Periacetabular reorientation osteotomies. Comparative study between triple pelvic osteotomy and periacetabular osteotomy

Sebastián Falcinelli, Horacio Gómez, Anibal Garrido, José I. Arrondo

Orthopedics Department, Sanatorio Dupuytrén, Ciudad Autónoma de Buenos Aires

Received on July 7th, 2014; accepted after evaluation on July 6th, 2016 • SEBASTIÁN FALCINELLI, MD • sebafalcinelli@me.com

Abstract

Introduction: The indication of acetabular osteotomies has varied over time. Over the past few years, Ganz's studies gave momentum back to these techniques. We carried out a comparative study between triple osteotomy and periacetabular osteotomy to evaluate biomechanics results.

Materials and Methods: We evaluated 12 cases with triple osteotomy and 12 cases with periacetabular osteotomy, assessing the displacement of the head rotation center towards the side and the front, the percentage of lateral and anterior coverage of the femoral head, and the acetabular angles of inclination and anteversion. All data were compared to that of the healthy contralateral hip.

Results: In triple osteotomy, we verified head rotation center's lateral displacement of +2.9 mm and anterior displacement of +2.47 mm as compared with the contralateral hip. In periacetabular osteotomy, lateralization was +7.6 mm and antepulsion, +6.67 mm. The average percentage of head coverage was lateral= 89% and anterior= 99.4% with triple osteotomy, and 88% and 80%, respectively, with periacetabular ostetomy. The acetabular angles of orientation were 39.4º-inclination and 27.1º-anteversion with triple osteotomy, and 45.5º- and 23.11º-, respectively, with periacetabular ostetomy.

Conclusions: We verified that keeping the bone bridge between the ilium and ischium bones limits rotations so as to provide the femoral head with anterior coverage, and takes the head rotation center towards the front; we prefer triple osteotomy when the lack of anterior femoral head coverage is significant.

Key words: Osteotomy; Ganz; triple; hip; dysplasia.
Level of evidence: IV

Osteotomías de reorientación acetabular. Estudio comparativo entre osteotomía triple y osteotomía periacetabular

Resumen

Introducción: La indicación de las osteotomías acetabulares ha variado con el tiempo. En los últimos años con los trabajos de Ganz volvió el auge por estas técnicas. Se realizó un estudio comparativo entre la triple osteotomía y la osteotomía periacetabular para evaluar los resultados biomecánicos.

Materiales y Métodos: Se evaluaron 12 casos con triple osteotomía y 12 casos con osteotomía periacetabular midiendo el desplazamiento del centro de rotación cefálico hacia lateral y anterior, el porcentaje de cabeza femoral cubierta, lateral y anterior, y los ángulos de inclinación y anteversión acetabular. Todos los datos fueron comparados con la cadera contralateral sin patología.

Conflict of interests: The authors have reported none.

Resultados: En la triple osteotomía, se comprobó un desplazamiento lateral de +2,9 mm y uno anterior de +2,47 mm del centro de rotación cefálico con respecto a la cadera contralateral. En la osteotomía periacetabular, la lateralización fue de +7,6 mm y la antepulsión, de +6,67 mm. El porcentaje promedio de cabeza femoral cubierta fue del 89% lateral y del 99,4% anterior con la triple osteotomía, y del 88% y 80%, respectivamente, con la osteotomía periacetabular. Los ángulos de orientación acetabular fueron de 39,4º de inclinación y 27,1º de anteversión con el primer procedimiento y de 45,5º y 23,11º, respectivamente, con el segundo.
Conclusiones: Se comprobó que la conservación del puente óseo entre el ilíaco y el isquion limita la rotación para dar cobertura anterior y desplaza el centro de rotación cefálico hacia adelante; se prefiere la triple osteotomía cuando la falta de cobertura anterior de la cabeza femoral es importante.

Palabras clave: Osteotomía; Ganz; triple; cadera; displasia.
Nivel de Evidencia: IV

Introduction

Hip pain in young adults (<45 years old) represents a problem difficult to solve. It is most frequently caused by biomechanics, congruence, inflammation and vascularization reasons; literature reports that 50%-70% of prosthetic replacements at this age follow the sequela of two specific conditions: hip dysplasia[1] and Perthes disease.

In young adults, prosthetic joint replacement is not a definite solution; bibliography reports high mid- and long-term failure rates, what is essentially caused by two reasons: the first one is that life expectancy is long, and the second one is that a <50-year old patient's lifestyle and activity levels imply greater joint friction, material wear and early failure. Let's remember that, on average, a 65-year old patient takes his or her hip to 1,500,000 cycles per year, whereas a 45 year-old patient takes it to 3,500,00 cycles.

New bearing surfaces (ceramic, crosslink, metal, etc.), prosthetic designs and materials suggest that replacements duration will improve, but patient's average survival rates are also on the increase.

Reconstruction or joint rescue surgeries were carried out as procedures of choice in the 1950s and the 1960s (pre-prosthetic age);[2,3] later on, the arrival of prosthetic replacements led surgeons to abandon these techniques. Nowadays, (following Ganz's publications), different surgical centers worldwide have started to indicate these types of surgeries for selected patients as alternative to joint replacement. This work deals with the techniques of acetabular reorientation looking comparatively for advantages and disadvantages of the triple technique with respect to the Ganz's periacetabular technique. These procedures have to be followed as early as possible in life, so as to re-establish hip anatomy with cure, prevention or rescue criteria.

Biomechanics basis

In the treatment of hip biomechanics disorders, there are basic concepts that should be taken into account:

1) Coverage
2) Concentricity
3) Congruence
4) Balance of forces

1) *Coverage:* total coverage of the femoral head implies greater surface for joint pressure bearing; therefore, it implies a decrease in pressure by surface unit, what leads to lesser overloading and joint suffering. This is one of the goals of the treatment—the coverage of the femoral head. Let's remember that while walking, a person's hip bears such pressure that is equivalent to threefold his or her weight.

