Relationship Between the Sphericity of Femoral Head-Acetabulum and the Low Incidence of Primary Osteoarthritis of the Hip Joint in Koreans

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I examined the sphericity and the congruity of the femoral head and the acetabulum in 172 Korean fetuses and in 655 Korean adults. I found that Korean fetal acetabuli and femoral heads are spherical and that the proportion of the head contained in the acetabulum remains constant and congruous throughout the fetal life. Adult acetabuli and femoral heads are also spherical in both gender and are there are no visible changes in the shape of the acetabuli and the femoral heads with respect to age. No evidence was found that the congruity of the hip joint is a cause of osteoarthritis of the hip joint. Clinical Relevance: Stable hip joints at the time of birth provide an explanation for the low incidence of congenital dislocation of the hip joint in Koreans. The spherical femoral head and acetabulum (congruous hip joint) seem to be a contributing factor to the low incidence of primary osteoarthritis of the hip in Koreans.

Key Words: Sphericity of hip joint, congruous hip joint, low incidence of osteoarthritis.

It has been reported that the incidence of primary osteoarthritis of the hip joint is lower in Chinese people than in Caucasians (Gunn 1964; Hodgson 1964; Hoaglund et al. 1973). Several factors have been claimed to lead to a low incidence of primary osteoarthritis of the hip joint in the Chinese population: 1) rare architectural abnormality in the hip joint resulting from unrecognized childhood hip disease such as congenital dysplasia of the hip, slipped capital femoral epiphysis, and Legg-Perthes disease (Murray 1965; Hoaglund et al. 1973; Stulberg and Harris 1974; Stulberg et al. 1975); 2) greater range of hip joint motion (because of capsular laxity), promoting a pumping mechanism which insures a proper nutrition by allowing synovial fluid to penetrate into deeper layers of cartilage; and 3) approximately 15% percent lower average force across the hip of the Chinese people (Hoaglund et al. 1973), making the total force to which articular cartilage is subjected to comparatively less.

Even though no formal study is available, the general consensus is that the incidence of primary osteoarthritis in Korean people is also considerably low. I hypothesize that the spherical femoral head and acetabulum in Korean people might be accountable for the lower incidence of osteoarthritis in that ethnic group.

In Caucasians, it has been observed that neither the acetabulum nor the femoral head is spherical (Cathcart 1971; Bullough et al. 1973; Clark and Amstutz 1975). It is said that because the joint surfaces are not spherical they cannot be congruent (Bullough et al. 1973).

Crues (1974) and Lloyd-Roberts (1955) emphasized that the incongruity of hip joints can lead to osteoarthritic changes. On the other land, others (Walmsley 1928; Harrison et al. 1953; Bullough et al. 1968; Goodfellow and Bullough 1968; Bullough et al. 1973; Day et al. 1975) observed that incongruity is a feature of normal human hip joints and that incongruity decreases with increasing age. They argued that congruous hip joint is a major factor for joint degeneration.

The purpose of my studies is: 1) to determine the sphericity of the femoral head and acetabulum in Korean people by examining fetuses, adult cadavers and patients with femoral neck fracture; 2) to learn the influence of aging on the sphericity of the hip joint of Koreans, and finally 3) to determine the relation-
ship between osteoarthritis and the sphericity the of femoral head and acetabulum.

MATERIALS AND METHODS

My investigation was composed of three parts: 1) evaluation of the sphericity of the femoral head and acetabulum in fetuses; 2) evaluation of the sphericity of the femoral head and acetabulum in adult cadavers and in the patients with femoral neck fracture at the time of total hip arthroplasty; and 3) taking roentgenographic measurements of the pelvis of patients who were hospitalized for reasons other than problems in the hip joint, which included the sphericity of the osseous femoral head, acetabular angle, acetabular roof angle, acetabular depth, center-edge (CE) angle and the distance between the centers of the femoral heads.

