opening plane was orientated in 21° ± 5° for version, 48° ± 4° for inclination and 19° ± 6° for acetabular tilt with no gender differences. We defined tilt as forward rotation of the entire acetabular cup around its central axis; because of interindividual variability of acetabular tilt, descriptions of acetabular lesions during surgery, CT scanning and MRI should be defined and recorded in relation to the acetabular notch. Acetabular tilt and pelvic tilt should be separately identified. We believe this information important for surgeons performing rim trimming in FAI surgery or performing acetabular osteotomies.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

W. Köhnlein (✉)
Department of Orthopaedics, Hôpital Universitaire de Genève, 24 Rue Micheli-du-Crest, 1211 Genève 14, Switzerland
e-mail: werner.koehnlein@gmx.ch

R. Ganz, M. Leunig
University of Berne, Berne, Switzerland

F. M. Impellizzeri, M. Leunig
Department of Orthopaedics, Schulthess Clinic, Zürich, Switzerland

Introduction

Several authors have recently amplified and refined the notion of femoroacetabular impingement (FAI) as a mechanism causing hip osteoarthritis [20, 21]. Direct damage to the hip can be caused by variations in size, shape, and orientation of either the proximal femur [15, 24, 27, 36, 47, 50], the acetabulum [11, 22, 54], or a combination of both [4]. The predilection for femoroacetabular abutment and subsequent lesions is the anterosuperior acetabular rim [3, 4, 26, 35, 37, 38, 58], with gender differences in the damage pattern for cam and pincer impingement [4, 26].

Only a limited number of studies have quantified the morphological characteristics of the human acetabulum. The outer contour of the acetabulum is variable and some have less than hemispheric acetabular shapes [40, 56, 65–68]. A recent study denoted four configurations along the anterior wall as curved, angular, irregular, or straight [40]. The posterior acetabular wall has been proposed to be hypoplastic, accounting for acetabular retroversion [23]. However, this notion was not confirmed by two more recent studies suggesting the entire acetabular complex may be maloriented into retroversion [28, 29]. Surgeons performing direct surgery at the acetabular rim or reorientation procedures to treat acetabular pathologies, such as hip dysplasia or femoroacetabular impingement [3, 18, 19, 31, 44, 45, 52, 58, 59], need to be aware of the detailed acetabular topography.

We therefore quantified and compared (1) the spatial acetabular rim profile, and topography of the articular lunate surface, as well as (2) the 3-D relationships of the acetabular opening plane to the pelvic frontal plane between women and men.

Materials and Methods

We examined 52 randomly selected bony pelves (104 acetabula) from the skeletal collection of the Institute for Anthropologic Research, Basel, Switzerland. These were derived from the population residing in Switzerland between the 6th and the 13th century. The average height of the male population in the Early Middle Ages was practically the same as today [60]. We excluded acetabula with bony destruction, dysplasia, or advanced osteoarthrosis, and unpaired hips. This left 66 acetabula (33 pelves; mean age, 47 ± 10 years; range, 18–60 years) available for detailed measurements. Sixteen were female (8 pelves; mean age, 44 ± 15 years; range, 18–60 years) and 42 were male (21 pelves; mean age, 48 ± 6 years; range, 30–60 years). On eight acetabula (four pelves), no information concerning age and gender was available.

All morphologic acetabular measurements were performed by one observer (WK) on plaster molds made from the entire bony acetabulum. A transparent plate, imprinted with a clock face overlaying a geographic coordinate system, was centered over the plaster mold. The tripod of the anterosuperior, the anteroinferior, and the posteroinferior rim prominences defined the acetabular opening plane and its spatial position. Placement of all three rim prominences on the same geographic circle of latitude centered the plate correctly. The 180° (6:00) meridian line was positioned over the midpoint of the acetabular notch. Thirty-six reference points in 10° increments along the rim were marked. The perpendicular projection of the center of the plate onto the fossa established the acetabular center pole. The length of the arc from center pole to the acetabular rim and to the fossa was then taken along the meridian line at each of the 36 rim points using a flexible measuring tape (Fig. 1A). To obtain the length of the arc of the articular surface, the length of fossa was subtracted from the corresponding length of rim arc. The width of the acetabular notch was measured by the inside jaws of a vernier caliper gauge. For comparison of acetabula of different diameter, all linear measurements were transformed into degrees. This conversion was made with the formula: alpha = 180 * arc/(Pi * radius). We used the function

