Acta of Bioengineering and Biomechanics
Vol. 10, No. 4, 2008

Influence of developmental hip dislocation on femoral head sphericity: experimental study in dogs

STANISŁAW JUNK[1], TOMASZ TOPOLIŃSKI[2, *], PIOTR J. BILIŃSKI

[1] Medical University Hospital, Bydgoszcz, Poland; Aberdeen University Hospital, U.K.
[2] University of Technology and Agriculture, Bydgoszcz, Poland.

The aim of this study was to assess the growth and the changes in the shape of a femoral head in dog puppies with dislocated and unstable hip joints.

Ten 5-week-old, mountain shepherd puppies were divided into two subgroups. In five animals, the femoral head was dislocated, and in the other five dogs, femoral head was reduced after the dislocation procedure, making the joint congruent but unstable. After 4 weeks the animals were euthanised.

The optical method of contour measurement of the femoral head sphericity was used. The shape of the dislocated femoral head differed from the normal one. The medial part was extended into beard-like form. The overgrowth of the femoral heads was significant and from 38% to 61% larger compared with the normal contralateral head. The unstable head of the second group did not differ in the shape nor in its size from the contralateral normal one.

The large adaptive and deforming changes of shape in the dislocated femoral heads in our study show the pronounced malformation of the joint. The shape of beard-like deformity may be explained by the enlargement of contact surface between the medial part of the head and illiac bone.

The restricting modelling role of the acetabulum, the minor vascular impairment during the surgery and the short time of follow-up were possible factors contributing to the minimal changes of the affected femoral head in the unstable but congruent hip joint.

Key words: *hip dislocation, sphericity, femoral head, dog*

1. Introduction

Developmental dislocation of the hip (DDH) in dogs is accompanied by adaptive and degenerative changes of the femoral head. However, reports on anatomical observations of these deformations in dislocated hips are rare [1], [2]. Development of the dysplastic canine hip has been well described by RISER [3].

During early postnatal growth a normal contact between the femoral head and acetabulum is the prerequisite for their normal growth and function. Asphericity is claimed to be the reason for joint incongruence leading to premature osteoarthritis [4], [5]. The shape of the head once dislocated and the subsequent shape changes are important in the prognosis and success of conservative and surgical treatment and its final result. As the canine model of hip can be referred to human one, the authors wanted to know whether the pattern of deformity in dislocated hip in dog can be used to assess infant hip dislocation in humans.

The aim of this study was to assess the growth and the changes of the shape of the femoral head in dislocated hip joint in puppies.

2. Material and methods

Ten 5-week-old, mountain shepherd puppies were operated on. Approval for experiments was obtained

* Corresponding author: Tomasz Topoliński, Chair of Mechanical Engineering Fundamentals and Mechanotronics, University of Technology and Agriculture, ul. Kaliskiego 7, 85-796 Bydgoszcz, Poland. E-mail: topol@atr.bydgoszcz.pl

Received: February 8th, 2008
Accepted for publication: December 2nd, 2008

from the Regional Committee for Experiments on Animals in Bydgoszcz, Poland.

Following premedication (Atropine, Polfa, Xylovet, Alfasan i.m.) under general anaesthesia (Diazepam, Polfa, Xylovet, Alfasan and Ketamine, Richter, Pharma i.v.) the right hip joint was exposed through a craniolateral approach. The dogs were divided into two subgroups, in five animals, the femoral head was dislocated ventrodorsally, the capsule was sutured and the tissues were closed. The dislocation was confirmed radiographically (figure 1). In the other five dogs, femoral head was reduced after the dislocation procedure. Thus the joint was congruent but unstable. In the early post-operative period, the dogs were given Metacam (Boehringer) and Rimadyl (Pfizer) to relieve the pain. The dislocation of the hip was controlled 2 weeks following the primary procedure. After 4 weeks, another pelvic radiograph was taken, and the animals were euthanised. The hip joints were excised, put into saline bath and further investigations were performed within 4 hours (figure 2).