Dysplasia or lack of femoral head coverage is typically assessed in anterior-posterior X-ray (external de-coverage); this behavior underestimates or does not consider the anterior lack of femoral head coverage, which can be more serious than the other one; therefore, axial studies are highly important.

2) *Concentricity:* the hip is a ball-and-socket type joint; therefore, it has a concentric rotation center in both the acetabular and the femoral components. Joint concentricity means that there is neither bone sub-luxation nor dislocation; there is neither lateral displacement nor rise of the head rotation center with respect to the acetabular cup.

3) *Congruency:* in hip sequela disorders (dysplasia, Perthes disease,[4] epiphysiolysis, septic arthritis sequela), there can be acetabular deformities.[5] The younger the patient, the greater the re-modeling potential of the joint for future congruence; we should consider the different types of dysplasia as stated by Tönnis: 1, concentric dysplasia; 2, 1-2-cm rise dysplasia; 3, double acetabular cup; 4, in-

congruence. It is important to know if joint surfaces are congruent, because this allows us reorientation of joint components in pursuit of restoration of normal anatomy and keep the hyaline cartilage as support surface, what is ideal. These are the ideal techniques (Salter, triple osteotomy, three-tangential, Ganz's).

All authors are currently focusing on the study of joint congruency before surgery decision-making, and use functional tests routinely to estimate joint congruence results after carrying out the osteotomy of choice.

4) *Balance of forces:* the pressure that joint surfaces bear are directly proportional to body weight and the distance between the body middle line and the femoral head rotation center (medial lever arm). This force should be balanced against the force of lateral gluteal muscles and their relationship with the lateral lever arm. This makes hip sub-luxation increase the medial lever arm and, therefore, it also increases joint pressure and greater compensation by lateral gluteal muscle is asked for.[6] The aim of the treatment is to reduce joint pressure (decreasing the medial lever arm) and leave a balanced hip (in forces) so as to avoid claudicating or Trendelenburg's.

Pre-operative evaluation

At the time of performing surgical planning, it is essential to pinpoint the main joint defect because this tells us what component to act upon. There are four possible defects:

- *Femoral predominance:* coxa vara or coxa valga; short neck; risen greater trochanter
- *Acetabular predominance: hip dysplasia; double acetabular cup.*
- *Mixed predominance:* both components are altered or they have suffered mutual adaptation over time.
- *Complementary defect:* it is that which shows in the pre-operative planning for the surgical treatment of the initial predominance; for example, roof insufficiency secondary to valgus osteotomy.

Data for surgical planning

There are key data for adequate surgical planning. In 1989, Zancolli et al.[7] published a thorough description of the topic (Table 1).

Table 1. Summary of pre-operative planning

Data	Study
Acetabular component's	
Angle of anteversion	CT scan[8]
	True lateral hip X-ray[9]
Angle of inclination[10]	Panoramic anterior-posterior X-ray[11,12]
Congruence	CT scan (transverse, coronal and sagittal sections)
	Anterior-posterior X-ray
	Center test
Acetabular cup diameter	Anterior-posterior X-ray (Mose's rule)
Femoral component's	
Angle of inclination	Internal rotation anterior-posterior X-ray
Angle of anteversion	True lateral hip X-ray[13,14]
	Ryder-Crane's X-ray[15]
	CT scan
Congruence	Anterior-posterior and lateral X-ray (Mose's rule)
	Center test, abduction-adduction
	CT scan
Joint surfaces relationship's	
Anterior head de-coverage	True lateral hip X-ray
	Fake lateral hip X-ray
	CT scan[16,17]
Lateral head de-coverage	Panoramic anterior-posterior X-ray
Medial lever arm	Panoramic anterior-posterior X-ray
Lateral lever arm	Panoramic anterior-posterior X-ray
Head rotation center displacement	Panoramic anterior-posterior X-ray
	CT scan

Basic indications for acetabular cup osteotomies

Symptomatic hips. There is temptation or a tendency to carry out joint reconstruction osteotomies in asymptomatic hips; this is subject to debate. Actually, it is not possible to affirm that a hip that has undergone osteotomy will get joint replacement later in life than one that has not. Moreover, it cannot be affirmed either that, by osteotomy, we are making an asymptomatic hip a symptomatic one.[18]

If a hip shows symptoms, surgical treatment aimed at an asymptomatic hip is justified, what is gotten in 90-95% of the cases.

80% mobility. It is worth remembering that this type of surgeries competes with joint prosthetic replacement; nowadays, it cannot be tolerated that a hip, even though it does not show symptoms, is limited in mobility function. It is not frequent that a hip that shows limited mobility gains range of motion (ROM) once it has been subject to acetabular cup osteotomy; however, it is so that it remains painless but with the same ROM as previously to the surgery.

Age <40/45 years old.[19] In an ANCHOR group's multicenter study,[20,21] they summoned 87 hips in 70 patients, aged 43.6 years old on average (ranging from 40 to 51), with average follow-up of 4.9 years (ranging from 2 to 13), and they got a rate of conversion to prosthesis of 24%. In the same sample, at the time of classifying patients by their osteoarthritis degree using the Tönnis' classification, they found that 12% of the grades 0 and 1 osteoarthritis had been converted to prosthesis, whereas, in grade 2, 27% suffered a hip replacement.

Biomechanics/congruence disorders. This type of treatment is founded on the presence of biomechanics or congruence disorders that can be correlated with the patient's symptoms; after studying such defects thoroughly so as to carry out surgical planning[22] and choose appropriate techniques, we can give the patient our indication. To sum up, there has to be a defect that can be corrected or compensated by surgery.

Grade of osteoarthritis. We use the Tönnis' classification of hip osteoarthritis.

