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RESEARCH ARTICLE

Is minimally invasive shelf acetabuloplasty in adults more reliable than periacetabular osteotomy? Long-term results

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SUMMARY
This is a retrospective, single-operator study which hypothesised that shelf acetabuloplasty for acetabular dysplasia with a centre-edge angle of Wiberg between 0° and 15° and stage 1 or 2 osteoarthritis, has comparable results to periacetabular osteotomy with less severe complications. *Patients and methods*: 95 hips, mean follow-up of 12.8 years (4-26.4), 70.5% female (67/95), 29.5% male (28/95), mean age of 34.7 years (16-61 years). The surgical technique was minimally invasive, intermuscular between the posterior border of the tensor facia lata muscle and the anterior border of the gluteus medius muscle as described by Chiron in 2007. Survival curves were analysed using the Kaplan Meier method with the Log Rank test; Cox power test: 0.832. *Results:* Complications: 4 graft lyses (4.2%); 3 non-unions (3.1%); 56.8% (54/95) screw removal; no infection, no lateral femoral cutaneous nerve injury, all low-grade complications with no high-grade.
Total hip replacements: 22.1% (21/95) of which 52.3% (11/21) were in the first 5 years. Age and gender had a significant impact on survival: under 30 years, 13.9% (6/43); over 30 years, 30% (15/50); under 25 years, 0% (0/13; mean follow-up 14.6 years; 9 - 26); females, 26.8% (18/67), males, 10.7% (3/28).
Survival: Overall (5 years: 90%, 10 years: 83,5%, 15 years: 77%); according to age: under 30 years (5 years: 95,3%, 10 years: 88,8%, 15 years: 84,3%), over 30 years (5 years: 84%, 10 years: 77,4%, 15 years: 69%), P-value 0.0004; according to gender: females (5 years: 86,3%, 10 years: 77,4%, 15 years: 68,9%), males (5 years: 96%, 10 years: 92,1%, 15 years: 92,1%), p-value: 0,0826; females over 30 years (5 years: 80,4%, 10 years: 75,1%, 15 years: 64,4%), females under 30 years (5 years: 91,6%, 10 years: 87,3%, 15 years: 80%), P-value: 0,1502
Survival rates were similar to those for peri acetabular arthroplasty, with no serious complications. Checking for any associated labral hip tears and arthroscopic treatment beforehand should improve the total hip replacement rate in the first 5 years.
Ideal patients are young males and those at risk are females over 30 years of age, but with results that are still acceptable for group at risk which justify this minimally invasive procedure

Keywords: Shelf arthroplasty, periacetabular osteotomy, arthroscopy, minimal invasive approach, survival curves.

Introduction:

Hip dysplasia is a frequent cause of osteoarthritis due to excessive pressure on the hyaline cartilage. It is the most frequent cause in young subjects[1]. In the event of painful hip dysplasia with osteoarthritic deterioration to Tönnis stages I and II (no bone-on-bone contact), periacetabular osteotomy[2] is currently the most common procedure. It is a complex procedure which must be performed by a trained surgeon and which presents many complications (12% high-grade[3]: direction error, acetabular necrosis, non-union, infection…). The effects are long-lasting and therefore return to work is slow. Shelf acetabuloplasty has proven its effectiveness in adult forms of acetabular dysplasia[4-8]. The technique and its principle were described by Koenig[9] in 1891 and revived by Lance[10,11] in 1925. A cortico-cancellous bone graft is placed in contact with the upper surface of the hip joint capsule, extra-articularly, to increase the load-bearing surface (the cartilage of the femoral head is supported by the labrum and the capsule stabilised by the graft), which reduces pressure. The approaches usually used are the Smith-Petersen[12], first and second techniques, which widely detach the muscle insertions from the iliac wing. Minimally invasive shelf acetabuloplasty[13] decreases the length of hospitalisation and convalescence, and normal, professional and sports activities can be resumed. For moderate forms of hip dysplasia, shelf acetabuloplasty is a simpler technique for the patient and the surgeon.

The aim of this study is to evaluate the long-term results of shelf acetabuloplasty in adults with no bone-on-bone osteoarthritis and a centred femoral head, performed by the intermuscular approach according to the technique used by Chiron[13].

The main hypothesis is that through minimally invasive shelf acetabuloplasty in these cases of minor dysplasia, total hip replacement (THR) can be avoided or postponed with results similar to those of periacetabular osteotomy.

The secondary hypothesis is that serious complications are less frequent than those encountered in periacetabular osteotomy.

Patients and methods:

This was a retrospective, single-operator, continuous study with inclusion between 1999 and 2015 whose review was terminated in 2020.

Inclusion criteria were: head centred acetabular dysplasia (unbroken Shenton's line); age of the patient at the time of surgery >15 years; patients operated on by the same surgeon; shelf acetabuloplasty by minimally invasive intermuscular approach; minimum follow-up of 5 years; Tönnis stage 1 or 2 osteoarthritis.

The exclusion criteria were as follows: eccentric hip dysplasia (broken Shenton's line); age <15 years; history of homolateral hip or pelvic surgery prior to shelf acetabuloplasty; surgery performed by another surgeon; learning curve of the first 5 patients; Tönnis stage 3 and 4 osteoarthritis.

The surgical technique was the one described in the initial article[13] with some slight differences in positioning (since 2004, the orthopaedic table is no longer used, patient in strict supine position) and compensating for the loss of substance by filling the harvesting site with a press-fit bone substitute (as of 2005) (Figure 1). The procedure consists of three steps: graft harvesting (Figure 2), graft preparation (Figure 3), intermuscular approach between the posterior edge of the tensor fascia lata muscle and the anterior edge of the gluteus medius muscle (Figure 4), and graft placement, for which the screw (stainless steel; only four titanium screws) is guided by a pin placed under image intensifier control (Figure 5) (Figure 6)

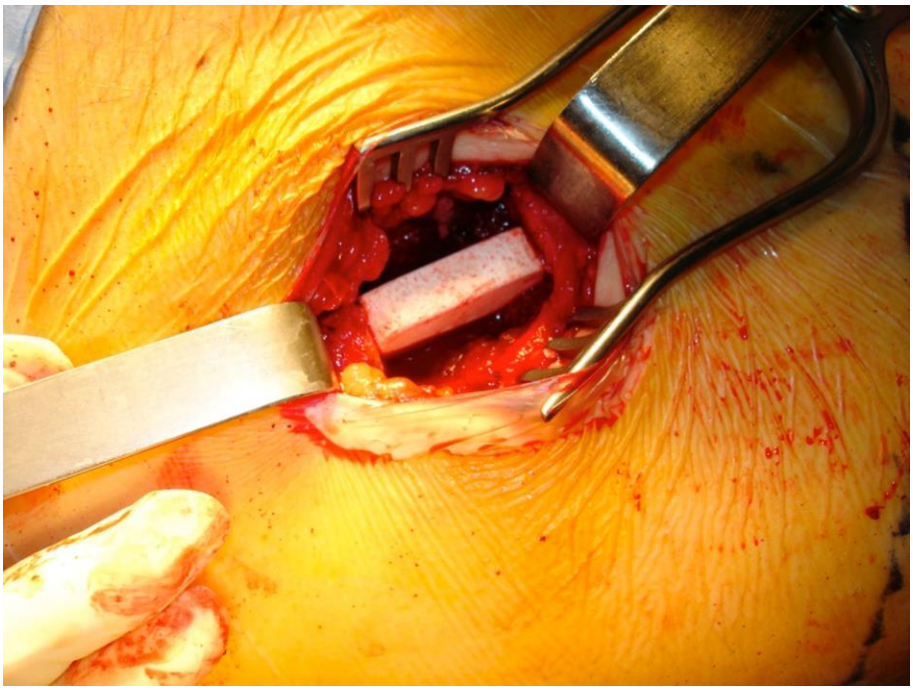

Figure 1: Filling of the cortico-cancellous sample with a substitute.