Fig. 1. Ventrodorsal radiograph of a dislocated hip joint 4 weeks after surgery

Fig. 2. Lateral radiograph of unstable (right) and control (left) hip after autopsy

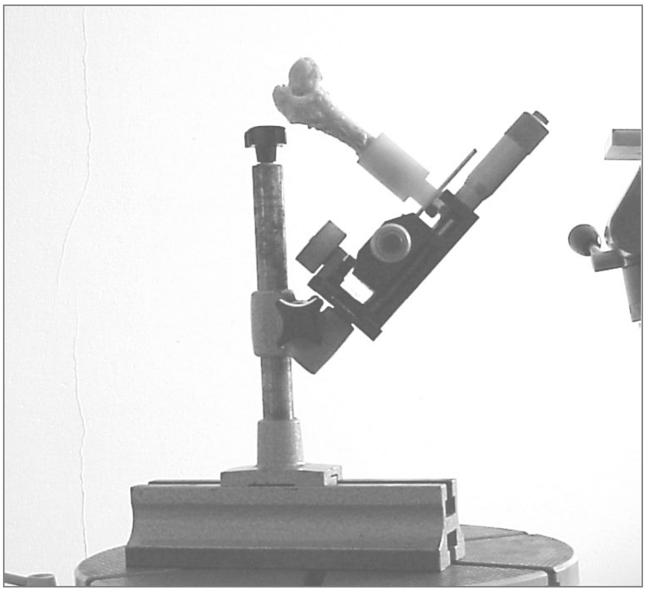


Fig. 3. Stand for optical measurement

a) b)

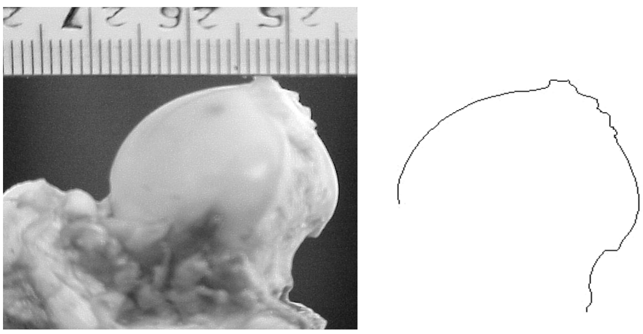
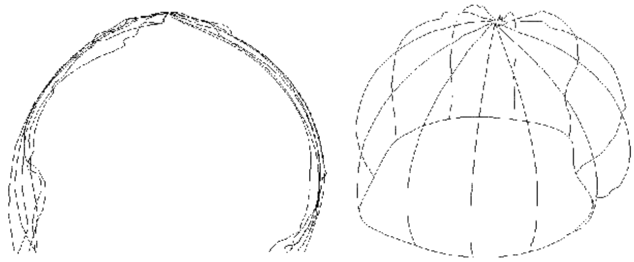


Fig. 4. Normal head (a) and its contour (b) by AutoCAD program



a) b)

b) rotated curves connected by scans

All the measurements were done in right (operated) and left (control) femoral heads. The optical method of contour measurement of the sphericity was used. The femur was attached to a rotational table (Zeiss Jena, Germany) (figure 3). This table with cross mounting system enabled the femoral neck axis and the table axis to be paralleled. While rotating the table, the series of digital pictures (Sony MVC-FD91) of the femoral head were taken every 30°. The pictures were described with Auto-CAD program. The contour of femoral head was pencilled in 10 × magnification (figure 4 a and b). The estimated error of this measurement was 0.05 mm. All contours for each head were elaborated with I-DEAS numerical program (EDS: Plano, USA) for modelling 3D surfaces (figure 5). This program enabled not only the measurement of the 3D linear difference, but also the estimation of the total volume of the femoral head.