Fetuses: Dissections were carried out on both hip joints from 172 fetuses who showed no evidence of a disorder of the locomotor system. The youngest fetus was fourteen weeks old and the oldest was thirty-eight weeks old.

In the fetuses over twenty weeks old, the study was made as follows. After removing the muscles, the hip joint capsule was excised but the acetabular labrum was preserved. The ligamentum teres was then divided and the joint components were separated.

In the acetabulum, the diameter was measured with a caliper by taking the greatest width of the cavity (a1), and the depth was measured using two wires. One wire was placed across the greatest diameter of the mouth of the cavity lying on the fibrocartilaginous labrum. The other was placed at right angle to the first one, and then the distance a2 was measured between this “bridge” (made by the first wire) and the deepest part of the socket. The sphericity of the acetabulum was determined from these measurements (Figs. 1-A and 1-B).

In the femoral head, the greatest diameter in the equatorial axis (b1) and the greatest diameter in the meridian axis (h2) were measured with a Caliper (Figs. 2-A and 2-B). The sphericity of the femoral head was determined from these measurements.

To measure the cover of the femoral head, the head was returned to the acetabulum to the position where it is completely covered, and where the axis of the cavity and the axis of the femoral neck are identical. The line of the acetabular margin was then marked out on the femoral head either with a fine felt-tipped pen or with a line of pins. The distance between this line and the convexity of the femoral head was measured (h3), so that the proportion of the total height of the femoral head covered by the acetabulum could be calculated (h3/h2) (Fig. 2-A).

In the fourteen to twenty-week-old fetuses, accurate measurement with a caliper proved to be impossible. Therefore, the joints were embedded in
paraffin, and serial histological sections were cut to allow measurements to be taken from the greatest dimensions of the femoral head and acetabulum.

Adult cadavers: To assess the sphericity of the acetabulum and femoral head in adults, hip joints were obtained from ninety-nine cadavers. Both hip joints were measured in all cadavers. Sixty-seven were male and thirty-two were female. The average age was 60.6 years, with a range from 26-103 years. The opposing articular cartilage of the femoral head and of the acetabulum was inspected macroscopically for surface degenerative changes and any other abnormalities. Specimens with any surface degenerative changes or abnormalities were discarded.

Adult hips at arthroplasty for femoral neck fractures: Hip joints of the patients with femoral neck fracture were also examined to evaluate the sphericity of the acetabulum and the femoral head at the time of a replacement arthroplasty. Twenty patients were male and thirty-six were female. There were thirty right hips and twenty-six left hips. The average age was 68.9 years, ranging from 36 to 86 years. Using comparative contour gauzes (Fig. 3), the cartilage contours were measured in the equatorial (A) and meridian (M)

Fig. 2-A. Schematic drawing of fetal femoral head measurement.

Fig. 2-B. Femoral head measurement in the thirty-six-week old fetus with a micro-caliper.

Fig. 3. Comparative contour gauzes for measuring joints in the 42 to 57 mm diameter range in increments of 1mm.
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Fig. 4-A. Three-dimensional view of the femoral head. Black circle denotes a fovea. M, Meridian plane; A. Equatorial plane. The intersection of the femoral neck axis (NN) with the superior surface of the femoral head forms a pole.

Fig. 4-B. Dotted line represents the midline of the cartilage bearing surface and circumferential measurements on this line are referred to as equatorial (A). Measurements in the corresponding orthogonal plane are referred to as meridian (M).

planes at five sites in both the acetabulum and the femoral head (Figs. 4-A and 4-B). To measure the acetabular cartilage contours, acrylic replicas were made from all acetabuli.

To determine any change of the sphericity of the acetabulum and femoral head with respect to age, cadavers and patients were divided into four age groups of 26 to 54, 55 to 64, 65 to 74, and 75 to 103 years and an approximately equal number of specimens (total of 155 cases) were obtained from each group. These were compared with the fetal group mentioned earlier (172 cases).

In order to compare the sphericity of the hip joints with respect to sex, corresponding measurements of each plane of the acetabulum and femoral head were taken from male and female hip joints.

