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Smoking May Be a Harbinger of Early Failure With Ultraporous Metal Acetabular Reconstruction

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Abstract

Background Smoking is considered a risk factor for surgical complications in total hip arthroplasty (THA) and has been linked to a higher rate of aseptic loosening in uncemented acetabular components. Acetabular reconstruction with newer ultraporous metals in both complex primary and revision THA has increased survivorship but it is unclear whether smoking affects survival of these implants.

Questions/purposes We reviewed our early experience with THA using ultraporous acetabular components to assess the incidence and etiology of early failure and examine if any preoperative variables, including smoking, related to failure.

Methods We used ultraporous acetabular components in 498 patients (534 hips), beginning with one case each in 1999 and 2004, 17 in 2005, and the majority from 2006 through March 2010. There were 159 complex primary and 375 revision cases. Of these patients, 17% were smokers (averaging 35 pack-years), 31% previous smokers (averaging 29 pack-years), 41% nonsmokers, and 1% unknown. Failure modes possibly related to smoking were infection, aseptic loosening, or periacetabular fracture and unrelated were dislocation and implant breakage. Minimum followup was 1 month (average, 32 months; range, 1–78 months).

Results There were 34 cup failures (6%): 17 infections, 14 aseptic loosening, and one each liner breakage, dislocation, and periacetabular fracture. The failure rate (uncontrolled for potentially confounding variables) was 10% in both current (9 of 89) and prior smokers (17 of 167) and 3% in nonsmokers 8 of 271).

Conclusion With ultraporous metal technology in complex primary and revision THA, smoking, both past and current, may be a risk factor for early failure.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Acetabular reconstruction with newer ultraporous metal in both complex primary and revision THA has been associated with survivorship of 86% to 100% at 1.5 to 10.2 years with stable fixation and few failures [3–5, 11–13, 15–18, 20, 23–29, 32, 33, 36–42, 48–50, 52, 54, 55, 57, 59, 62, 67–69, 72, 73, 75, 76]. The benefits of ultraporous metal constructs include: immediate mechanical stability, short-term fixation, osteoconductivity, and promotion of enhanced vascularized bone ingrowth [3, 6–8, 59, 72]. Smoking is considered a risk factor for general surgical complications including transfusion, delayed wound healing, infection, and cardiopulmonary [21, 46, 47, 58]. Smoking has also been correlated to complications specific to orthopaedic surgery, including THA such as decreased survivorship, increased surgical site infection (SSI), increased recovery time, and higher mortality [1, 2, 14, 22, 30, 34, 43, 45, 46, 53, 56, 60, 61, 64–66]. One study of the effect of smoking on implant survival in THA reported a 4.5-fold greater risk for cup or stem revision secondary to aseptic loosening in smokers [43]. Preoperative smoking cessation can reduce the rate of postoperative complications including delayed wound healing, wound infection, pulmonary, and cardiovascular [35, 66, 70, 71].

Smoking adversely affects fracture repair and union, bone regeneration, and osteointegration [2, 10, 14, 31, 44, 53, 58, 63, 64]. Durable fixation of ultraporous acetabular devices requires both repair of the bony injury necessitated by acetabular reaming and osteointegration of porous metal into host bone. During the smoking of tobacco, hazardous chemicals and gases are released into the bloodstream, including nicotine, carbon monoxide, tar, and hydrogen cyanide. These chemicals and byproducts reduce blood flow, impair delivery of nutrients, oxygen, and lymphocytes to the tissues, reducing aerobe metabolism, injure host DNA, cause genetic mutations, interfere with cellular processes, and disrupt the complex cascade integral to bone and soft tissue healing [2, 10, 14, 58, 63, 65].

We asked whether current or previous smoking is a risk factor for early failure in complex primary and revision THA with ultraporous acetabular reconstruction.

Patients and Methods

A search of our practice registry revealed 5799 hip arthroplasty procedures performed in 4726 patients by the two senior authors (AVL, KRB) between May 1999 and March 2010. Of these procedures, ultraporous acetabular components were used in 500 patients (536 hips), beginning with one case each in 1999 and 2004, 17 in 2005, and the majority from 2006. Regenerex ($TiAl_6V_4$ substrate; Biomet, Warsaw, IN, USA) devices were used in 277 (52%) hips, Trabecular Metal (tantalum substrate; initially sold as Hedrocel by Implex Corporation, Allendale, NJ, USA, marketed by Zimmer, Warsaw, IN, USA, since 2000 and fully acquired in 2004) in 184 (35%) hips, and Trident Tritanium (titanium substrate; Stryker, Mahwah, NJ, USA) in 72 (14%). All three devices are approved for the uses described in our study by the US Food and Drug Administration. The indications for these devices were (1) complex primary THA defined as acetabuli that allowed not greater than 70% coverage of the porous component; (2) acetabuli compromised by substantial osteopenia; (3) acetabuli compromised by posttraumatic arthritis with or without the presence of hardware; and (4) all revision THAs. The major contraindication for the use of ultraporous cups was acetabuli characterized by substantial segmental bone loss, which could not be reconstructed with the use of an acetabular component and augments. These acetabuli were treated with patient-matched implants. Two patients (two hips) declined to participate in research reviews leaving 534 hips (498 patients). There were 215 (43%) male patients and 283 (57%) females. Mean patient age was 64 years (range, 16–94 years; SD 14) and mean body mass index was 30 kg/m^2 (range, 16–59 kg/m^2; SD 7). No patients were lost to followup. Minimum followup was 1 month (average, 32 months; range, 1–78 months). Followup longer than 2 years was available for 79% of patients. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. All patients signed institutional review board-approved general research consent allowing for retrospective review.