$$f(x) = 2r * \sin(a/2r) - c, \ (a = \text{arch},\ c = \text{chord},\ r = \text{radius})$$

to compute the unknown radius. Chord and arc length were therefore measured along the 90° and the opposing 270° meridian of each acetabulum (Fig. 1B). The Excel® solver program (Microsoft® Office Excel® 2003; Microsoft Corp, Redmond, WA) was used for root finding of this formula according to the Newton-Raphson method. Our approach was analogous to that of the earth's globe: distances along the meridian were given in degrees with reference to the acetabular (center) pole at 0° and defined as depth (latitudes). The extent along the acetabular rim was defined as width (longitudes), given in degrees [4]. The 90° latitude

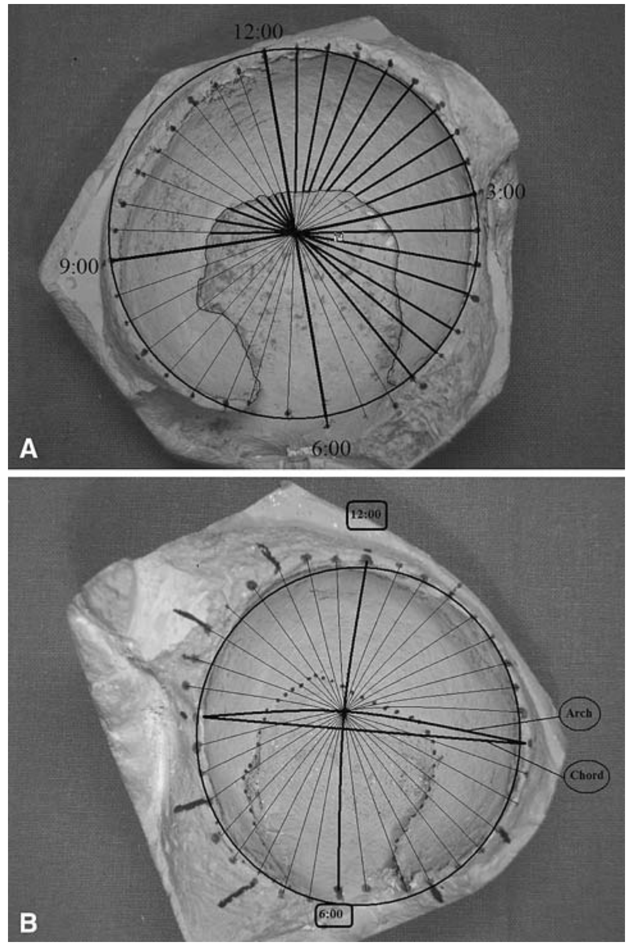

Fig. 1A–B (**A**) Measurements of the length of the arc from acetabular center (pole) to the different structures of interest along the meridian at each of the 36 rim points (= depth) as shown in bold lines. Depth of the rim is shown in the right lower quadrant, depth of the articular surface in the right upper quadrant, and, depth of the fossa in the left upper quadrant. The width of these structures was given as the distance in a clockwise manner along the rim. (**B**) Measurement of chord and arc from 3:00 (90° anterior) to 9:00 (270° posterior) for calculation of the radius.

circle defined the equatorial line of a hemisphere. Locations along the rim were given in a clock-like manner in hours (00:00) and minutes (′). For illustration and comparison purposes, all data on left-sided acetabula were mirrored along the 180° meridian line and are shown as right-sided acetabula. While we assumed symmetry, this was possible because the axes of symmetry through the middle of the acetabular notch were similar for the left and right side.

Spatial measurements of the acetabular opening plane in relation to the pelvic frontal plane required reconstruction of all pelves (which had been separated at the sacroiliac joint) proportional to the pelvic shape and size [9, 16, 64], using glue and radiolucent spacers of 2 to 11 mm. We defined spatial position of the acetabular opening plane by the aforementioned transparent measuring plate, which was placed directly onto the acetabula of the bony pelvis in the same manner as on the plaster molds and fixed with removable adhesive (Blu-tack®; Bostik Findley Ltd, Stafford, UK). The bony pelvic specimens were placed in prone position onto a flat measuring grid table. Both anterior superior iliac spines (ASIS) and the pubic tubercle of the pubic symphysis defined the anatomic reference plane [2, 41]. We measured acetabular inclination and version with a goniometer as the radiological projection of the opening plane according to the definition given by Murray [46]. Direct acetabular version was measured in addition as the angle of the cord along the anterior and posterior rim and the parasagittal plane. We measured a third variant of spatial acetabular position: the acetabular tilt. Acetabular tilt was defined as rotation of the entire acetabular cup around its central axis going through the center of the acetabular sphere and the pole and measured as the angle between the pelvic frontal plane and the projection of the 180° meridian line on the opening plane (Fig. 2). Forward tilt of the acetabular notch was given

