Use of morselized allografts for acetabular reconstruction during THA revision: French multicenter study of 508 cases with 8 years' average follow-up

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Original article

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Abstract

Background

In the context of acetabular reconstruction, bone defects can be filled with processed or unprocessed bone allografts. Published data are often contradictory on this topic and few studies have been done comparing processed allografts to fresh-frozen ones. This led us to conduct a large study to measure the factors impacting the survival of THA revision: 1) type of allograft and cup, 2) technical factors or patient-related factors.

Hypothesis

Acetabular reconstruction can be performed equally well with frozen or processed morselized allografts.

Materials and methods

This retrospective, multicenter study of acetabular reconstruction included 508 cases with a minimum follow-up of 5 years. The follow-up for the frozen grafts was shorter (7.86 years ± 1.89 [5–12.32]) than that of the processed grafts (8.22 years ± 1.77 [5.05–15.48]) (p=0.029). However, the patients were younger at the time of the primary THA procedure in the frozen allograft group (51.5 years ± 14.2 [17–80]) than in the processed group (57.5 years ± 13.0 [12–94]) (p<0.001) and were also younger at the time of THA revision (67.8 years ± 12.2 [36.9–89.3] versus 70 years ± 11.7 [25–94.5])(p=0.041).

Results

There were more complications overall in the frozen allograft group (46/242=19.0%) than the processed allograft group (35/256=13.2%) (p=0.044) with more instances of loosening in the frozen group (20/242 (8.2%)) than in the processed group (6/266 (3.3%))(p=0.001). Conversely, the dislocation rate (16/242=6.6% vs 17/266=6.4%) (p=0.844) and infection rate (18/242=7.4% vs 15/266=5.7%) (p=0.264) did not differ between groups. The subgroup analysis reveal a correlation between the occurrence of a complication and higher body mass index (BMI) (p=0.037) with a higher overall risk of complications in patients with a BMI above 30 or under 20 (p=0.006) and a relative risk of 1.95 (95% CI: 1.26–2.93). Being overweight was associated with a higher risk of dislocation (relative risk of 2.46; 95% CI: 1.23–4.70) (p=0.007). Loosening was more likely to occur in younger patients at the time of the procedure (relative risk of 2.77; 95% CI: 1.52–6.51) (p=0.040) before 60 years during the revision. Lastly, patients who were less active preoperatively based on the Devane scale had an increased risk of dislocation (relative risk of 2.51; 95% CI: 1.26–8.26) (p=0.022).

Discussion

Our hypothesis was not confirmed. The groups were not comparable initially, which may explain the differences found since the larger number of loosening cases in the frozen allograft group can be attributed to group heterogeneity. Nevertheless, morselized allografts appear to be suitable for acetabular bone defect reconstruction. A randomized study would be needed to determine whether frozen or processed allografts are superior.

Level of evidence: III, comparative retrospective study

Keywords: allograft, THA revision, bone reconstruction, bone loss, acetabular revision, bone defect

1. Introduction

During revision of total hip arthroplasty (THA), there are two concerns on the acetabular side: how to reconstruct the bone defect and how to stabilize the new cup [1]. The bone defect can be filled with bone graft material (autograft, processed or unprocessed allograft) or by massive structural bone allografts [1–5]. When performing reconstruction with bone allografts, the cup can be secured by directly cementing it to the bone graft or through an acetabular reinforcement device (mesh, cross, ring) or by using an impacted or screwed cup. The results of these different techniques are contradictory in the literature because of small study samples and variable follow-up [6–9]. The type of graft selected often depends on its availability and the practices of the hospital. For those who prefer processed grafts, the logistics are easier, and the theoretical risk of infection is minimized. For those who prefer fresh-frozen grafts, the biocompatibility and mechanical properties are better, without irradiation or chemical processing [10].

Published data are often contradictory on this topic and few studies have been done comparing processed allografts to fresh-frozen ones. This led us to conduct a large study to measure the factors impacting the survival of THA revision: 1) type of allograft and cup, 2) technical factors or patient-related factors. We hypothesized that acetabular reconstruction can be performed equally well with frozen or processed morselized allografts.

2. Patients and methods

2.1 Patients

This multicenter study captures the practices in France during the 2000 decade for THA revision and acetabular reconstruction. Two cohorts were compared: one receiving fresh-frozen allografts (Frozen group) and the other receiving processed allografts (Processed group). The initial population came from 11 hospitals between January 2004 and December 2009. It included 619 cases of acetabular reconstruction, of which 508 had a minimum follow-up of 5 years; the other 111 patients (18%) were lost to follow-up (Figure 1).

The cohort evaluated consisted of 508 revisions in 504 patients of which 305 were women (59.8%) and 203 were men (40.2%), with a mean age of 68.92 ± 11.98 years [25–94] at the time of THA revision surgery and a preoperative body mass index (BMI) of 25.88 ± 4.15 [15.05–43.72]. The indication for THA revision was loosening in 425 cases (83.7%), infection in 23 cases (4.5%), dislocation in 27 cases (5.3%) and other reasons in 33 cases (6.5%). The preoperative Charnley [11] score was 43.1% type A (219 patients), 41.5% type B (211 patients), 14.6% type C (74 patients), and no data in 0.8% (4 patients). The preoperative activity level according to Devane et al. [12] was 5.7% type 1 (29 patients), 42.7% type 2 (217 patients), 17.5% type 3 (89 patients), 7.1% type 4 (36 patients), 6.9% type 5 (35 patients), and no data in 20.1% of cases (102 patients). At the last review, 508 revision cases were included; 85 patients had died but the relevant data was available, 313 were reviewed in person and underwent clinical and radiological examinations, 56 responded to a telephone survey and sent in radiographs, while 54 responded to the telephone survey only. All of these patients had a minimum of 5 years' follow-up.

The preoperative and intraoperative data for the two groups are given in Table 1. In terms of age at the time of primary THA surgery, there was a significant difference in the average age of 51.5 ± 14.2 [17–80] for the Frozen group versus 57.5 ± 13.0 [12–94] for the Processed group ($p<0.001$). There was also a significant difference in the average age at the time of THA revision with an age of 67.8 ± 12.2 years [36.9–89.3] in the

Frozen group versus 70.0 ± 11.7 [25–94.5] in the Processed group (p=0.041). We also found significant differences (Table 1) in the gender ratio, with more women in the Processed group, a difference in distribution between hospitals doing the surgery, and more multijoint disease in the Frozen group according to Charnley (Table 1). While the distribution of AAOS stages was different (Table 1), the bone defects were not more severe between groups (Table 1). These elements (age at surgery, sex, number of joints involved, distribution between participating centers) meant the two study populations were not exactly comparable.

2.2 Surgical techniques

The acetabular bone defect was reconstructed with allograft in all cases. All grafts were supplied by tissue banks in accordance with French regulations [13]. In 242 cases (47.6%), the allograft was fresh-frozen at −80°C without chemical processing or irradiation. In 266 cases (52.4%), it was processed and decellularized using a chemical and physical process of virus inactivation allowing it to be stored at room temperature after irradiation. Various types of processing methods were used [13]: Biobank™ (Presles en Brie, France) in 4 cases (1.5%), Osteopure™ (Clermont Ferrand, France) in 195 cases (73.3%), TBF™ (Mions, France) in 63 cases (including one case combined with Osteopure) (23.7%) and another method in 5 cases (1.9%). The cup used had a metal-back shell in 54 cases (10.6%), was cemented directly to the graft in 21 cases (4.1%) and was cemented to an acetabular reinforcement device in 433 cases (85.2%); there was no difference between groups regarding cup fixation (Table 1). The femoral stem was revised in 277 cases (54.5%) and there was a significant difference between the two groups (153/242 Frozen (63%) versus 124/266 (46%) Processed (p<0.001)).

2.3 Assessment methods

Clinically, at the last follow-up visit, the patients were evaluated using the Charnley score [11] for comorbidities, Devane score [12] for activity, and the Merle d'Aubigné (PMA) [14] for pain, walking and mobility.

Radiologically, the bone defects were evaluated on x-rays using the AAOS classification [15] and located using the zones defined by Delee and Charnley [16]. Postoperatively, we looked for radiolucent lines between the host bone and graft, and between the graft and implant; cup migration was measured using the technique described by Nunn et al. [17], and the change in the grafts' radiological appearance was determined based on Conn's criteria [18]. The failures were recorded as infection, dislocation or acetabular loosening (revision or radiological failure: more than 5 mm migration, progressive radiolucent line larger than 2 mm, implant breakage).

