Dysplastic Hip Joint Configuration After Bernese Periacetabular Osteotomy

Kamil Kołodziejczyk (kkolodziej111@gmail.com)
Professor Adam Gruca Hospital: Samodzielny Publiczny Szpital Kliniczny im. Prof. Adama Grucy CMKP
https://orcid.org/0000-0001-5226-4911
Adam Czwojdziński
Professor Adam Gruca Hospital: Samodzielny Publiczny Szpital Kliniczny im. Prof. Adama Grucy CMKP
Andrzej Sionek
Professor Adam Gruca Hospital: Samodzielny Publiczny Szpital Kliniczny im. Prof. Adama Grucy CMKP
Jarosław Czubak
Professor Adam Gruca Hospital: Samodzielny Publiczny Szpital Kliniczny im. Prof. Adama Grucy CMKP

Research article

Keywords: hip dysplasia, Bernese periacetabular osteotomy, medialization, distalization, ilio-ischial angle

Posted Date: April 1st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-366929/v1

Abstract

Background: Residual hip dysplasia is one of the factors contributing to early hip joint osteoarthritis. The main problems caused by residual dysplasia are pain and instability of the hip joint caused by the lack of sufficient bony covering of the femoral head. The aim of this work was to radiologically assess the configuration change of a dysplastic hip joint after surgical treatment using the Bernese periacetabular osteotomy procedure.

Methods: We assessed the radiological parameters of patients with hip dysplasia treated by Bernense periacetabular osteotomy by performing a digital antero-posterior pelvis X-ray: central edge angle and femoral head coverage, medialization, distalization and ilio-ischial angle parameters. For normally distributed parameters, we used Student's t-test; for parameters without a normal distribution, we used the Wilcoxon signed-rank test. Correlations were assessed according to a normal distribution using the Pearson and Spearman method.

Results: For all parameters, we observed statistically significant differences in the measurements of dysplastic hip joints before and after the surgery. We also observed a statistically significant difference between the structure of dysplastic hip joints prior to the surgery and healthy hip joints from the control group based on all radiological parameters. The resulting medialization was 2.68 mm, distalization was 3.65 mm, and the ilio-ischial angle was changed by 2.62°. There was also an improvement in the femoral head bony covering: CEA by 17.61° and FHC by 16.46%.

Conclusions: Based on all the radiological parameters, we presented the difference between healthy and dysplastic hip joints. Learning the parameter values that are used to describe dysplastic hip joints will allow us to improve the imaging of the condition and will also allow for better planning and proper qualification of patients for surgical treatment of hip joint dysplasia.

Trial registration: Consent of the bioethics commission Medical Centre of Postgraduate Education 83/PB/2015 18.11.2015 Warsaw

Background

Residual hip joint dysplasia is a sequela of incorrect development of the hip joint acetabulum during fetal development or a result of incorrect treatment during infancy. It is estimated that in among young patients, up to 80-90% of cases of hip joint osteoarthritis develop as a result of hip joint dysplasia [1,2,3]. Bernese periacetabular osteotomy is one of the methods used to surgically "save" the patient's hip joint [4,5,6,7,8,9,10,11,12,13, 14,15,16,17,18,19]. The procedure involves a periacetabular cut of the pubic, ischium, and ilium in an attempt to change the configuration of the joint socket and achieve the stability of the dysplastic hip joint. This osteotomy technique makes it possible to save the back column of the socket, which in turn guarantees the stability of the pelvic ring after the procedure and allows patients to quickly resume walking [8,9,19]. The correction of the socket part of the hip joint improves the bony covering of the femoral head, as well as the medialization and distalization of the joint. The abovementioned parameters are important because of the repositioning of the femoral head and bringing it closer to the ischium. This position offers favorable conditions for improving the dynamic stability of the joint and extends the lever arm for gluteal muscles. It increases the moment of hip joint stabilizing force and decreases the arm of body weight force acting on the joint [1,8,9,15,20,21,22]. The main assumption of this procedure is stopping or slowing down, as well as preventing, the development of hip joint osteoarthritis, which might potentially result in the joint being replaced by endoprosthesis. Many authors emphasize the fact that computed tomography (CT) is the basic test enabling the accurate assessment of dysplastic hip joints and surrounding anatomical structures [23,24,25]. On the other hand, a CT scan is characterized by a much higher dose of ionizing radiation and higher costs of the examination [24,25]. This research is also necessary to determine an easy, cheap, repeatable and nonburdensome method to configure dysplastic hip joints. Bearing in mind the patient's well-being and awareness of symptomatic dysplastic disease, mainly in young women, we decided to work on the basis of digital X-ray in the anterior-posterior (AP) view of the pelvis. The aim of this work was to radiologically assess the configuration change of a dysplastic hip joint after surgical treatment using the Bernese periacetabular osteotomy procedure.

Materials And Methods

The retrospective study group consisted of patients with residual dysplasia who qualified for surgical treatment using the abovementioned method in our department and met the following inclusion and exclusion criteria.