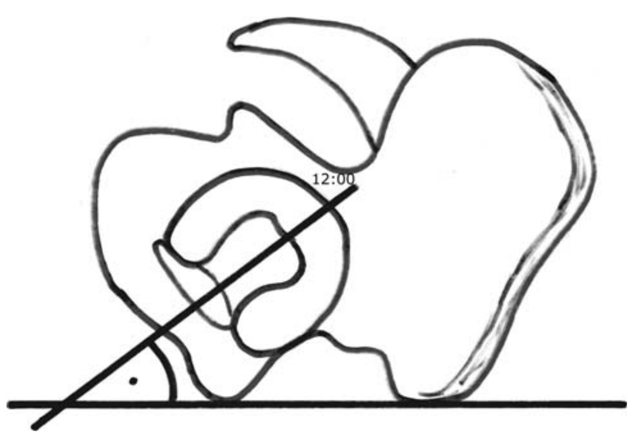

Fig. 2 Acetabular tilt was measured as the angle between the pelvic frontal plane and the acetabular meridian line from 12:00 to 6:00. Forward tilt of the acetabular notch was given with positive values in degrees.

with positive values in degrees. Results in metric measurements and calculations in degrees were rounded to full numbers. Longitudinal rim locations were rounded to the nearest 10° point (=20 minutes).

Data are presented as mean ± standard deviation. Eighty percent of the data were normally distributed using the Kolmogorov-Smirnov test and from visual inspection of the normality plot. For the remaining data set the skew and kurtosis values divided by their standard errors suggested a relatively small deviation from normality. Therefore a parametric approach was chosen for analysis. Two-way mixed analysis of variance (ANOVA) on each dependent variable, with one within-subject factor (side) on two levels (right and left side), and one between-subject factor (gender) on two levels (male and female) was used. When possible the exact p level, the mean difference, and its confidence interval (95%) were given. The Cohen effect sizes (*d*) as the mean difference divided by the pooled standard deviation was supplied with descriptors for the interpretation of *d* according to the benchmarks of Cohen: < 0.2 = trivial, between 0.2 and 0.5 = small, between 0.5 and 0.8 = medium, > 0.8 = large [8]. We observed no correlations in any of the dependent variables when these were expressed in degree, indicating no violation of the independence assumption. Statistical tests were carried out with SPSS (version 13.0, SPSS Inc, Chicago, IL).

Results

The outer acetabular bony rim was shaped in a regular wave-like manner with three constant prominences and two depressions (Fig. 3). The prominences were anterosuperior, anteroinferior, and posteroinferior. The depressions were at the anterior wall and along the posterosuperior wall. The opening plane, defined by the peaks of the three prominences extended slightly above the hemispheric level. The anterior depression was 9° below the level of a hemisphere. The posterosuperior depression was 21° below hemisphere (Table 1). The profile of the entire outer rim, including the locations of prominences and depressions, were not different in females and males (Table 2, Fig. 4A).

The depth of the articular surface in females was less than in males in the cranial area from 10:00 to 12:20 ($0.002 < p < 0.033$, Cohen descriptor: medium to large) and adjacent to the acetabular notch, (Fig. 4B). The mean location of deepest extent of the articular lunate surface was at 1:00 (anterosuperior), with a mean depth of 76°. In 94% of all acetabula this was situated at ± 20′ from this location. In 99% of males and 91% of females, the depth of the articular surface was not less than 55° along the rim sector from 10:00 to 2:00 (Fig. 5). The craniosuperior border of the fossa was situated closely adjacent to the