3. Results

The shape of the dislocated femoral head differed from the normal one (figure 6). Its medial part was extended into beard-like form. The overgrowth of the femoral heads was significant and from 38 to 61% larger compared with the normal contralateral head. Each unstable head in the second group did not differ in its shape nor in its size from the contralateral normal one (figure 7). The unstable femoral heads were up to 9% bigger than the control ones. The summary of the changes in the femoral heads are shown in the table. The differences in the shape of contours between identical cross planes of heads in the normal and dislocated hips (group 1) are shown in figure 8b and c, respectively, and in unstable (group 2) hips – in figure 8a.

a) b)

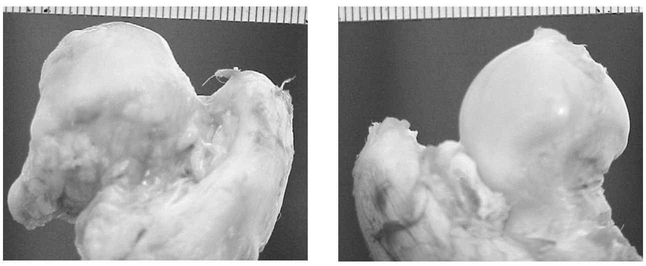


Fig. 6. Femoral heads of dislocated (a) and control (b) joints

a) b)

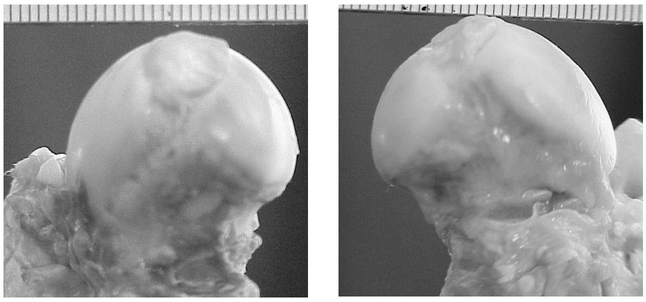


Fig. 7. Femoral heads of unstable (a) and control (b) joint

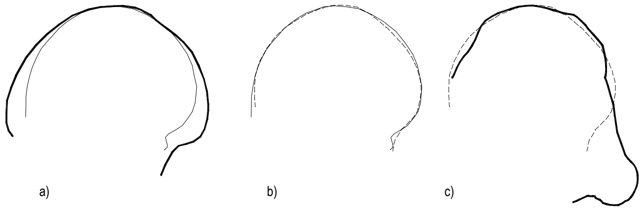


Fig. 8. Contours of pairs of cross planes of normal femoral head (b) and affected ones in: a) unstable hip, c) dislocated hip. Broken lines represent normal head

4. Discussion

Several methods for evaluating the femoral head sphericity were applied to in vivo studies in humans [6]–[8]. The mathematical and graphic presentation of the femoral head in vitro for the measurement of 3D macrogeometry is difficult. These difficulties result from: (1) large differences in shapes and sizes of the bodies of different individuals, (2) various hardness of different areas of the body in contact measurements, (3) the impossibility of unequivocal determining the borders of the structure [9], [10].

The optical method was useful to present the spherical deformities of femoral heads in dislocated and unstable hips and to show the differences between these pairs of heads. The error of the measurement had no influence on the comparative quantitative analyses of the pairs of the heads. We are aware that the control contralateral head was not truly normal as being overweighted. Normal function of this joint allowed us to consider this side as normal one.

Table. Characteristics of the dislocated (group 1) and unstable (group 2) femoral heads

Group	Number	Shape	Size	Volume per cent increase compared to normal side
Dislocated	5	beard-like (4)	overgrowth	38–61%
		small beard-like (1)	overgrowth	
Unstable	5	spherical	overgrowth	< 9 %

When comparing the natural history of hip disorders in human and dog, one must be aware of the main difference: developmental dislocation in humans occurs in highly dysplastic hip, while in dogs a non-traumatic dislocation of this type has not been reported. However, dogs are regarded as a good animal model for the observation of hip development and many anatomical and structural similarities make that data obtained in this animal model pertinent to man [11]. Experimentally-induced dysplasia was described in rabbits, and hip dislocation model was also applied in these animals [12]. The role of an ideal sphericity in normal function of hip joint is well known [4], [13]. KIM [5] correlates the spherical femoral head with the low incidence of hip osteoarthritis in Koreans. Any disturbance in head sphericity leads inevitably to the restrictions of joint movement and degenerative changes resulting in osteoarthritis [4].