Inclusion criteria:

- Hip joints have not been treated surgically in early childhood
- Symptomatic residual hip joint dysplasia
- Full and correct radiological documentation of the entire treatment period
- Completed treatment process (removal of binding material)
- Bone fusion in the osteotomy area
- No degenerative changes

Exclusion criteria:

- Secondary hip acetabulum
- Patients have previously undergone hip joint acetabulum surgery
- Patients with femoral head deformation

Ninety-nine patients qualified for a retrospective study (119 hip joints), with an average age of 29.2 years (14-55 years old). There were 61 left and 58 right hip joints, and there were 89 women and 10 men.

The control group for the retrospective study consisted of people not diagnosed with hip joint dysplasia who were treated in our hospital. Ninety patients (90 hip joints) were analyzed in the control group, with an average age of 34 years (19-62 years old). There were 74 women and 16 men.

The material for retrospective analysis consisted of digital AP pelvis X-rays of patients with residual hip dysplasia who underwent surgical procedure of Bernese periacetabular osteotomy, as well as digital AP pelvis X-rays of patients not diagnosed with hip dysplasia who served as the control group. The radiological assessment included the measurements of the femoral head coverage: Wiberg angle (CEA- central edge angle), Heyman's and Herndon's acetabular-head factor (FHC- femoral head coverage), as well as parameters of medialization (line connecting the body midline and edge of femoral head closest to the midline) (Figure 1), distalization (line connecting the baseline, which connects the tuber ischii, and the lowest edge of femoral head) (Figure 2) and the reorientation of the acetabulum measured as the ilio-ischial angle (angle between the ilio-ischium line and the line connecting the tuber ischii) (Figure 3) based on the radiograms in AP digital X-ray projection. We expected that CEA and FHC would be increased after surgery and that medialization, distalization and ilio-ischial angle would be decreased after surgery. Three independent studies with various levels of experience also conducted an analysis verifying the accuracy and repeatability of radiological measurements. To assess the level of residual hip joint dysplasia, we used Crowe's Classification [26].

This study was approved by the institutional review board. Informed consent was obtained from patients for participation in the study.

Statistical analysis:

We checked the normal distribution using the Shapiro-Wilk test. For normally distributed parameters, we used Student's t-test; for parameters without a normal distribution, we used the Wilcoxon signed-rank test. The significance criterion was $p<0.05$. Correlations were assessed according to a normal distribution using the Pearson and Spearman analyses. Measurement accuracy: angles - 0.5 degrees, distances – 0.5 mm (all measurements were done in CareStream Solution software). The main measurements were made by one surgical researcher.

Results

According to Crowe's Classification, there were type I – 62 hip joints (52%); type II – 50 hip joints (42%); and type III – 7 hip joints (6%). Mean follow-up was 36 months (12-48 months). For all parameters, we observed statistically significant ($p<0.05$) measurement differences in dysplastic hip joints before and after the surgery (Table 1). We also observed a statistically significant ($p<0.05$) difference in the anatomy of dysplastic hip joints before the surgery and healthy hip joints from the control group based on all radiological parameters (Table 2). We obtained a strong positive Pearson correlation (0.756) between CEA and FHC (Figure 4) and a negative Pearson correlation (-0.522) between CEA and the ilio-ischial angle (Figure 5). We also observed a statistically significant negative Spearman correlation (-0,517) between CEA and distalization parameters (Figure 6). The analysis verifying the correctness and repeatability of radiological parameters did not reveal any statistically significant differences between studies of various levels of experience.

The retrospective study of radiological measurements we presented showed statistically significant differences in the structure of healthy and dysplastic hip joints. The medialization, distalization, and ilio-ischial angle parameters describe the hip joint in a statistically significant way. The ilio-ischial angle and distalization parameters seem to be of high importance, statistically significantly correlating with other parameters established in the literature.

Discussion

There are many documented and widely accepted parameters for assessing the configuration of hip joints. However, they are insufficient to assess the configuration change of the acetabulum subjected to acetabular osteotomy. Zhang et al. described the LCEA value as a key radiological parameter of clinical and prognostic importance in the surgical treatment of hip dysplasia using the PAO method [17]. Two of these parameters are the so-called medialization and distalization of the acetabular fragment. Medialization is the acetabular fragment's displacement toward the body's midline and, as a result, a displacement of the entire hip joint toward the body's central axis. Distalization is a parameter describing the correction of a subluxed hip joint in the frontal plane toward the patient's extremities. The literature available on that topic lacks any reports regarding the assessment of hip joint distalization after PAO. Hip joint medialization and distalization are important parameters due to the repositioning of the femoral head and bringing it closer to the ischium. This position offers favorable conditions for improving the joint's dynamic stabilization and lengthens the arm of gluteal muscles. It increases the moment of force stabilizing the hip joints and reduces the arm of body weight force acting on the joint [2,7,9,13,20,27,28]. In a retrospective study, we determined that the differences shown are noticeable not only in the structure of the hip acetabulum itself but also in the entire pelvis, covered by residual hip dysplasia. This is evidenced by a statistically significant postoperative change in the iliosischial angle and its difference in healthy hips. The difference between healthy and dysplastic hip joints was 8.3 degrees. It shows a more vertical configuration of the structure of the iliac wing and ischium bone as a result of the steep and shallow dysplastic acetabulum of the hip joint. It seems that hip dysplasia does not concern only the hip acetabulum but its entire pelvis spatial configuration. We can define such a pelvis as a dysplastic model in the course of residual hip dysplasia.