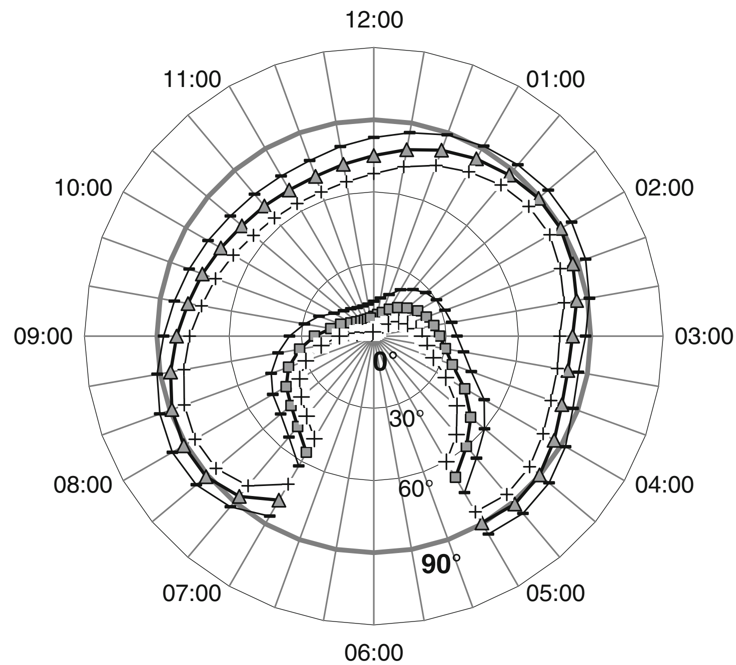

Fig. 3 The figure shows mean and standard deviation of rim and fossa values as a function of its geographical reconstruction in degree. 0° is at the pole of the acetabular hemisphere, 30°, 60°, and 90° are indicating the depth of the cup (latitude). The circle at 90° marks the equatorial level of the hemisphere. The rim, fossa, and articular surface locations are indicated in a clockwise distribution from 1:00 to 12:00 with the acetabular notch as the caudal landmark for 6:00 (longitude). The three prominent areas are anterosuperior, anteroinferior, and posteroinferior. The two depressions along the anterior and posterosuperior wall can clearly be distinguished.

Table 1. Distribution of prominences and depressions along the rim given in a clock-like manner as mean with standard deviation and range, mean and range is indicated as hours and minutes, standard deviation is indicated in minutes

Rim configuration	Acetabular location	Rim location clock-like [hour:minute]	Depth (latitude) [°]
Prominences	Anterosuperior	01:50 ± 20 (01:00–02:30)	90 ± 5 (76–102)
	Anteroinferior	04:40 ± 10 (04:20–05:00)	92 ± 5 (79–104)
	Posteroinferior	07:50 ± 10 (07:20–08:20)	92 ± 5 (78–106)
Depressions	Anterior wall	03:20 ± 20 (02:40–04:00)	81 ± 5 (70–94)
	Posterosuperior wall	11:00 ± 20 (10:00–12:00)	69 ± 7 (49–82)

All results are rounded to 10 minutes. The depth gives the distance at those locations measured from acetabular center (pole) to the rim in degree with mean, standard deviation, and ranges, results were rounded to one degree.

acetabular center-pole at around 11:00. The fossa was deeper in females than in males at several areas: centrally from 10:20 to 12:20 and adjacent to the acetabular notch ($0.0001 < p < 0.052$, Cohen descriptor: medium to large) (Fig. 4C). The width of the acetabular notch was 51° ± 6°, and it was wider in females than in males ($p = 0.00007$, Cohen descriptor: large) (Table 3). The gender differences in the depth of the articular surface were characterized by the size of the fossa and the width of the notch rather than by the outer rim profile (Fig. 4A–C). The mean calculated acetabular diameter was 52 mm ± 4 mm. It was smaller in females than in males ($p < 0.00001$, Cohen descriptor: large) (Table 4).

The acetabular opening plane was orientated 21° ± 5° for version, 48° ± 4° for inclination, and 19° ± 6° for tilt. Version measured on direct rim measure was 18° ± 6°. Version was different between females and males on direct rim measures ($p = 0.013$, Cohen descriptor: medium), but not for the opening plane measures ($p = 0.336$, Cohen descriptor: small). The correlation coefficient for the two measuring methods of acetabular version was 0.797. There was no difference for inclination and tilt in females and males. Despite the relatively narrow interval of confidence, the minimum and maximum values for all spatial measurements differed widely (Tables 4 and 5).

