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Morphological Characteristics of the Acetabulum

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A B S T R A C T

The aim of this research was to accurately measure the surface of the semi lunar articular surface of the pelvis (facies lunata acetabuli) and the variability of the acetabular geometry, as well as to determine the correlation between measured parameters. 30 macerated anatomical specimens of pelvic bones were measured. The radius and depth were measured in the classical way, while cartilaginous surface area was measured using small fragments of measuring paper to avoid errors in measurement due to the curvature of the surface. Computerized calculations provided accurate surface values. In our research, facies lunata acetabuli measured 2294±329 mm^2. Diameter of the opening of the acetabulum measured 25.8±1.9 mm. Acetabular depth was 30±3.2 mm. Correlations between the surface area of the facies lunata acetabuli and the radius of the acetabular opening curvature (r=0.71), surface area of the facies lunata acetabuli and the depth of the acetabulum (r=0.80) and the radius of the acetabular opening curvature and the depth of the acetabulum (r=0.80) were confirmed. For precise assessment of the facies lunata acetabuli surface area, the simplest and the cheapest method is the method of measurement using small fragments of measuring paper and software analysis. There is a significant correlation between the depth, opening of the acetabulum and surface area of the facies lunata.

***Key words**: acetabulum, facies lunata, hip joint*

Introduction

For many years, human hip joint has been an object of investigation for morphologists, anthropologists and biomechanics and many clinical branches: surgery, orthopedics, rheumatology, physical medicine and radiology.

Load is transferred from spine to the pelvic bones through sacro-iliac joint and

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from pelvis to the lower extremities through hip joint. Sacro-iliac and hip joint represent a unique functional unit and have complex biomechanical construction. The complexity is presented in both static and dynamic conditions. Strain forces are transferred from the body to the pelvis, not just as compressive forces through articular surface of sacro-iliac joint, but in the same level as shear forces through the sacro-iliac ligament.

The relationship in arrangement of forces and strains in particular joint are very variable under dynamic circumstances. For example, even during normal walking, straining of the femur head is several folds higher than the force itself (the weight of the body plus the weight of the opposite raised leg). That force, during walking, may reach approximately 2500–3000 N, and during running it is even more dynamically increased.

The force is transduced to the femur through the contact surface. Exertion in the hip joint correlates to the straining force spread out through the contact surface. The bigger the straining force and the smaller the contact surface is, the exertion on the unit of surface will be higher. If there is a congruency in joint bodies of the hip joint the exertion in that joint will be in the range of optimal or allowed physiological borders, unless the body weight is not too big and contact surface too small.

From the variation anatomy, geometry and joint cartilage contact surface structure analysis point of view, transfer of the force and load from spine and sacrum to the lower extremities is inadequately investigated.

Material and Methods

30 macerated anatomical specimens of pelvic bones from the osteologic collection of the Department of Anatomy »Drago Perović« were measured. Some specimens were entire pelvis, while most specimens were individual iliac bones.

The process of measurement and data analysis was divided into three parts, regarding the goals. We measured: 1) curvature radius of the acetabular opening; 2) depth of the acetabulum; 3) surface area of the facies lunata acetabuli. Finally, correlations between measured parameters were calculated.

Acetabular opening was measured. Since the limbus acetabuli is not the part of a perfect circle, we measured the diameter and the perpendicular distance from this line to the limbus acetabuli (Figure 1). Finally, for every individual acetabulum, we calculated mean radius of curvature of the limbus acetabuli (one third of the sum of the diameter and the perpendicular distance to the limbus).

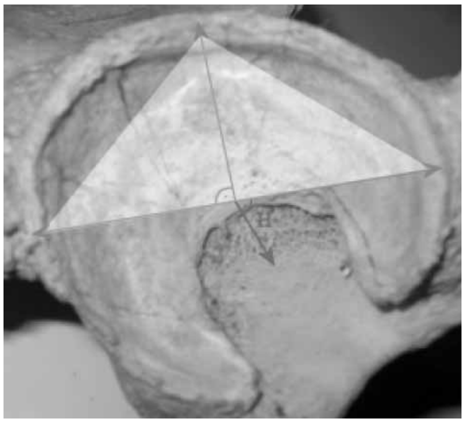

Fig. 1. The acetabulum depth and acetabulum aperture radius.