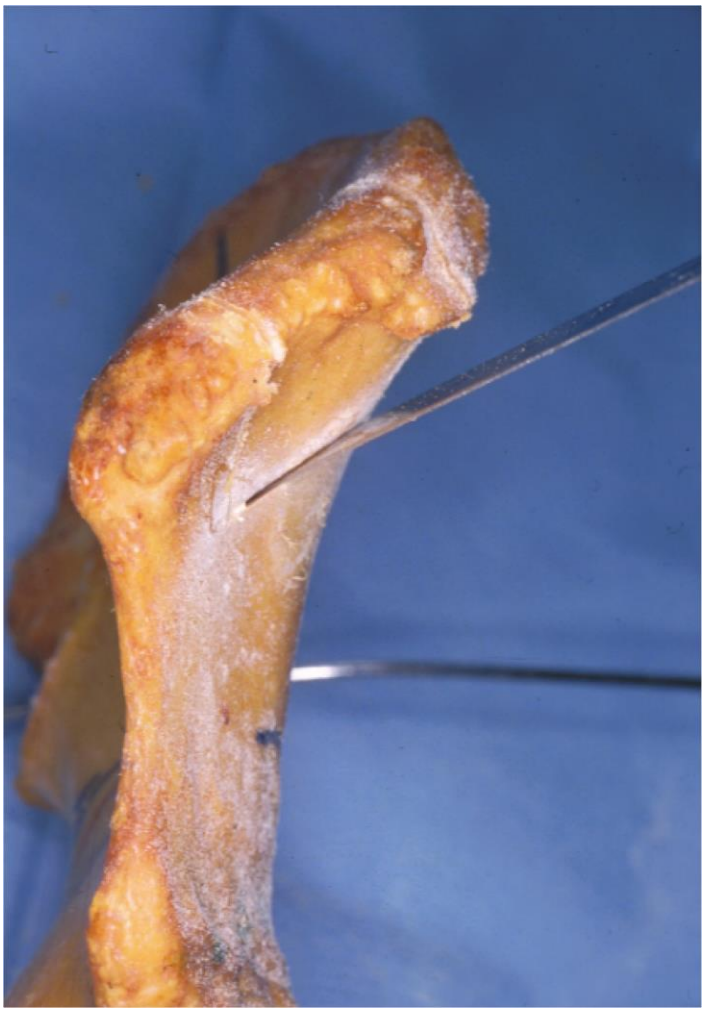

Figure 2: Removal of the iliac wing graft.

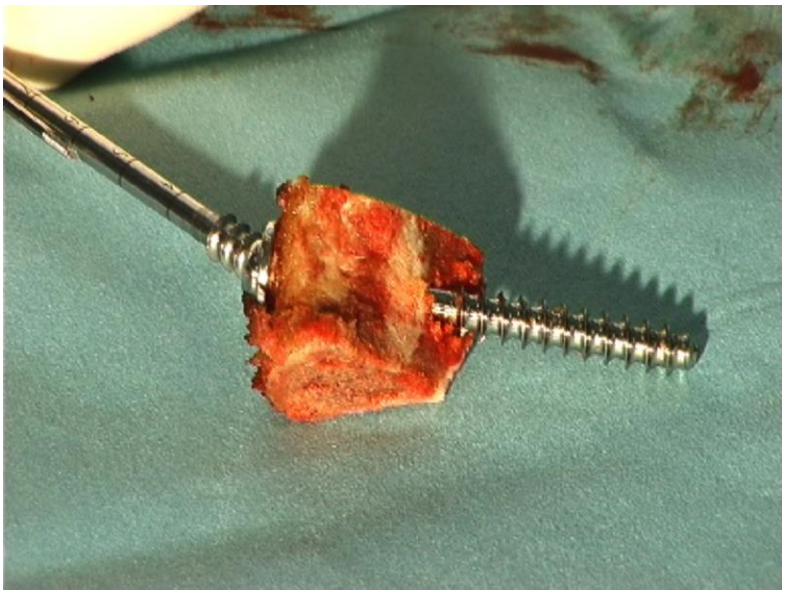

Figure 3: Preparation of the graft.

Figure 4: Marks for the guide pin.

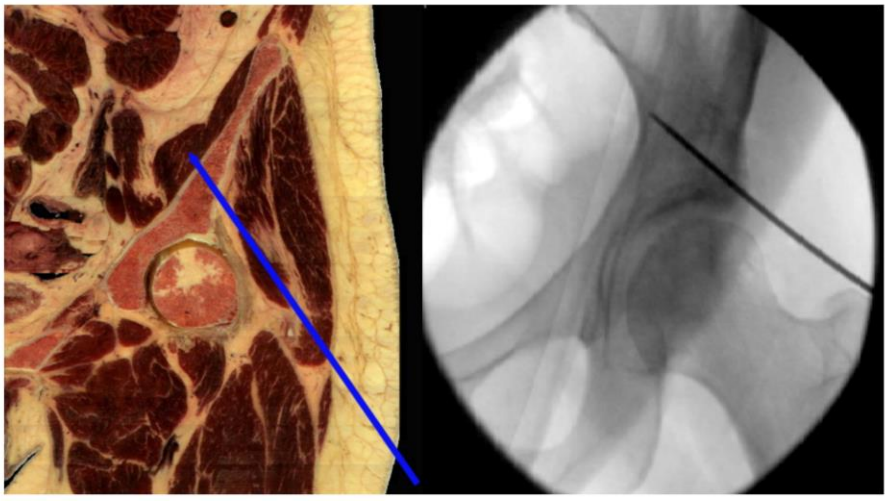

Figure 5: Guide pin positioning.

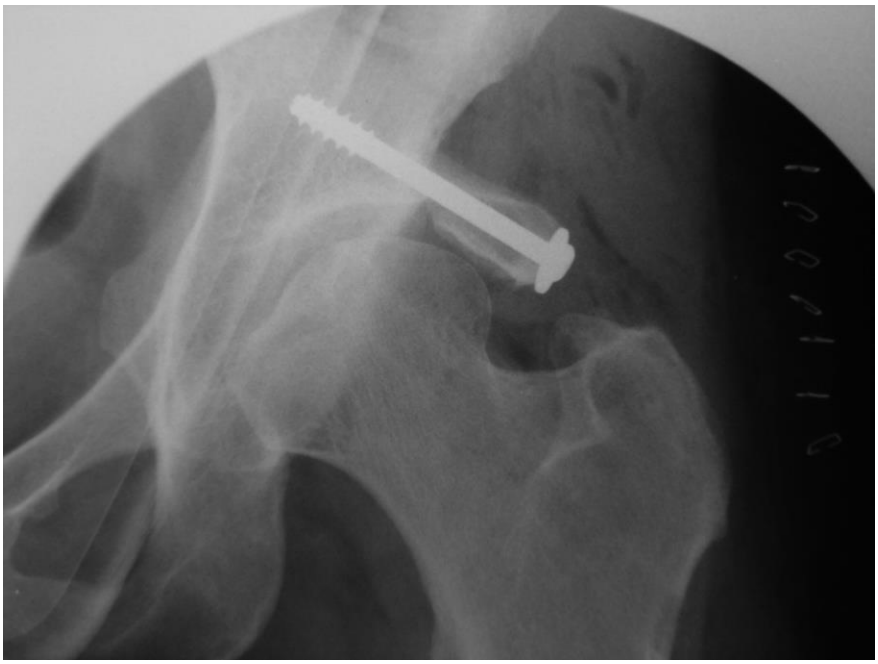

Figure 6: The graft is screwed.