2.4 Statistics

The statistical analysis was performed with SAS software, version 9.3 (SAS Institute Inc., Cary, NC, USA). The qualitative data were summarized by counts and percentages, while numeric data were summarized by their mean, standard deviation, median and interquartile range values. While the mortality rate was very high, we retained only the cases with information available in the analysis. We used the cumulative incidence method to take into account mortality as a latent event. This method weighs the mortality over time. This model summarizes survival data in the presence of competitive risks. For survival, three events were analyzed: all-cause revision, revision for acetabular loosening, and revision for acetabular loosening and radiographic failure. The Gray test was used to compare survival between groups and a Cox model was used to determine whether there were any links between various patient-related and technique-related factors and the failures. The type I risk was set at 5%.

3. Results

While the groups were not comparable, and the age difference may be a risk factor for complications, we compared various outcomes for the Frozen and Processed groups.

3.1 Clinical

The mean follow-up was 8.05 ± 1.84 years [5.0–15.5]. There was a significant difference in the length of follow-up with the Frozen group having an average of 7.86 years ± 1.89 [5.00–12.32] and the Processed group having an average of 8.22 years ± 1.77 [5.05–15.48] (p=0.029); however, this difference was not relevant clinically. Preoperatively, the PMA score was not different between the Frozen group (7.7 ± 4.3) and the Processed group (8.1 ± 6.7) (p=0.397). However, at the last follow-up, there was a significant difference between the Frozen group (10.3 ± 5.3) and the Processed group (11.8 ± 6.9) (p=0.008).

3.2 Radiological

Complete radiological records were available in 423 cases at the longest follow-up. Radiolucent lines were found in 36 cases (8.5%) between the graft and host bone and in 42 cases (9.9%) between the graft and implant. At the graft/host bone junction, a radiolucent line was found in 19 patients in the Frozen group (8 in zone 1, 6 in zone 2 and 13 in zone 3) and in 17 patients in the Processed group (8 in zone 1, 11 in zone 2, 10 in zone 3) (some patients had multiple zones affected). For the graft/implant junction, a radiolucent line was found in 17 patients in the Frozen group (9 in zone 1, 10 in zone 2, 14 in zone 3) and in 24 patients in the Processed group (10 in zone 1, 13 in zone 2 and 16 in zone 3). There was no difference between the two groups (Table 2).

3.3 Complications and failures

The findings related to complications are shown in Table 3. Overall, there were more complications in the Frozen group (20/242 (8.2%)) than in the Processed group (6/266 (3.3%)) (p=0.044) (Figure 2) with a relative risk (RR) of 1.44 (95% CI: 1.02–2.27). There were more instances of loosening in the Frozen group than in the Processed group with a RR of 3.66 (95% CI: 1.56–8.79) (p=0.001) (Figure 3). However, neither the number of dislocations (p=0,844) or infections (p=0,264) (Figures 4, [4A, 4B]) nor the time to development of these complications differed between these two groups (Table 3). The type of graft processing had no effect on the occurrence of complications (p=0.113) with 1 complication in the 4 cases using Biobank™ (or 25% for this type of graft), 19 complications in the 195 cases using Osteopure™ (9.7%), 13 complications in the 63 cases using TBF™ (20.6%) and 2 complications in the 5 cases (40.0%) with another treatment method. The cup fixation method had no effect on the occurrence of complications (p=0.287) with 8 complications in the 54 cases with a metal-back shell (14.8%), 6 complications in the 21 cases with a cup cemented directly to the graft (28.6%) and 67 complications in the 433 cases with the cup cemented to an acetabular reinforcement device (15.5%).

3.4 Sub-group analysis and potential risk factors

The subgroup analysis revealed that overall, complications were not related to the patients' age at the time of the procedure with a hazard ratio (HR) of 0.99 (95% CI: 0.97–1.00) (p=0.110). Conversely, there was a correlation between the occurrence of complications and a higher BMI, with an HR of 1.06 (95% CI: 1.00–1.11) (p=0.037). When the BMI values were broken down into 5-point brackets, the overall risk of complications was higher in patients with a BMI over 30 or under 20 (Figure 5) with a RR of 1.95 (95% CI: 1.26–2.93) ($p=0.006$). The fixation method had no significant effect on the occurrence of complications; however there was a trend towards more complications when the patient had a cup cemented directly to the bone with a RR of 1.86 (95% CI: 0.94–3.6) ($p=0.13$). The AAOS bone defect grade had no effect on the occurrence of complications ($p=0.164$) or the occurrence of loosening ($p=0.14$).

As for loosening, it was more frequent in younger patients at the time of the procedure, with an HR of 0.97 (95% CI: 0.94–0.99) ($p=0.040$). The relative risk of experiencing loosening before 60 years of age was 2.77 (95% CI: 1.52–6.51) ($p<0.001$) relative to being 60 years of age or older at the time of revision. The BMI had no effect, with an HR of 1.05 (95% CI: 0.96–1.15) ($p=0.251$).

As for the risk of infection, there was no significant difference based on age, with an HR of 0.99 (95% CI: 0.96–1.01) ($p=0.229$); however, the infection risk was higher when the BMI was higher with an HR of 1.10 (95% CI: 1.02–1.19) ($p= 0.013$). There was a RR of 1.48 (95% CI: 0.69–3.12) when the BMI was under 20 or over 30, but not a significant one ($p=0.148$).

As for the dislocation risk, there was no significant difference based on patient age with an HR of 0.99 (95% CI: 0.97–1.02) ($p=0.865$) or based on patient BMI with an HR of 1.06 (95% CI: 0.99–1.15) ($p=0.101$). However, dividing the patients into 5-point BMI groups identified a higher risk when the BMI was less than 20 or more than 30 with a RR of 2.46 (95% CI: 1.23–4.70) ($p=0.007$) (Figure 6). Lastly, the patients who were less active on the Devane scale [12] preoperatively had an increased risk of dislocation with a RR of 2.51 (95% CI: 1.26–8.26) ($p=0.022$) (Figure 7).

4. Discussion

Study justification

We measured factors that impact THA survival after revision: 1) In terms of the type of allograft, frozen grafts appear to have a higher loosening rate than virus-inactivated grafts, but the fact that the two study populations differed preoperatively makes it impossible to draw any conclusions about this finding. Our hypothesis that acetabular reconstruction could be done equally well with frozen or processed morselized allograft is not verified by this study. 2) Other risk factors identified were that younger patients have a higher risk of loosening, and that the risk of infection and dislocation was higher when the BMI was less than 20 or more than 30, while patients who were not very active preoperatively had a higher risk of dislocation.

Fixation methods and patients

Acetabular fixation methods used in primary THA can also be used in revision THA in patients with AAOS stage 1 or 2 bone defects [19,20,21] (Figure 8). With more severe defects (stage 3, 4), most authors agree that a cup cemented to an acetabular reinforcement device resting on allograft can be used; the literature and our study are similar in this aspect [22–24] (Figure 9). While an autograft is the gold standard from a biological point of view, its use can be limited by the lack of available volume, hence the needed to resort to other types of grafts in some cases.

In our study, we found no significant difference in the fixation method for the revision cup, but it is customary to use a reinforcement ring when a primary cup cannot be used. In our study, less than 5% of cases were done by cementing a cup directly into the bone graft without a reinforcement ring; there was a trend towards more complications, which was not significant likely due to the small sample size.

Technical factors

Allografts can be used for all types of acetabular bone defects, whether structural or combined, at all stages of loosening and no matter the indication for revision (dislocation, loosening or infection) [25]. Morselized grafts can be used to fill defects of any shape, thus provide optimal adaptation to the host bone and implant. The graft size matters, thus it is preferable to use blocks at least 5 mm in size [26]. According to some authors, we should not hesitate to combine morselized allograft with structural allograft [27] when the defect is larger than 2 cm [28] or when it is associated with a structural defect [29]. This element was not analyzed in our study. Similarly, we did not study the distraction used with metal substitutes in case of pelvic discontinuity, even though it is a major risk factor for integration [30].

In the literature, the method used to preserve fresh-frozen or processed grafts does not impact the results of reconstruction, which is confirmed by various authors [31,32] but not confirmed in our study. Nevertheless, our groups were not comparable initially, which may explain the differences found: the higher number of loosening cases in the Frozen group can be explained by the younger age, the uneven distribution in the initial bone defects, the higher number of femoral stem revisions and the fact there were more men in the Frozen group in our study.

Future prospects

To configure the ideal bone graft, we would need a human or synthetic mineral matrix, to control the immune response, to manage the neighboring vascularization, and to include osteogenic cells and growth factors. This is a challenge for tissue engineering as the ideal graft for all situations and patients does not exist, which means the graft needs to be personalized to each situation and patient [33]. By definition, these grafts are inert tissues and optimization of bone reconstruction happens through the possibility of combining element that improve its osteoinductive properties. The ideal way to improve graft integration would be to have a graft that is decellularized without chemical products so as to no alter cell repopulation and without irradiation so as to not alter the mechanical properties. While the combination of mesenchymal cells and allograft seems promising [34], the combination with autograft [35], bone substitutes[36] and osteoinductive factors [37] has not been shown to be effective.

