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THE SPHERICITY OF THE FEMORAL HEAD*

B. T. HAMMOND and JOHN CHARNLEY

Centre for Hip Surgery, Wrightington Hospital, Wigan, Lancs., England

Abstract—Ten femoral heads, three of them grossly pathological, have been examined to determine their shape, employing seven types of testing. We found the sagittal section of the normal femoral head to be remarkably circular, with very close concentricity of the surface of the articular cartilage and the underlying bone. The surface of the cartilage seen in the sagittal section was even more truly circular than the surface of the underlying bone. Comparing the circularity of sections in three planes the greatest deviation from true circularity was found in the section seen in the frontal plane.

We found no position of the hip joint in which the femoral head protrudes from the acetabulum more than in any other, nor have our observations revealed any inherent stability of the hip joint attributable to peculiarities in the shape of the opposed surface, enabling these to lock one into the other.

Study of the circularity of the eburnated parts of arthritic femoral heads suggests that the process which keeps the normal femoral head spherical is well-known in production engineering, and is of such a nature that the attainment of high degrees of sphericity is not at all surprising.

RECENT advances in prosthetic hip surgery, and studies of the mechanism of lubrication of animal joints, make it important to have exact information about the shape of the normal femoral head. A review of the literature on this topic revealed nothing of particular note other than the much quoted paper of WALMSLEY (1927). Some initial tests of Walmsley's statements appeared to us to challenge his views and suggested that the whole subject should be re-studied. Walmsley's conclusion were:—

(1) For every weight-bearing joint there is a single position only where the joint is stable per se, and in the case of the hip-joint this is in full extension, the thigh being extended 15° beyond the vertical.

(2) At this point the joint surfaces are fully congruous, and at no other position in the range of hip movement.

(3) Stability is due to the complete congruity of the opposed surfaces and is independent of muscle, ligament or capsule. It occurs *above and beyond the modifying influences of the articular cartilage*.

(4) *The head of the femur is not perfectly spherical.* It is a *rotational ellipsoid of which the greater axis lies horizontally; that is, the radius of curvature of the meridian is greater than the radius of curvature of the equator*, on the average by 1·7 mm. This difference is believed to be acquired and varies from individual to individual.

(5) The femoral head in hip extension is *screwed home*, being at that point seated at its deepest in the acetabulum and in flexion, becoming *unscrewed, ... emerging from the acetabulum.*

METHODS AND MATERIALS

Ten specimens were tested, seven being preserved in formalin and three being fresh and stored in deep freeze. With the exception of one hip, from a male of 19-years-of-age, all were from cadavers over 60 years at the time of death,

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which doubtless explains why three of these hips were not completely normal.

Seven different methods of examination were used in the following manner.

(1) *Engineer's Blue*

The simplest form of examination was by applying Engineer's Blue as a thin smear on the surface of the femoral head, so demonstrating the area of contact with the acetabulum when the head was inserted in different positions. This was one of the last in each series of tests to be carried out, because it involved total removal of the capsule, ligamentum teres, and glenoid labrum, but it is mentioned first because it revealed a feature which sets a limit to the accuracy with which any tests of sphericity of the hip-joint can be made.

The most consistent area of contact between femoral head and the acetabulum was found to lie round the rim of the acetabulum, and this almost invariably prevented the summit of the femoral head making contact with the deep, central, part of the acetabulum. It is emphasised that this state of affairs was present when all the fibro-cartilage of the glenoid labrum had been dissected away and the ligamentum teres had been removed. This finding would seem to indicate that the femoral head is slightly larger than its socket or, and, that the socket is very slightly smaller than the head. This made us think that after death articular cartilage, since it is known to be hydrophylic, might swell slightly, so reducing the capacity of the acetabulum and enlarging the volume of the femoral head. A change in the diameters of acetabulum and head by as little as one-thousandth of an inch would be sufficient to produce this result since the force used in this test to press the head into the socket was only a light manual pressure.

(2) *Plaster and acrylic casts of acetabulum and femoral head*

This technique, the fitting together of carefully made casts of the head and the socket in preference to the actual joint, as used by Walmsley, we found unsatisfactory for the same reason as in the Engineer's Blue test; we also did not feel that the casts represented the fit of the head and socket quite as well as the real specimen.