Mavcic et al. mathematically calculated the tension distribution in healthy and dysplastic hip joints and proved that the forces acting on a dysplastic hip joint are twice as strong as those acting on a healthy joint [29]. Delp and Malloney described the effects medialization and distalization of the center of the hip joint have on abductor muscle strength. The authors proved how much significance the lowering of the center of hip joint has on the force and arm of the hip abductors [30]. According to them, simultaneous medialization and distalization have the most significant impact on the reconfiguration of muscle forces acting on the joint. There have been a number of publications describing the medialization parameter after PAO. Siebenrock et al., Junfeng Zhu et al., and Clohisy et al. assessed hip joint medialization after

PAO by measuring the distance between the medial edge of the femoral head and the ilio-ischium line (Kohler's line) [7,14,16]. Based on our observations, we believe that the medialization measurements performed using the methods of the abovementioned authors can be distorted by the configuration change of the whole acetabular fragment, which results in the change of location and configuration of the "Kochler's tears" and consequently the ilio-ischium line (Kochler's line). This is proof of the statistically significant change in the ilio-ischial angle parameter that we introduced. Mimura et al. measured the center of the femoral head lateralization index (HLI – Head Lateralization Index) after triple pelvis osteotomy [1]. Tanaka et al. assessed medialization based on DBSPFH measurements and the head lateralization index (HLI) using 3D computer tomography. The authors pointed out the difficulties in achieving repeatability in determining the middle of the femoral head, which is very important in millimeter measurements [22]. Jae Suk Chang et al. measured the distance between the pubic symphysis and femoral head (DBSPFH) in patients who underwent PAO with hip joint dysplasia and femoral head deformation [31]. Goronzy et al. assessed the predictors of coxarthrosis after PAO on the basis of AP X-ray and MRI. The authors described that only posteriorly deformed femoral heads had an influence on the functional outcome without alternating degeneration in the 5-year interval [18].

The justification for conducting the research was an attempt to find the abovementioned hip joint medialization and distalization parameters. There is a need for objective assessment of parameters before and after surgery. It seems that they are often intuitively assessed as correct during mid-surgery control under an X-ray monitor by the surgeon performing the procedure.

Conclusion

Learning about the values of parameters describing a dysplastic hip joint allowed us to improve the imaging of the condition and proved to be helpful in planning for surgical treatment of residual hip joint dysplasia. The measurement methods of dysplastic hip joints presented in this manuscript are suggestions for further observation and open discussion of the dysplastic hip joint configuration. In the future, we plan to conduct a study based on prospective data that includes radiological measurements in correlation with clinical data.

Abbreviations

CT – computed tomography

AP – anteroposterior

CEA – central edge angle

FHC –femoral head coverage

PAO – periacetabular osteotomy

LCEA – lateral center edge angle

HLI – head lateralization index

DBSPFH – distance between symphysis pubis and femoral head

MRI – magnetic resonance imaging

Declarations

Ethics approval and consent to participate: The manuscript is a retrospective clinical study. Consent number 83/PB/2015 18.11.2015 of the Bioethics Commission of Medical Centre of Postgraduate Education in Warsaw.

Consent for publication: Not applicable

Availability of data and materials: Not applicable

Competing interests: The authors declare that they have no competing interests.

Funding: Not applicable

Authors' contributions: KK performed the design study, data collection and analysis, and manuscript writing. AC was responsible for the design study, data analysis and manuscript editing. AS prepared and edited the manuscript. JC is the editing of manuscripts. All authors read and approved the final manuscript.

Acknowledgments: Not applicable

References

1. Mimura T, Mori K, Kawasaki T, Imai S, Matsusue Y. Triple pelvic osteotomy: Report of our mid-term results and review of literature. World J Orthop. 2014 Jan;5(1):14-22
2. Naito M, Nakamura Y. Curved periacetabular osteotomy for the treatment of dysplastic hips. Clin Orthop Surg. 2014 Jan;6(2):127-137.
3. Takahashi Y, Takahira N, Uchiyama K, Fukushima K, Moriya M, Shibuya M, Tsuda K, Tozaki K, Kudo S, Kaneda H, Sekita J, Takaso M. Sports activity participation after curved periacetabular osteotomy for acetabular dysplasia BMC Musculoskeletal Disorders (2020) 21:637 https://doi.org/10.1186/s12891-020-03625-3
4. Lehmann Ch, Nepple J, Baca G, Schoenecker P, Clohisy J. Do Fluoroscopy and Postoperative Radiographs Correlate for Periacetabular Osteotomy Corrections? Clin Orthop Relat Res. 2012 Dec;470(12):3508-3514

