Outcomes of total hip arthroplasty in patients with osteonecrosis of the femoral head—a current review

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Abstract The purpose of this review was to analyze (1) patient-reported outcomes and implant survivorship of osteonecrosis (ON) patients following total hip arthroplasty (THA), (2) if prior hip-preserving procedures influence these outcomes, (3) if resurfacing procedures alter outcomes; and (4) how these outcomes may have been impacted by the choice of different bearing surfaces. Today, with implant innovations such as cementless constructs, ceramic bearing surfaces, and highly cross-linked polyethylene, ON patients derive great benefit and have high survivorship following THA. Most studies have shown that previous hip-preserving procedures do not have a deleterious effect on outcomes. Literature on the use of ceramic and highly cross-linked polyethylene bearing surfaces have shown that these implant designs are useful in younger and more active patients. Future research should evaluate the long-term outcomes and survivorship of these new THA constructs.

Keywords Total hip arthroplasty · Osteonecrosis · Ceramic surfaces · Highly cross-linked polyethylene

Introduction

Patients with osteonecrosis (ON) of the femoral head are subjected to a large number of hip-preserving surgical procedures [1–4]. However, if these procedures fail to prevent the collapse of the femoral head or the acetabulum has degenerative changes, it is common for these patients to need a total hip arthroplasty (THA) [5]. Approximately 5 to 12 % of all hip arthroplasties in the USA are performed for patients with ON [6–8]. These patients have been reported to experience great improvements in functional status and quality of life [5, 8–12]. However, because patients with ON are relatively young in age, implant durability has remained a primary concern [13].

To improve implant function and durability, various arthroplasty constructs have evolved greatly over the past 25 years. Cemented arthroplasties were once the standard of care [10, 14, 15], but more recently, cementless press-fit implants have become increasingly used, regardless of underlying hip condition [6]. In order to ensure that patients with ON have improved function and longevity following THA, it is necessary to determine which implant-related factors, as well as patient characteristics, may lead to optimal outcomes and survivorship. Therefore, the purpose of this review was to analyze (1) patient-reported outcomes and implant survivorship of ON patients following total hip arthroplasty (THA); (2) if prior hip-preserving procedures influenced these outcomes; (3) if resurfacing procedures altered outcomes; and (4) how these outcomes may have been impacted by the choice of different bearing surfaces.

Outcomes and survivorship

Previously, THA patients with ON had inferior outcomes compared to those with primary osteoarthritis (OA), possibly

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due to osteonecrosis-related failure of implant bony on/ingrowth [9, 10, 12, 14–17]. However, with the use of more modern press-fit constructs, outcomes of THA in patients with osteonecrosis have become satisfactory with higher functional outcome scores [9, 12, 18–28] (Table 1), and the all-cause survivorship rates in the reported studies performed since 2008 was equivalent to or greater than 95 % [9, 12, 18–28]. Johansson et al. [12] evaluated the outcomes of osteonecrosis in a systematic literature review ($n=3258$ hips) and showed substantially more revisions for arthroplasties done before 1990 versus after 1990 (17 vs 3 %; respectively; $p<0.0001$).

Some studies have attributed unsatisfactory outcomes to the osteonecrosis etiology or associated risk factors. In the systematic review performed by Johansson et al. [12], they found significantly higher revision rates for those with a history of renal failure and/or transplant (22 %; $p=0.003$), those diagnosed with sickle cell disease (32 %; $p=0.001$), and those with Gaucher's disease (33 %; $p=0.022$), compared to the overall pooled revision rate of 13 % (the majority of these revisions were on initial arthroplasties performed before 1990). Conversely, they found significantly lower revision rates in patients with idiopathic ON (9 %; $p=0.001$), those with a history of heart transplant (0 %; $p=0.023$), and anyone with a diagnosis of systemic lupus erythematosus (4 %; $p=0.002$). The authors concluded that the overall revision rates were similar to the general population.

More recently, ON patients may be experiencing greater benefits from modern THA constructs, which was not described in previous historical studies. However, it is important for the reconstructive surgeon to be aware that the associated conditions with ON may also influence post-THA outcomes and revision rates and to ensure a complete assessment of the patient.

Effect of previous hip-preserving procedures

In ON patients with precollapse disease, hip-preserving procedures are usually advocated to prevent or delay THA, and occasionally, multiple procedures may have been attempted to preserve the femoral head. However, there are concerns that should a THA be required, these procedures may deleteriously affect outcomes following arthroplasty. The following describes the outcomes of THA after prior core decompression, bone grafting, rotational osteotomy, and resurfacings.