Study limitations

The retrospective nature of this study is a limitation; however, it also allowed us to gather a large number of patients for our analysis. The multicenter nature of the study means that each center may have different techniques; however, the large number of patients and different centers helps to smooth out these differences, even if we found significant differences in the practices between centers. The main limitation of this study was the fact that the two groups were not comparable initially, which certainly impacts our findings. This could be avoided in the future by performing a randomized study. One of the strengths of this study was the similar number of cases receiving a Frozen allograft and Processed allograft. However, this distribution does not reflect the use of morselized allografts in France, as the majority of these morselized grafts are processed, allowing them to be stored at room temperature in the operating suite [13]. This may have impacted our findings, which seem to favor processed grafts, possibly due to patient selection. Despite these limitations, the outcomes in the Frozen group were good, even in the difficult context of THA revision cases with acetabular bone defects.

5. Conclusion

Morselized allografts are suitable for the reconstruction of acetabular bone defects. A randomized study would be needed to determine whether the frozen or processed form is superior. Age and a BMI under 20 or over 30 seem to contribute to poor outcomes.

Conflict of interest: Jacques Caton is a consultant for the TBF tissue bank related to this study and outside this study he is the Associate Editor for International Orthopaedics and SICOT Journal and receives fees from Lépine and royalties from Ceraver and Lépine. Jean Louis Rouvillain has no conflicts of interest related to this study, but outside this study he is a consultant for FH Orthopedics and Science et médecine. Bertrand Boyer has no conflicts of interest related to this study, but outside this study he is a consultant for SERF. Olivier Roche has no conflicts of interest related to this study, but outside this study he is a consultant for SERF, Corin, Zimmer-Biomet. Stéphane Boisgard has no conflicts of interest related to this study, but outside this study he is a consultant for Zimmer-Biomet. The other authors have no conflicts of interest related to this study or outside this study.

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Authors'contribution:

RE : statistical study, writing and correction of the manuscript. PAM, BB, NR, RCR, SM, TS, OR, JC, JLR, GM : conceptualization and data collection. NR and AM: statistical study. SD and SB: statistical study, the concept of the study, data collection, supervising and correction of the paper.

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Figure legends

Figure 1: Flowchart for the study

Figure 2: Survival rate for all types of complications by graft type

Figure 3: Survival rate for loosening by graft type

Figure 4A: Survival rate for infection by graft type

4B: Survival rate for dislocation by graft type

Figure 5: Survival rate for all types of complications by body mass index

Figure 6: Survival rate for dislocation by body mass index

Figure 7: Survival rate for dislocation by activity level as defined by Devane et al. [12].

Figure 8: In AAOS stage 1 and 2 defects: Primary metal-back shell with filling allografts. Preoperative, immediate postoperative and last follow-up (8 years) radiographs

Figure 9: In AAOS stage 3 and 4 defects: Cup cemented in a reinforcement ring supported by allografts. Preoperative, immediate postoperative and last follow-up (6 years) radiographs

Table 1: Preoperative and intraoperative characteristics of the patients.

		Frozen	Processed	P
Number of patients		242	266	
Age at revision		67.76 ± 12.2 [36.9-89.3]	69.98 ± 11.7 [25-94.5]	**0.045**
Weight		70.68 ± 14.6 [37-132]	69.77 ± 13.67 [38-112]	0.364
Height		164.63 ± 9.3 [134-188]	164.24 ± 8.8 [147-187]	0.67
Body Mass Index		26.00 ± 4.3 [16.0-43.7]	25.74 ± 3.9 [15.0-39.4]	0.369
Side	Left	114 (47.1%)	108 (40.6%)	0.154
	Right	128 (52.9%)	158 (59.4%)	
Gender	Female	133 (55.0%)	172 (64.7%)	**0.035**
	Male	109 (45.0%)	94 (35.3%)	
Patient's original center	**Clermont-Ferrand**	8 (3.3%)	93 (35.0%)	**<0.001**
	Fort-de-France	0 (0%)	13 (4.9%)	
	Grenoble	0 (0%)	44 (16.5%)	
	Limoges	52 (21.5%)	0 (0%)	
	Lyon	0 (0%)	26 (9.8%)	
	Montpellier	49 (20.2%)	0 (0%)	
	Paris	74 (30.6%)	0 (0%)	
	Saint-Etienne	0 (0%)	77 (28.9%)	
	Strasbourg	3 (1.2%)	13 (4.9%)	
	Toulouse	56 (23.1%)	0 (0%)	
Initial THA indication	**Osteoarthritis**	133 (55.0%)	162 (60.9%)	0.101
	Rapidly destructive hip arthritis	0 (0%)	1 (0.4%)	
	Dysplasia	35 (14.4%)	39 (14.7%)	
	Fracture	12 (5.0%)	17 (6.4%)	
	Avascular necrosis	13 (5.4%)	8 (3.0%)	
	Sequelae of trauma	13 (5.4%)	16 (6.0%)	
	Hip rheumatoid arthritis	19 (7.9%)	8 (3.0%)	
	Other	9 (3.7%)	15 (5.6%)	
	Missing data	8 (3.3%)	0 (0%)	
Revision THA indication	**Infection**	3 (1.2%)	20 (7.5%)	0.981
	Loosening	228 (94.2%)	194 (72.2%)	
	Dislocation	6 (2.5%)	18 (6.8%)	
	Other	3 (1.2%)	32 (12.0%)	
	Missing data	2 (0.8%)	2 (0 .8%)	
Charnley preoperative [11]	**A**	106 (43.8%)	114 (42.9%)	**<0.001**
	B	81 (33.5%)	130 (48.9%)	
	C	53 (21.9%)	21 (7.9%)	
	Missing data	2 (0.8%)	1 (0.4%)	
Devane preoperative [12]	**1**	21 (8.7%)	8 (3.0%)	0.786
	2	111 (45.9%)	106 (39.8%)	
	3	34 (14.0%)	55 (20.7%)	
	4	12 (5.0%)	24 (9.0%)	
	5	2 (0.8%)	5 (1.9%)	
	Missing data	62 (25.6%)	68 (25.6%)	
AAOS type [15]*	**1**	7 (2.9%)	28 (10.5%)	**<0.001**

	2	101 (41.7%)	74 (27.8%)	
	3	120 (49.6%)	126 (47.4%)	
	4	14 (5.7%)	36 (13.5%)	
	5	0 (0%)	1 (0.4%)	
	Missing data	0 (0%)	1 (0.4%)	
Femoral stem revision	Yes	153 (63.2%)	124 (46.6%)	**<0.001**
	No	89 (36.8%)	141 (53.0%)	
	Missing data	0 (0%)	1 (0.4%)	
Metal-back cup	Yes	26 (10.7%)	28 (10.5%)	0.39
Cemented cup only	Yes	7 (2.9%)	14 (5.2%)	
Cup cemented into ring	Yes	209 (86.4%)	224 (84.2%)	

Bold p values indicate significant differences
THA: total hip arthroplasty
*while the distribution of AAOS stages differs between groups, the bone defects were not more severe (stages 1 and 2 108/242 (44.6%) Frozen versus 102/266 (38.5%) Processed and stages 3 to 5 134/242 (55.4%) Frozen versus 163/266 Processed (55.4%) (p = 0.1).