There were 82 patients in the series, with no loss to follow-up or death (young cohort); 13 bilateral shelf acetabuloplasties were performed, which is 95 hips studied. An analysis was performed whether or not a total hip replacement was performed at the last follow-up. The data was collected in 2022, during appointments as well as by telephone and e-mail.

The coxometric measurements were obtained from digitised images, integrated into the Orthowave software by Aria™, which includes Pict-in measurement software (https://www.orthowave.net/); the data obtained were digitised and exploitable.

The statistical analysis was performed using XLSTAT™. The Cox power test was 0.832. Survival analyses were based on the Kaplan Meier method, with conversion to total hip replacement considered as the event code and the last event-free contact as the censored code. The 95% confidence intervals were detailed for the survival analyses. Survival curves were compared using the Log-Rank test.

Results:

The mean follow-up was 12.8 years (0.4 / 26.3 years); mean age at the time of surgery 34.7 years (16 to 61 years); mean age at revision 43.8 years (24 to 72 years); 70.5% females (67/95), 29.5% males (28/95); 57.8% right side, 37.2% left side (55/40). On coxometry, the mean Wiberg (VCE) angle was 9.7° (0-18°) (normal >25°), the acetabular angle (THE) which assesses the roof slope averaged 23.2°(14-34°) (normal <10°), the average cervical angle (CCD) was 138.6° (133-145°) (normal 128-134°); all femoral heads were centred, with no break in Shenton's line, Grade 1 on the Crowe-Ranawat classification (Minor dysplasia, centred femoral head: < 50%), Efketar / Postel-Merle d'Aubigné Type 1.

Complications:

There were 4 cases of graft lysis (4.2%), one of which was bilateral which led to a bilateral prosthesis; in all 4 cases, the screw was titanium. There were 3 cases of non-union (3.1%) 2 without pain, only one of which had a prosthesis. Removal of the screw due to pain was justified in 56.8% of the cases (54/95) with a mean period of 2.7 years (0.15 to 9.4 years). There was 1 bone substitute displacement without painful or aesthetic consequences. No infection. No paraesthesia or pain in the lateral femoral cutaneous nerve of the hip.

Total hip replacement (THR): at the last follow-up, 21 total hip replacements were performed: 22.1% (21/95); Deterioration was early for 52.3% (11/21) of the total hip replacement within the first 5 years (Figure 7). The mean age at the time of total hip replacement was 41.15 years (25-61 years). Age and gender had a significant impact on survival. For patients under 30 years of age the rate of Total hip replacement was 13.9% (6/43), for those over 30 years of age it was 30% (15/50). It should be noted that for

patients under 25 years of age (13/95), no total hip replacement was performed, 0% (0/13) for an average follow-up of 14.6 years (9 to 26 years). According to gender, there were 26.8% (18/67) total hip replacement in women and 10.7% (3/28) total hip replacement in men.

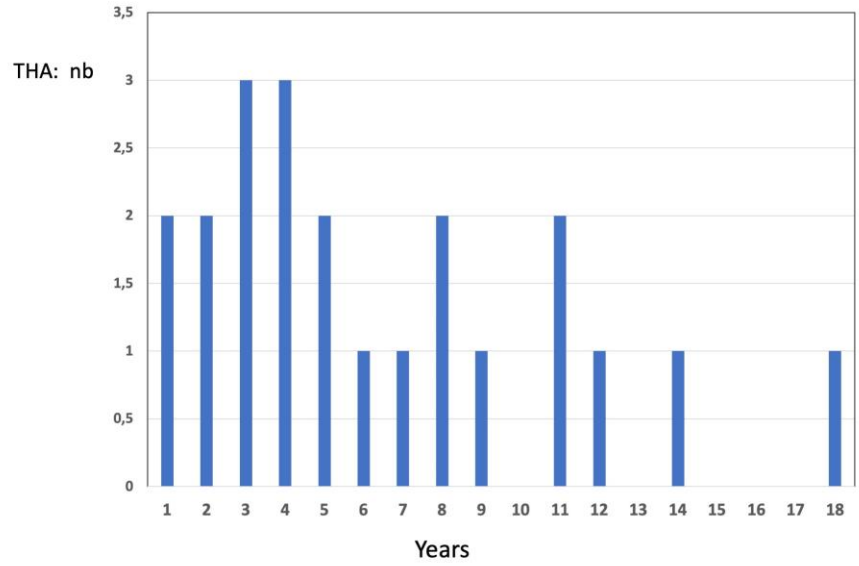

Figure 7: Peak of hip prostheses before 5 years.

Survival The overall survival curve indicated an expected survival of 18.8 years with a standard deviation of 0.786, a lower bound of 17.342 and an upper bound of 20.421. Survival at 5 years was 90%, at 10 years 83.5%, and at 15 years 77%. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 8).

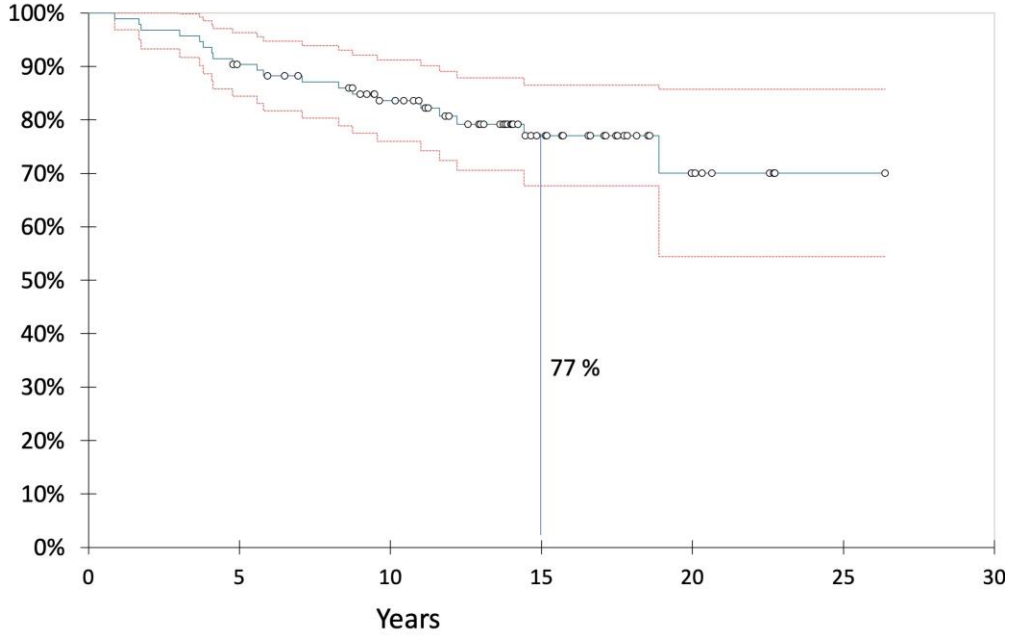

Figure 8: Overall Series Survival Curve.

The survival curve for the group of patients aged 30 years or less on the day of surgery (6 THR/43 hips) indicated an expected survival time of 20.2 years with a standard deviation of 1.041, a lower bound of 18.2 and an upper bound of 22.8. Survival at 5 years was 95.3%, at 10 years 88.8% and at 15 years 84.8% with an estimated 84.8% at 20 years. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 9).