The greatest depth of the acetabulum was also measured. We determined the depth as the distance from the virtual plane determined by three most exposed points of the limbus acetabuli to the deepest point in the acetabulum[1] that was always within or in close proximity to the center of the fossa acetabuli, i.e. the point where this distance is the greatest. The

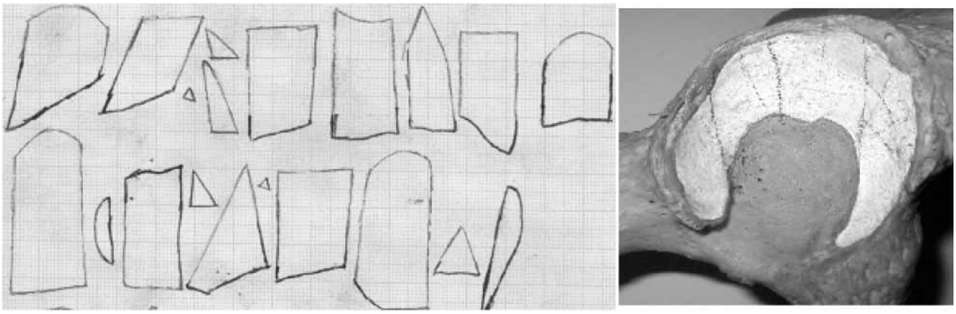

Fig. 2. Facies lunata divided into fragments (right), fragments on millimetric grid (left).

distance from this plane was defined by the length on the line perpendicular to the surface (Figure 1).

During our research, we encountered a problem regarding the measurement of tri-axial curved area of facies lunata. Considering, the acetabulum may be approximated as the half-sphere; its area could be calculated using expression:

$$Ac = 0.5 \times 4 \times r^2 \times \pi$$

Where the only variable is actually the radius of the sphere. From the calculated area, the approximated non-cartilaginous area could be subtracted, thus giving us area of facies lunata.

However, this kind of measurement encounters great deal of limitations and inaccuracies (sphere center, non-cartilaginous area approximation, imperfect sphere etc.) so it can't be used as acceptable method.

The method of measurement had to be precise, but not expensive, so that measurements can be performed in every department, using computer assistance. Therefore, measurement method using small fragments of measuring paper was used. To avoid the influence of the surface curvature, we divided measuring paper into small fragments. For surfaces with greater radius of curvature, larger fragments could be used (cc. 500 mm^2), while on edges and in areas with much accentuated curvatures very small fragments (5–10 mm^2) had to be used (Figure 2).

Since manual counting would be impossible, computer calculation was used. Fragments of measuring paper were scanned and saved in JPEG format in 1:1 ratio. For evaluation and analysis we used AutoCAD software. Importing the image, outlining surface edges and summing areas (AREA command) of individual fragments we got vector representation of fragments and total surface area. The distribution of surface areas was presented graphically and statistically evaluated using Microsoft Excel and Microsoft Word software.

Results

Surface area of facies lunata was in the range of 1,667.5 mm^2 till 2,893 mm^2 with mean value of 2,294 mm^2. Standard deviation was 329.5 mm^2 (Figure 3).

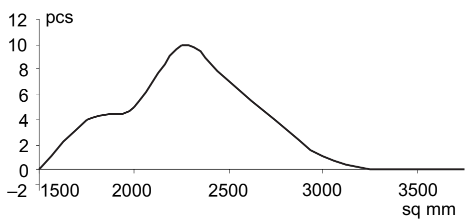

Fig. 3. Distribution of area values of facies lunata.

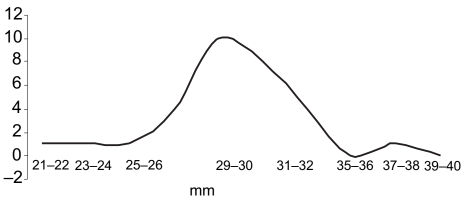

Fig. 4. Distribution of acetabulum depth values.

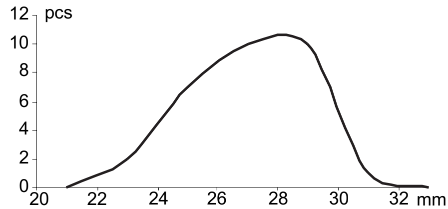

Fig. 5. Distribution of acetabulum depth values.

TABLE 1
SPEARMAN'S FACTOR OF CORRELATION OF GIVEN PARAMETERS

	Surface – radius of the opening	Surface – depth	Radius – depth
ρ	0,713570693	0,801335	0,796923
t	5,389596867	7,088184	6,980716

The depths of the acetabulum were in the range of 21–38 mm; with man value of 30 mm. Standard deviation was 3.2 mm (Figure 4).