Table 2: Comparison of postoperative data, bold = significant

		Frozen	Processed	P
Number of patients		242	266	
PMA:	Preoperative	7.7	8.1	0.397
	Postoperative	10.3	11.8	**0.008**
Satisfaction:	Very satisfied	86	116	0.212
	Satisfied	72	77	
	Average	12	13	
	Dissatisfied	0	1	
	Missing data	72	59	

Length difference (mean cm ± standard deviation [min–max])		+0.67 ± 1.14 [−0.8 to +6]	−0.38 ± 4.15 [−5 to +7.5]	**0.002**
X-ray at last follow-up visit	graft/bone radiolucent line	20	17	0.156
	graft/implant radiolucent line	18	24	0.971
Osteointegration criteria [18]*	Stage 0 No bone	2	3	**<0.001**
	Stage 1 Heterogeneous	3	2	
	Stage 2 Homogeneous	11	10	
	Stage 3 Consolidation	30	47	
	Stage 4 Trabecular remodeling	108	42	
	Stage 5 Cortical repair	28	60	
Radiolucent lines	graft/host bone	19	11	0.334
	graft/implant	18	17	
Cup migration	Number	40	12	**<0.001**
	Millimeters (mean cm ± standard deviation [min–max])	7.43 ± 5.36 [1.5 – 21.6]	13.35 ± 12.89 [2.2 – 49.2]	**0.024**

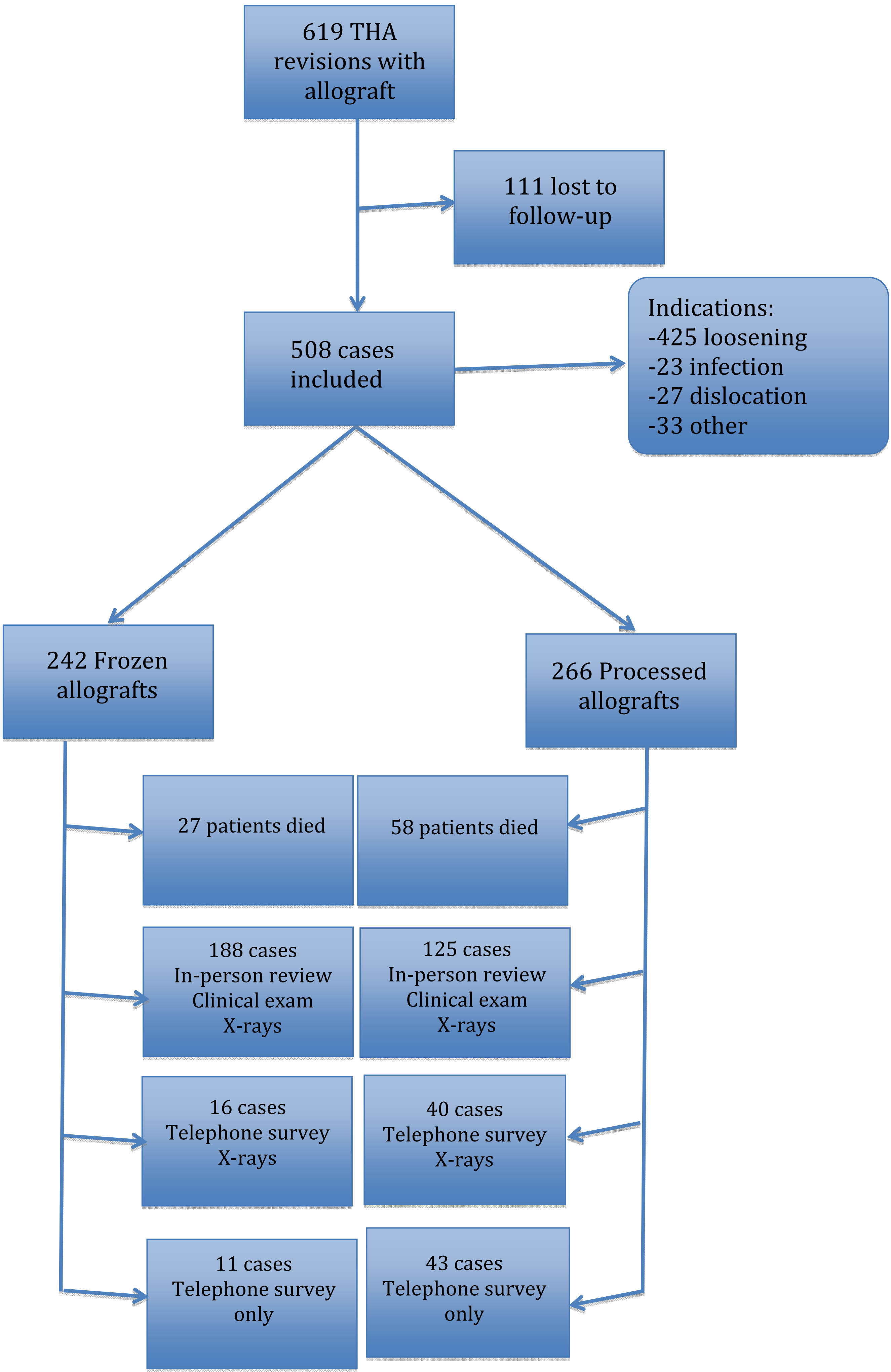
Bold p values indicate significant differences. *The distribution of osteointegration signs differed; however if stages 3 to 5 are pooled, the difference between groups is no longer significant: Frozen 166/182 (91%) versus Processed149/164 (90.8%) (p = 1)

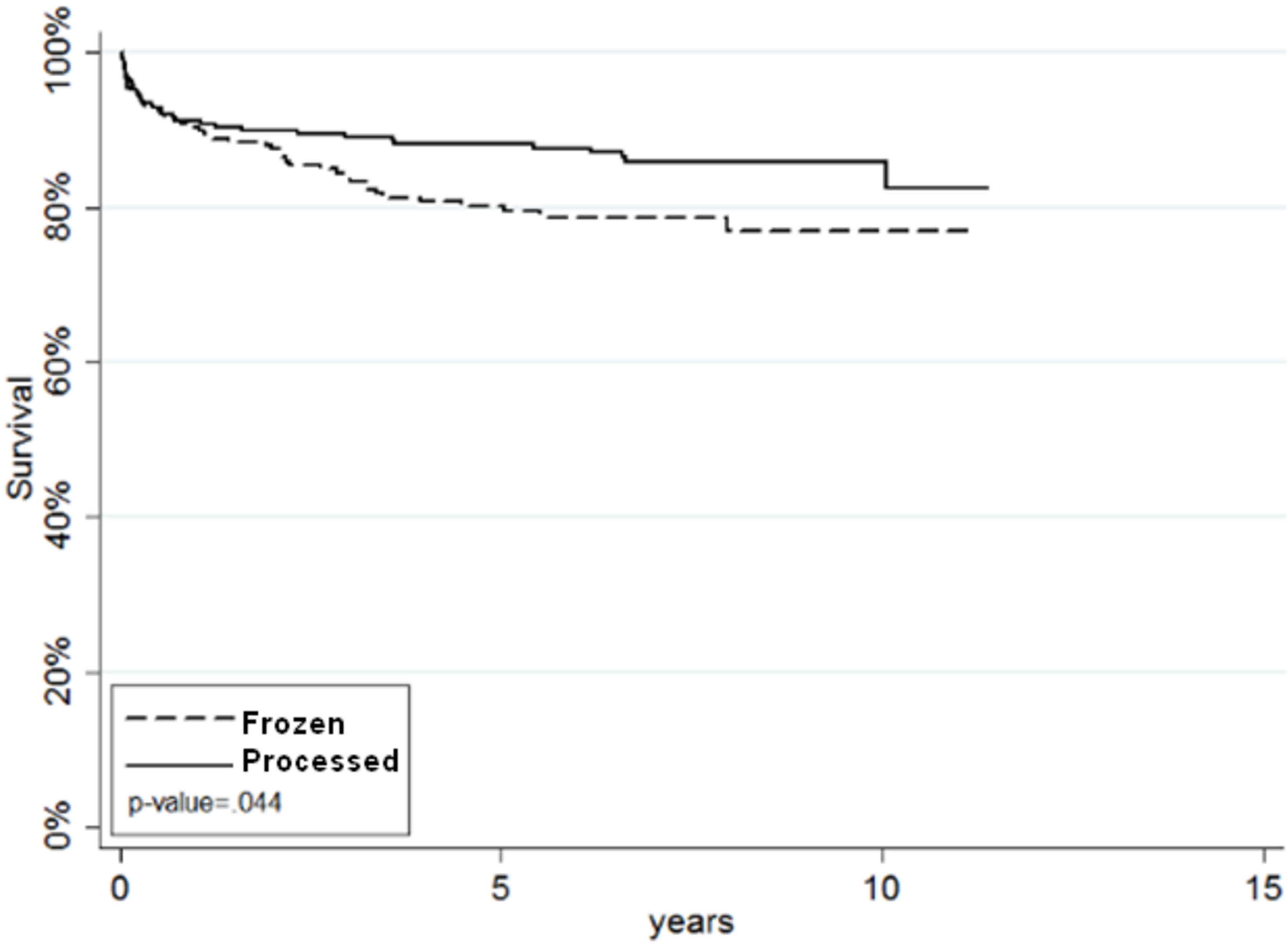
Table 3: Complication by type of graft used.