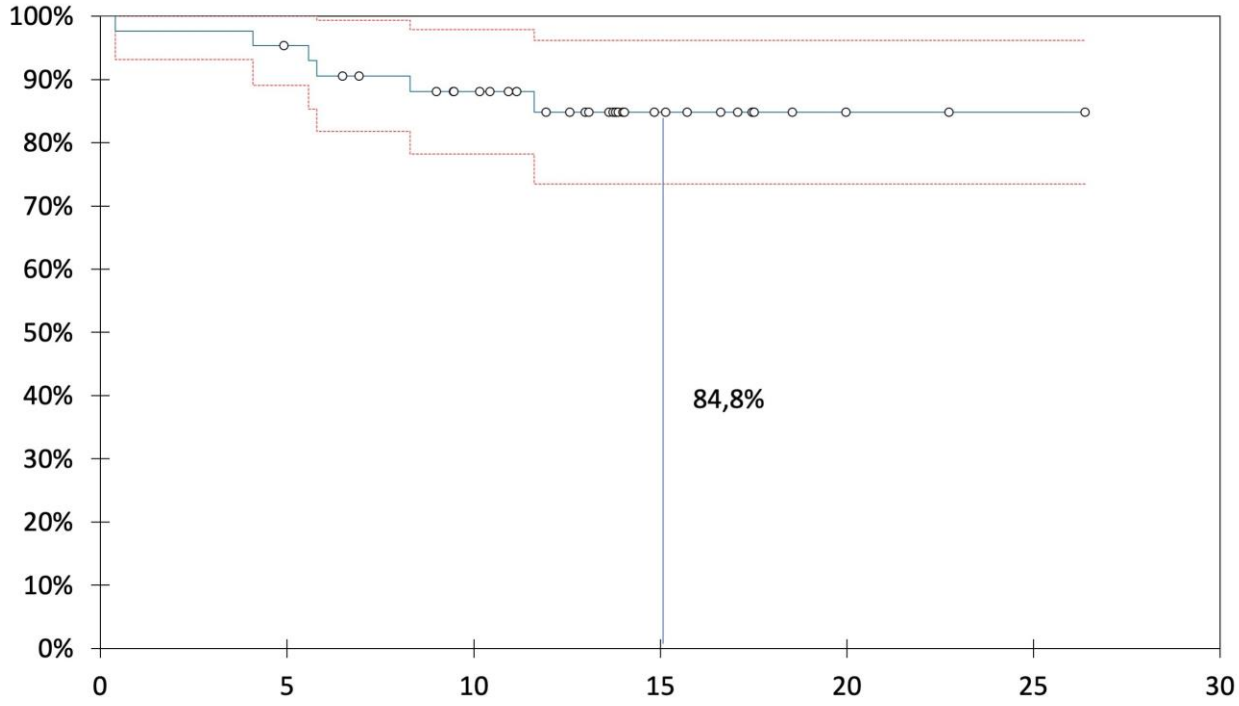

Figure 9: Survival curve before age 30 years.

The survival curve for the group of patients aged more than 30 years on the day of surgery (15 THR/50 hips) indicated an expected survival time of 17.4 years with a standard deviation of 1.182, a lower bound of 15.109 and an upper bound of 19.742. Survival at 5 years was 84%, at 10 years 77.4%, and at 15 years 69% with an estimated 60% at 20 years. The curve seems to have subsequently stabilised, but this was still open to interpretation (Figure 10).

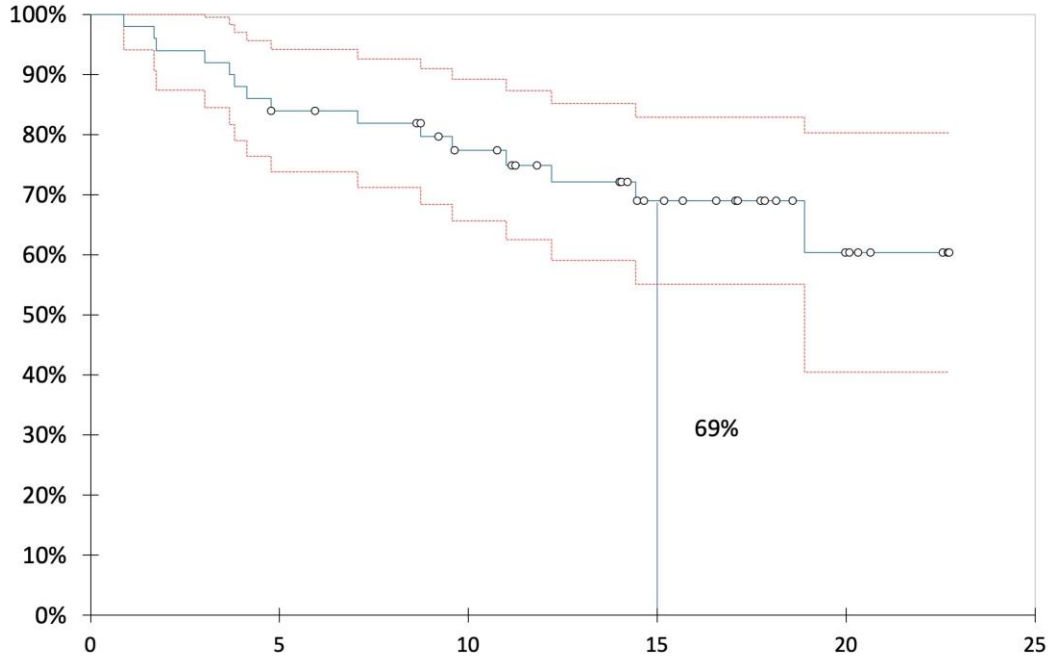

Figure 10: Survival curve after 30 years.

A comparison of the curves of the two groups according to age, analysed by Log-Rank test, showed a P-value of: 0.0004 (very strong evidence against the null hypothesis) and a chi-squared (X^2) test statistic of: 12.312 (Figure 11).

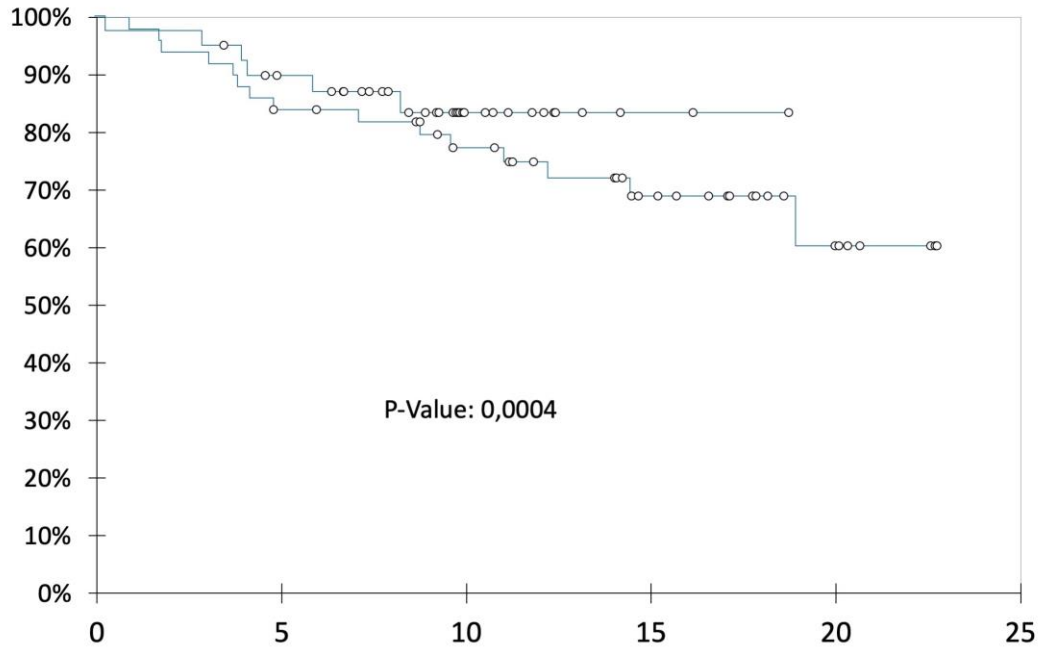

Figure 11: Log-Rank test before and after 30 years.