(3) *Blind palpation*

This very simple test consisted in giving the acetabulum and femoral head to different observers who, after practice in acquiring the feel of rotating the femoral head in the acetabulum, were then asked to try to find any position in which the head seemed to fit "with more stability" than it did anywhere else. This test was even more impressive when done with eyes closed; it was impossible to find any point where there was a sensation of locking of the surfaces as implied in Walmsley's description.

(4) *Joint sectioned sagittaly*

As recommended by Walmsley, the hip-joint was sectioned sagittaly on a band-saw and the degree of contact between the articular surfaces viewed on the cut sections of the joint with the head in different positions of flexion and extension. Walmsley's paper led us to expect a gap to appear between the upper part of the acetabulum and the femoral head when the latter was in the flexed position, and that this gap would disappear when the joint was fully extended. In three joints so tested, one preserved in formalin and two fresh, there was no evidence of any such space appearing between hea d acetabulum. In a fourth specimen a gap was detected, but a moment's study of the illustration (Fig. 1) shows that the gap corresponds with an area of thinned cartilage at the site of early osteoarthrosis.

(5) *Lateral movement of femoral head during flexion/extension movement*

To test the idea that the femoral head moves in and out of the acetabulum, with a screw or cam action, in different positions of flexion and extension, cadaveric hip-joints were mounted on a specially constructed frame (Fig. 2). This frame rigidly immobilised the acetabulum in the anatomical position with reference to vertical

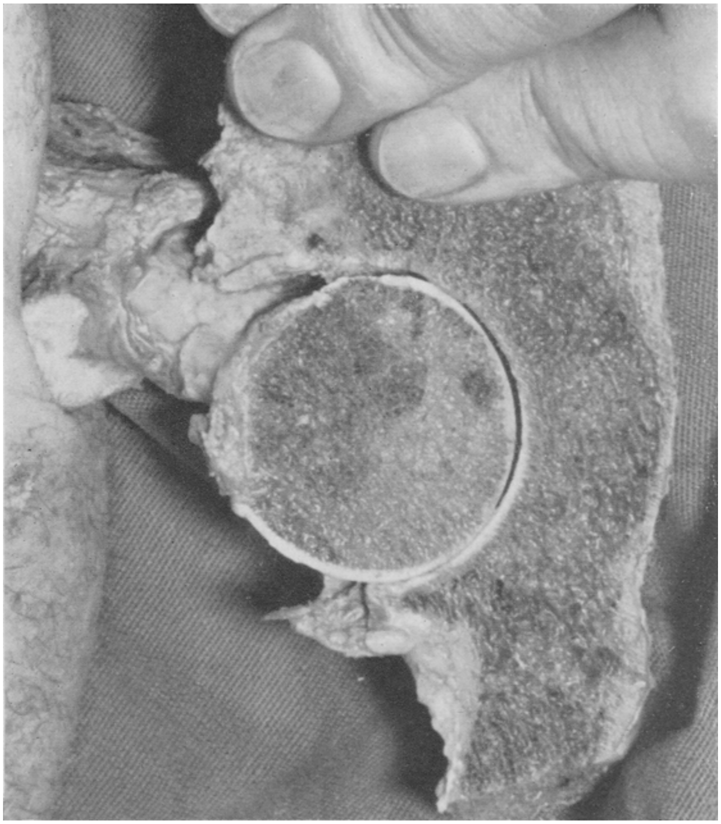

FIG. 1. Sagittal section of the hip-joint showing a concentric gap in joint space in flexion, disappearing in extension. Case of early osteoarthrosis. This gap is not seen in normal hips.