Core decompression

Currently, there is a paucity of studies that specifically address the outcomes of THA following a failed core decompression. Issa et al. [29••] assessed the outcomes in patients with ON who had undergone core decompression ($n=19$ hips) versus

Table 1 Literature review of THA outcomes and survivorship in patients with ON

Category	Author, year	No. of hips	Mean follow-up (range), years	Cohort description	All-cause survivorship, %	Mean HHS, points
Age	Kim et al. [27]	64	15.8 (15 to 16.8)	Age<50 years	93.8	93
	Wang et al. [24]	92	6 (5 to 12)	Age>80 years	95	80
Etiology of ON	Chang et al. [26]	74	10.2 (5 to 16.4)	Post-kidney transplant	96.6	89
	Issa et al. [25]	44	7 (4 to 11)	HIV	95	85
		78		Other ON	96.5	87
When surgery performed	Johansson et al. [12]	944	9 (1 to 28)	Surgery before 1990	83	–
		395	6 (1 to 11)	Surgery after 1990	97	–
History of previous hip procedures	Lim et al. [30]	23	4.6 (2 to 10.3)	Previous core decompression	96	92
		13		Previous osteotomy or VBG	100	91
		39		No previous procedures	97	93
	Issa et al. [29••]	19	5.6 (3.7 to 8.9)	Previous core decompression	95	85
		29	6.3 (1.1 to 10.2)	Previous bone grafting	97	86
		9	7.6 (2.8 to 10.2)	Previous hemi-resurfacing	88	84
		35	5.6 (2.8 to 9)	Previous resurfacing	91	84
		121	6.4 (3.2 to 10.3)	No previous procedures	98	87
	Rijnen et al. [31]	17	2 (0.5 to 6)	Previous NVBG	94	91
		16		Previous TRO	88	89
	Berend et al. [32]	89	9 (5 to 15)	Previous VBG	87	78
	Park et al. [34•]	18	4.6 (2.2 to 9.2)	Previous TRO	–	95

HHS Harris Hip Scores, – not reported, ON osteonecrosis, NVBG non-vascularized bone grafting, VBG vascularized bone grafting

patients who had no surgeries prior to THA ($n=121$ hips). After a mean follow-up of 75 months (range, 24 to 125 months), there was no difference in the mean Harris Hip Score (HHS) (85 versus 87 points, respectively; $p=0.87$) or survivorship rates (95 vs 98 %, respectively; $p=0.45$) between both cohorts. Therefore, the authors concluded that undergoing a prior core decompression did not negatively impact those who may eventually require THA.

Similarly, Lim et al. [30] compared outcomes following THA in those who had a previously failed core decompression ($n=23$ hips) to those who had failed more invasive joint-preserving procedures such as vascularized grafting or rotational osteotomy ($n=13$ hips). For the THA, a modular stem implant was used. After a mean follow-up of 55 months (range 24 to 123 months), there was no difference between the cohorts in terms of mean HHS (92 vs 91 points, respectively; $p=0.624$) or implant survivorship (96 vs 100 %, respectively; $p=0.9$). Moreover, when comparing both of these cohorts to a separate group of patients with ON who did not have any previous hip procedures ($n=39$ hips), they found no differences in HHS (92 vs 93 points, respectively; $p=0.7$) or implant survivorship (97 vs 97 %, respectively; $p=0.9$). Therefore, the authors concluded that despite the level of invasiveness and difficulty of different joint-preserving procedures, the mid-term outcomes following THA did not differ significantly.

Based on this evidence, we conclude that failed core decompression does not negatively impact patient outcomes following THA.

Bone grafting (non-vascularized, vascularized)

Many studies have shown that patients with ON can still benefit from a THA despite previous bone grafting. Rijnen et al. [31] evaluated the outcomes of THA in patients approximately 2 years (range, 0.5 to 6 years) after undergoing non-vascularized bone grafting ($n=17$ hips). After a mean follow-up of 4 years (range, 2 to 7 years), the cohort had a mean HHS of 91 points (range, 40 to 100 points), and there was only one revision for aseptic loosening. Thus, the authors concluded that the use of bone impaction grafting does not negatively affect the potential for patients to benefit from a THA.

However, those who have undergone a failed vascularized bone grafting procedure may have slightly worse outcomes following THA. Berend et al. [32] evaluated the outcomes of patients following THA who underwent a failed vascularized fibular graft ($n=89$ hips). After a mean follow-up of 9 years (range, 5 to 15 years), the implant survivorship was 87 % and the mean HHS was approximately 78 points. Although the overall outcomes were positive, the authors concluded that patients should be notified that they may not

achieve outcomes as good as those who did not undergo vascularized bone graft.