5. Albers Ch, Steppacher S, Ganz R, Tannast M, Siebenrock K. Impingement Adversely Affects 10-year survivorship after Periacetabular Osteotomy for DDH. Clin Orthop Relat Res. 2013 May;471(5):1602–1614.
6. Clohisy J, Schutz A, John L, Schoenecker P, Wright R. Periacetabular Osteotomy A Systematic Literature Review. Clin Orthop Relat Res. 2009 Aug;467(8):2041–2052.
7. Clohisy J, Barrett S, Gordon J, Delgado E, Schoenecker P. Medial translation of the hip joint center associated with the bernese periacetabular osteotomy. Iowa Orthop J. 2004;24: p. 43–48.
8. Czubak J. “Configuration of hip joint acetabulum after Dega pelvis osteotomy in its morphological, clinical, and radiological studies approach” habilitation thesis, Poznań, Poland, 2000
9. Dede O, Ward T. Bernese Periacetabular Osteotomy in the Surgical Management of Adolescent Acetabular Dysplasia. Oper Tech Orthop. 2013 Sep;23(3):127-133.
10. Fujii M, Nakashima Y, Sato T, Akiyama M, Iwamoto Y. Pelvic Deformity Influences Acetabular Version and Coverage in Hip Dysplasia. Clin Orthop Relat Res. 2011 Jan;469(6):1735–1742.
11. Lankester B.J.A., Gargan M.F. Adolescent hip dysplasia. Ortopaedics & Trauma. 2004 Aug;18(4): 262–272.
12. Leunig M, Ganz R. Bernese periacetabular osteotomy. Current Orthopaedics. 2007 Apr;21(2):100–108.
13. Marciniak W., A. Szulc, *Wiktora Degi orthopaedic and rehabilitation*. Poland, PZWL. 2008,171-180.
14. Siebenrock K, Leunig M, Ganz R. Periacetabular Osteotomy: the Bernese Experience. JBJS 2001 Mar;83(3);449.
15. Steppacher S, Tannast M, Ganz R, Siebenrock K. Mean 20-year follow up of Bernese periacetabular osteotomy. Clin Orthop Relat Res. 2008 Jul;466(7):1633-1644.
16. Zhu J, Chen X, Cui Y, Shen Ch, Cai G. Mid-term results of Bernese periacetabular osteotomy for developmental dysplasia of hip in middle aged patients. International Orthopaedics. 2013 Apr;37(4):589–594.
17. Zhang D, Pan X, Zhang H, Luo D, Cheng H, Xiao K. The lateral center-edge angle as radiographic selection criteria for periacetabular osteotomy for developmental dysplasia of the hip in patients aged above 13 years. BMC Musculoskeletal Disorders (2020) 21:493; https://doi.org/10.1186/s12891-020-03515-8
18. Goronzy J, Franken L, Hartmann A, Thielemann F, Blum S, Günther KP, Nowotny J, Postler A. Acetabular- and femoral orientation after periacetabular osteotomy as a predictor for outcome and osteoarthritis. BMC Musculoskeletal Disorders (2020) 21:846; https://doi.org/10.1186/s12891-020-03878-y
19. Ganz R, Klaue K, Vinh T S, Mast J W. A new periacetabular osteotomy for the treatment of hip dysplasia. Technique and preliminary results. Clin Orthop Relat Res. 1988 Jul;232:26-36.
20. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J. Anat. 1989 Oct;166:179-189.

21. Lubovsky O, Wright D, Hardisty M, Kiss A, Kreder H, Whyne C. Acetabular orientation: anatomical and functional measurement. Int J Comput Assist Radiol Surg. 2012 Mar;7(2):233–240.
22. Tanaka Y, Moriyama Sh, Nakamura Y, Naito M. Analysis of medialisation of the femoral head in periacetabular osteotomy using three-dimensional computer tomography. Hip Int. 2014 Dec;24(6):624-630.
23. Anda S, Svenningsen S, Dale L G, Benum P. The acetabular sector angle of the adult hip determind by computed tomography. Acta Radiol Diagn (Stockh). 1986 Jul-Aug;27(4):443-447.
24. Azuma H, Taneda H, Igarashi H, Fujioka M. Preoperative and Postoperative Assessment of Rotational Acetabular Osteotomy for Dysplastic Hips in Children by Three-Dimensional Surface Reconstruction Computed Tomography Imaging. J Pediatr Orthop. 1990 Jan-Feb;10(1):33-38.
25. Roach JW, Hobatho MC, Baker KJ, Ashman RB. Three-Dimensional Computer Analysis of Complex Acetabular Insufficiency. J Pediatr Orthop. 1997 Mar-Apr;17(2):158-164.
26. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am. 1979 Jan;61(1):15–23.
27. Mirza SB, Dunlop DG, Panesar SS, Naqvi SG, Gangoo Sh, Salih S. Basic Science Considerations in Primary Total Hip Replacement Arthroplasty. Open Orthop J. 2010 May;4:169–180.
28. Department of Rehabilitation. Science,*Online Referencing.* The University of Oklahoma; http://moon.ouhsc.edu, 1988-2001
29. Mavcic B, Pompe B, Antolic V, Daniel M, Iglic A, Kralj-Iglic V. Mathematical estimation of stress distribution in normal and dysplastic human hips. Journal of Orthopaedic Research 2002 Sep;20(5):1025-1030.
30. Delp SL, Maloney W. Effects of hip center location on the moment- generating capacity of the muscles. Journal of Biomechanics. 1993 Apr–May;26(4–5):485-499
31. Chang JS, Oh HK, Kim JW, Hong SH. Periacetabular Osteotomy in Hip Dysplasia with Deformed Femoral Head. Journal of the Korean Orthopaedic Association. 2008 Jan;43(6):718-727.