The survival curve for the female group (18 THR/ 66 hips) estimated a survival time of 20.1 years with a standard deviation of 0.712, a lower bound of 18.705 and an upper bound of 21.495. Survival at 5 years was 86.3%, at 10 years 76.4% and at 15 years 68.9%. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 12).

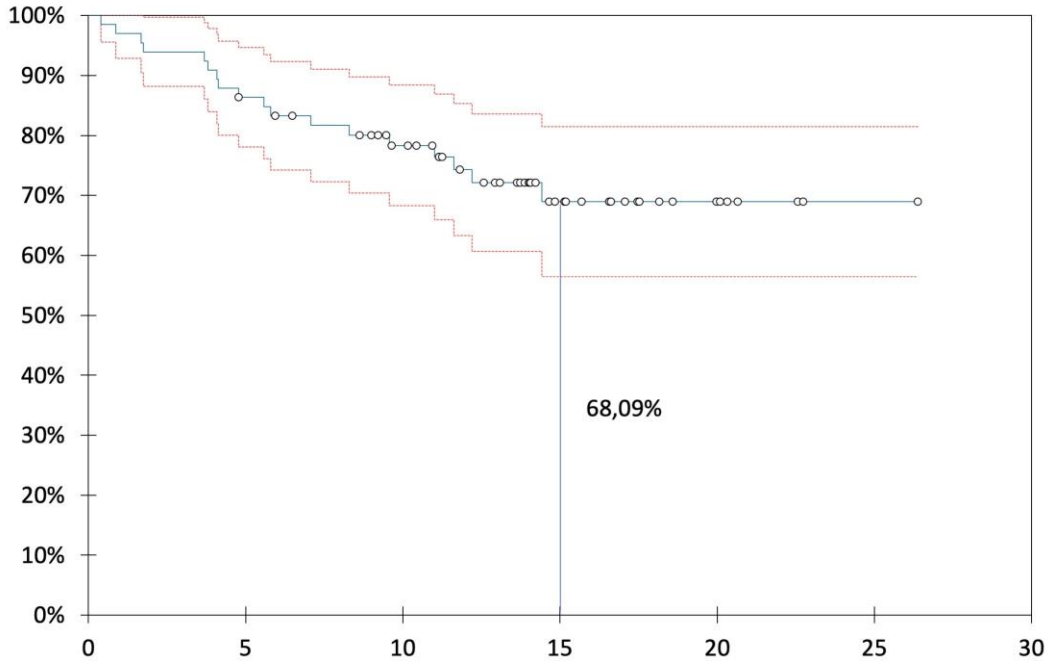

Figure 12: Survival curve female group.

The survival curve for the male group (3 THR/ 27 hips) estimated an expected survival time of 20.501 years with a standard deviation of 1.390, a lower bound of 17.776 and an upper bound of 23.226. Survival at 5 years was 96%, at 10 years 92.1% and at 15 years 92.1%. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 13).

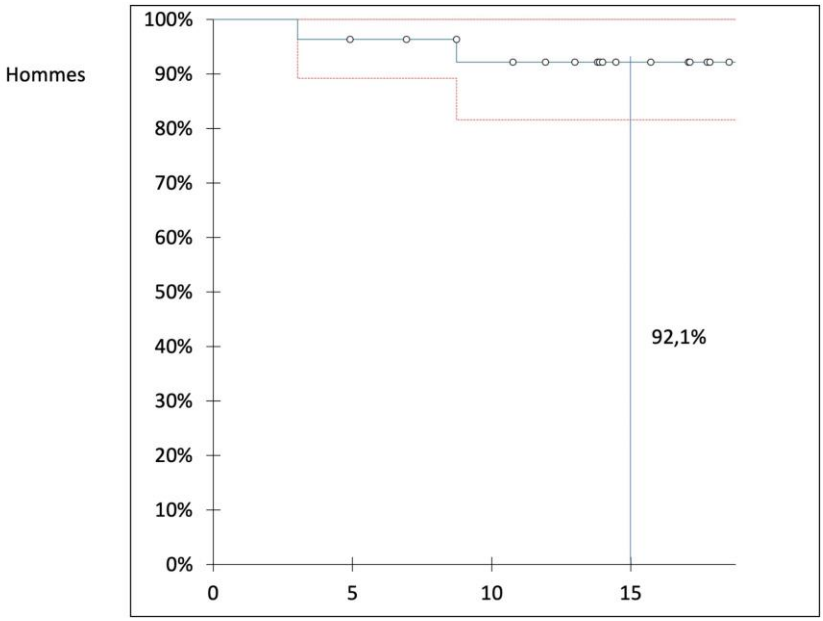

Figure 13: Survival curve male group.

A comparison of the curves of the two groups according to gender, analysed by Log-Rank test, showed a P-value of: 0.0826 (weak evidence against the null hypothesis) and a chi-squared (X^2) test statistic of: 3.0121. (Figure 14)

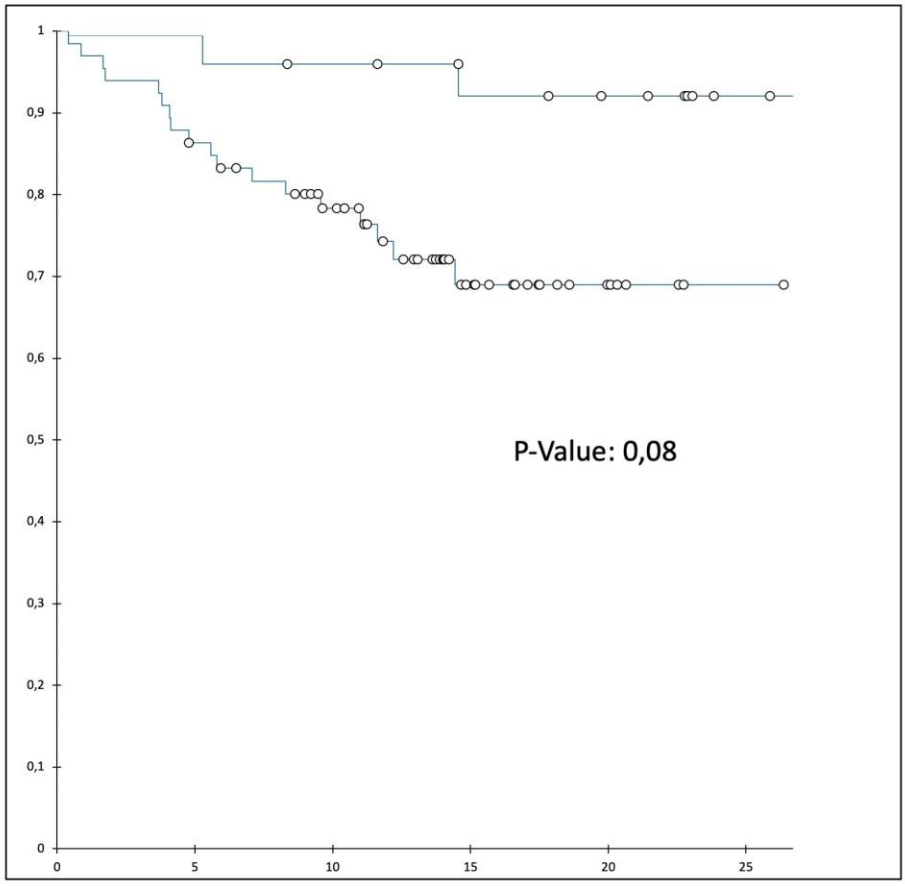

Figure 14: Log-Rank test female / male.