Grade 0: no osteoarthritis

Grade 1: progressive sclerosis of hip head and acetabular cup; mild joint space narrowing; minimal osteophyte

Grade 2: small cysts in hip acetabular cup or head; greater joint space narrowing; beginning of incongruence

Grade 3: significant cysts in hip head or acetabular cup; great joint space narrowing; erosion; incongruence; necrosis

Acetabular cup osteotomies are indicated in Tönnis's grades 0 or 1, especially if the surgery consists of reorientation of hyaline cartilage; in more advanced grades, rates and good results decrease significantly. Rescue osteotomies that interpose fiber-cartilage tissue can be carried out up to Tönnis' grade 2, with acceptable results.

Acetabular cup osteotomy

After studying the hip and making sure that the predominant defect is mainly acetabular, this component has to be treated looking for greater femoral head coverage.

As it has already been stated, acetabular cup osteotomies can be divided into three large groups:

- Acetabular cup reorientation techniques. The most widely used are:
  - Salter's osteotomy[23] (modified by Kalamichi)
  - Double osteotomy (Sutherland[25] and Zancolli)
  - Triple osteotomy (Steel, Le Couer,[26-28] Tönnis, Hopf, Zancolli) [29,30]
  - Ganz's osteotomy
  - Wagner's osteotomy [31,32]

- Techniques of reduction of the acetabular cup diameter. These are the ones that have the triradiate cartilage as roof rotation and descent reference:
  - Dega's osteotomy (modified by San Diego) [33,34]
  - Pemberton's osteotomy[35]

- Roof augmentation techniques. These are the ones that leave the joint capsule interposed for it to undergo metaplasia to fiber-cartilage tissue:
  - Roof plastic surgery (Stahely) [36]
  - Chiari's osteotomy [37-44]

What follows is a description of the most important techniques, with advantages, disadvantages and indications:

Basic concepts in acetabular cup osteotomies

At the time of carrying out pre-operative planning, there are some items that should be taken into account:

1) That all pelvic osteotomies are aimed at giving containment (coverage) to the femoral head, i.e. larger surfaces for pressure transmission and lower pressure by surface unit

2) That the other biomechanics effect it can have is on the medial lever arm, reducing it. As we know, the pressure load that the body bears equals body weight by the medial lever arm; by reducing the latter, intra-articular pressure decreases.

3) That it is preferable to use hyaline cartilage than fiber-cartilage (Chiari's rescue osteotomy) [45-51] as joint support surface, but this depends on the original condition and the degree of de-coverage and congruence,

4) That, many times, acetabular cup osteotomies should be associated with femoral osteotomies so as to restore desired joint biomechanics.

Techniques of hyaline cartilage reorientation, rotating the acetabular cup to coverage positions, are the ideal ones. The most widely used techniques are: a) iliac triple osteotomy, which has evolved with different descriptions or modifications (Le Coeur, Steel, Hopf, Tönnis, Zancolli,

etc.) and b) Ganz's periacetabular osteotomy. Both have great coverage power, and there is great controversy over the comparison between the two of them. Further down we describe their advantages and disadvantage.

Materials and Methods

Our experience with tripe osteotomy involves 74 cases aged 21 years old on average (ranging from 9 to 36) and with average follow-up of 14 years and 3 months (ranging from 6 months to 31 years). There were five conversions to prosthesis; in X-ray assessment we found seven cases of non-union in the ilium-ischium bone, and four in the ilium-pubic bone, all of which were asymptomatic.

Our experience with the Ganz's periacetabular technique, since 2005 up to now, consists of 44 cases operated on who averaged 24 years old. We verified four cases of non-union in the ilium-pubic bone, none in the ilium-ischium bone, one conversion to prosthesis in a case of incongruence, and one symptomatic patient with associated coxa valga waiting for varum osteotomy.

Re-orientation techniques for the acetabular cup

Ilium triple osteotomy

This osteotomy was described by numerous authors,[52, 53] and, among us, by Dr. Zancolli.[54] It is founded on the osteotomy of the three bones that join the acetabular cup with the pelvis (ilium, ischium, pubic bones) taking acetabular rotation to a normal anatomic position (Figure 1). These techniques differ in surgical approach and osteotomy level. In our cases, we used a sole reduced anterior approach (Figure 2).[55]

The advantages of this osteotomy are:

- great power for mobilization of the acetabular fragment or head coverage,
- it does not alter biomechanics, nor does it displace the femoral head rotation center,[56]
- it is not an easy technique, but it is associated with lower complications rates than techniques which are similar or similarly indicated,
- it is feasible in patients with open triradiate cartilage.[57]

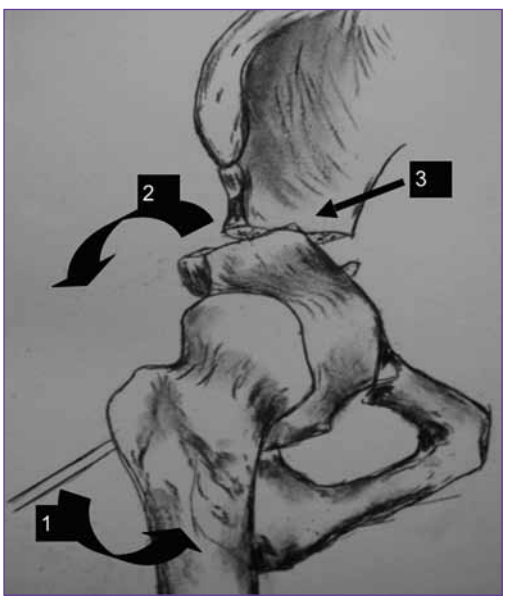

Figure 1. Technique for triple osteotomy, anterior view of the hip. **1.** The lower limb is taken to functional position (both limbs parallel). **2.** It shows how the acetabular fragment rotates together with the femur, keeping femoral head coverage. **3.** The superior-medial angle of the acetabular fragment is left in contact with the ilium, what causes hip descent; if that is not the desired effect, such angle should be osteotomized parallel to the ilium.