Discussion

Appropriate surgical concepts for treating femoroacetabular impingement require a precise appreciation of the native acetabular anatomy. We therefore quantified and compared (1) the spatial acetabular rim profile and topography of the articular lunate surface as well as (2) the 3-D relationships of the acetabular opening plane in relation to the pelvic frontal plane between female and male pelves.

Table 2. Gender differences concerning the rim location and the depth at the prominent and depressed rim areas. Rim location is abbreviated with "rim", distance from acetabular center to rim is abbreviated with "depth"

Rim configuration and acetabular location	Mean difference Female/Male	CI95% Lower	CI95% Upper	G x S P level	G P level	S P level	*d* Value	*d* Descriptor
Prominence								
Rim anterosuperior	−2.7	−8.1	2.7	0.469	0.319	0.045	0.30	Small
Rim anteroinferior	−1.5	−5.1	2.1	0.449	0.420	0.531	0.25	Small
Rim posteroinferior	−0.5	−4.1	3.1	0.876	0.798	0.616	0.07	Trivial
Depth anterosuperior	−2.2	−5.2	0.8	0.898	0.152	0.872	0.42	Small
Depth anteroinferior	−1.6	−4.5	1.3	0.285	0.285	0.668	0.31	Small
Depth posteroinferior	−1.5	−4.5	1.4	0.421	0.302	0.782	0.30	Small
Depression								
Rim anterior wall	−3.8	−8.6	1.0	0.843	0.117	0.743	0.49	Small
Rim posterosuperior	2.8	−4.3	−1.0	0.628	0.429	0.016	−0.22	Small
Depth anterior wall	−0.4	−3.1	2.4	0.946	0.800	0.893	0.08	Trivial
Depth posterosuperior	−1.3	−5.3	2.8	0.824	0.528	0.667	0.19	Trivial

CI = confidence interval; G = ANOVA for female and male gender; S = ANOVA for left and right side; *d*-value = Cohen effect size; *d*-descriptor = benchmarks according to Cohen

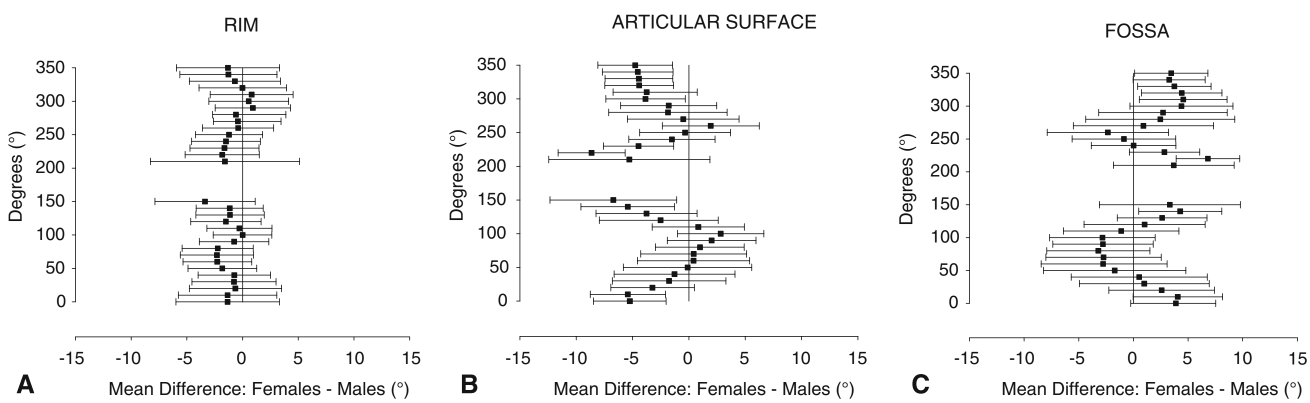

Fig. 4A–C The mean difference with confidence interval (x-axis) between genders at different locations along the circumferential rim (y-axis) is shown. (**A**) Rim, (**B**) articular surface, (**C**) fossa. The gender differences in the depth of the articular surface were determined by the size of the fossa and the width of the notch, rather than by the outer rim profile.