The sizes and the shapes of the acetabuli were compared with their corresponding femoral heads. The data of the acetabuli were derived from measurements of 254 acrylic cored replicas.

Roentgenological evaluations: In the last part of my investigation, I took 500 patients (244 male and 256 female) who were hospitalized for various reasons other than problems in the hip joint. The average age of the male patients was 58.4 years, ranging from 19 to 88 years. The average age of the female patients was 59.2 years, ranging from 19 to 88 years. The patients were divided into four age groups: 19 to 54, 55 to 64, 65 to 74, and 75 to 88 years. There was an approximately equal number of patients in each group.

I studied roentgenograms of the pelvis of these 500 patients: 1) to detect any abnormalities in the configuration of the acetabulum and/or femoral head, and 2) to determine the incidence of osteoarthritis in this particular patient group. For this purpose, I assessed the sphericity of the osseous femoral head, acetabular angle, acetabular roof angle, acetabular depth, center-edge (CE) angle and the distance between the centers of the femoral heads in all patients.

The sphericity of the osseous femoral head was assessed, along with the position of the femoral head relative to the axis of the femoral neck and the contours of the femoral neck. Particular attention was paid to deformities that occurred after a minimal slipping of the capital femoral epiphysis and mild cases of Legg-Perthes disease. The sphericity of the osseous femoral head was measured with a Mose ring as well.

The slope of the acetabulum was measured by the acetabular angle as follows. In the anterio-posterior radiograph of a pelvis, I found two relatively constant points on the acetabulum: one at the inferior tip of the U figure (or "pelvic tear drop") and the other at the lateral edge of the acetabular roof. The U figure represents the floor or the acetabular fossa, while the lateral edge of the acetabular roof is a radiographic projection of a ridge of bone running anteroposteriorly, approximately parallel with the X-ray beam. The acetabular angle is formed by the intersection of a line connecting these two points with a horizontal line.
(Hilgenreiner's line) connecting the inferior tips of the U figure.

The slope of the lateral edge of the acetabular roof is determined by measuring the angle formed by the intersection of the line parallel to Hilgenreiner's line tangent to the roof of the acetabulum and the line parallel to the lateral edge of the acetabular roof.

Acetabular depth is determined by measuring the perpendicular distance from the deepest point of the acetabular surface to the line connecting the inferior tip of the U figure to the lateral edge of the acetabular roof.

The center-edge angle represents the intersection of two lines radiating from the center of the femoral head, one passing through the outer edge of the acetabular roof and the other perpendicular to a line connecting the centers of the femoral heads. The angle reflects the position of the femoral head relative to the acetabulum; the more laterally displaced the head is, the smaller is the center-edge angle.

RESULTS

Fetal acetabulum: In the twenty-four hips of the twelve fetuses (between fourteen and sixteen weeks old) the sections showed that the acetabulum was a deep-set cavity substantially enclosing the head (average, 65.9 per cent in the fourteen-week-old fetus, 64.9 per cent in the fifteen-week-old fetus, and 64.8 per cent in the sixteen-week-old fetus). From the sixteenth to about the eighteenth week of fetal life, the acetabulum became shallower than before but after that it remained constant until the time of birth.

The equatorial axis of the acetabulum was larger than the meridian axis in 296 hips (86 per cent) by an average of 0.16 millimeter (range, 0.01 to 0.36 millimeter). The meridian axis was larger than the equatorial axis in forty-eight hips (14 per cent) by an average of 0.2 millimeter (range, 0.05 to 0.34 millimeter). These data led me to conclude that the Korean fetal acetabuli are spherical.

Fetal femoral head: The equatorial axis of the femoral head was larger than the meridian axis in 228 hips (66.3 per cent) by an average of 0.12 millimeter (range, 0.02 to 0.29 millimeter). The meridian axis was larger than the equatorial axis in ninety-two hips (26.6 per cent) by an average of 0.08 millimeter (range, 0.01 to 0.13 millimeter). The meridian axis was the same as the equatorial axis in twenty-four hips (7.0 per cent). These findings indicate that in Korean fetuses, the femoral heads are spherical as are the acetabuli.