Figure 2. Twenty three-year old female with right hip pain. **A.** Anterior-posterior X-ray. It shows a dysplastic and concentric hip with acetabular suffering and Tonnis' grade 1osteoarthritis. **B.** Tridimensional reconstruction that shows anterior de-coverage. **C.** Triple osteotomy rotated so as to give total head coverage; note that the angle of the acetabular fragment was re-osteotomized. **D.** Nine years later: Bone healing with non-union of ilium-ischium bone and no symptoms.

Among associated complications, we can mention:

- lack of bone healing of the ilium-ischium bone or the ilium-pubic bone, but with no evident symptoms,[58]
- neuropraxia of femoral cutaneous nerve

This type of osteotomies are indicated in symptomatic hips with mild or serious dysplasia, grades 1 or 2 (congruent and with loss of concentricity <1cm) with no remarkable signs of osteoarthritis and mobile (80% mobility or more). Due to all these patients' requirements, it is not frequently performed. As we can see in Table 2, mid-term results vary between 70% and 96% of good results.[59]

Ganz's peri-acetabular osteotomy

The principle is the same as that of the ilium triple osteotomy—to leave the acetabular cup totally free from its links with the ilium, ischium and pubic bones (Figure 3). Modifications consist of carrying out the osteotomy leaving a linking posterior bone bridge between the ilium and the ischium bones (Figure 4). [60-62]

Indications are the same as those for triple osteotomy, and results are similar too. As associated advantages we can mention:

- it leaves a 1.5-2-cm posterior bone bridge linking the proximal with the distal pelvis,
- the acetabular fragment is left totally free with neither muscular nor ligament attachments (sacrospinous ligament); it can be freely rotated.

Table 2. Mid-term results with ilium triple osteotomy

Author	Cases	Follow-up	Results
Tönnis[52] (1994) adults	138	7.7 years	82%
Faciszewski[57] (1993)	56	7 years	94%
Kleuver (1990)	51	4 years	70%
Koolijman (1990)	51	10 years	96%

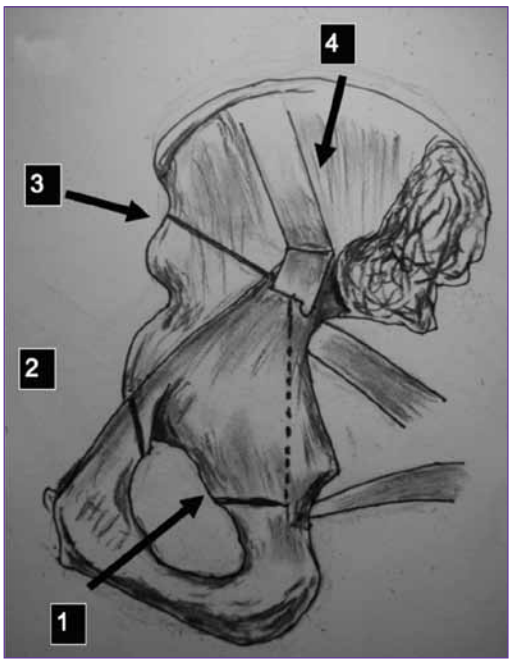

Figure 3. Ganz's technique **1.** Osteotomy of the anterior half of the ilium-ischium bone was carried out (intrapelvic view) using the same approach as in triple osteotomy. **2.** Osteotomy of ilium-pubic bone (intrapelvic view). **3.** With a 45°-angle chisel osteotomy of ilium bone is carried out from ilium osteotomy up to ischium osteotomy.

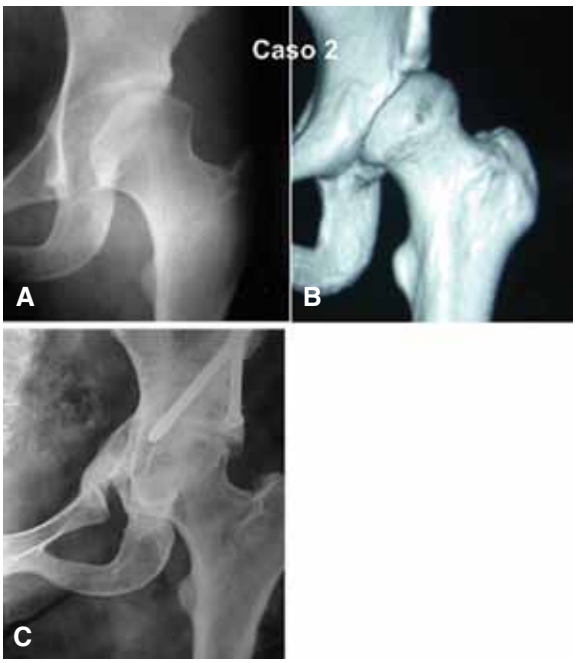

Figure 4. Ganz's technique. Nineteen-year old patient with symptomatic left hip. **A.** Anterior-posterior X-ray showing acetabular dysplasia, congruent, with no signs of osteoarthritis. **B.** Tridimensional reconstruction of the same hip. **C.** 5-year old osteotomy that shows improvement in acetabular index and head coverage.

Disadvantages are:

- it is a technique more demanding than tripe osteotomy,
- the learning curve is long because this is an infrequent disorder,[63]
- it is associated with high complication rates (joint penetration of the chisel, osteonecrosis of the acetabular fragment, etc.).[64]

Table 3 shows results published by some authors who are proficient in the technique;[65] as we can see, results are similar to those ones published in triple osteotomy: they vary between mid-term 73% and 97%. In acetabular osteotomies for reorientation of the hyaline cartilage, both triple and periacetabular osteotomies, the aims are the same:

- To reduce the medial lever arm (approximately to the contralateral one).
- To avoid anterior displacement of the femoral head rotation center.
- To get total lateral coverage of the femoral head.
- To get total anterior coverage of the femoral head.
- To take the acetabular angle of inclination to normal (45º).
- To take the acetabular angle of anteversion to normal (20ª).