Tables

Table 1. Results of pre- and postoperative changes in the hip joint configuration based on radiological measurements.

	Pre-op (95% CI) n=119	Post-op (95% CI) n=119	p-value
CEA (degrees)	3.48±10.58 (4.94-7.76)	21.09±8.1 (19.5-22.5)	p<0.0001
FHC (%)	53.07±11.82 (50.93-55.22)	69.53±7.53 (68.6-71.5)	p<0.0001
Medialization (mm)	83.72±5.75 (82.68-84.76)	81.04±6.33 (79.9-82.2)	p=0.0001
Distalization (mm)	58.05±9.66 (56.30-59.81)	54.4±10.02 (52.6-56.4)	p<0.0001
Ilio-ischial angle (degrees)	86.5±3.10 (85.94-87.07)	83.88±3.02 (83.4-84.6)	p<0.0001

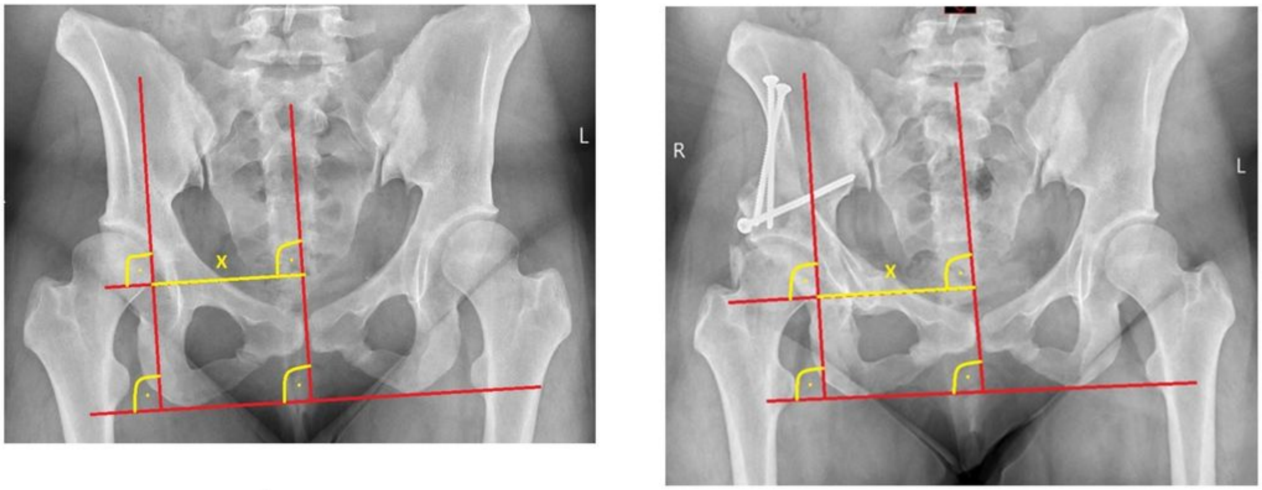
mm- millimeter

Table 2. Results at preoperation compared to the control group hip joint configuration based on radiological measurements.

	Pre-op (95% CI) n=119	Control (95% CI) n=90	p-value
CEA (degrees)	3.48±10.58 (4.94-7.76)	29.4±4.43 (28.48-30.3)	p<0.0001
FHC (%)	53.07±11.82 (50.93-55.22)	76.6±4.11 (75.75-77.47)	p<0.0001
Medialization (mm)	83.72±5.75 (82.68-84.76)	78.56±4.74 (77.57-79.56)	p=0.0019
Distalization (mm)	58.05±9.66 (56.30-59.81)	47.52±6.89 (46.08-48.97)	p<0.0001
Ilio-ischial angle (degrees)	86.5±3.10 (85.94-87.07)	78.17±3.07 (77.53-78.81)	p<0.0001