The survival curve for the female group aged less than 30 years (4 THR/ 24 hips) estimated a survival time of 15.476 years with a standard deviation of 1.087, a lower bound of 13.346 and an upper bound of 17.606. Survival at 5 years was 91.6%, at 10 years 87.3% and at 15 years 80%. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 15).

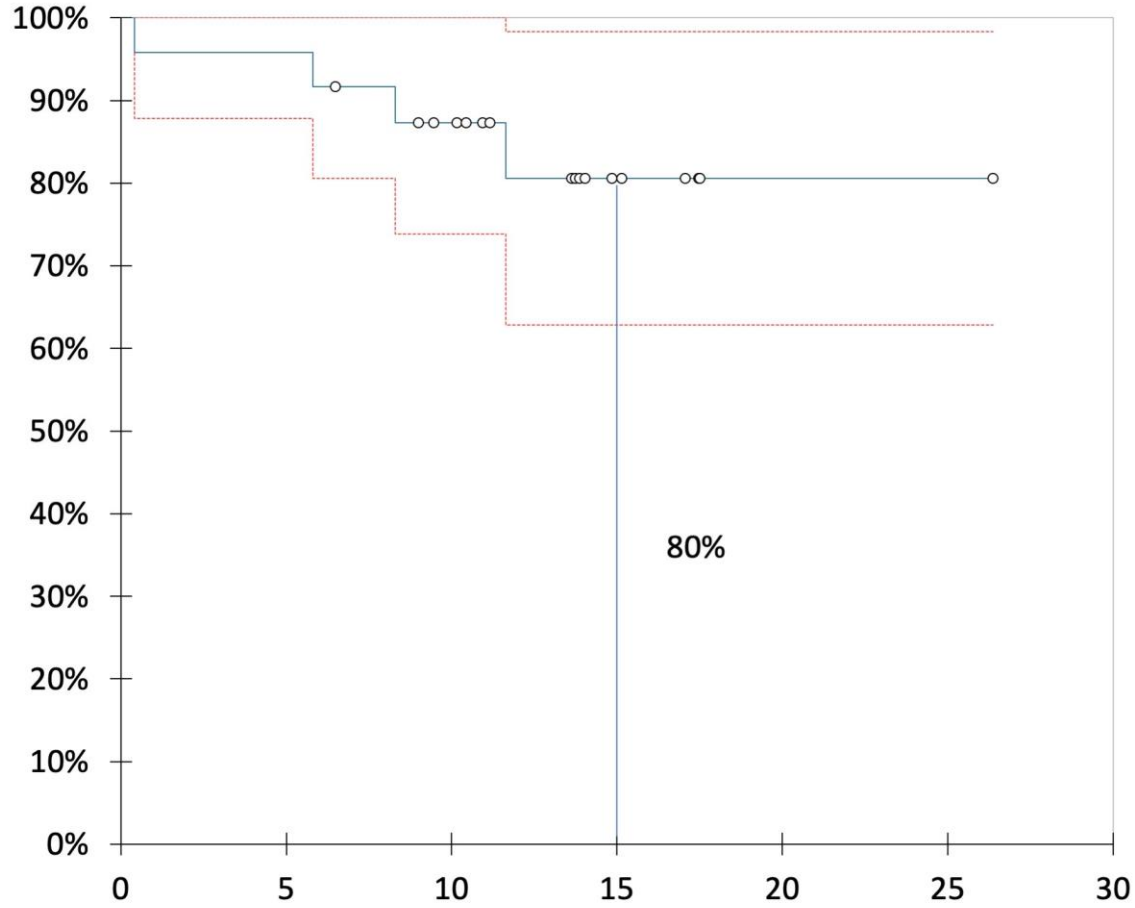

Figure 15: Survival curve female less than 30 years.

The survival curve for the female group aged more than 30 years (13 THR/ 41 hips) estimated a survival time of 16.923 years with a standard deviation of 1.357, a lower bound of 4.263 and an upper bound of 19.584. Survival at 5 years was 80.4%, at 10 years 75.1% and at 15 years 64.4%. The curve seems to have subsequently stabilised, but this is still open to interpretation (Figure 16).

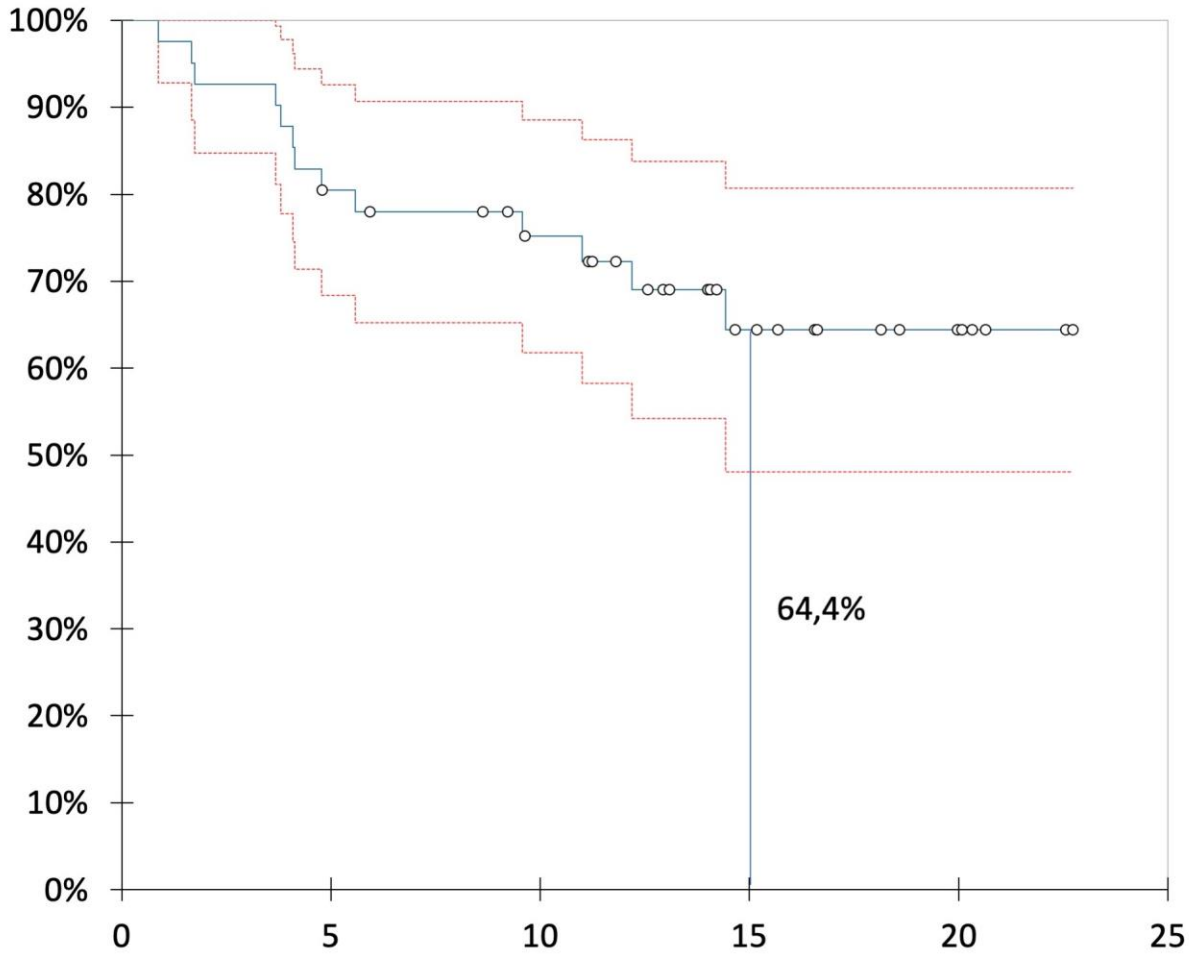

Figure 16: Survival curve female more than 30 years.