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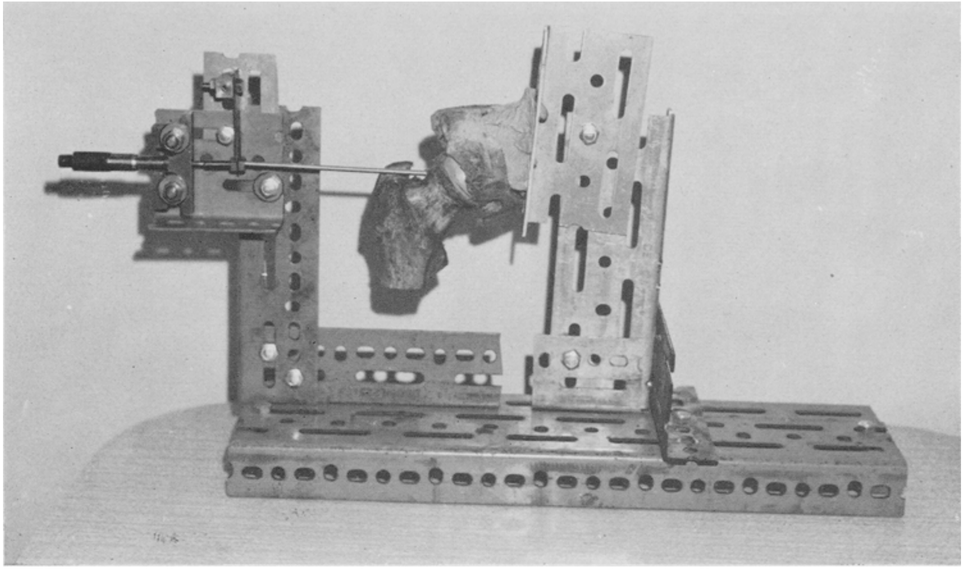

FIG. 2. Rig for testing for "screwing home" of the femoral head; see text.

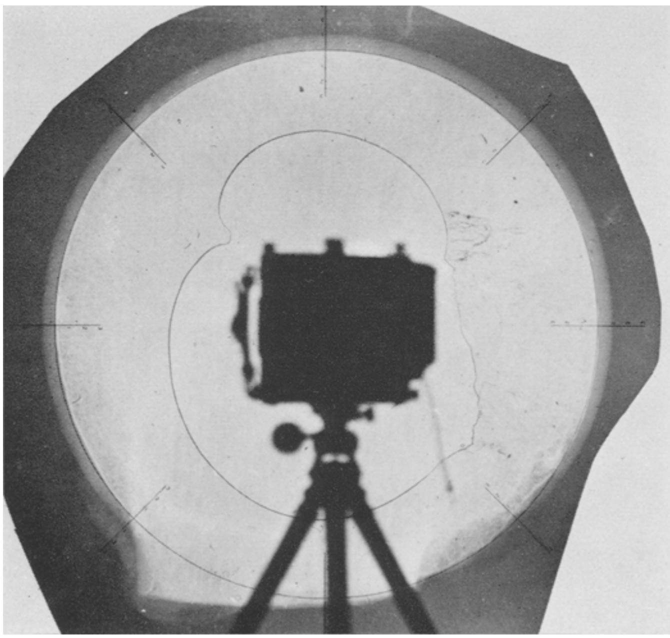

FIG. 3. Appearance of the projected, and thus enlarged, radiograph of the femoral head, on a screen on which a 36 in. dia. circle has been inscribed (fine circular black line). The grey zone outside this line is articular cartilage. The shell of cortical bone is seen as a white line, obscured in part, by the reference circle. The shadow of the camera making this photograph is also projected on the screen.

FIG. 5. Two specimens of arthritic femoral heads from patients who had preserved 90° of flexion range. Note congruity of the estimated segment to a reference circle.

and horizontal co-ordinates. Into the head of the femur a 4 mm Steinman pin was driven so as to lie in the horizontal axis of flexion/extension. The lateral end of the nail engaged in a spring-loaded socket carried on an adjustable part of the frame. Spring pressure on the lateral end of the nail retained the head in the acetabulum but permitted it to emerge or recede according to the relative congruity of the opposed surfaces. This lateral–medium movement could be measured with accuracy to 0·001 in., by means of a micrometer gauge. This arrangement enabled the head to be self-centring in the acetabulum and eliminated errors from failure to make the axis of the nail coincide exactly with the centre of the femoral head.