mm- millimeter

Figures

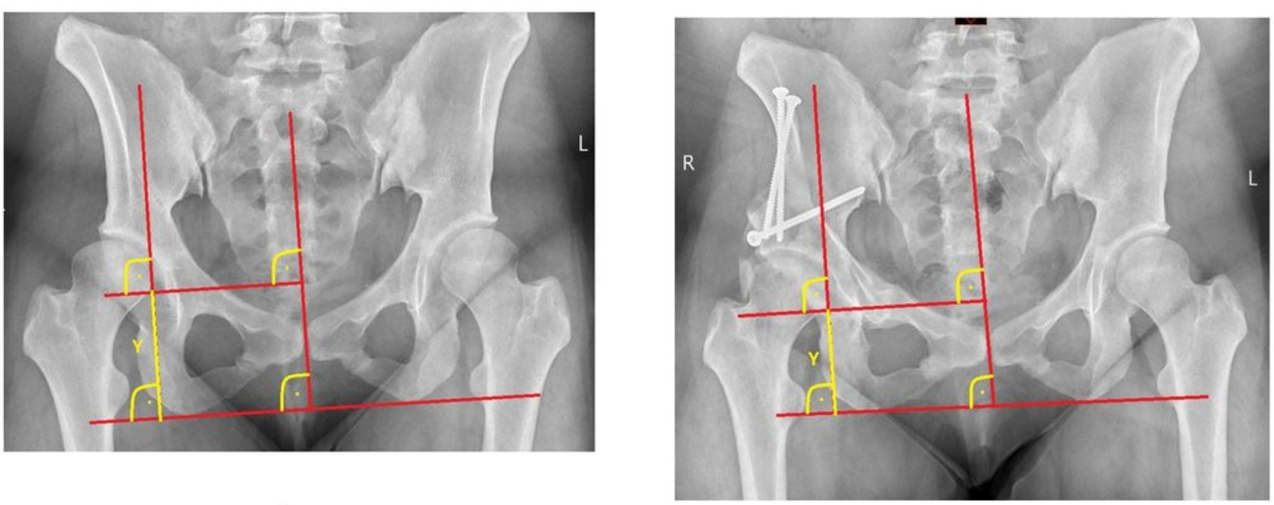


A

B

Figure 1

Hip joint medialization (x) – (line connecting the body midline and medial edge of femoral head); a- preoperation; b- postoperation.

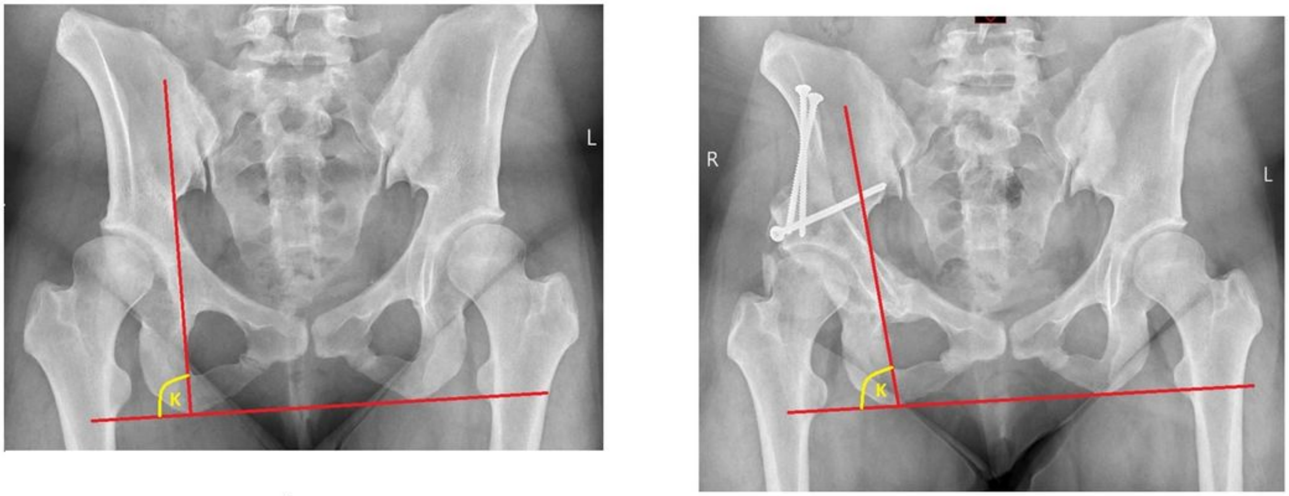


A

B

Figure 2

Hip joint distalization (y) – (line connecting the baseline and the lowest edge of the femoral head); a- preoperation; b- postoperation.



A

B

Figure 3

Ilio-ischial angle (k) – angle between the ilio-ischial line and the line connecting the ischiatic tuber; a- preoperation; b- postoperation.