Fetal femoral head cover: My study showed that the proportion of the femoral head contained in the acetabulum remains constant throughout the fetal life.

Adults: To verify the sphericity of cadaver hips and hips of the patients with femoral neck fracture, each plane of the acetabulum was measured. In the male, the average diameter of the equatorial axis was 49.3 millimeters (range, 44.3 to 53.8 millimeters) and the meridian axis was 49.5 millimeters (range, 44.3 to 54 millimeters). The equatorial diameter of the acetabulum was greater than the meridian diameter in forty-six hips (29.9 per cent) with an average of 0.3 millimeter (range, 0.2 to 0.7 millimeter). The meridian diameter was greater than the equatorial diameter in seventy-six hips (49.3 per cent) with an average of 0.5 millimeter (range, 0.1 to 1.5 millimeters). In the remaining thirty-two hips (20.8 per cent), both diameters were equal.

In the female, the average equatorial diameter was 43.7 millimeters (range, 43 to 44.3 millimeters) and the meridian diameter was 43.6 millimeters (range, 42.8 to 44.3 millimeters). The equatorial diameter was greater than the meridian diameter in fifty hips (50 per cent) by an average of 0.1 millimeter (range, 0.1 to 0.2 millimeter). In the remaining fifty hips (50 per cent), both diameters were equal. These data indicated that the acetabuli are spherical in both genders.

In order to determine the sphericity of the femoral head, the diameters of each plane were compared. In the male, the average equatorial diameter was 49.3 millimeters (range, 44 to 53.8 millimeters) and the average meridian was 49.5 millimeters (range, 44 to 54 millimeters). The equatorial diameter was greater than the meridian diameter in fifty-one of 154 hips (33.1 per cent) by an average of 0.4 millimeter (range, 0.2 to 0.8 millimeter). The meridian diameter was greater than the equatorial diameter in sixty-nine hips (44.8 per cent) by an average of 0.4 millimeter (range, 0.1 to 1.6 millimeters). In the remaining thirty-four hips (22.1 per cent), both diameters were equal.

In the female, the average equatorial diameter was 43.7 millimeters (range, 43 to 44.3 millimeters) and the meridian diameter was 43.6 millimeters (range, 42.6 to 44 millimeters). The equatorial diameter was greater than the meridian diameter in twenty-two hips (28.0 per cent) by an average of 0.1 millimeter (range, 0.1 to 0.5 millimeter). The meridian diameter was greater than the equatorial diameter in sixteen (16.0 per cent) by an average of 0.2 millimeter (range, 0.1 to 0.6 millimeter). In the remaining fifty-six hips (56.0 per cent), both diameters were equal. These data demonstrated that the femoral heads in both genders were also spherical.

There were no visible changes in the shape of
acetabuli and femoral heads with respect to sex and age. There were no significant differences in size and shape of the replica of the acetabulum and femoral head in all cases; the acetabuli were almost mirror images of the mating femoral heads.

The sphericity of the femoral head in the radiograph of the pelvis was examined with respect to the position of the femoral head relative to the axis of the femoral neck and the contours of the femoral neck, and no hip had the so-called "pistol grip deformity" (Stulberg et al. 1975). When measured with a Mose ring, the femoral head was nearly spherical (within two millimeters out of roundness in all hips).