			Frozen	Processed	P
Total number of patients			242	266	
Complication	Infection	Number	18	15	0.264
		Time	1.74 ± 2.41 [0.03–7.96]	2.02 ± 2.99 [0.02–0.05]	0.770
	Dislocation	Number	16	17	0.844
		Time	1.02 ± 1.15 [0.03–3.36]	0.91 ± 1.71 [0.02–6.64]	0.841
	Acetabular loosening	Number	20	6	**0.001**
		Time	2.05 ± 2.56 [0.23–6.59]	2.24 ± 1.56 [0.31–5.34]	0.823
	TOTAL	Number	46	35	**0.044**

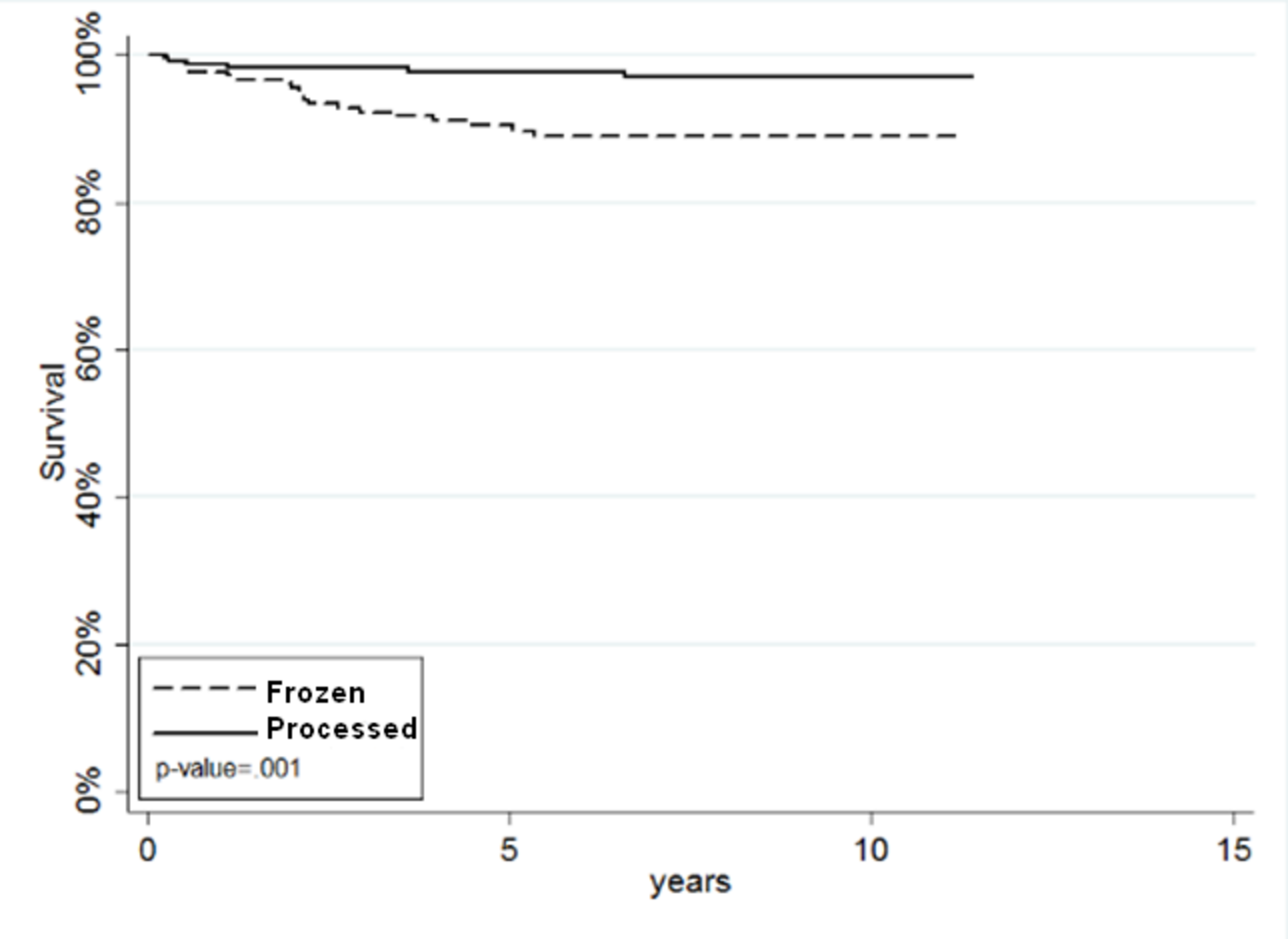
Bold p values indicate a significant difference

Figure 1:

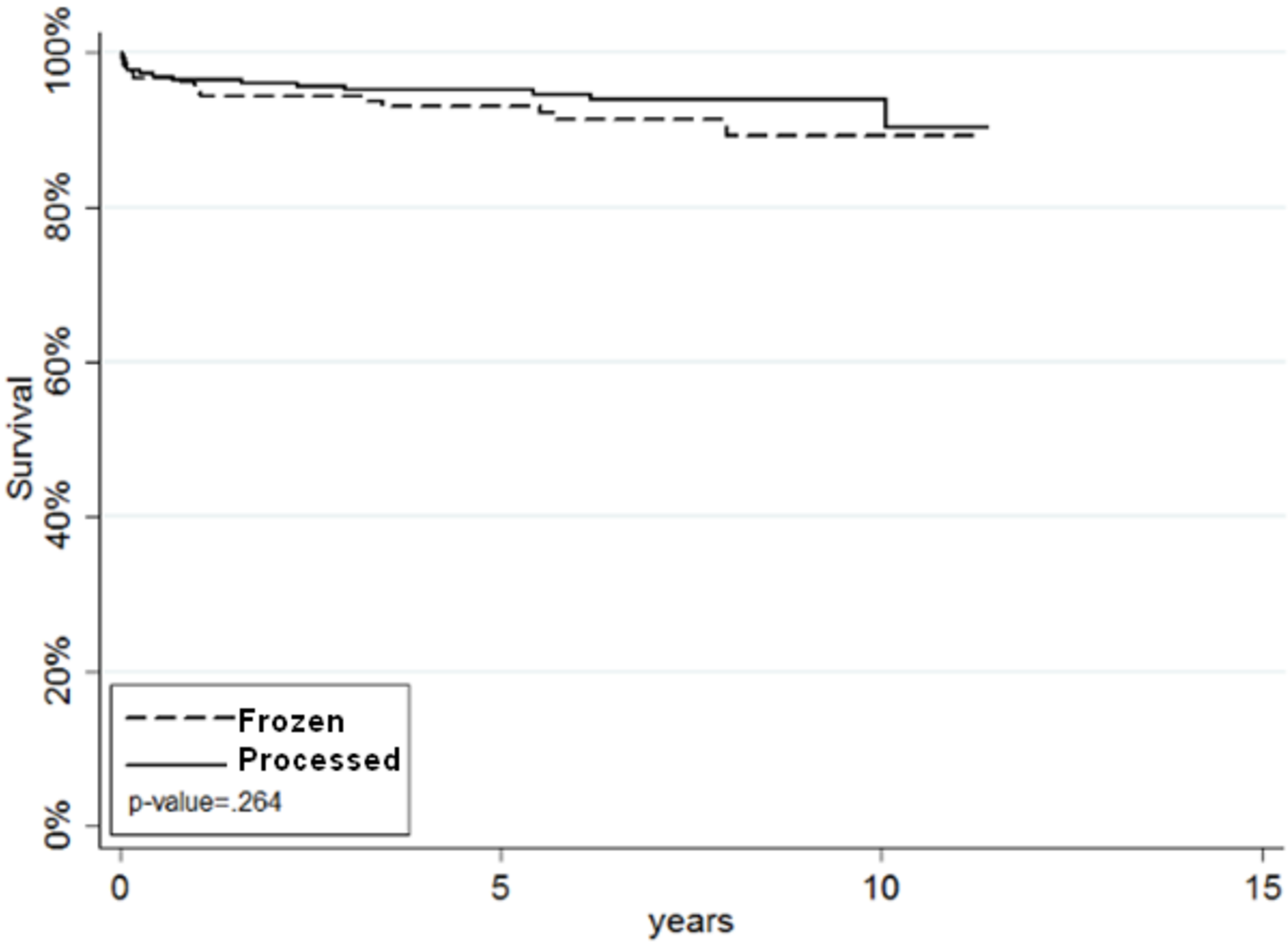

619 THA revisions with allograft
111 lost to follow-up
508 cases included
Indications:
-425 loosening
-23 infection
-27 dislocation
-33 other
242 Frozen allografts
266 Processed allografts
27 patients died
58 patients died
188 cases In-person review Clinical exam X-rays
125 cases In-person review Clinical exam X-rays
16 cases Telephone survey X-rays
40 cases Telephone survey X-rays
11 cases Telephone survey only
43 cases Telephone survey only