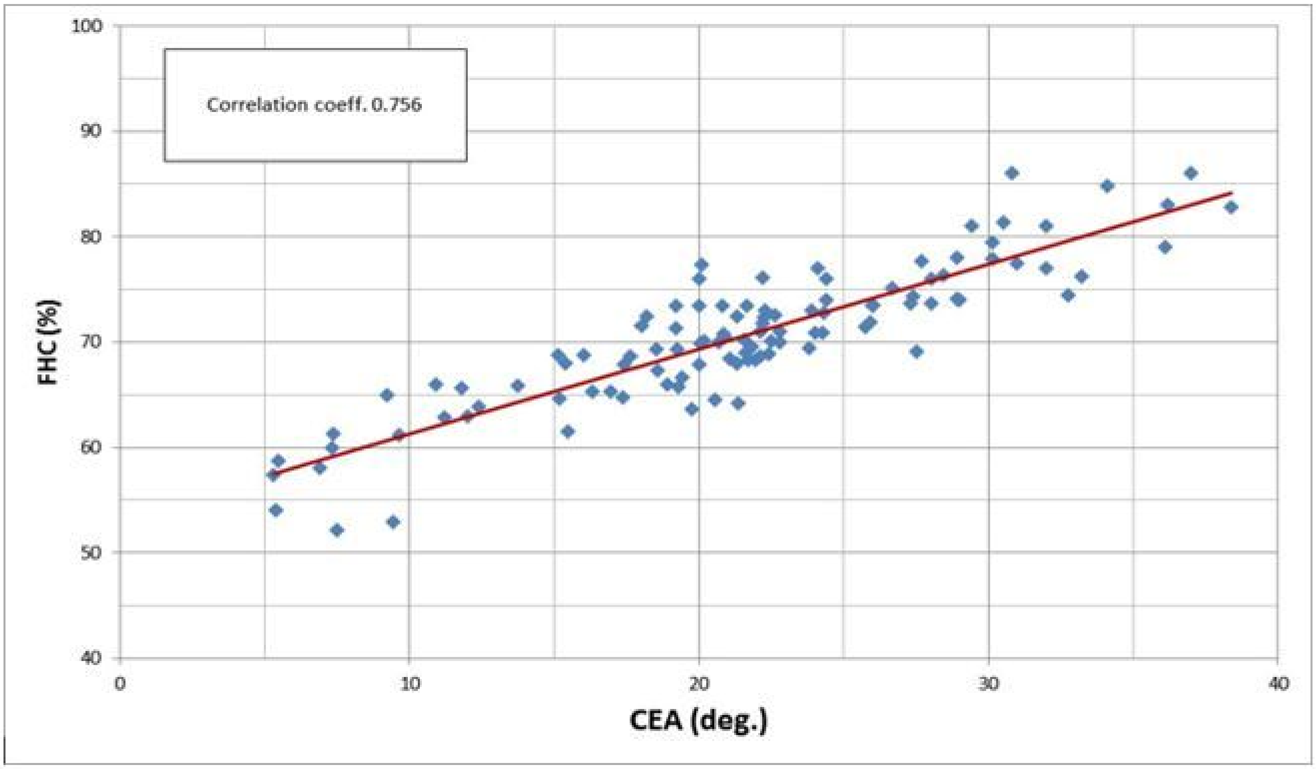


Figure 4

Pearson correlation between CEA and FHC.