A comparison of the curves of the two female groups according to age, analysed by Log-Rank test, showed a P-value of: 0.1502 (weak evidence against the null hypothesis) and a chi-squared (X^2) test statistic of: 2.9693. (Figure 17)

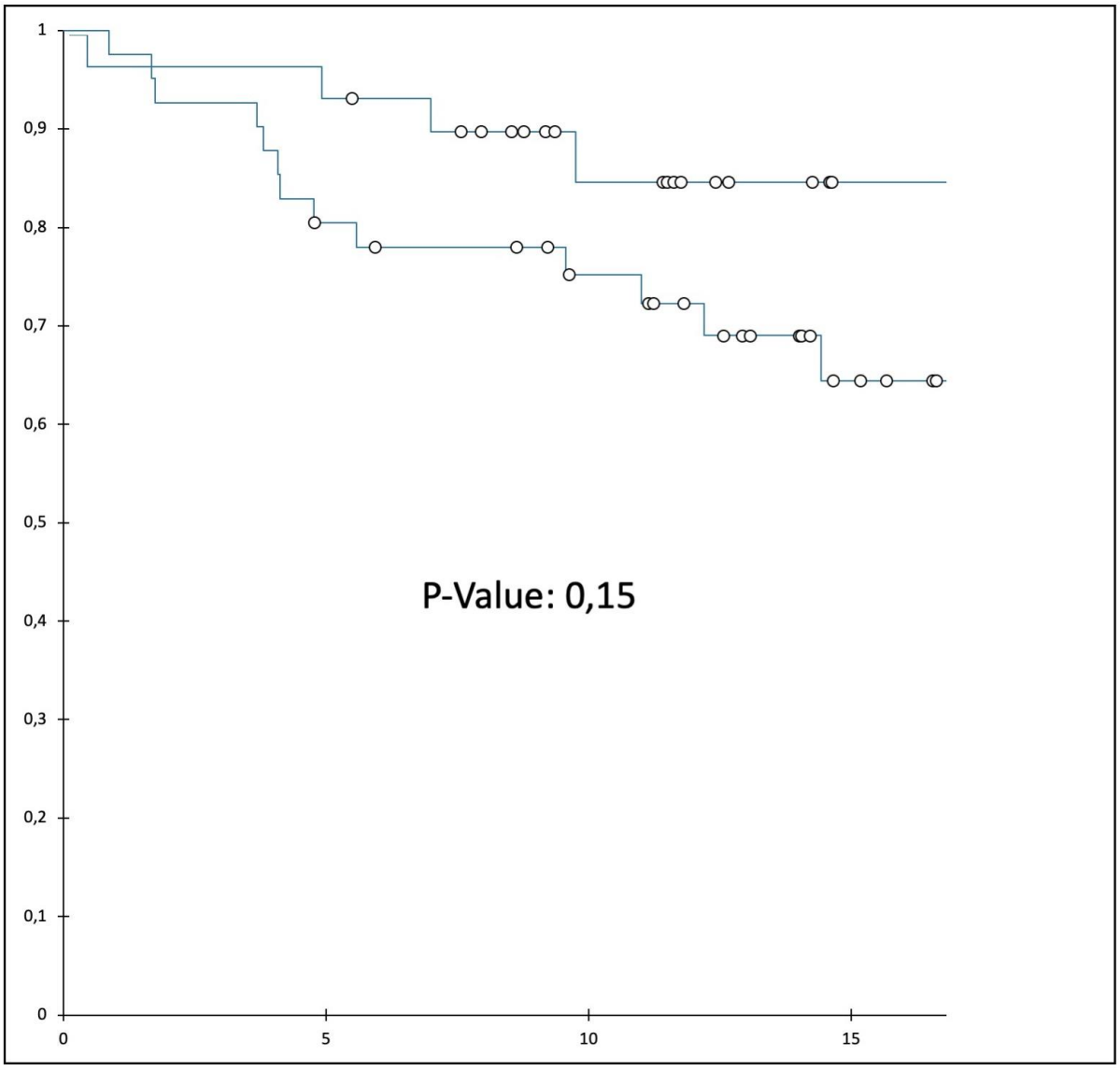

Figure 17: Log-Rank test female less and more than 30 years.

Table 1

Shelf acetabuloplasty	Nb Hips	Nb PTH	5 years	10 years	15 years
Global	95	21	90%	83,5%	77%
< 30 old	43	6	**95,3%**	88,8%	84,8%
> 30 old	50	15	84%	74,4%	69%
Female	66	18	86,3%	76,4%	68,9%
Male	27	3	96	**92,1**	**92,1**
Female < 30 old	24	4%	91,1%	87,3%	80%
Female > 30 old	41	13%	80,4%	75,1%	64,4%

Discussion

Highlights of the study: There was a sufficient number of cases for statistical analysis and cases were followed for a significant amount of time as the patients were young at the time of the procedure. This is the only study that compares significant survival curves according to age and gender.

Weaknesses: Lack of clinical follow-up of a retrospective study spread out over time; Lack of correlation between radiographic analysis and outcomes; No systematic CT scan to analyse labral tears. Early deterioration during the first 5 years leading to THR (90% survival at 5 years) may be due to the wrong surgical indications; more advanced osteoarthritis (stage 3) than estimated, neglect of labral tears which are factors of a poor outcome[14] (Berton[15], 83% survival at 20 years if the labrum is intact, 15% if it is torn). An MR arthrogram (which is reliable for diagnosing labral tears[14]) before deciding on the surgical indication would allow the elimination of patients who are most at risk or to suggest arthroscopy[16-18] before shelf acetabuloplasty to repair the labral tear and revivify the iliac bone after resection of the indirect tendon of the rectus femoris muscle. As the joint capsule is an important interposing element, its resection, which is sometimes suggested, should be avoided during arthroscopy.

There was a difference in the *survival curves according to age*; the younger the patient, the more likely they were to have a good outcome (84.8% survival at 15 years for those under 30 years of age/ 69% for those over 30 years of age, P-value 0.0004). Before the age of 25, none of the patients had had a total hip replacement, with an average follow-up of 14.6 years. These results are reported in other publications[4]. This can be partially explained by the fact that younger patients initially have less advanced osteoarthritis without joint impingement, and cartilage that has been exposed to excessive pressure for less time.

There is moderate evidence against the null hypothesis between the *survival curves according to gender*. Women had a greater risk of deterioration (68.9% survival at 15 years for women / 92.6% for men). The male cohort was too small (29.5%) compared to the female cohort (70.5%) for sufficient power. These results are not reported in the literature and should be confirmed. Hormonal cause?