Smoking status was obtained as part of the patient history at the time of initial assessment or from the hospital history report in cases of direct admission. Smoking is defined as the inhalation of the smoke of burning tobacco in the form of cigarettes, pipes, or cigars on a daily basis. Pack-years at the time of surgery were calculated by multiplying the number of packs of cigarettes smoked per day times the number of years a patient had smoked. One pack-year would be roughly equivalent to smoking 20 cigarettes (one pack) per day for 1 year. Of the patients studied, 89 (17%) were smokers, 167 (31%) were previous smokers, and 271 (51%) were nonsmokers. Smoking status could not be determined for seven (1%) patients. Current smokers had an average 35 pack-years (range, 4–105 pack-years; SD 22.8). Prior smokers had an average 24 pack-years (range, 0.3–133 pack-years; SD 26.1) and had quit smoking on average 21 years before the index surgery (range, 0.3–62 years; SD 15.2). Other comorbidities included a history of infection in 20%, diabetes mellitus in 14%, cardiac disease in 29%, and cancer (other than skin cancers) in 5%. Sixteen percent of hips had a prior metal-on-metal bearing.

Preoperative acetabular bone deficiency was graded according to the classification of Paprosky et al. [51] and Weeden and Paprosky [74]. Preoperative acetabular deficiencies were Paprosky Type I in 93 hips (17%), IIA in 155 (29%), IIB in 114 (21%), IIC in 83 (16%), IIIA in 83 (16%), and IIIB in six (1%).

Current smokers were younger than either prior or nonsmokers (55 years versus 66 and 65 years) (Table 1). There were more female than male nonsmokers (64% versus 36%; p = 0.003) compared with a more equal sex distribution among both current and prior smokers. Likely as a consequence of the preponderance of females, who nationally average 63.8 inches in height compared with 69.4 inches in men [9], in the nonsmoking group, average height was shorter (p = 0.013) than in either the current or prior smoking groups (66 inches versus 67 inches). However, there were no differences in weight or body mass index between smoking groups. There was no difference in distribution of procedure type or severity of preoperative acetabular defect between smoking groups. Although use of augments was similar between smoking groups, more current smokers had constrained liners (27% versus 17% in prior smokers and 15% in nonsmokers; p = 0.030). History of infection, history of cancer, and number of hips with a prior metal-on-metal bearing were similar between smoking groups. More current smokers had a history of diabetes (27% versus 13% in prior smokers and 10% in nonsmokers; p = 0.000) and more prior smokers had a history of cardiac disease (38% versus 29% in current smokers and 23% in nonsmokers; p = 0.004).

Primary THAs were classified as complex at the discretion of the surgeon based on the adequacy of the remaining