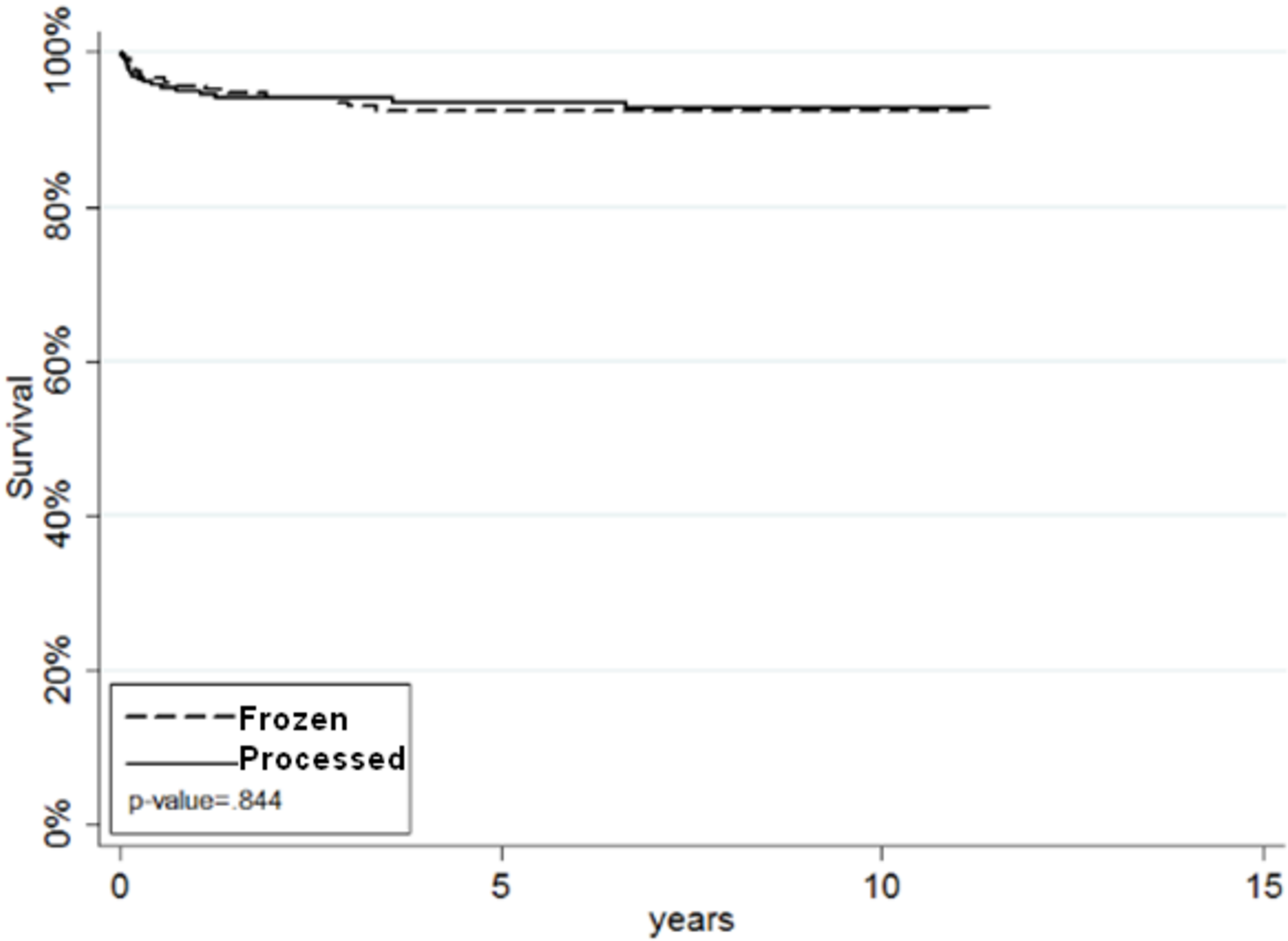


100%
80%
60%
40%
20%
0%
Survival
0
5
10
15
years
Frozen
Processed
p-value=.044

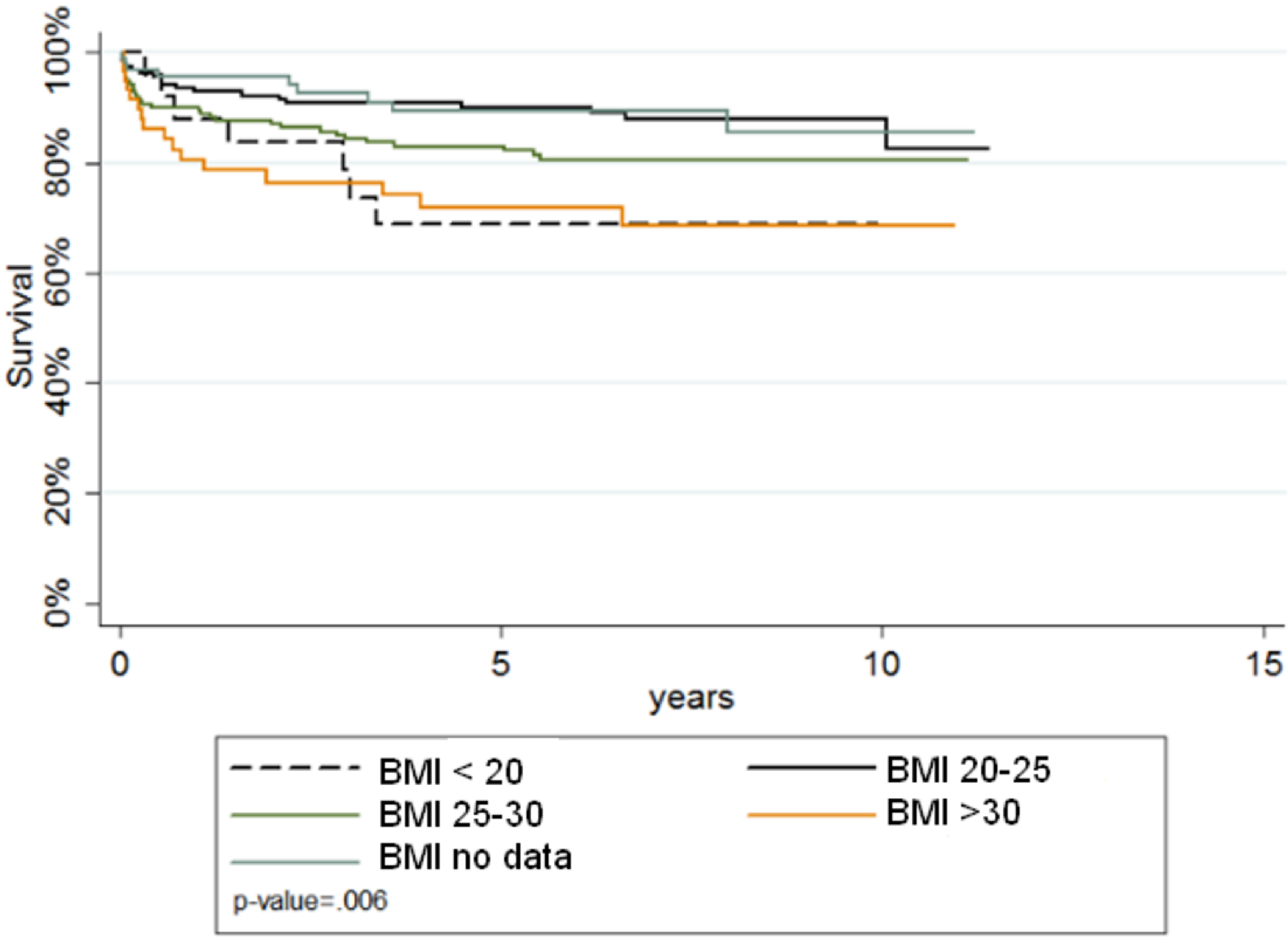


100%
80%
60%
40%
20%
0%
Survival
0
5
10
15
years
Frozen
Processed
p-value=.001

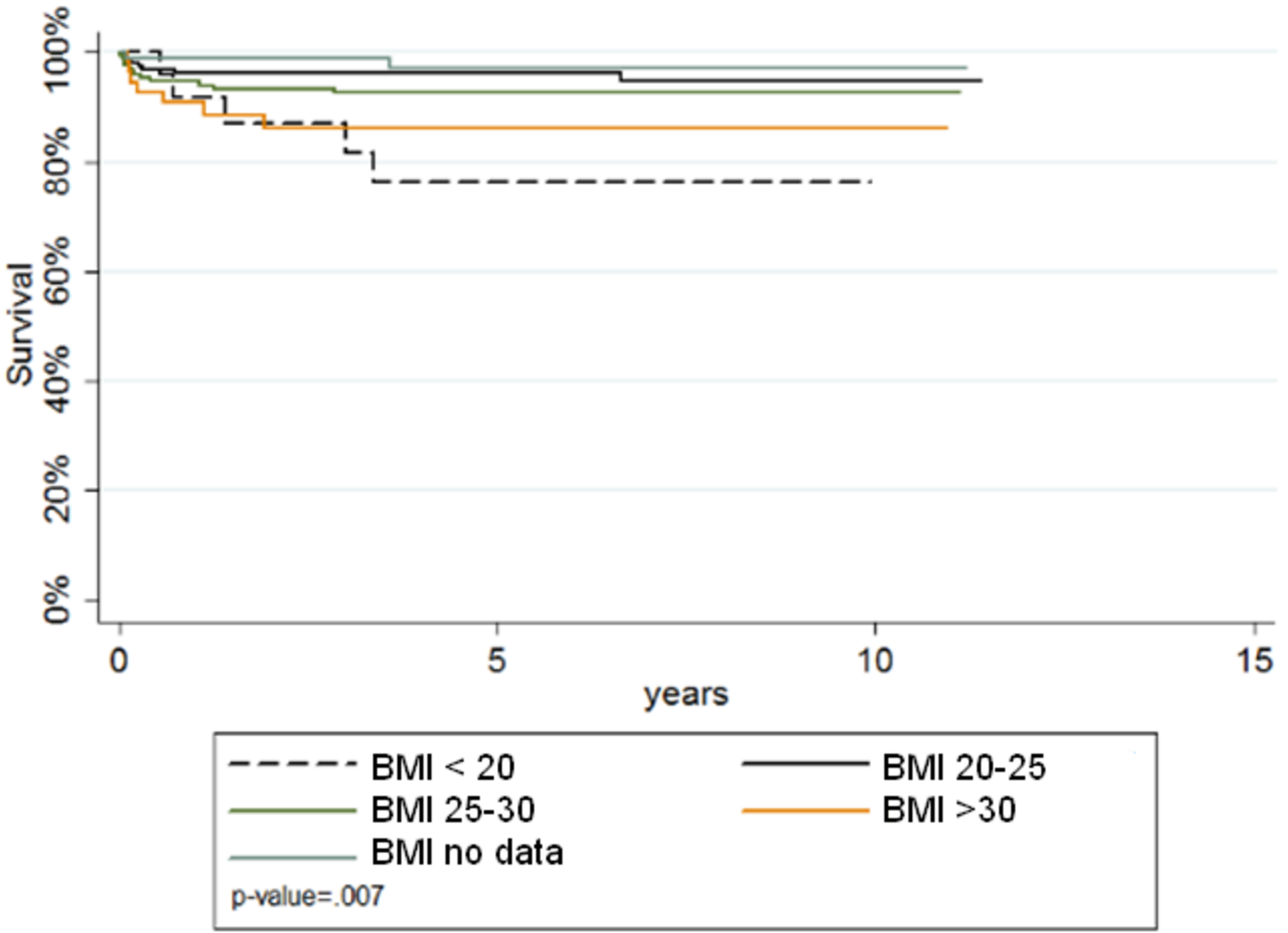

100%
80%
60%
40%
20%
0%
Survival
0