Results

We ruled out the fist 20 candidates in the series (learning curve); among the remaining subjects we chose randomly 12 cases for each technique and we studied them with panoramic anterior-posterior and true lateral hip X-rays, and transversal, coronal and sagittal CT scan sections. The techniques used were:

Panoramic anterior-posterior hip X-ray: with 10º-medially rotated, parallel lower limbs. Focus on pubic symphysis; pelvic antepulsion or retropulsion would distort results, especially the acetabular angle of inclination and head coverage.

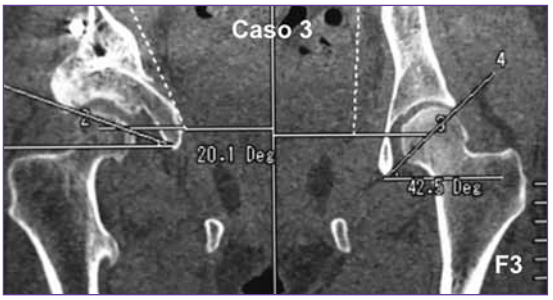

Figure 5. CT scan, coronal section, projection of the body middle line, comparative evaluation of both lever arms; assessment of the acetabular angle of inclination. Lateral displacement +2.9 mm in triple osteotomy and +7.6 mm in periacetabular osteotomy.

True lateral hip X-ray:[66] with 90º-bent hip and knee in contralateral limb and focused limb in functional position; X-ray plate under hypochondrium being studied, parallel to de floor (on the table); the X-ray beam is directed to the patient's inguinal area being studied (groin) to evaluate with a beam angle (with respect to the line that links both ASISs) which equals the acetabular angle of inclination evaluated in the anterior-posterior X-ray.

CT scan: transverse, coronal and sagittal sections. Evaluation of femoral anteversion with femoral neck and both condyles overlapped. Tridimensional reconstruction is useful but not essential for pre-operative planning. In such studies, we collected specifically the following data:

Methodology for data acquisition

- Lateral displacement of femoral head rotation center (Figure 5), which we evaluated in the panoramic anterior-posterior X-ray drawing a pelvic vertical line linking the spine of the first sacral vertebra and a middle landmark on the pubic symphysis; then we established the pelvic vertical line distance to the bilateral femoral head rotation center (medial lever arm).

Table 3. Mid-term results with Ganz's osteotomy

Author	Cases	Follow-up	Results
Ganz (1999)	75	11.3 years	73%
Kralj (2005)	26	7-15 years	85%
Trousdale (1995)	42	4 years	80%
Pogliacomi (2005)	36	4 years	97%

In transverse and coronal CT scan sections we evaluated the same parameters. On the transverse section we drew an anterior-posterior line linking a sacral middle landmark with the aforementioned pubic middle landmark, and then we established the distance between the head rotation center and such line (medial lever arm).

These features are pointed out in the hip operated on and in the contralateral one; we determined the difference between both hips in the series of 12 hips with triple osteotomy and we verified an average lateral displacement of 2.9 cm in the hip operated on as compared to the contralateal hip; extremes were 8-mm medialization vs. 13-mm lateralization (coxa magna).

With (Ganz's) periacetabular osteotomy, also carried out in 12 cases, we verified an average lateral displacement from the head rotation center (medial lever arm) of 7.6 mm with respect to the contralateral hip; extremes were 0-mm medialization vs. 14-mm lateralization (coxa magna).

- Anterior displacement of femoral head rotation center (Figure 6), which we evaluated on transverse CT sections drawing the pelvic horizontal line that goes by the anterior edge of the sacrum at S2 level; then, we established the distance from such line to the head rotation center (femoral head antepulsion) (medial lever arm).

These features are pointed out in the hip operated on and in the contralateral one; we established the difference between both hips in the series of 12 hips with triple osteotomy and we verified an average anterior displacement of 2.47 mm in the hip operated on as compared with the contralateral hip; extremes were 4-mm retropulsion vs. 14-mm antepulsion (coxa magna).

- Lateral head coverage (Figure 7), which we evaluated in the panoramic anterior-posterior X-ray drawing the pelvic horizontal line by the pelvic teardrop. Then, we drew three lines normal to the former—one by the head medial edge, another one by the lateral acetabular edge, and the third one by the head lateral edge, and then we measured the head width and the width of head coverage and, this way, we established the coverage percentage of the femoral head (Heiman and Herson). [67,68]

In the 12 cases that were assessed, average coverage was 99.5% in the femoral head with triple osteotomy (only in one case it was 95%) and 85% with periacetabular osteotomy, with minimal extreme of 70%.

- Anterior head coverage (Figure 7), which we also evaluated as coverage percentage of the femoral head and the same way as we describe for lateral coverage, but this time in true lateral X-ray and sagittal CT scan sections.

Average head coverage was 89% with triple osteotomy (only one case showed 70%) and 88% with periacetabular osteotomy; minimal extreme of 80%.

- Acetabular angle of inclination (Figure 5), which we evaluated in the panoramic anterior-posterior X-ray,[69] drawing the pelvic horizontal line by the pelvic teardrop. Then, we drew a line linking the lateral acetabular edge and the lowest border of the teardrop. We measured the angle between both lines; the average angle of inclination was 39.4º (with extremes of 35º and 45º) with the triple osteotomy, and 45.5º (with extremes of 60º and 40º) with periacetabular osteotomy.

- Acetabular angle of anteversion (Figure 6), which we evaluated drawing the horizontal pelvic line on the acetabular transverse section that goes by the anterior edge of the sacrum at S2 level; then, we draw a line linking the anterior and posterior edges of the acetabular cup right in the middle of it. Between both lines there is an angle which is the acetabular angle of anteversion. In the true lateral X-ray, we measured such angle between the horizontal X-ray line and the line that links both acetabular edges (the anterior and posterior edges).