Table 1. Demographic comparison by smoking status

Demographic	Overall	Never smoked	Prior smoker	Current smoker	p value
Number of hips	534	271	167	89	
Average age (years)	64	65	66	55	0.000
Average height (inches)	66	66	67	67	0.013
Average weight (pounds)	188	187	188	191	0.777
Average body mass index (kg/m^2)	30	30	30	30	0.685
Sex					
Males	228 (43%)	97 (36%)	83 (50%)	46 (52%)	0.003
Females	306 (57%)	174 (64%)	84 (50%)	43 (48%)	
Procedure					
Primary	142 (27%)	74 (27%)	50 (30%)	18 (20%)	0.244
Conversion	17 (3%)	7 (3%)	7 (4%)	2 (2%)	0.567
Revision	310 (58%)	157 (58%)	93 (56%)	55 (62%)	0.641
Reimplantation	63 (12%)	31 (11%)	17 (10%)	14 (16%)	0.411
Total femur	2 (< 1%)	2 (1%)	0 (0%)	0 (0%)	0.574
Paprosky class					
I	93 (17%)	45 (17%)	36 (22%)	12 (14%)	0.221
IIA	155 (29%)	79 (29%)	46 28%)	29 (33%)	0.700
IIB	114 (21%)	56 (21%)	33 (20%)	23 (26%)	0.497
IIC	83 (16%)	44 (16%)	26 (16%)	11 (12%)	0.677
IIIA	83 (16%)	43 (16%)	26 (16%)	12 (14%)	0.860
IIIB	6 (1.1%)	4 (2%)	0 (0%)	2 (2%)	0.205
Augments used	44 (8%)	20 (7%)	14 (8%)	9 (10%)	0.710
Constraint used	95 (18%)	40 (15%)	28 (17%)	24 (27%)	0.030
History of infection	107 (20%)	56 (21%)	32 (19%)	18 (20%)	0.923
History of diabetes	73 (14%)	27 (10%)	21 (13%)	24 (27%)	0.000
History of cardiac disease	153 (29%)	62 (23%)	63 (38%)	26 (29%)	0.004
History of cancer	27 (5%)	11 (4%)	11 (7%)	5 (6%)	0.494
Prior metal-on-metal	85 (16%)	39 (14%)	29 (17%)	16 (18%)	0.602
Preoperative HHS	49	49	50	46	0.286
Postoperative HHS	72	74	72	67	0.016
HHS improvement	24	25	23	23	0.660

HHS = Harris hip score (0–100 possible with 100 being best).

bone stock for implant ingrowth. The surgical procedure was complex primary in 142 (27%), conversion in 17 (3%), revision in 310 (58%), reimplantation after radical débridement for two-stage treatment of infection in 63 (12%), and total femur replacement in two cases. Surgical approach was either less invasive or standard direct lateral in all cases except for 56 (11%) anterior supine intermuscular, five with extended trochanteric osteotomy, one posterior, and two total femur split. Revision was conducted through adequate exposure of the acetabulum facilitated by placement of appropriate anterior and posterior retractors. Periacetabular scar tissue was excised and the acetabular component was removed using atraumatic techniques. In cases of cemented acetabular components, the polyethylene-cement interface was violated with osteotomes, the polyethylene component was removed, followed by removal of cement with a combination of hand tools and high-speed burrs. In the case of a cementless acetabular component, atraumatic size-specific curved osteotomes were used to directly debond the porous coating from the host bone. Next any screws present were removed. On removal of the components, integrity of the acetabulum was assessed. The acetabulum was then reamed to within 2 mm of the appropriate size. If the bone was considered to be severely osteopenic, reaming was performed in a reverse fashion and cavitary defects were treated with fresh-frozen irradiated morselized bone graft impacted using a reverse reaming technique. The ultraporous acetabular components were placed in 45° of abduction and 20° of anteversion achieving a scratch fit secondary to the 2 mm underreaming. Multiple screws were placed to enhance fixation. An appropriate polyethylene liner was inserted. A constrained liner was used in 18% of cases and a porous augment was used in 8% of cases.

Postoperatively patients remained at bedrest for the first 24 hours. Physical therapy was instituted on postoperative day 2. Therapists instructed patients regarding the use of a walker and toe-touch ambulation for the first 6 weeks postoperatively. Patients were instructed to be out of bed as tolerated, to ambulate in a toe-touch fashion with the use of a walker, and to return to our office for a followup appointment at 6 weeks. Weightbearing was advanced based on clinical and radiographic evaluation and patients were instructed in ROM exercises. No formal physical therapy was ordered. In the ensuing 6 weeks, patients were allowed to wean from a walker to a cane as tolerated.

Patients were asked to return at 3-month followup if they were experiencing any symptoms or if they were not advised to advance weightbearing at the 6-week followup. All patients were then asked to return for routine clinical and radiographic evaluation annually thereafter or immediately if adverse symptoms developed in the operated hip. Clinical examination using the Harris hip score [19] and radiographic evaluation with plain radiographs with AP pelvis and frog leg lateral views were performed at these intervals. Failure was defined as revision or removal of the acetabular shell. Failures possibly related to smoking were considered any infection, aseptic loosening, or periacetabular fracture. Failures not considered smoking-related included dislocation and implant breakage.

Differences in survivorship were measured using chi square analyses. A one-way analysis of variance was used to compare differences in mean age, height, weight, body mass index, and pre- and postoperative lower extremity activity scales, and Harris hip total scores and pain scores among the three groups. Student's t-test was used to compare differences in mean pack-years between past and current smokers. Ninety-five percent confidence intervals were used in all analyses.

Results

Harris hip scores improved from a preoperative mean of 49 (range, 4–98.5; SD 17.8) to a mean of 72 (range, 21.5–100; SD 17.7) at most recent followup. Harris hip scores in current smokers were lower ($p = 0.019$) than in prior or nonsmokers (67 versus 72 and 73); however, Harris hip score improvement was similar ($p = 0.795$) between smoking groups.