5
10
15
years
Frozen
Processed
p-value=.264



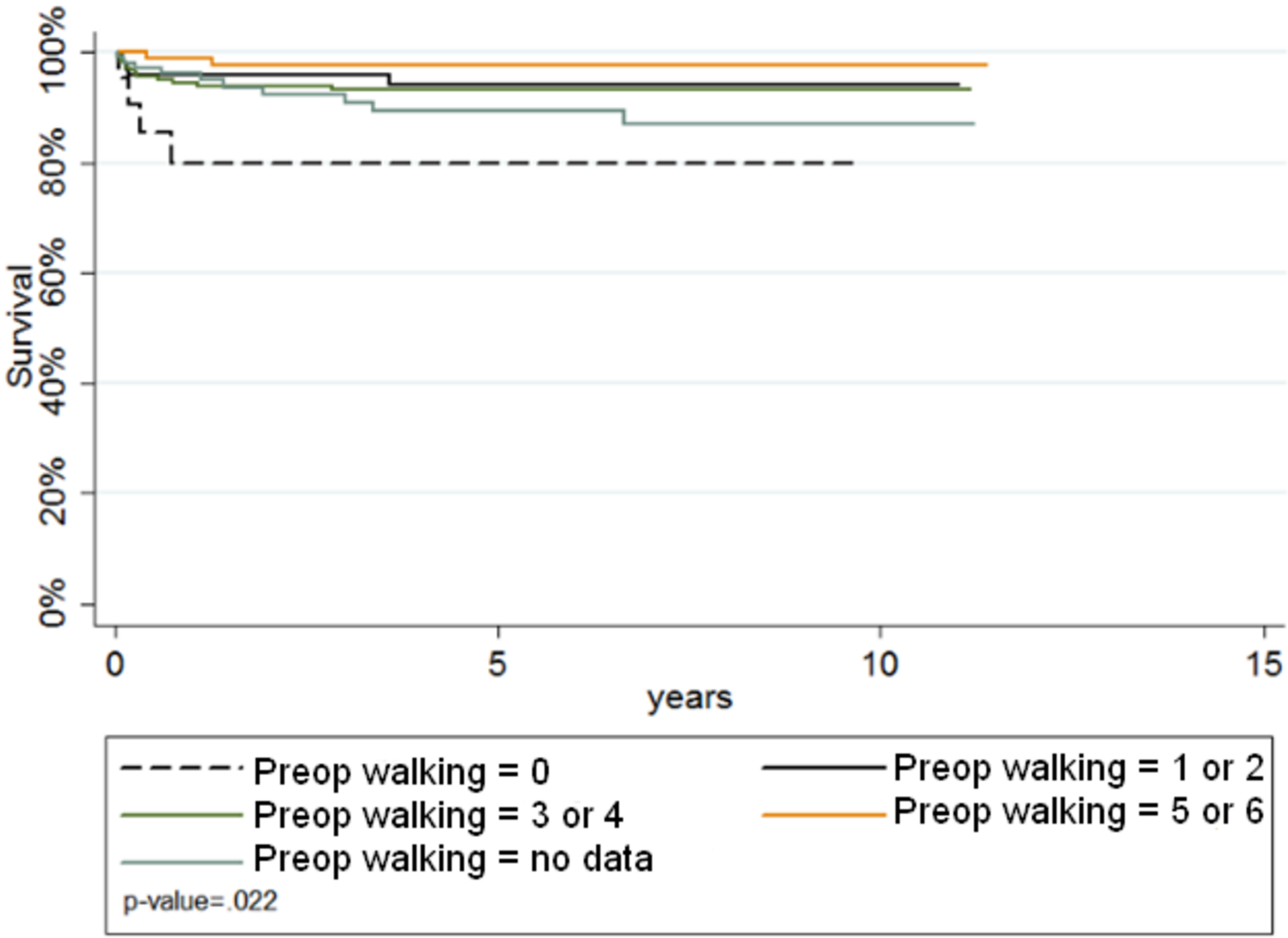
100%
80%
60%
40%
20%
0%
Survival
Frozen
Processed
p-value=.844
0
5
10
15
years



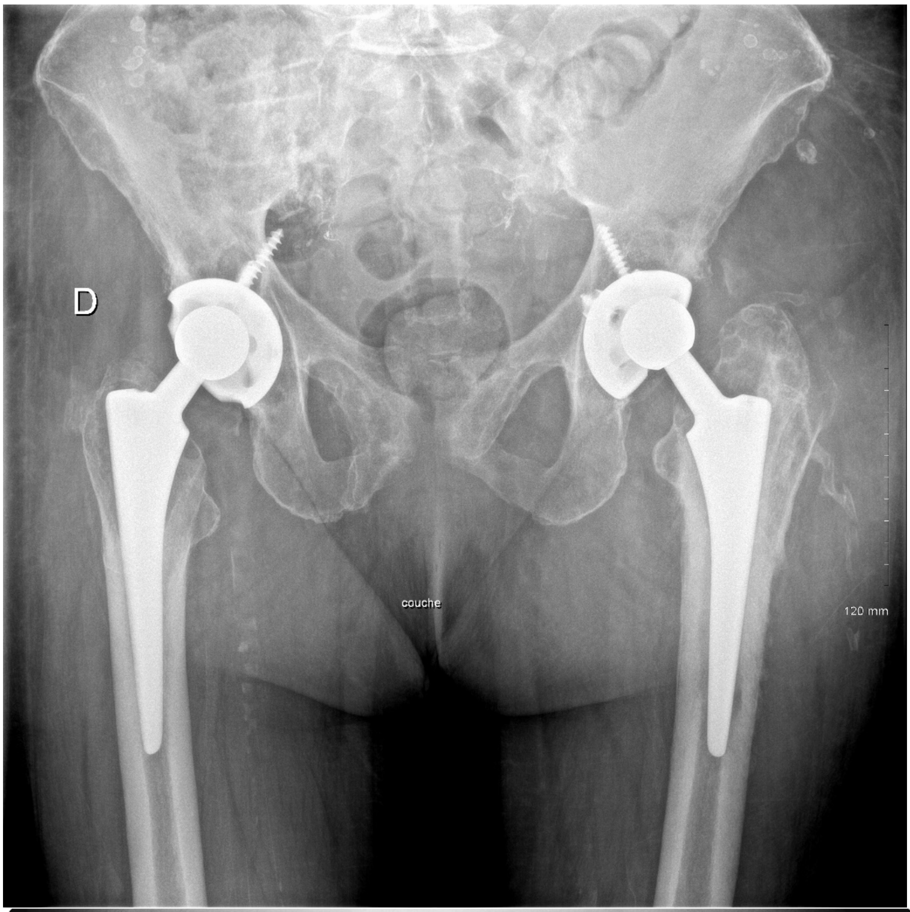
Survival
100%
80%
60%
40%
20%
0%
0
5
10
15
years
BMI < 20
BMI 20-25
BMI 25-30
BMI >30
BMI no data
p-value=.006