Interpretation of our data may be limited because the collection of specimens did not include those with dysplasia and coxarthrosis. However, we believe the features of normal anatomy should be known for comparing to pathological deviations. Another limitation may be that all measurements were performed manually by one observer with relatively simple measurement devices and that no inter- or intraobserver measurements were performed. Plaster molds are considered the gold standard in orthodontic treatment due to their high accuracy and reliability. Comparative studies suggest no differences between computer-guided and manual measures [53, 62]. The acetabular surface is only approximately spherical, with ellipsoid or conchoid deviations of the radius in the magnitude from < 0.1 mm to 1.8 mm [5, 13, 25, 42, 56]. Such incongruence may have influenced our mathematical calculations. Most previous studies on acetabular measurements similarly assumed sphericity of the acetabulum and are therefore amenable for comparison [51, 65, 67]. We tested the sphericity assumption with the Mauchly test. Violation of this assumption was taken into account adjusting the degrees of freedom with Huynh-Feldt correction. Comparison of our calculated radius with previous studies further suggests validity of our data (Table 6) [7, 14, 49, 56, 61, 63, 65, 68]. The interpretation of our 3-D studies of the acetabular opening plane may be limited by the unknown individual pelvic tilt of the archeological specimen. Spatial measurements were therefore related to the frontal pelvic plane, which is commonly used as a reference [2, 41].

Our measurements of the rim profile unites and confirms previous reports on irregularities of the outer shape of the acetabulum or of a smaller than hemispheric acetabular size [40, 56, 65–68]. One study denoted four configurations

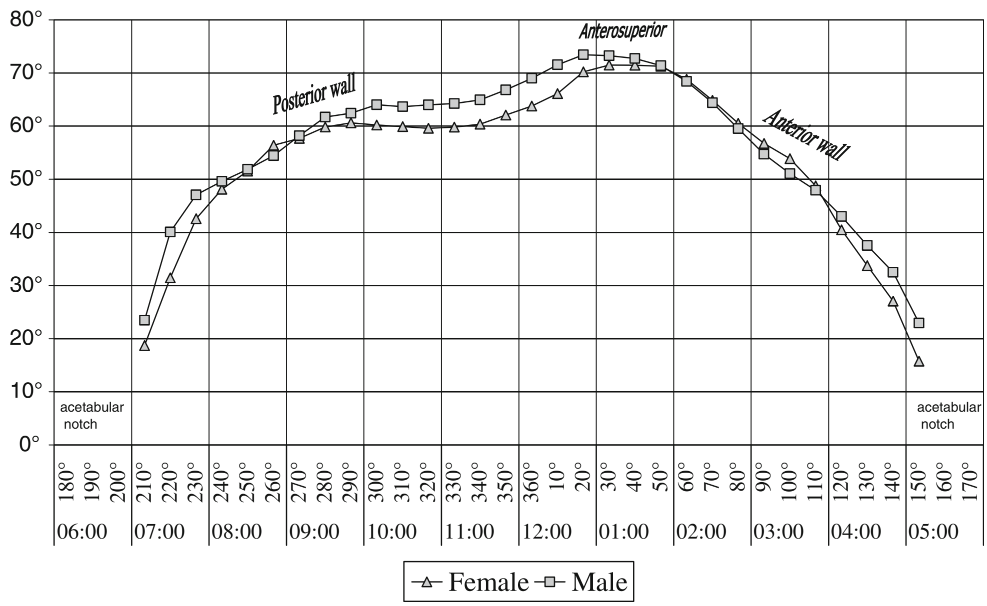

Fig. 5 The measurements of the depth of the articular surface in degrees of men and women are shown in a 2-D presentation with cylindrical coordinates. On the x-axis, a clockwise indication of circumferential rim locations is overlaying a geographic system in degrees; the acetabular notch can be seen at both extremities. The mean depth of the articular surface is given on the y-axis in degrees for females and males separately. Gender differences can be distinguished centrally, from 10:00 to 12:20 and towards the acetabular notch anteriorly and posteriorly.