Seven experiments were performed upon four hips, one being formalin-preserved and the remainder fresh. One joint was tested firstly with capsule unopened, then with capsule removed but ligamentum teres intact, and finally without the ligamentum teres. Another was tested with and without the ligamentum teres; the rest were tested after removal of all ligaments and capsule, including the ligamentum teres. The inward and outward movements of the head was measured from full extension of the hip (15° beyond the vertical position of the femur) to 135° of flexion.

The average inward and outward excursion for all seven tests was 0·022 in. When the ligamentum teres and capsule had been removed, the range of movement was less, averaging 0·014 in., which suggested that 'bunching' of the ligamentum teres might push the head out in some cases. The actual measurements are recorded in Table 1 where the zero reading is the position where the head projects most from out of the socket, and the highest figure is where the head is deepest in the acetabulum.

Walmsley's findings had led us to expect maximum projection somewhere in flexion, with minimum projection in full extension. In point of fact, this was observed in one only of the seven tests performed, and this was in an intact joint in a fresh specimen. With the other six tests the direction of the extensions was unpredictable and maximum emergence (shown "zero" on the table) occurred as many times in the fully extended position (3) as it did in the fully flexed position. Minimum projection, instead of being confined to full extension (vertical + 15°

Table 1

	Name or specimen	Vertical +15° (in.)	Vertical (in.)	Flexion 45° (in.)	Flexion 90° (in.)	Flexion 135° (in.)	Range of lateral movement (in.)
1.	Bailey W. Intact joint (M—72 rt., fresh)	0·053	0·053	0·050	Zero	—	0·053
2.	Without capsule (same jt.)	Zero	0·005	0·005	0·007	—	0·007
3.	Without lig. ter. (same jt.)	Zero	0·001	0·013	0·011	—	0·013
4.	Lindop M—19, L fresh with lig. ter.	0·032	0·024	0·019	0·037	Zero	0·037
5.	Without lig. teres (same jt.)	0·019	0·006	0·005	0·028	Zero	0·028
6.	Bailey W. left—fresh without lig. teres.	0·004	0·003	0·007	0·006	Zero	0·007
7.	Formalin spec. M—69	Zero	Zero	—	0·002	0·007	0·007

extension) at some time in the series was observed in every one of the positions tested. The average position for minimum projection was with the hip in approximately 70° of flexion.

The presence of the intact capsule, especially the ligament of Bigelow, appeared to exert an inward pull upon the fully extended hip, which is to be expected in view of its anatomical conformation. Apart from this, our findings did not support Walmsley's belief in a "screwing-home" of the femoral head occurring "independently of muscle, ligament or capsule".

(6) *Femoral head direct measurement*

Various diameters of the femoral head were measured and compared, using a vernier caliper. Although the same possibility of error existed here as the Engineer's Blue test, (i.e. the possibility of slight post-mortem swelling of the articular cartilage), it was felt that direct measurements were of interest. To avoid error through indenting of the cartilage by the jaws of the vernier calipers, a lens was used to determine the precise moment when contact was made between caliper jaws and head rather than rely upon the feel of metal against yielding cartilage. It was not possible to obtain vertical diameters since the inferior surface of the head is not cartilage-covered and a continuous circle does not exist in the sagittal section (though Walmsley talks about vertical dimensions). Oblique diameters were therefore taken (i.e. transverse to the axis of the femoral neck) which ran from super-laterally to infero-medially. Horizontal diameters presented no problem.

The results are presented in Table 2, which are clearly different from those of Walmsley. Walmsley spoke in terms of the radii of the head (not of diameters), and said that the vertical radius was longer than the horizontal by an average of 1·7 mm. In terms of diameters this difference is 3·4 mm, and corresponds to a difference of nearly 7 per cent. Our findings reveal a mean difference of only 0·007 in. (0·17 mm) between horizontal and oblique diameter or only 0·35 per cent difference. We found that the oblique diameter was greater than the horizontal diameter in two heads, smaller in two, and approximately equal in three.