The dramatic adaptive and deforming changes of shape in the dogs with the dislocated femoral heads in our study show the pronounced malformation of the joint while the shape of left-control heads was spherical. The shape of beard-like deformity may be explained by the enlargement of contact surface between the medial part of the head and illiac bone. The loss of sphericity and irregularity of the medial part of the head was reported in post-reduction avascular necrosis following reduction in hip dislocation [13]. The mechanism of the similar bone formation is observed in degenerative changes of spine or knee when the osteophytes make the joint surface larger.

Similarities of deformities of head's shape are also observed in human as the result of Legg–Calve–Perthes (LCP) disease [14], [15], although the etiology of these two disorders (DDH and LCP) is different. A severely-deformed head has often the shape of a mushroom or cauliflower. It may also be flatter. The variety of these deformities depends on the position of the head within the acetabulum during the long (about 18 months) course of disease. These deformities occur when the affected head is only partly covered with acetabulum. High pressure is generated between the contact surfaces in LCP disease and with reduced contact affects the shape of regenerating femoral head [16].

The role of an adequate contact of femoral head with acetabulum in the early months of life was again confirmed in our study. The shape of the unstable head did not change and maintained its spherical form. This can be explained by the restricting influence of the acetabulum. The clinical observations show the overgrowth of the head after inflammatory processes [17]–[19] or surgical interventions [20], [21]. This phenomenon can be explained by hyperaemia [22], [23]. The overgrowth of femoral head can reach 15–20% or more of the size of contralateral femoral head (coxa magna) [20], [24]. These reports on the femoral head's growth following open reduction in infants with DDH resembles the observation of the femoral head changes in group 1 (dislocated joint). The developmental hip dislocation is found within the first 4–6 months. Similar deformation of the femoral head was reported both in the late diagnosed DDH and in avascular necrosis following the treatment of DDH.

The size of the unstable head in group 2 did not differ from that of the normal contralateral head. Its growth was multidirectional and uniform. Such situation is observed in some children with Legg–Calve–Perthes disease, when the femoral head, although with some changes of size, may show no shape deformity. The spherical femoral head is only observed in the joint with full contact of the head and acetabulum maintained during the disease progression [14], [15]. We explain these minimal changes of the affected femoral head in the unstable but congruent joint by the minor vascular impairment during the surgery and the short time to express the growth changes. The restricting and modelling role of the acetabulum may fulfil an important function in promotion of the femoral head development.

5. Conclusion

The lack of normal contact of femoral head with acetabulum causes its enlargement and spherical deformation. The femoral head in unstable joint develops with small alteration of the shape and sphericity.

Acknowledgements

The authors wish to express their thanks to Professor Jan Mikołajczak for his help in various stages of their experiment.

References

[1] CAMPOS da PAZ A. Jr., KALIL R.K., *Congenital dislocation of the hip in the newborns. A correlation of clinical, roentgenographic and anatomical findings*, Ital. J. Orthop. Traumatol., 1976, 2, 261–72.

[2] SIFFERT R.S., *Patterns of deformity of the developing hip*, Clin. Orthop., 1981, 160, 14–29.

[3] RISER W.H., *The dog as a model for the study of hip dysplasia. Growth, form, and development of the normal and dysplastic hip joint*, Vet. Pathol., 1975, 12, 234–334.

[4] HOWELL D., *Ethiopathogenesis of osteoarthritis*, [in:] *Osteoarthritis: Diagnosis and Management*, Moskowitz R.W., Howell D.S., Goldberg V.M., Mankin H.J., (eds.), Philadelphia, WB Saunders Co, 1984, 129–46.

[5] KIM Y.H., *Relationship between the sphericity of femoral head – acetabulum and the low incidence of primary osteoartrithis of the hip joint in Koreans*, Yonsei Med. J., 1989, Vol. 30, 280–287.