Values of the limbus acetabuli curvature radius were in the range of 21.8–30.5 mm, with mean value of 25.8 mm. Standard deviation was 1.9 mm (Figure 5).

Spearman's factor of correlation was used for determination of correlation between examined parameters using 28 degrees of freedom.

For $\alpha = 0.05$ with 28 degrees of freedom, tgr = 1.701. This means that in all three cases t > tgr, meaning that the correlation was statistically significant.

Discussion

Recently, the technique of artificial joint implantation is used on patients with pathological changes of the joint cartilage and its reparation inability. On the specimen of 23,000 people aged 35–85 years in England in 1999, Frankel et al. have determined that the hip pain was present in 107 per 1000 men as well as in 173 per 1000 women. On the same specimen, in 1.5% surgery was necessary[9].

Aloplastic joint implantations can today result in painless and well mobile joint[9]. Indications generally include common degenerative and inflammatory joint diseases (most commonly osteoarthritis) as well as some, also common, traumatic hip lesions (fracture of the femoral neck).

Analysis of still unexplained failures was generally related to the problem of pathologic prosthesis mobility caused by specific biomechanical relations of the implant and its osseous bed. Mechanical relation of load transmission with bending momentum acting on the implant in its bed, as well as different mechanical properties of the allopathic material, osseous cement and the bone itself, are the major causes of prosthetic instability. Shortly, nonphysiologic load transmission on the endoprosthesis is the cause of most problems.

The results of the physical and biomechanical research are all included in the final construction of the aloplastic implants in the locomotion system. Among others, there is still an unresolved issue of regarding friction, representing one of the most important features of the artificial joint, and depending on characteristics of both articular components. The friction between articular surfaces also results in harmful distribution of load from one articular surface to another, which can have negative effect on the fixation of endoprosthesis.

Articular cartilage is also important with its properties of smoothness and elastic dampening, and absorption of energy of impact in intermittent loading[1]. Besides its relation to the coefficient of friction and many acting forces, friction momentum depends also on the radius of curvature of the head of endoprosthesis. Namely, with smaller radius the friction momentum also decreases, indicating that in different models of endoprostheses with different diameters of the head there are different friction momentums.

The choice of the head of prosthesis has to be in accordance with dimensions and the shape of acetabulum, with properly designed mechanical elements important for load transmission and mobility of endoprosthesis[11].

Conclusion

For assessing precise surface area of facies lunata the simplest and cheapest method is measurement with small fragments of measuring paper. Facies lunata surface area is 2,294±329 mm^2. The depth of the acetabulum is 30±3.2 mm. The radius of curvature of limbus acetabuli is 25.8±1.9 mm, which is in accordance to the results of Lanz and Wachsmuth from 1938[1].

Correlation between all three measured parameters is statistically significant:

Surface-radius of opening: ρ =0.71;
Surface-depth: ρ =0.80;
Radius-depth: ρ =0.80.

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MORFOLOŠKE OSOBINE ACETABULUMA

S A Ž E T A K

Cilj ovog istraživanja bio je točno izmjeriti površinu semilunarne zglobne površine pelvisa (facies lunata acetabuli) kao i varijabilnost geometrije acetabuluma te korelirati izmjerene parametre. Izmjereno je 30 maceriranih anatomskih uzoraka kostiju zdjelice. Promjer i dubina izmjereni su na uobičajen način, dok je područje hrskavice mjereno korištenjem malih odsječaka mjernog papira kako bi se izbjegle pogreške u mjerenju nastale zbog zakrivljenosti površine. Računalnim operacijama postignute su točne vrijednosti površine. U našem istraživanju, facies lunata acetabuli imala je površinu 2.294±329 mm^2. Raspon otvora acetabuluma iznosio je 25.8±1.9 mm, dok je dubina acetabuluma iznosila 30±3.2 mm. Korelacije između površine facies lunata acetabuli i promjera zakrivljenog otvora acetabuluma iznosila je 0.71, površine facies lunata acetabuli i dubine acetabuluma bila je 0.80, dok su promjer zakrivljenog otvora i dubine acetabuluma korelirali na razini 0.80. Pokazalo se kako je za točnu procjenu površine facies lunata acetabuluma, najjednostavnija i najjeftinija metoda ona koja koristi male odsječke papira i računalnu analizu rezultata. To potvrđuje činjenica da se ovom metodom postiže značajna korelacija dubine i promjera otvora acetabuluma te površine facies lunata.