In addition to less optimal outcomes, those who have undergone bone grafting may present a more difficult operation for the surgeon performing the THA. Fehrl et al. [33] evaluated patients following cementless THA who had a prior non-vascularized tibial strut grafting ($n=13$ hips). Intra-operatively, these patients had a mean blood loss of 920 cc (range, 300 to 1350 cc) and a mean operative time of 2 h and 50 min (range, 2 to 3 h and 45 min). They believed that the operative time would have been shorter and the blood loss would have been less had they not had a prior hip surgery. Furthermore, because of their prior bone grafting, they noted that a longer time was taken to insert the femoral head in the proper alignment.

In summary, a failed non-vascularized grafting procedure has not shown a negative impact on outcomes following arthroplasty. Furthermore, this procedure may be more challenging and with increased blood loss, which may be attributed to a more meticulous placement of the femoral component (prior grafting) and previous soft tissue damage around the hip. Moreover, although functional outcome scores post-THA in patients who have had failed vascularized bone grafting may be relatively lower, we believe that these patients may still derive great benefit from a THA.

Osteotomy

Although not commonly performed today, there are many patients who may require THA after a previous osteotomy. Park et al. [34•] compared the outcomes following THA between those who underwent a failed transtrochanteric rotational osteotomy (TRO) for ON ($n=18$ hips) and a matched cohort of patients with ON ($n=18$ hips). After a mean follow-up of 55 months (range, 26 to 110 months), they found no difference in HHS (95 vs 95 points, respectively; $p=0.99$) or Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores (28 vs 26 points, respectively; $p=0.47$) between the cohorts. Similarly, the previously mentioned study performed by Rijnen et al. [31] also assessed the outcomes following THA in a cohort of patients that underwent TRO ($n=16$ hips). After a mean follow-up of approximately 6 years (range, 2 to 13 years), their mean HHS was 89 points (range, 53 to 100); however, the authors reported that two patients were revised due to instability. As such, it appears that THA may also still be beneficial in those who have had a failed TRO. In addition, Benke et al. [35] evaluated outcomes following THA in a cohort who underwent a prior upper femoral osteotomy ($n=105$ hips). Intra-operatively, there was a complication rate of 17 %. However, after a 5-year mean follow-up (range, 1 to 14 years), 82 % of patients reported little to no pain. Therefore, THA appears to give great benefit to those who have

underwent a failed osteotomy, although it may present intra-operative challenges as well.

In summary, these studies support the premise that a previous history of head-preserving procedures for early ON is unlikely to have a negative impact on post-operative outcomes following THA. In some cases, the surgery can be more difficult, with increased blood loss and more technical precision required. Despite this, we can conclude that THA may still be beneficial in patients with progressive ON, regardless of previous surgeries.

Effect of prior resurfacing

To our knowledge, there are two studies that have analyzed the outcomes of THA in patients who underwent a failed resurfacing arthroplasty for osteonecrosis. In the study by Issa et al. [29•], the authors assessed the post-THA outcomes of ON patients who underwent resurfacing ($n=35$ hips) or hemi-resurfacing ($n=9$ hips) and compared their outcomes to a cohort of ON patients with no previous head-preserving surgeries ($n=121$ hips). After a mean follow-up of 75 months (range, 24 to 125 months), those in the hemi-resurfacing cohort had a mean HHS of 84 points (range, 65 to 100 points) while those in the resurfacing cohort had a mean HHS of 85 points (range, 71 to 100 points). The cohort with no prior surgery had a mean HHS of 87 points (range, 70 to 100 points), but there were no significant differences between these cohorts ($p>0.05$). The authors also reported no differences in survivorship rates between the cohorts (91 vs 88 vs 98 %, respectively; $p>0.05$).

In summary, conversion to a THA from a hip resurfacing has not shown a negative impact on outcomes compared to those who have not have prior hip procedures.

Role of different bearing surfaces

As patients who have ON often undergo THA at a much younger age than osteoarthritic patients [5, 36], they are more likely to encounter implant wear during their lifetime. Therefore, it is particularly important to evaluate the outcomes of different bearing surfaces in this cohort to determine potential long-lasting implants which aim to reduce the need for future revision.