The average angle of anteversion was 27.1º (with extremes of 20º and 45º) with triple osteotomy, and 23.1º (with extremes of 50º and 10º) with periacetabular osteotomy.

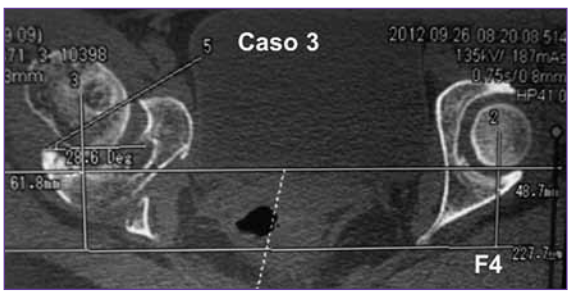

Figure 6. Transverse CT section, projection of the body horizontal line (anterior sacral line), comparative evaluation of antepulsion of the head rotation center; triple osteotomy +2.47 mm, peri-acetabular osteotomy +6.67 mm; evaluation of the acetabular angle of anteversion: triple osteotomy 27.1º, periacetabular osteotomy 23.11º.

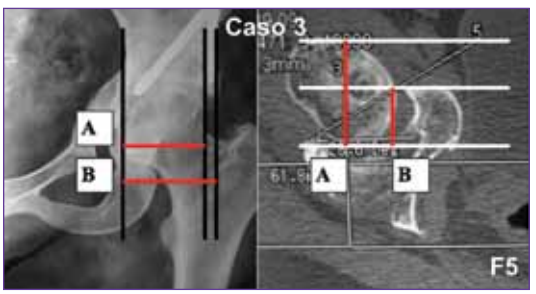

Figure 7. Evaluation of the percentage of head coverage. Lateral coverage (left), anterior coverage (right). A= head diameter, B= acetabular coverage. The equation B/A x 100 equals the percentage of coverage. Anterior coverage: 89% (triple osteotomy), 88% (Ganz's); lateral coverage: 99,4% and 80%, respectively.

Discussion

The surgical approach is similar for both techniques (10-12-cm inguinal approach). With both techniques we implemented the same rehabilitation program. Triple osteotomy is associated with higher ischium non-union rates, whereas peri-acetabular osteotomy poses the risk of joint penetration.

Comparison between both techniques shows better restoration of the head rotation center back to normal with the use of the modified triple technique rather than the periacetabular osteotomy technique. Table 4 shows that periacetabular osteotomy takes the head rotation center, on average, 5 mm towards the side and 5 mm towards the front more than the triple osteotomy, what means that the diagonal addition of the femoral head rotation center is displaced 12 mm; let's remember that Chiari reports 15-mm displacement as increasing joint pressure 20%.[70,72]

In our study, head coverage with periacetabular osteotomy is 19% smaller than with triple osteotomy on the anterior-posterior plane, whereas it is 9% smaller on the lateral plane. This implies a smaller loading surface. The increase in joint pressure (greater medial lever arm) plus a smaller loading surface (poorer femoral head coverage) results in greater loading by surface unit.

In our hands, the remains of the bone bridge linking the ilium and the ischium limits the rotation of the acetabular fragment towards the front, in cases of serious dysplasia with lack of anterior coverage of the femoral head. By getting good anterior coverage, the contact between the posterior bone bridge and the acetabular cup takes the femoral head rotation center to the front.

Table 4. Comparative biomechanics studies between both osteotomies

Technique	Triple osteotomy	Periacetabular osteotomy
Lateral displacement	+2.9 mm	+7.6 mm
Anterior displacement	+2.47 mm	+6.67 mm
Lateral coverage	99.4%	80%
Anterior coverage	89%	88%
Angle of inclination	39.4º	45.5º
Angle of anteversion	27.1º	23.11º

Conclusions

We believe that, before choosing the procedure, it is necessary to analyze if the lack of head coverage is mainly lateral or anterior to get as good surgical results as possible. If the defect is predominantly anterior, we prefer ilium triple osteotomy because it allows us reorientation of the acetabular cup on both planes without the limitations described in the context of the Ganz's periacetabular osteotomy.

Bibliography

1. Niethard F, Fernandez NR, Gussbacher A. La osteotomía pélvica según Chiari en el tratamiento de la displasia-coxoartrosis. *Rev Asoc Arg Ortop Traumatol* 1983;48(4):523-527.
2. Dunn HK, Smith JT, Coleman SS. Pelvic osteotomy: an alternative to total hip replacement in the young adult. *Hip* 1984;3: 13-20.
3. Gallinaro P, Massè A. Flexion osteotomy in the treatment of avascular necrosis of the hip. *Clin Orthop Relat Res* 2001;(386): 79-84.
4. Stulberg SD, Salter RB. The natural course of Legg-Perthes disease and its relationship to degenerative arthritis of the hip a long-term follow-up study. *Orthop Trans* 1977;1:385-386.
5. Clohisy JC, Keeney JA, Schoenecker PL. Preliminary assessment and treatment guidelines for hip disorders in young adults. *Clin Orthop Relat Res* 2005;441:168-179.
6. Pemberton PA. Pericapsular osteotomy of the ilium for treatment of congenital dislocation of the hip. *J Bone Joint Surg Am* 1965;47:65-86.
7. Zancolli EA, Befaro F, Gómez HA. Displasia y subluxación congénita inveteradas de la cadera. Evaluación radiológica pre e intraoperatoria para la programación quirúrgica. *Rev Asoc Argent Ortop Traumatol* 1984;49(4):274-285.
8. Mitchell GP. Chiari medial displacement osteotomy. *Clin Orthop* 1974;98:146-151.
9. Gómez H, Garrido A, Mufano R. Evaluación radiológica de la cadera - importancia del perfil real (quirúrgico). *Rev Asoc Argent Ortop Traumatol* 1989;54(4):488-502.