The complications of shelf acetabuloplasty are all low-grade; partial lysis, pain related to the presence of screws, and with the Smith Petersen approach, 17% paraesthesia of the lateral femoral cutaneous nerve. The long-term results of minimally invasive shelf acetabuloplasty are parallel to or better than those via the extended approach. The postoperative follow-up of minimally invasive approaches is simpler with a short hospitalisation time or ambulatory procedure, no rehabilitation, moderate pain and no scarring or aesthetic effects[16-19].

Not only does periacetabular osteotomy have a more complex postoperative follow-up and lengthy consolidation with no weight bearing, but most of all, there is approximately 12.5% serious complications and 31.6% mild complications[3]. Non-unions of the ilio-pubic and ischio-pubic rami are frequent after PAO[20]. Graft stabilisation: by compression screwing is a proven technique, which ensures better positioning of the graft through intraoperative verification by image intensifier. Titanium screws should be avoided as they are a source of non-union and lysis. The patient should be informed before the procedure that it might be necessary to remove the screw after approximately two years.

The overall survival curve is 77% at 15 years for the minimally invasive approach, and on average for articles with sufficient follow-up is 81.3% (77 to 93%). For the triple periacetabular osteotomy operation, it is on average at 15 years of 72.13% (60 to 85%). These results are superimposable; certain articles quoted correspond to older series, at a time when performing a total hip prosthesis replacement was delayed, their survival being less good than today. Table 2.

Table 2

Author	Procedure	Casuistry Nb of hips	Follow-up Years	5 years	10 years	15 years	20 years
Chiron[13] 2022	Shelf Minimal invasive	95	12,8	90%	83.5%	77%	72%
Migaud[6,7] 2004	Shelf Smith Petersen	65	20			87%	
Fawzy[21] 2005	Shelf Smith Petersen	76	11	97%	75%		
Hamaniski[22] 1992	Shelf Smith Petersen	124	10		71%		
Hirose[5] 2011	Shelf Smith Petersen	28	25	100%		93%	71%
Love[23] 1980	Shelf Smith Petersen	45	10		80%		
Stetzelberger[24] 2021	PAO	115	22				67%
Steppacher[25] 2008	PAO	75	24.5		87%	78%	61%
Lerch[26] 2016	PAO	30	10		85%	60%	30%
Ahmad[27] 2021	PAO	Meta-analysis 2,268	?	96.1%	91.3%	85%	60%
Shelf mean	6 articles	433		188/199 **94.4%**	260/340 **76.4 %**	153/188 **81.3%**	93/123 **76%**
PAO mean	3 articles	220			90/105 **85.7%**	58/18 **72.13%**	140/220 **63.6**

The ideal indication seems to be a young male before the age of 25 years with no joint impingement, but a painful hip with a centred femoral head and a positive Wiberg angle. However, survival remains good in both genders after the age of 30. Shelf acetabuloplasty can ensure several decades before it is time for a total hip replacement. A proportion of patients (77%) will not receive a total hip replacement. However, even in women, the results remain satisfactory overall (survival of 69.8% at 15 years). Patients at risk are women over 30 years of age with stage 2 osteoarthritis (80% survival before 30 years / 64% after 30 years; moderate evidence, P-value 0.15).

Shelf acetabuloplasty does not exclude the placement of a total hip replacement later on under the right conditions[28]. Shelf acetabuloplasty even allows coverage of the prosthetic cup of a hip that was initially dysplastic. The cup should be placed before resecting the bone graft, if necessary, in case of a conflict. The graft can be re-shaped either by an anterior or a posterior approach. Removal of

the screw within two years of shelf acetabuloplasty simplifies any subsequent arthroplasty procedure. Prosthetic replacement after a peri acetabular osteotomy does not consistently give good results for both pain and mobility[29,30].

The main hypothesis is confirmed: he survival for minimally invasive shelf acetabuloplasty in cases of acetabular dysplasia with moderate osteoarthritis (stage 2 and 3 osteoarthritis should be excluded[7]) without joint impingement parallels that of periacetabular osteotomy procedures at the longest follow-up.

The secondary hypothesis is confirmed: the high-grade complication are none with shelf acetabuloplasty and greater than 10% within the framework of peri acetabular osteotomy.

Summary The flow chart (Figure 18) summarises the indications.

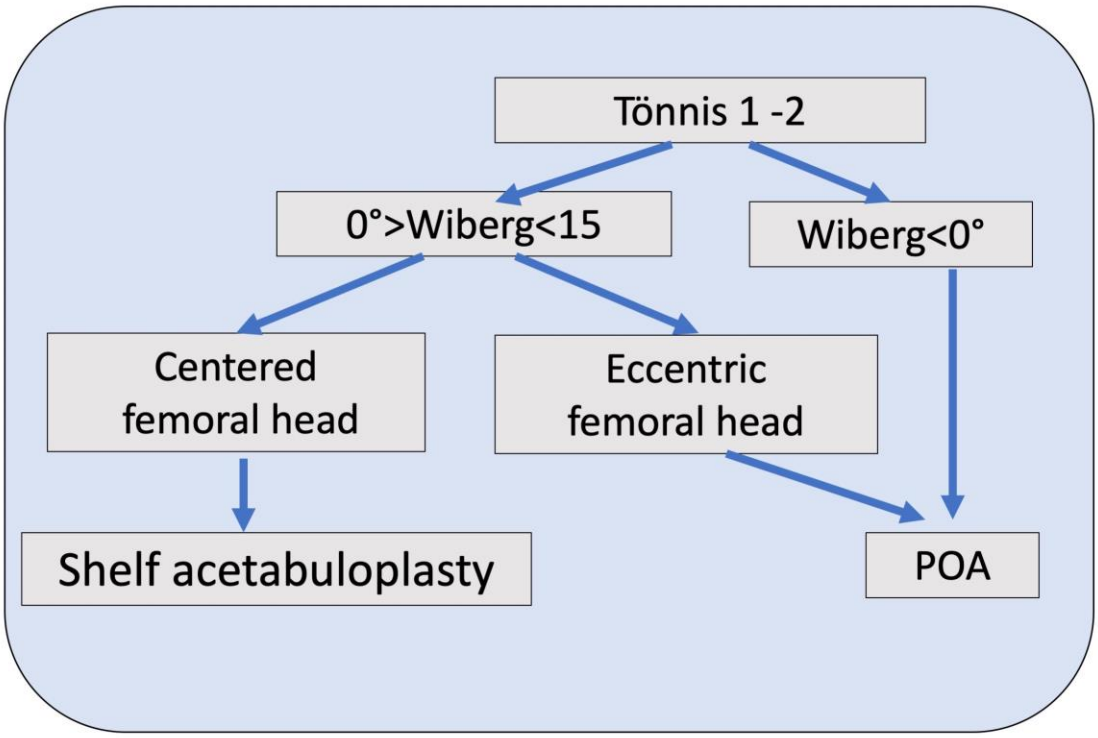

Figure 18: flow chart of indications Self Acetabuloplasty / POA

Conclusion Shelf acetabuloplasty is a simple reliable procedure that can be performed by any orthopaedic surgeon and which allows dysplastic hips with a centred femoral head, no impingement or moderate joint impingement to survive for several decades. The younger the subject, the longer the survival. Survival in male patients is longer than in female patients. However, survival in female patients over 30 years of age remains satisfactory enough for this procedure to be proposed. With identical results, the balance leans in favor of the shelf acetabuloplasty, if we consider the scar ransom, the recovery time, all the zero rate of serious complications and the good results of a hip prosthesis after shelf arthroplasty. Shelf acetabuloplasty should be chosen over periacetabular osteotomy in case of a centred femoral head with moderate osteoarthritis.

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