Table 3. Values for radius and acetabular notch with significant gender differences for both variables

Variable	Mean difference Female/Male	CI95% Lower	CI95% Upper	G x S P level	G P level	S P level	*d* Value	*d* Descriptor
Notch [°]	7.1	3.8	10.4	0.802	0.00007	0.891	−1.11	Large
Radius	−3.2	−4.1	−2.4	0.832	< 0.00001	0.832	1.66	Large

Table 4. Statistical evaluation of spatial measurements for the opening plane. The only difference seems to be in version of direct rim measure, with a p-level of 0.013 and descriptor of Cohen effect size medium

Variable	Mean difference Female/Male	CI95% Lower	CI95% Upper	G x S P level	G P level	S P level	*d* Value	*d* Descriptor
Age	−4.2	−10.0	1.6	1.000	0.155	1.000	0.43	Small
Version direct rim	4.1	0.9	7.4	0.251	0.013	0.939	−0.76	Medium
Version opening plane	1.6	−1.7	5.0	0.699	0.336	0.495	−0.30	Small
Tilt opening plane	−1.3	−4.6	2.1	0.265	0.457	0.107	0.22	Small
Inclination opening plane	1.7	−0.8	4.1	0.648	0.183	0.876	−0.38	Small

Table 5. Spatial measurements of the acetabular opening plane in relation to the pelvic frontal plane for version, inclination and tilt

Variable	[°]		
	All acetabula (n = 66)	Female (n = 16)	Male (n = 42)
Version (direct rim)	18.3 ± 5.5 (4–34)	21.0 ± 6.7 (12–34)	16.9 ± 4.8 (4–26)
Version (opening plane)	21.1 ± 5.4 (10–39)	22.3 ± 7.7 (11–39)	20.6 ± 4.5 (10–33)
Inclination	48.3 ± 4.4 (36–58)	49.8 ± 4.1 (43–58)	48.1 ± 4.1 (46–56)
Tilt	18.9 ± 5.6 (5–32)	17.9 ± 6.2 (9–32)	19.2 ± 5.4 (5–32)

Version was measured in addition directly along the posterior and the anterior rim. All results are given as mean values with standard deviation and ranges in degree.

along the anterior rim as curved, angular, irregular, or straight [40]. In agreement with a recent study [68], we measured the irregular configurations, but found the anterior rim depression was never straight. Two studies described a wave-like profile of the acetabular rim similar to that in our study [67, 68]. Differences in the individual extent of the anterior and the posterior depressions in the more recent of these studies may be related to differences

Table 6. Comparison of hip diameter values

Study	Both genders	Female	Male	Measuring method
Clarke et al. [7]	48.3 ± 3.8	45.1 ± 2.3	51.3 ± 3.0	Skeleton, femoral head
Noble et al. [49]	46.1 ± 4.8			Radiography, female head
Sugano et al. [63]	44.9 ± 4.3			Radiography, female head
Shiino [56]		49.2	54.0	Skeleton, acetabulum
Stein et al. [61]		48.5 ± 4.8	55.7 ± 7.4	Skeleton, acetabulum
Thompson et al. [65]	50.9 ± 3.6	49.0 ± 1.45	52.9 ± 1.7	Skeleton, acetabulum
Effenberger et al. [14]	51.4 ± 3.7			Skeleton, acetabulum
Vandenbussche et al. [68]	48.5 ± 4.4	45.1 ± 2.2	51.9 ± 3.1	Three-dimensional computed tomography scan
Our study	52.3 ± 3.9	47.5 ± 2.7	54.0 ± 2.8	Skeleton, acetabulum

Results are given in millimeter as mean ± standard deviation.

Table 7. Comparison of different subtended angles in the literature

Author	Gender	Anteroinferior to posterosuperior	Anterior wall to posterior wall	Anterosuperior to posteroinferior
Oberländer et al. [51]	Both		157°	
Anda et al. [1]	Female		168°	
	Male		166°	
Thompson et al. [65]	Both	152°	158°	175°
Our study	Both	159°	165°	175°

For this comparison, we supplied values without distinction of gender. In the direction anterior to posterior wall, our measurements for females and males were both at 165°. The exact rim location of measurements from one study to the other was difficult to determine, but the results show a good consistency.

in the definition of the acetabular opening plane. A definition of the profile of the acetabular cup by subtended angles was given in a cadaveric study [65]. Sets of paired opposing radial angles subtended by the acetabular rim were summed in four principal directions. Similar angles measured by other investigators [1, 51, 65], and summation of analogous rim locations of our measurements showed comparable values (Table 7).

Regardless of the individual acetabular depth in our study, the wave-like rim profile with its depressions and prominences was a constant finding. We did not identify posterior wall hypoplasia in our specimen, as it was suggested for retroverted acetabuli [23].