10. Sharp IK. Acetabular dysplasia. The acetabular angle. *J Bone Joint Surg Br* 1961;43(2):268-272.
11. Meuli HC, Hafner E. *Radiologic Examination in Orthopaedics: Methods and Techniques*, Baltimore, Maryland: University Park Press; 1976.
12. Mubarak SJ, Valencia EG, Wenger AR. One-stage correction of the spastic dislocated hip. *J Bone Joint Surg Am* 1992;74: 1347-1357.
13. Lequesne M, de Sèze S. [False profile of the pelvis: a new radiographic incidence for the study of the hip: its use in dysplasias and different coxopathies]. *Rev Rhum Mal Osteoartic* 1961;28:643-652.
14. Matsuno T, Ichioka Y, Kaneda K. Modified Chiari pelvic osteotomy: a long-term follow-up study. *J Bone Joint Surg Am* 1992; 74(4):470-478.
15. Ryder CT, Crane L. Measuring femoral anteversion: the problem and a method. *J Bone Joint Surg Am* 1953;35:321-328.
16. Donaldson SW, Badgley C. Lateral view of the pelvis in examination for hip dislocation. *J Bone Joint Surg Am* 1948;30(2): 502-504.
17. Wenger DR, Frick SL, Kim SK. Pre- and postoperative three-dimensional tomography. Analysis of triple innominate osteotomy for hip dysplasia. *J Pediatr Orthop* 2000;20(1):116-123.
18. Murphy SB, Kijewski PK, Millis MB, Harles A. Acetabular dysplasia in the adolescent and young adult. *Clin Orthop* 1990; (261):214-223.
19. Teratani T, Naito M, Kiyama T, Maeyama A. Periacetabular osteotomy in patients fifty years of age or older. *J Bone Joint Surg Am* 2010;92:31-41.
20. Millis MB, Kain M, Sierra R, Trousdale R, Taunton MJ, Kim YJ, et al. Periacetabular osteotomy for acetabular dysplasia in patients older than 40 years: a preliminary study. *Clin Orthop Relat Res* 2009;467(9):2228-2234.
21. Millis MB, Murphy SB. Use of computed tomographic reconstruction in planning osteotomies of the hip. *Clin Orthop* 1992;(274):154-159.
22. Turgeon TR, Phillips W, Kantor SR, Santore RF. The role of acetabular and femoral osteotomies in reconstructive surgery of the hip: 2005 and beyond. *Clin Orthop Relat Res* 2005;441:188-199.
23. Salter RB. Innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. *J Bone Joint Surg* 1961; 33:5-18.
24. Kalamchi A. Modified Salter osteotomy. *J Bone Joint Surg Am* 1982;64(2):183-187.
25. Sutherland DH, Greenfield R. Double innominate osteotomy. *J Bone Joint Surg Am* 1977;59(8):1082-1091.
26. Steel HH. Triple osteotomy of the innominate bone. A procedure to accomplish coverage of the dislocated or subluxated femoral head in the older pacient. *Clin Orthop* 1977;(122):116-127.
27. Steel HH. Triple osteotomy of the innominate bone. *J Bone Joint Surg Am* 1973;55(2):343-350.
28. Steel HH, Lee DY, Choi IH, Ahn JH, Chung CY. Triple innominate osteotomy for hip stabilisation and transiliac leg lengthening after poliomyelitis. *J Bone Joint Surg Br* 1993;75(6):858-864.
29. Kotz R, Da Vid T, Helwig U, Uyka D, Wanivenhaus A, Windhager R. Polygonal triple osteotomy of the pelvis. A correction for dysplastic hip joints. *Int Orthop* 1992;16(4):311-316.
30. Le Coeur P. [Correction des défauts d'orientation de l'articulation coxofémorale par ostéotomie de l'itsme iliaque]. *Rev Chir Orthop Reparatrice Appart Mot* 1965;51:211-212.
31. Schramm M, Hohmann D, Radespiel-Troger M, Pitto RP. The Wagner spherical osteotomy of the acetabulum. *J Bone Joint Surg Am* 2003;85:808-814.
32. Wagner H. Osteotomies for congenital hip dislocation. Scientific Meeting of the Hip Society, St. Louis, 1976, p. 45.
33. Dega W, Polakowsky L. Surgical treatment of congenital dislocation of the hip in children: a one stage procedure. *J Bone Joint Surg Am* 1959;41(5):920-934.
34. Delp S, Bleck E, Zajac F, Bollini G. Biomechanical analysis of the Chiari pelvic osteotomy. *Clin Orthop* 1988;254:189-197.
35. Clohisy J, Schutz A, St. John L, Schoenecker PL, Wright R. Periacetabular osteotomy: a systematic literature review. *Clin Orthop* 2009;467:2041-2052.
36. Staheli LT. Slotted acetabular augmentation in childhood and adolescence. *Pediatr Orthop* 1973;1:321-327.
37. Chiari K. Pelvic osteotomy for hip subluxation. *J Bone Joint Surg Br* 1970;52:174.
38. Chiari K. Iliac osteotomy in young adults. *Hip* 1979;7:260-277.
39. Chiari K. Medial displacement osteotomy of the pelvis. *Clin Orthop* 1974;98:55-71.
40. Colton CL. Chiari osteotomy for acetabular dysplasia in young subjects. *J Bone Joint Surg Br* 1972;54(4): 578-589.

41. Magilligan PJ. Calculation of the angle of anteversion by means of horizontal lateral roentgenographic. *J Bone Joint Surg Am* 1956;38:1231-1246.

42. Migaud H, Duquennoy A, Gougeon F, Fontaine C, Pasquier G. Outcome of Chiari pelvic osteotomy in adults-90 hips with 2-15 years follow-up. *Acta Orthop Scand* 1955;66(2):127-131.

43. Millis MB, Hall JE. Transiliac lengthening of the lower extremity. A modified innominate osteotomy for the treatment of postural imbalance. *J Bone Joint Surg Am* 1979;61(8):1182-1194.