Ceramic-on-ceramic bearings have been reported to have the lowest wear rates when compared to other bearing surfaces [37–40], and multiple studies have shown beneficial outcomes in patients with ON. Millar et al. [41] compared the outcomes of ceramic-on-ceramic bearings between a cohort with ON ($n=24$ hips) and a matched cohort with primary OA ($n=24$ hips). After a mean follow-up of 34 months (range, 25 to 51 months), there was no difference in HHS (86 vs 87 points, respectively) and no patient was revised in either cohort. Thus,

the authors concluded that this articulating surface could provide similar outcomes regardless of the etiology of hip disease. In addition, Finkbone et al. [42] evaluated the outcomes of this bearing surface in a cohort of patients under 20 years of age ($n=24$ hips). After a mean follow-up of 52 months (range, 25 to 123 months), the cohort had an implant survival rate of 96 % and a mean HHS of 93 points (range, 66 to 100). Shortly thereafter, Byun et al. [43] assessed the outcomes of a third generation ceramic-on-ceramic THA in patients younger than 30 years of age ($n=56$ hips). After a mean follow-up of approximately 8 years (range, 6 to 9 years), patients had a mean HHS of 98 points, a mean WOMAC of 25 points, and no revisions were required. These studies demonstrated that ceramic-on-ceramic bearings can provide satisfactory clinical and radiological outcomes at mid-term follow-up in younger, more active patients with ON.

A specific type of ceramic bearing, alumina, has been investigated for its potential benefit in improving post-operative outcomes. One prospective, randomized trial compared this bearing surface ($n=79$ hips) to a more conventional surface ($n=26$ hips) in patients who have ON [44]. After a mean follow-up of approximately 4 years (range, 1 to 8 years), the groups had similar mean HHS (96 vs 96 points, respectively) and survival rates (96 vs 92 %, respectively; $p=0.3$). Although the difference in survivorship did not achieve statistical significance, the authors believed that the difference may have clinical significance and alumina-on-alumina bearings could be a viable option for younger, more active patients with ON. Furthermore, Solarino et al. [45•] assessed outcomes of alumina-on-alumina THA ($n=61$ hips). After a mean follow-up of 13 years (range, 11 to 15 years), the mean HHS was 91 points (range, 68 to 100 points) and the survivorship rate was 98 %. Similarly, in a study of 102 hips, Park et al. [46] observed that after a mean follow-up of 115 months (range, 84 to 133 months), the mean HHS was 95 points (range, 85 to 100 points) and the 10-year Kaplan-Meir survivorship was approximately 95 %. Baek and Kim [47], after 7 years follow-up, noted a mean HHS of 97 points in their patients ($n=71$ hips), and none required revisions in their cohort. These authors concluded that aluminum bearings can be used as long-lasting THAs in patients with ON.

Highly cross-linked polyethylene bearings have been utilized as well. Although many surgeons are using these constructs in their arthroplasties, there have been few high-level studies evaluating their use. Recently, Min et al. [48] evaluated the outcomes and survivorship of a cohort of THA patients with ON using highly cross-linked polyethylene ($n=162$ hips). After a minimum follow-up of 5 years, they found a 100 % survivorship, a mean HHS of 93 points (range, 77 to 98 points), and a mean liner polyethylene wear of 0.037 mm/year. Similarly, Lee et al. [49] assessed the survivorship and outcomes of a similar cohort of patients who underwent THA using a highly cross-linked polyethylene component ($n=113$

hips). After a mean follow-up of approximately 8 years (range, 7 to 11 years), there was a mean wear rate of 0.031 mm/year and a mean HHS of 93 points (range, 80 to 100 points). Therefore, although mid-term follow-up results are promising, further studies are needed with longer term follow-up.

In addition, Kim et al. [50] evaluated this polyethylene design in conjunction with an alumina femoral bearing surface in a cohort of patients ($n=73$ hips) who had a mean age of 46 years (range, 20 to 50 years). After a follow-up of 8.5 years (range, 7 to 9 years), the mean HHS was 96 points, with no revisions among the cohort. Thus, the authors concluded that an alumina on highly cross-linked polyethylene can provide good outcomes in younger, more active patients.

In summary, the variety of newer bearings appears to provide good post-operative outcomes and survivorship at mid-term follow-up. More prospective studies are needed with long-term follow-up that assess their survivorship and wear rates.

Conclusion

Total hip arthroplasty remains the most definitive treatment for late-stage ON involving collapse of the femoral head and degenerative changes to the acetabulum. It is often a concern that these patients may have inferior outcomes due to multiple prior hip-preserving procedures or underlying medical diagnoses. Fortunately, studies on previous joint-preserving procedures have shown no evidence that these operations will have a deleterious effect. New innovations in the implant design such as press-fit constructs, ceramic bearings, and highly cross-linked polyethylenes have had a positive impact on patient-reported outcomes and implant survivorship. Future studies should focus on long-term outcomes and survivorship of these newer THA constructs in patients with osteonecrosis.

Compliance with Ethics Guidelines

Conflict of Interest Todd P. Pierce, Randa K. Elmallah, Julio J. Jauregui, and Daniel F. Verna declare that they have no conflict of interest.

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