The few studies reporting the depth of the articular surface provide comparable data [51, 56, 66]. Depth has usually been reported as a 2-D acetabular angle [34] measured on AP pelvic radiographs for femoral head coverage. While the width of the acetabular notch has been reported [14, 51, 56, 66], no information had been available on the size of the acetabular fossa. Our data suggest gender differences in the depth of the articular surface of the cranial acetabulum were dominated by the size of the fossa rather than by the outer rim topography. The smaller articular surface in females adjacent to the acetabular notch was caused by the substantially wider notch in women.

Acetabular tilt has been subject to only one previous study, reporting an almost identical value of 18.3°, without studying for gender [51]. We found no gender differences. In a sonographic study of hips in newborns [17], forward rotation of the ultrasound beam of 30° revealed best vision into the acetabular notch, which suggests acetabular anterior tilt. Likewise, backward tilt of a horizontal line along the transverse acetabular ligament was described in another study [43]. Allocations of acetabular surface particularities or lesions were given either with reference to the acetabular incision [4, 6, 35, 39, 55, 66] or in relation to the vertical axis of the patient as seen during surgery [30, 38, 58]. The individual acetabular tilt and variations in pelvic tilt [2, 10, 12, 32, 33, 41, 48, 57] complicate comparison of these data.

The same applies to measurements of acetabular version on CT scan, where difficulties and potential errors for measurements were reported [2, 32]. Apart from variations in pelvic tilt [2, 10, 12, 32, 33, 41, 48, 57], this can now be explained by variations of acetabular tilt, which influences spatial positions of peaks and depressions along the rim. The results of our measurements for version are comparable to other anatomical studies (Table 8).

Decreased acetabular version has been suggested as a factor leading to FAI [54]. The influence of acetabular inclination or tilt on FAI has not been systematically

Table 8. Comparison of our anatomic measurements of acetabular version with previous studies, including gender indications where applicable

Study	Version [°]			Method
	Both genders	Female	Male	
Shiino [56]		15.5	12.5	Middle of 2 planes
McKibbin [41]	16.5	19.0	14.0	Direct rim
Maruyama et al. [40]	19.9 ± 6.6	21.3	18.5	Direct rim
Jamali et al. [28]	20.1 ± 6.4			Direct rim
Vandenbussche et al. [67]	20.9 ± 9.1	24.1 ± 7.8	15.7 ± 8.8	Navigation
Our results	18.6 ± 5.5	21.7 ± 6.6	17.0 ± 4.7	Direct rim
Our results	21.5 ± 5.6	23.2 ± 7.8	20.8 ± 4.5	Opening plane

Values were given as mean with standard deviation. The higher version of our acetabular opening plane values compared to direct rim measures, were probably caused by the deeper posterior rim in relation to the anterior rim, where direct rim measurements were commonly taken. The spatial orientation of the overlaying opening plane depends entirely on the three rim prominences.

examined yet. Low individual acetabular inclination is likely to decrease anterosuperior hip clearance leading to pincer impingement. Likewise decreased acetabular tilt will place the constant rim prominences more inferior causing decreased clearance. Although the acetabular opening plane and the pelvis have a slightly different axis of rotation due to acetabular version and inclination, the entire acetabulum rotates with pelvic tilt, thereby placing rim prominences and depressions at different positions of the radiological beam. Pelvic forward tilt probably rotates the anterosuperior rim prominence into a laterally prominent radiological projection and at the same time the posterosuperior rim depression into a medial projection. These radiological changes have been attributed to altered acetabular version [23, 28, 54, 57], but maybe the 3-D situation is more complex.

This study revealed several important clinical aspects mostly for impingement surgery,

First, descriptions of acetabular lesions should be given using the acetabular notch as the landmark for 6:00. Acetabular tilt and pelvic tilt should be indicated separately. Second, the acetabular cup is smaller than a hemisphere, with a constant succession of peaks and depressions along the rim. Spatial positions of these are influenced by acetabular tilt. This needs to be considered for measurements of version on CT scans. Third, consideration of the topography of articular surface as a function of the acetabular fossa is important to avoid over-débridement of the acetabular rim, particularly in female patients. Knowledge of topography of the rim and articular surface is important in reorientation osteotomies to avoid impingement [58], or placement of a small articular surface into the main weight-bearing area. Certainly, further studies are needed to prove whether pincer FAI can result from prominence through individual spatial positions in version, inclination, tilt, or a combination of these in otherwise normal acetabula.

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