The average acetabular angle in 488 hips (244 men) was 36.4 degrees, ranging from 26 to 56 degrees. In 512 female hips (256 women), the average acetabular angle was 37.6 degrees, ranging from 28 to 48 degrees. The slope of the acetabular roof was greater than zero degree in all hips. The average depth of the acetabulum was 20.3 millimeters (range, 15 to 29 millimeters) in male and 18.1 millimeters (range, 14 to 25 millimeters) in female patients. The average center-edge (CE) angle was 33.2 degrees (range, 20 to 48 degrees) in male and 32.1 degrees (range, 17 to 55 degrees) in female patients. The average distance between the centers of the femoral heads was 202.2 millimeters (range, 188 to 224 millimeters) in men and 201.2 millimeters (range, 183 to 232 millimeters) in women. Interestingly, there was no significant difference in mean distance between the centers of femoral heads in men and women.

There was no change with increasing age in the acetabular angle, slope of the acetabular roof, depth of the acetabulum, the center-edge angle, roundness of the femoral head and the distance between the centers of the femoral head.

Osteoarthritis of the hip joint evinced in the radiographs was graded on a scale of 0 (normal) to 4, using the criteria of Kellgren and Lawrence (1957): Grade 1, doubtful; Grade 2, minimum; Grade 3, moderate; Grade 4, severe. Of the 500 patients, none had Grade 3 or Grade 4 osteoarthritis. In only one of the 1000 hips, the CE angle was less than 17 degrees (abnormal), but it had no osteoarthritic changes.

**DISCUSSION**

It has been reported that the human acetabulum is the shallowest at birth, and there has been a concern about the stability of the hip joint on this account (LeDamany 1912; Ralis and McKibbin 1973). The rationale was that a shallow hip would be less stable than a deep hip, so the human hip would be most unstable around the time of birth.

On the contrary, my studies of 172 Korean fetuses revealed that there was no evidence that the acetabulum was the shallowest around the time of birth. I found that until the sixteenth week of fetal life, the acetabular socket substantially enclosed the femoral head (about 65 percent). After the sixteenth week, the acetabulum grew shallower, however, from. After the eighteenth week it remained constant until the time of birth. Hence, the hip joints are stable around the time of birth.

It is noteworthy that there is a considerably low incidence of congenital dislocation of the hip joint in Korean children and my finding seems to provide a good explanation for this phenomenon. I am led to conclude that there are inherent differences in the development of hip joints between the Caucasian and the Korean people from early fetal life.

The difference between the diameters in the equatorial and the meridian planes apparently was appreciated already by anatomists of the nineteenth and early twentieth centuries, and also by recent investigators (Cathcart 1971; Clark and Amstutz 1975). The average out of roundness was reported as 3.4 millimeters by Schmid (1876), and 2.8 millimeters by Cathcart (1971). Clarke and Amstutz (1975) reported an average out of roundness of 1.9 millimeters: 2.9 millimeters in males, and 0.9 millimeter in females. They concluded that, in the (Caucasian) female population, the difference between the equatorial and the meridian diameters is not profound; hence, the female femoral heads can be considered spherical; in the (Caucasian) male population the meridian diameter is generally greater than the equational diemeter; hence, the aspherical nature is much more pronounced, resembling an exaggerated barrel-like shape.

In my study, the average out of roundness was 0.15 millimeter in both the acetabulum and femoral head, 0.2 millimeter in males and 0.1 millimeter in females. This finding indicates that the acetabulum and the femoral head are much more spherical in Koreans than in Caucasians. I speculate that the considerably lower incidence of primary osteoarthritis in the Korean population might be attributed to the spherical femoral head and acetabulum constituting a conhip joint.

Greenwald and Haynes (1972) insisted that hip joints become more congruous with increase of age. They said that in some of the aged specimens, the femoral head and the acetabulum appeared to be quite congruent and under a light load they came into full contact with each other. Similarly, Clarke and Am-
stutz (1975) found congruency between the femoral head and acetabulum in thirteen replicated hips from the 45 to 80 years age group.

In my study of Korean hips, however, I found that the sphericity of the acetabulum and the femoral head remained constant in all ages. In the fetus, the average out of roundness in the acetabulum was 0.18 millimeter and 0.1 millimeter in the femoral head. These values were very close to those of adult hips (0.15 millimeter in both acetabulum and the femoral head). On the basis of these findings in Koreans, I cannot support the concept that the hip joint becomes congruous with increasing age.