Table 2

Specimen	A–P Oblique (in.)	Transverse (lateral View) (in.)	Difference (in.)
Male 1 (Formalin)	1·999	2·013	0·014
Benfold (M) (Formalin)	1·824	1·791	0·033
Female 2 (Formalin)	1·676	1·676	0·000
Formalin spec (M—69 yr)	1·981	1·973	0·008
Bailey (M) left (fresh)	2·050	2·050	0·000
right (fresh)	1·991	1·995	0·004
Lindop (M) left (fresh) (19 yr)	2·077	2·0775 (av)	0·0005
Averages	1·944	1·939	0·007

(7) *Projection*

These observations were made by comparing the projected image of radiographs of the femoral head with a perfect circle drawn on a projection screen at an enlargement of 18 to 20 times (the diameter of the test circle being 36 in.). The accuracy with which deviations from a circle could be determined by this technique was quite remarkable; it was quite easy to detect a deviation from the perfect circle corresponding to 0·0025 in. on the actual specimen.

In the first experiments by this method radiographs in three planes were made centred on two different axes (i.e. six radiographs in all for each head). One set of orthogonal planes was centred on the anatomical axis of the femoral neck; the other set of planes was centred on the anatomical axis of the pelvis, ignoring the axis of the femoral neck. Since no outstanding difference was found between the results obtained in these two sets of planes it was decided to study only the sagittal, coronal and horizontal planes, because the sagittal plane is the plane in which flexion/extension occurs in the weight-bearing phase of walking, and the horizontal plane is that in which internal and external rotation occur during the weight-bearing phase. It would seem reasonable to suppose that if any high degree of circularity were to exist in any section of the femoral head it would be found in these planes. Our interest was principally to look for circularity of the section in the arc or quadrant concerned in transmitting load during walking; it seemed likely that less perfect circularity of sections might be present in those parts of the head not subjected to repeated load.

Details of technique

Radiographs of cadaveric femoral heads were taken with a 6 ft tube distance from front, side, and above, with the head in anatomical position. The films were deliberately under-exposed, so that the shadow of the cartilage could be discerned, Fig. 3. The radiographs were then mounted on slides and projected on to the screen on which had been inscribed a circle 36 in. dia. Calibrations at the eight principal compass points permitted measurements of the magnified image to be made with accuracy of 0·05 in. on either side of the test circle (0·0025 in. on the specimen). By repeated adjustments of position and magnification an attempt was made to superimpose the shadow of the projected head upon the test circle. To do this, the following rule was followed: in the A–P view, the oblique diameter of the femoral head was made to coincide with the diameter of the test circle in position and in length; in the lateral and superior views, the transverse diameter was made to coincide in position and length with the corresponding diameter of the test circle. The test readings at each end of this diameter would therefore be zero. If the head shadow and the test circle superimpose exactly the figures at all other points on the circle will also be zero. If the head shadow lies outside the test circle, the figure recorded is the actual measurement (in inches) on the screen by which the image fell outside the reference circle. If the head shadow fell inside the test circle a minus reading is shown. In the A–P and superior views not infrequently the perfect outline of the femoral head was marred by interference from the point of attachment of the ligamentum teres, resulting in local deviations much greater than the average deviation from sphericity.

Having made measurements of the bony outline of the femoral head, the outline of the cartilage was tested by changing the magnification to bring the cartilage shadow in coincidence with the reference circle. The illustrations (Fig. 4) show the method of recording measurements in each case: the inner circle represents the outline of the bony head and the outer circle that of the cartilage. The results in Table 3 are shown as the corrected figures for the actual size of the femoral head, and are the average variation from true circularity of the section in each plane. This figure is obtained by adding the maximum distance by which the projected outline overlay the test circle, if such were the case, to the maximum amount by which it fell short of the test circle. Where there was no deviation from true sphericity and the two circles corresponded precisely, the reading of course is zero.

It will be noted that the readings made in the sagittal plane approximate most closely to true circularity; the readings in the horizontal and the frontal planes follow in that order. Figures for cartilage and bone show a surprising degree of agreement and therefore of concentricity. The closest approximation to a perfect circle is seen at the surface of the cartilage rather than the surface of the bone. The most perfect circularity was seen on the surface of the cartilage in the sagittal plane; in this plane the curvature of the cartilage did not deviate from the perfect circle by more than 0·001 in.