[6] HEFTI F., *Spherical assessment of the hip on standard AP radiographs: a simple method for the measurement of the contact area between acetabulum and femoral head and of acetabular orientation*, J. Pediatr. Orthop., 1995, 15, 797–805.

[7] JARAMILLO D., GALEN T.A., WINALSKI C.S., DICANZIO J., ZURAKOWSKI D., MULKERN R.V., MCDOUGALL P.A., VILLEGAS-MEDINA O.L., JOLESZ F.A., KASSER J.R., *Legg–Calve–Perthes disease: MR imaging evaluation during manual positioning of the hip-comparison with conventional arthrography*, Radiology, 1999, 212, 519–25.

[8] WALKER J.M., *Human fetal femoral head sphericity*, Clin. Orthop., 1980, 147, 301–5.

[9] HOEHNE K.H., FUCHS H., PIZER S.M., *3D imaging in medicine: algorithms, systems, applications*, Springer-Verlag, Berlin, 1990, p. 241.

[10] WEBSTER J.G., *The measurement, instrumentation and sensors handbook*. Series: *Electrical Engineering Handbook*, Vol. 14, CRC Press, 1998, p. 1500.

[11] LAW E.G., HEISTAD D.D., MARCUS M.L., MICKELSON M.R., *Effect of hip position on blood flow to the femur in puppies*, J. Pediatr. Orthop., 1982, 2, 133–7.

[12] HUANG S.C., LIU H.C., HOW S.W., *Experimental hip dysplasia in the rabbit*, J. Formos Med. Assoc., 1990, 89, 319–25.

[13] COOPERMAN D.R., WALLENSTEN R., STULBERG S.D., *Postreduction avascular necrosis in congenital dislocation of the hip*, J. Bone Surg. Am., 1980, 62, 247–58.

[14] MACEWEN G.D., *Conservative treatment of Legg–Calve–Perthes condition*, The Hip, 1985, 17–23.

[15] THOMPSON G.H., SALTER R.B., *Legg–Calve–Perthes disease. Current concepts and controversies*, Orhop. Clin. North Am., 1987, 18, 617–35.

[16] KING E.W., FISHER R.L., GAGE J.R., GOSSLING H.R., *Ambulation – abduction treatment in Legg–Calve–Perthes disease (LCPD)*, Clin. Orthop., 1980, 150, 43–8.

[17] CHOI I.H., PIZZUTILLO P.D., BOWEN J.R., DRAGANN R., MALHIS T., *Sequelae and reconstruction after septic arthritis of the hip in infants*, J. Bone Joint Surg. Am., 1990, 72, 1150–65.

[18] KALLIO P.E., *Coxa magna following transient synovitis of the hip*, Clin. Orthop., 1988, 228, 49–56.

[19] PATRIQUIN H.B., CAMERLAIN M., TRIAS A., *Late sequelae of juvenile rheumatoid arthritis of the hip: a follow-up study into adulthood*, Pediatr. Radiol., 1984, 14, 151–7.

[20] GAMBLE J.G., MOCHIZUKI C., BLECK E.E., RINSKY L.A., *Coxa magna following surgical treatment of congenital hip dislocation*, J. Pediatr. Orthop., 1985, 5, 528–33.

[21] LEITCH J.M., PATERSON D.C., FOSTER B.K., *Growth disturbance in Legg–Calve–Perthes disease and the consequences of surgical treatment*, Clin. Orthop., 1991, 262, 178–84.

[22] POWERS J.A., BACH P.J., *Coxa magna*, South Med. J., 1977, 70, 1297–9.

[23] YNGVE D.A., ROBERTS J.M., *Acetabular hypertrophy in Legg-Calve-Perthes disease*, J. Pediatr. Orthop., 1985, 5, 416–21.

[24] IMATANI J., MIYAKE Y., NAKATSUKA Y., AKAZAWA H., MITANI S., *Coxa magna after open reduction for developmental dislocation of the hip*, J. Pediatr. Orthop., 1995, 15, 337–41.