Of particular interest in my study were the results that in all fetuses, 86 percent of the acetabular specimens had the equatorial diameter greater than the meridian diameter and 73.3 percent of the femoral head specimens had an equatorial axis greater than, or equal to, the meridian diameter. In adult hips, the number of specimens which have a greater equatorial diameter decreases substantially, while the proportion of specimens with a greater meridian diameter increases.

This finding supports Walmsey's conclusion (1928) that the load transmission on the superior aspects of the joint surfaces must be responsible for retarding the growth in the equatorial plane. Consequently, it indicates that the onset of walking changes the shape of the femoral head.

However, in all my cases, the sphericity of the hip joint in the adult remained the same as that of the fetus while the ratio of the equatorial and the meridian diameters was changed. In Caucasian adults, the equatorial axis is much shorter than the meridian axis, resulting in the formation of an egg-shell-like femoral head and acetabulum. I speculate that a wide range of motion of the hip joint in Korean people, from sitting on the floor and squatting, allows a relatively even pressure distribution in the hip joint: thus, the overall sphericity of the acetabulum and the femoral head is maintained throughout the course of their lives.

My study leads me to think that utilization of the hip joint over a wide range of motion might be an important factor in preventing osteoarthritis by maintaining the spherical femoral head and acetabulum. If this is the case, then yoga-type exercise (stretching the hip joints on the floor) would be highly recommendable for the Caucasians whose range of hip joint motion is relatively limited by cultural pattern.

After assessing many roentgenographic parameters of normal and abnormal acetabular appearance, Stulberg and Harris (1974) selected four criteria as the most valuable parameters for the determination of the abnormality of the acetabulum: acetabular angle, acetabular roof angle, acetabular depth, and center-edge (CE) angle. Using these four criteria they measured the acetabular configuration of a large group of patients with so-called idiopathic osteoarthritis. They found that more than 40 percent had previously unrecognized acetabular dysplasia. They reported that women with osteoarthrosis were particularly likely to have acetabular dysplasia. More than two-thirds of their female patients with osteoarthritis of the hip had acetabular dysplasia. Further examination of the roentgenograms of these patients revealed that there also was a "pistol-grip" deformity of the femoral head/neck which was associated with an increased incidence of degenerative joint disease of the hip.

Murray (1965) also called attention to mild epiphysiolysis or a tilt of the femoral head in Caucasians, associated with osteoarthrosis. In his series, 60 percent of the patients with so-called primary osteoarthrosis showed a tilt of the femoral head or an architectural abnormality that he believed predisposed the patients to osteoarthritis of the hip. Again, his work suggests the possibility that unrecognized architectural relationships may cause osteoarthritis, or protect against it. These observations are consistent with the fact that there is a low incidence of primary osteoarthritis of the hip joint in the Chinese in Hong Kong, where the incidence of childhood hip disease is low (Hoaglund et al. 1973).

My study supports Stulberg-Harris and Murray's theses. In my series, normal values of acetabular angle, acetabular depth, acetabular roof angle and center-edge angle were comparable to those of Caucasians (Stulberg and Harris 1974). There was no architectural abnormality of the femoral head in the 1000 hips. The absence of architectural abnormality of the hip joint in Koreans might be related to a low incidence of congenital hip dysplasia, which in turn might be related to a low incidence of primary osteoarthritis of the hip joint in Koreans.

In conclusion, I believe that the normal hip joint is congruous in fetal life and remains congruous throughout acquired life. The factors leading to a low incidence of primary osteoarthritis of the hip joint in Korean people seem to be the spherical femoral head and acetabulum (consequently, congruous hip joint), and a rare architectural abnormality of the hip joint from unrecognized childhood hip disease. The fact that the sphericity of the femoral head and the acetabulum may have something to do with a wide range of motion of the hip joint deserves the attention of orthopaedists in the west.
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