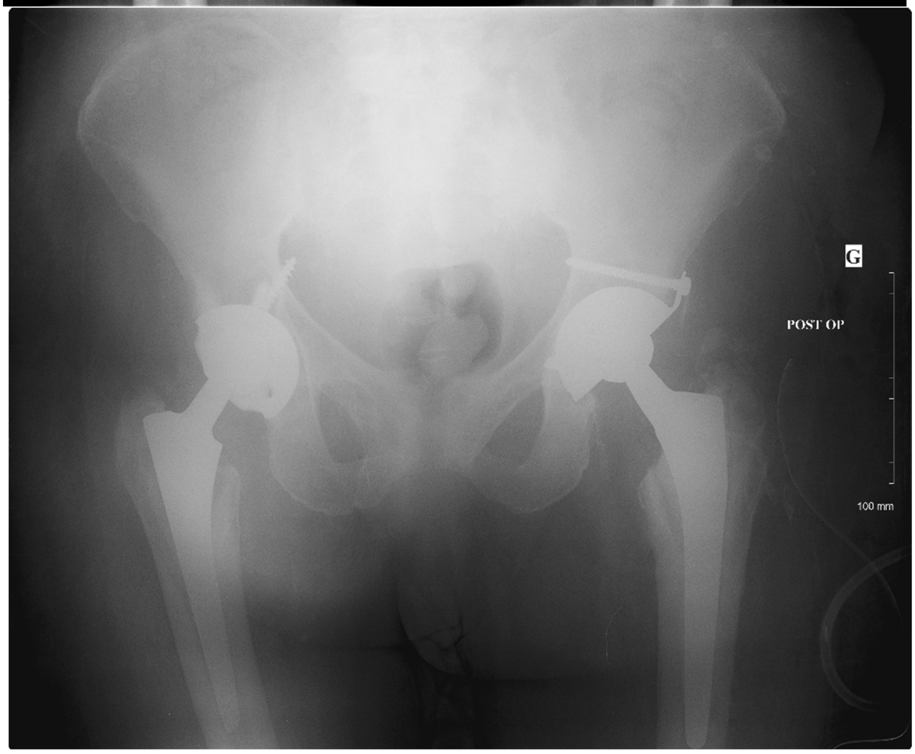


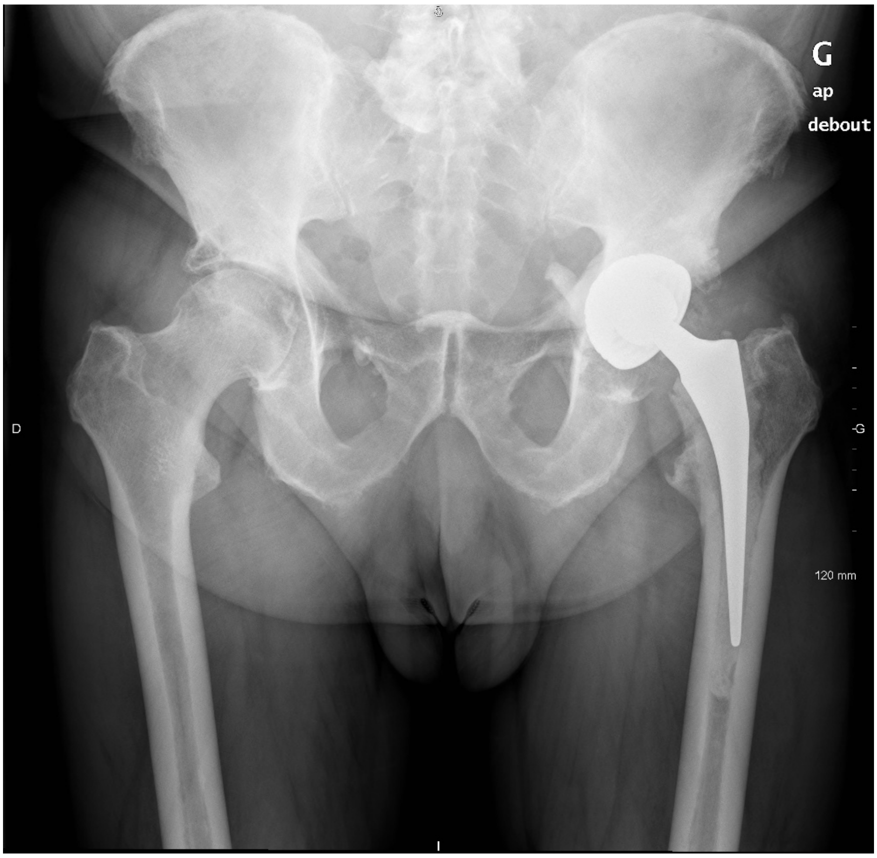
Survival
100%
80%
60%
40%
20%
0%
0
5
10
15
years
BMI < 20
BMI 20-25
BMI 25-30
BMI >30
BMI no data
p-value=.007

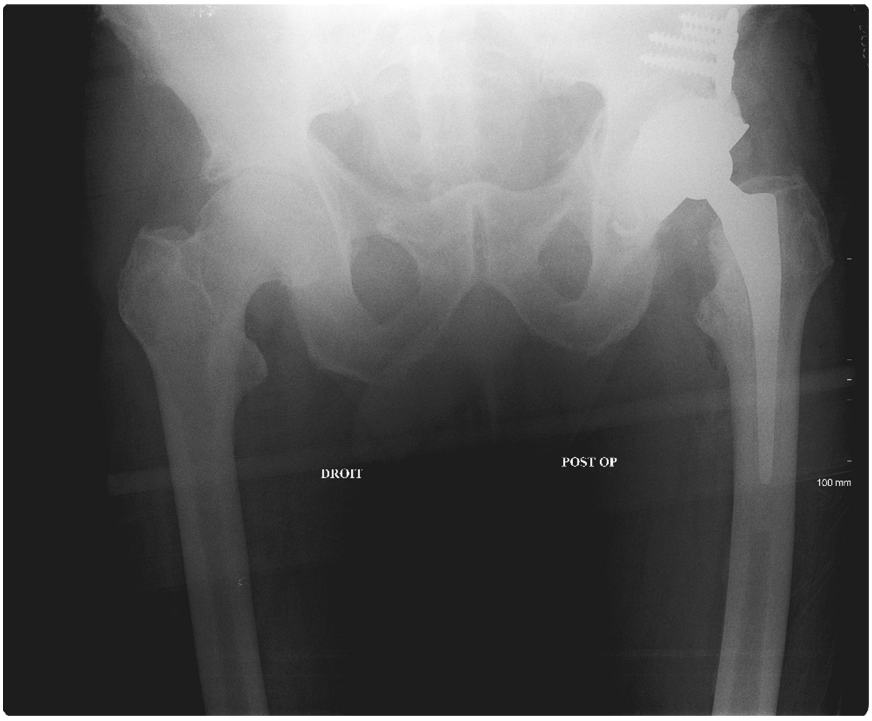


100%
80%
60%
40%
20%
0%
Survival
0
5
10
15
years
Preop walking = 0
Preop walking = 1 or 2
Preop walking = 3 or 4
Preop walking = 5 or 6
Preop walking = no data
p-value=.022


D
couche
120 mm


G
POST OP
100 mm


G
ap
debout
D
G
120 mm


DROIT
POST OP
100 mm