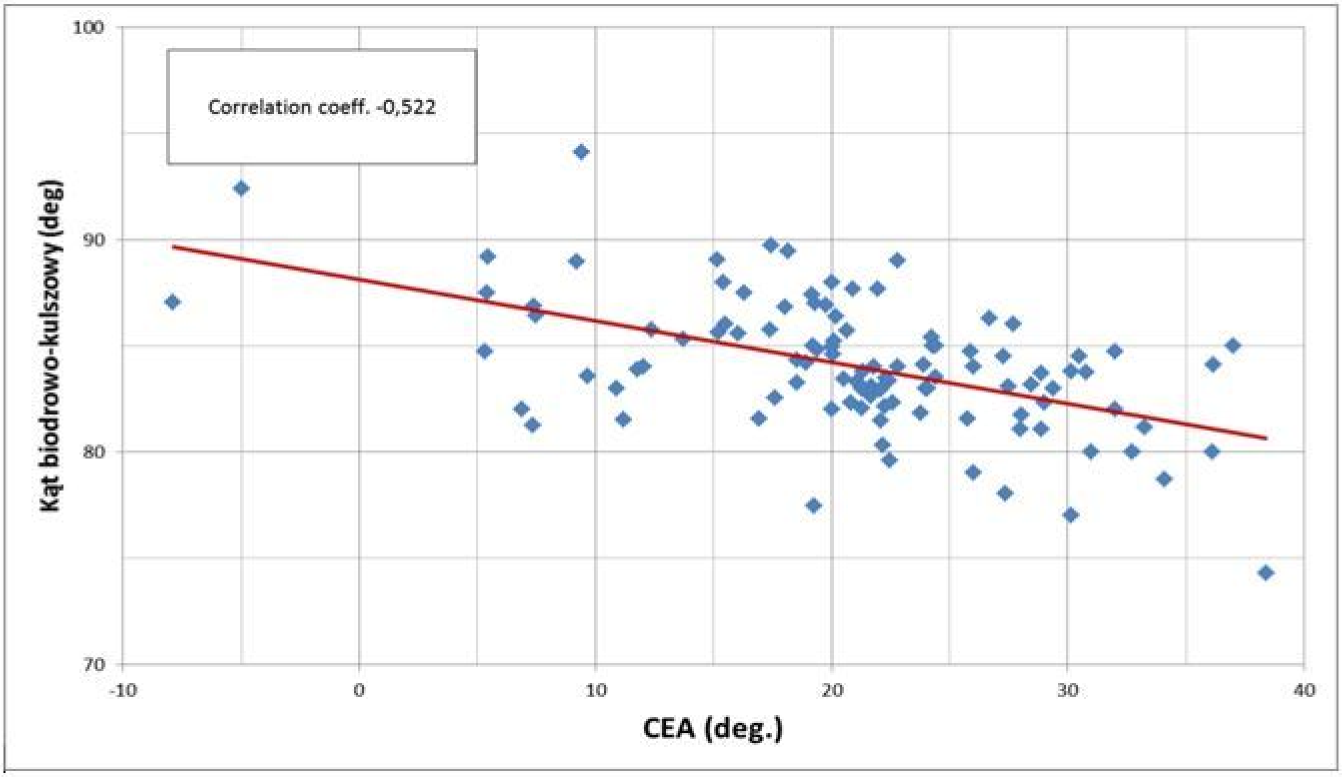


Figure 5

Pearson correlation between CEA and the ilio-ischial angle.

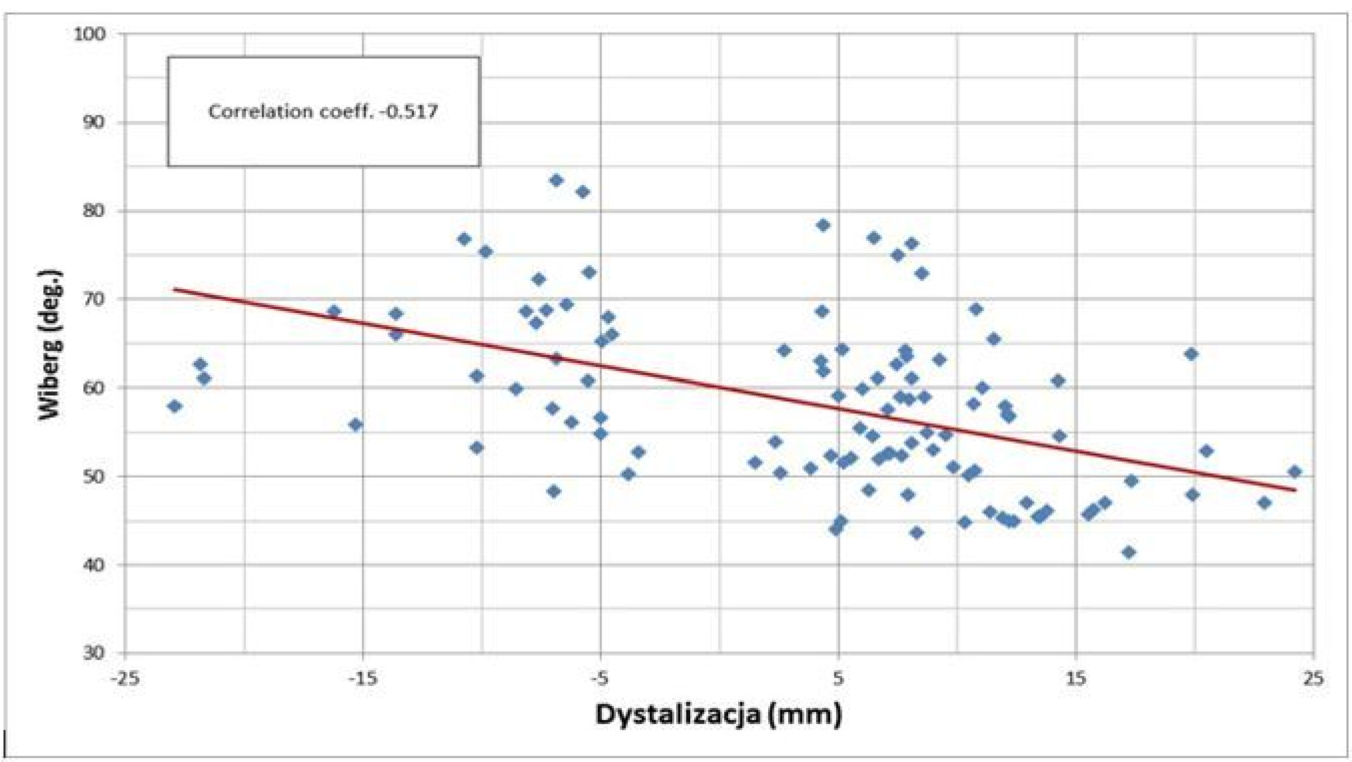


Figure 6

Spearman correlation between CEA and distalization.