Geometry of femoral heads in arthrosis

To complete this study some observations were made on the circularity of the sagittal section through femoral heads in osteoarthrosis. In osteoarthrosis the femoral head loses its spherical shape and becomes roller, or saddle, shaped; this shape is consistent with clinical experience that serious loss of rotation and abduction/adduction can occur even through

90° of flexion range can persist. We were interested to observe the degree of circularity of the femoral head in sagittal sections in such cases.

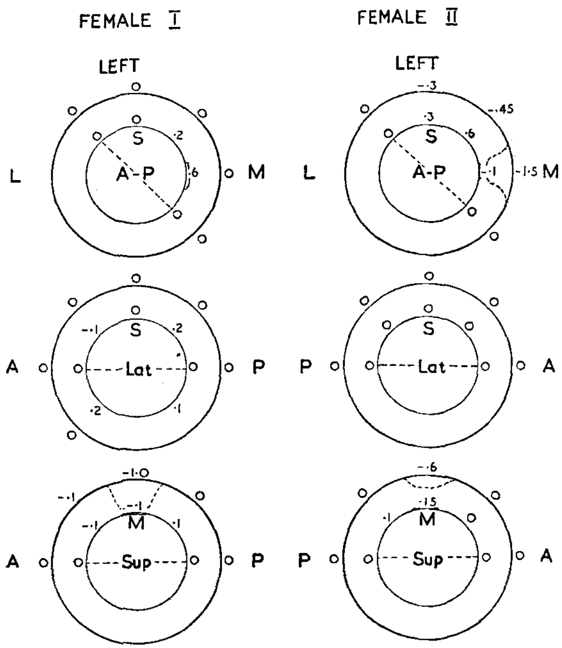

FIG. 4. System for recording deviations from the reference circle of projected radiograph of femoral head. Inner circle represents surface of bone, outer circle surface of cartilage. For actual deviation on the femoral head, in inches, divide by 20.

Two femoral heads resected from patients with osteoarthrosis were examined but since the arc formed by the eburnated part of the head was less than 180° it was not possible to use the extreme accuracy available in the projection method. For this reason measurements which might be of doubtful accuracy were not attempted, but some idea of the circularity of these relatively short lengths of circumference can be gathered from the illustrations (Fig. 5). These illustrations were made by drawing a circle on the enlarged photographic print after finding the centre by simple geometry.

DISCUSSION

To judge from the literature, as reviewed for instance by BARNETT, DAVIES and MACCONAILL (1961) no precise statement has yet been made on the shape of the normal femoral head. The general opinion would appear to be that the femoral head occasionally may appear to be spherical but that usually it is egg-shaped. The egg-shape is considered to have special significance in regard to lubrication and to general theories of joint function, but if the head is egg-shaped no indication is given of the direction in which the major axis of an egg-shaped femoral head might be expected to lie in relation to the hip joint.

It would appear from the present study that the only way to describe the shape of the femoral head would be to call it a sphere with minor and inconstant deviations from perfection. The shape cannot be called a spheroid, since a spheroidal surface is produced by the rotation of an elipse round the major or minor axis in which case the shape would be perfect and the axis of symmetry would be constant in direction and would need to be defined in relation to the hip joint.

In Table 3 the averages of deviations from the perfect circle, as measured on three different sections through the femoral head, do not relate to any constant shape. In the frontal plane the maximum deviation averaged 1·2 per cent of the total diameter, whereas the maximum deviation in the lateral view was only 0·04 per cent. If the 1·2 per cent deviation were to be the result always of the horizontal axis being 1·2 per cent longer than the vertical axis this would suggest, in combination with a deviation of only 0·04 per cent in the lateral view, that the femoral head is egg-shaped, with the axis of symmetry more or less horizontal. But this deduction would be incorrect because the 1·2 per cent deviation from perfect circularity in the frontal plane did not relate to any constant diameter. The average deviation did not concern differences in diameters, but represented the difference in height between the summits and the valleys as the contour of the head deviated, positively or negatively, in relation to the outline of a perfect circle on to which it was superimposed.