44. Mose K. Methods of measuring in Legg-Calve-Perthes disease with special regard to the prognosis. *Clin Orthop* 1980;(150): 103-109.

45. Hiranuma S, Higuchi F, Inove A, Miyazaki M. Changes in the interposed capsule after Chiari osteotomy. *J Bone Joint Surg Br* 1992;74(3):463-467.

46. Hogh J, Macnicol MF. The Chiari pelvic osteotomy. A long-term review of clinical and radiographic results. *J Bone Joint Surg Br* 1987;69(3):365-373.

47. Koberle G. Osteotomia Chiari. *Acta Ort Lat* 1976;111(2):191-207.

48. Lack W, Windhager R, Kutscherd HP, Engel A. Chiari pelvic osteotomy for osteoarthritis secondary to hip dysplasia-indications and long-term results. *J Bone Joint Surg Br* 1991;53(2):229-233.

49. Lord G, Marotie H, Blauchard JP, Guillamon JC, Deplus P. L'osteotomie de Chiari chez 1'adults - Technique y etude bio-mécanique et premiers resultáis. *Rev Chir Orthop* 1975;61:487-506.

50. Pauwels F. Des affections de la hanche d'origine et de leur treatement par l'osteotomie d'adduction. *Rec Chir Orthop* 1951;37: 22-30.

51. Rejholec M, Frantisek S, Rybka V, Polpelka S. Chiari osteotomy of the pelvis: a long-term study. *J Pediatr Orthop* 1990;10(1): 21-27.

52. Tönnis D, Arning A, Bloch M, Heinecke A, Kalchschmidt K. Triple pelvic osteotomy. *J Pediatr Orthop* 1994;3:54-67.

53. Hopf A. Hip acetabular displacement by double pelvic osteotomy in the treatment of hip joint dysplasia and subluxation in young people and adults. *Z Orthop Ihre Grenzgeb* 1966;101(4):559-586.

54. Zancolli EA. Alternativas de la artroplastía total de cadera. Osteotomías del ilíaco en displasias de adolescentes y adultos jóvenes. XXIII Congreso Argentino de Ortopedia y Traumatología. Resúmenes del Programa Científico, Buenos Aires, 42-43, 1986.

55. Zancolli EA, Gómez H, Garrido A, Peirano F, Arrondo J, Lopez R. Triple osteotomía del ilíaco tritangencial en la displasia de cadera: único abordaje anterior. *Rev Asoc Argent Ortop Traumatol* 2003;68(4):246-253.

56. Hsin J, Saluja R, Eilert RE, Wiedel JD. Evaluation of the biomechanics of the hip following a triple osteotomy of the innominate bone. *J Bone Joint Surg Am* 1996;78(6):855-862.

57. Faciszewski T, Coleman SS, Biddulph G. Triple innominate osteotomy for acetabular dysplasia. *J Pediatr Orthop* 1993;13(4): 426-430.

58. Tschauner C, Sylkin A, Hofmann S, Graf R. Painful nonunion after triple pelvic osteotomy. Report of five cases. *J Bone Joint Surg Br* 2003;85(7):953-955.

59. Wagner M, Wagner H. Verhindert die Osteotomie der dysplastischen Huftpfanne eine Arthrose? Analyse einer Serie mit minimal 19 Jahren Nachuntersuchungszeit. *Z Orthop Ihre Grenzgeb* 1998;136:A34.

60. Clohisy JC, Nunley RM, Curry MC, Schoenecker PL. Periacetabular osteotomy for the treatment of acetabular dysplasia associated with major spherical femoral head deformities. *J Bone Joint Surg Am* 2007;89(7):1417-1423.

61. Ganz R, Horowitz K, Leunig M. Algorithm for femoral and periacetabular osteotomies in complex hip deformities. *Clin Orthop Relat Res* 2010;468(12):3168-3180.

62. Ganz R, Klaue K, Vinh TS, Mast JW. A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary. *Clin Orthop* 1988;(232):26-36.

63. Peters CL, Erickson JA, Hines JL. Early results of the Bernese periacetabular osteotomy: the learning curve at an Academic Medical Center. *J Bone Joint Surg Am* 2006;88:1920-1926.

64. Thawrani D, Sucato DJ, Podeszwa DA, DeLaRocha A. Complications associated with the Bernese periacetabular osteotomy for hip dysplasia in adolescents. *J Bone Joint Surg Am* 2010;92(8):1707-1714.

65. Clohisy JC, Barrett SE, Gordon JE, Delgado ED, Schoenecker PL. Periacetabular osteotomy for the treatment of severe acetabular dysplasia. *J Bone Joint Surg Am* 2005;87:254-259.

66. Laage H. Horizontal lateral roentgenographic of the hip children. A preliminary report. *J Bone Joint Surg Am* 1953;35:387-398.

67. Herdon, CH, Heyman CH. Legg Perthes disease as evaluation of treatment by traction and ischial weight bearine brace. *J Bone Joint Surg* 1952;34:25-46.

68. Heyman CH, Herndon CH. Legg-Perthes disease; a method for the measurement of the roentgenographic result. *J Bone Joint Surg Am* 1950;32:767-778.

69. Wiberg C. Studies on dysplastic acetabular and congenital subluxations of the hip joint: with special reference to the complication of osteoarthritis. *Acta Chir Scand* 1939;83:29-37.

70. Benson MKD, Evans ACJ. The pelvic osteotomy of Chiari: an anatomical study of the hazards and misleading radiographic appearances. *J Bone Joint Surg Br* 1976;58(2):164-168.

71. Fernández D, Isler B, Muller M. Chiari's osteotomy. *Clin Orthop* 1984;185:53-58.

72. Handelsman JE. The Chiari pelvic sliding osteotomy. *Clin Orthop* 1980;11(1):105-125.