Table 3. *Maximum deviation from circularity*

Specimen		A–P	Lateral	Superior
Males 1	Bone	0·045	0·028	0·005
	Cartilage	0·043	0·000	0·005
Female 2	Bone	0·003	0·000	0·007
	Cartilage	0·021	0·000	0·028
Benfold (M)	Bone	0·04	0·001	0·011
	Cartilage	0·005	0·0025	0·005
Barlow (M)	Bone	0·03	0·008	0·02
	Cartilage	0·005	0·005	0·015
Female 1	Bone	0·01	0·005	0·007
	Cartilage	0·000	0·000	0·004
Kelly (M)	Bone	0·01	0·003	0·005
	Cartilage	0·02	0·000	0·010
Bailey (M) Left (Fresh)	Bone	0·047	0·005	0·01
	Cartilage	0·035	0·000	0·000
Right (Fresh)	Bone	0·045	0·005	0·015
	Cartilage	0·045	0·000	0·023
Lindop (M) (Fresh)	Bone	0·03	0·007	0·015
	Cartilage	0·045	0·000	0·015
Averages (Deviation in each projection)	Bone	0·032	0·004	0·011
	Cartilage	0·024	0·0008	0·012
Deviation in each projection expressed as % of diameter	Bone	1·6%	0·20%	0·55 %
	Cartilage	1·2%	0·04%	0·60 %

The experiment in which we measured the inward and outward movement of the femoral head during flexion and extension indicates that there is no constant "cam" action in the hip joint. During the movement of extension as many hips extruded as intruded. While one could readily accept that there would be differences in the amount of extrusion and intrusion in different cases, it would seem unreasonable to attribute biological significance to the movement if there is no constancy in the direction of movement in extension. The actual amount of movement in all cases was so small that it could not exert any locking action on the joint.

One feature which impressed us was how accurately in many of the sections, the contour of the articular cartilage followed the contour of the bone. A common criticism of attempts to measure the sphericity of the femoral head is that formalin preservation or post-mortem changes, might alter the shape of the head. The fact, however, that the contour of the articular cartilage was so close to that of the bony contour would seem to suggest that if any post-mortem change did exist, it was uniform and whilst it might alter the absolute measurement of the head it might be concluded on these gronuds that it did not alter the shape.

Our observations on sagittal sections through femoral heads which are the site of osteoarthritis are of particular interest in suggesting a mechanism which might be responsible for producing the sphericity of the normal femoral head. In the arthritic femoral head the upper surface of the head loses the articular cartilage and bare bone is exposed in a highly polished state("eburnation"). The arthritic femoral head takes on a cylindrical or saddle shape and this coincides with the fact that motion in the arthritic head becomes more or less restricted to the one plane of flexion and extension. In studying the shape of the sagittal section on these cases it was found that the eburnated surfaces corresponded closely to a portion of a true circle, but a circle of a greater radius than that of the original femoral head.

The process by which this circular section is generated, and hence the process by which the normal spherical head might receive its sphericity, is known in production engineering as the "generation" of spherical or cylindrical surfaces. The process of generating a cylindrical or spherical surface is unlike the ordinary cutting methods of which turning in a lathe is typical. When turning a spherical surface in a lathe the workpiece is rigidly fixed to the position of the cutting tool; because of this fixity the shape of the product depends on the accuracy of the machine. In the process of generating a spherical surface, of which the grinding of a ball bearing is typical, the workpiece can be considered to be free from the machine and therefore free from the inaccuracies in the machine which could be transferred to the final product. On this theory it would be rather surprising *not* to find an almost spherical surface in a naturally occurring ball and socket. If a naturally occurring ball and socket did not develop an almost perfect sphere this would indicate that it was being constrained to move in a restricted arc rather than being used fully over a full range. In the case of young human subjects there would seem no reason to believe that the head of the femur was constrained to work continuously in one axis but with the passage of years there is no doubt that movement in the sagittal plane probably predominates and eventually the head of the femur becomes arthritic and loses rotation and abduction and adduction with a slow change of the head of the femur to a roller shape. It is possible that the failure to recognize this fact in anatomical circles has lead to some of the past confusion.

In reviewing the literature on the shape of the femoral head it is remarkable that the paper of Walmsley should have been so widely quoted without having been challenged in the intervening forty years. It is possible that attempts to make accurate measurements of cadaveric specimens have been considered unprofitable by many workers since even if the surfaces were found to lack absolute sphericity the compliance of the cartilagenous surfaces under the weight of the body could be expected to render them accurately coapted. In the present investigation it can be confidently asserted that the deviation from true sphericity is so small as to be well within the compliance available in the elasticity of two layers of articular cartilage. It would therefore seem to be the case that in the hip joint, very perfect contact of all parts of the cartilagenous surfaces is to be expected in any position of the hip joint. In this respect the hip joint would appear to differ from joints such as the knee and elbow where differences in the shape of the mating surfaces in extension and flexion can be recognized even with the naked eye, which differences have been described by MacConaill as the "close packed" and "loose packed" positions. It is to be noted that these joints are basically hinge joints and MacConaill has described how in these a theoretical point on one articular surface will describe a curved track on the other surface which is more complex than a segment of a circle. In the case of the hip joint, however, a theoretical point in the head of the femur is not constrained to move in a track determined by external structures and in this way everything is set for nature to generate a surface approximating closely to a perfect sphere.

CONCLUSIONS

This investigation disproves on almost every count the statements made by Walmsley (1927) regarding the shape of the normal femoral head. We conclude that the femoral head, and particularly the cartilagenous surface of the normal femoral head, deviates from a true sphere by a remarkably small amount, and in a pattern which would appear to be inconstant from patient to patient. It would appear that the head of the femur is not spheroidal with an axis of symmetry in constant position. The amount of deviation from a true spherical surface is so small that it would be completely accommodated under the load of the weight of the body in the compliance of two layers of normal articular cartilage.

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SPHERICITE DE LA TETE DE FEMUR

Sommaire—On a classé dix têtes de fémur, dont trois nettement pathologiques, afin de déterminer leur forme au moyen de sept types de critères. Nous avons trouvé que la section ragittale de la tête de fémur normale présentait une remarquable sphéricité, avec une concentricité très réelle entre la surface du cartilage articulaire et le milieu asseux sous-jacent. En comparant la circularité des sections suivant trois plans, on remarque que l'écart le plus important par rapport au cercle parfait a été trouvé dans la section suivant le plan frontal. Nous n'avons remarqué qu'une position particulière de l'articulation de la hanche pour laquelle la tête de fémur fasse raillie hors de la cavité cotyloïde plus que pour toute autre; nous n'avons pas observé non plus de stabilité propre de l'articulation qui soit liée à une disposition particulière des surfaces en regard et s'emboitant l'une dans l'autre. L'étude de la circularité des parties enflammées d'une tête de fémur d'arthritique met en évidence le phénomène assurant la spéricité de la tête, procèdé bien connu des techniques de fabrication, de nature telle que la haut degré de sphéricité qui est atteint n'apparait pas comme tellement surprenant.

DIE SPHÄRIZITÄT DES FEMURKOPFES

Zusammenfassung—Zehn Femurköpfe, drei davon stark pathologisch, wurden auf ihre Form hin nach sieben Testverfahren geprüft. Wir fanden, daβ der Sagittalschnitt des normalen Femurkopfes bemerkenswert zirkulär war mit sehr genauer Konzentrizität der Oberfläche des Gelenkknorpels und des darunterliegenden Knochens. Im Vergleich der Zirkularität von Schnitten in drei Ebenen wurde die gröβte Abweichung von vollständiger Zirkularität im Schnitt in der Frontalebene gesehen. Wir fanden keine Hüftgelenksposition, in welcher der Femurkopf besonders aus dem Azetabulum hervorgetreten wäre. Unsere Untersuchungen ergaben auch keine inhärente Stabilität des Hüftgelenks, die auf die Form der gegenüberliegenden Flächen als Verkeilungsmöglichkeiten zurückgeführt werden könnte. Die Untersuchung der Zirkularität der eburnifizierten Teile von arthritischen Femurköpfen weist darauf hin, daβ der Prozeβ, der den normalen Femurkopf sphärisch erhält, in der Produktionstechnik gut bekannt ist; dieser ist derartig, daβ ein hoher Sphärizitätsgrad nicht überraschend ist.