There were 34 cup failures at an average of 21 months postoperatively (Table 2) for a failure rate of 6%: 17

Table 2. Reason for failure requiring revision of the acetabular component by smoking status

Failure mode	Overall (n = 534)	Nonsmokers (n = 271)	Previous smokers (n = 167)	Current smokers (n = 89)	p value
Infection*	17 (3.2%)	4 (1.5%)	6 (3.6%)	7 (7.9%)	0.012
Aseptic loosening*	14 (2.6%)	4 (1.5%)	9 (5.4%)	1 (1.1%)	0.029
Periacetabular fracture*	1 (0.2%)	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.340
Liner breakage	1 (0.2%)	0 (0.0%)	0 (0.0%)	1 (1.1%)	0.085
Dislocation	1 (0.6%)	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.340
Total overall	34 (6.4%)	8 (3.0%)	17 (10.2%)	9 (10.1%)	0.003
Total smoking-related*	32 (6.0%)	8 (3.0%)	16 (9.6%)	8 (9.0%)	0.008

Asterisk denotes smoking-related failure mode.

infections, 14 aseptic loosening or failure of ingrowth, and one each liner breakage, dislocation, and periacetabular fracture. The failure rate was higher (p = 0.01) in current and previous smokers (both 10%) than nonsmokers (3%). With only smoking-related failures included, rates again were higher (p = 0.02) in current and previous smokers (both 9%) than in nonsmokers (3%). When comparing failures and nonfailures, the average pack-years was higher (p = 0.010) for failures versus nonfailures (23 versus 12). Average age, height, weight, body mass index, and preoperative Harris hip score were similar between failures and nonfailures, whereas failures had poorer (both p = 0.000) postoperative Harris hip score and Harris hip score improvement. When comparing failures and nonfailures by procedure type, the rate of cup failure was highest (p = 0.006) after reimplantation THA (14% [nine of 63]) compared with 7% after revision THA (23 of 310) and only 1% after primary THA (two of 142) (Table 3). However, there

Table 3. Demographic comparison between failures and nonfailures

Demographic	Overall	Failures	Nonfailures	p value
Number of hips	534	34	500	
Average age (years)	64	61	64	0.288
Average height (inches)	66	66	66	0.569
Average weight (pounds)	188	187	188	0.885
Average body mass index (kg/m^2)	30	30	30	0.831
Average pack-years	12	22	12	0.009
Smoking status				0.008
Unknown	7 (1%)	0 (0%)	7 (1%)	
Nonsmoker	271 (51%)	8 (24%)	263 (53%)	
Prior smoker	167 (31%)	17 (50%)	150 (30%)	
Current smoker	89 (17%)	9 (27%)	80 (16%)	
Sex				0.587
Males	228 (43%)	13 (38%)	215 (43%)	
Females	306 (57%)	21 (62%)	285 (57%)	
Procedure				0.006
Primary	142 (27%)	2 (6%)	140 (28%)	
Conversion	17 (3%)	0 (0%)	17 (3%)	
Revision	310 (58%)	23 (68%)	287 (57%)	
Reimplantation	63 (12%)	9 (26%)	54 (11%)	
Total femur	2 (< 1%)	0 (0%)	2 (< 1%)	
Paprosky class				0.148
I	93 (17%)	4 (12%)	89 (18%)	
IIA	155 (29%)	12 (35%)	143 (29%)	
IIB	114 (21%)	8 (24%)	106 (21%)	
IIC	83 (16%)	1 (3%)	82 (16%)	
IIIA	83 (16%)	9 (27%)	74 (15%)	
IIIB	6 (1.1%)	0 (0%)	6 (1%)	
Augments used	28 (5%)	4 (12%)	24 (5%)	0.439
Constraint used	95 (18%)	9 (27%)	86 (17%)	0.171
History of infection	107 (20%)	11 (32%)	96 (19%)	0.070
History of diabetes	73 (14%)	8 (24%)	65 (13%)	0.090
History of cardiac disease	153 (29%)	9 (26%)	144 (29%)	0.739
History of cancer	27 (5%)	2 (6%)	25 (5%)	0.831
Prior metal-on-metal	85 (16%)	8 (24%)	77 (15%)	0.171
Preoperative HHS	49	48	49	0.778
Postoperative HHS	72	59	73	0.000
HHS improvement	24	9	25	0.000

HHS = Harris hip score (0–100 possible with 100 being best).

was no difference (p = 0.07) in failure rates between patients with and without a history of infection (10% versus 5%). There were no differences in failure incidence between sexes, between Paprosky defect classification groups, and between patients with or without constrained liners used, augments used, prior metal-on-metal bearing, and history of diabetes, cardiac disease, or cancer.

Discussion

The use of ultraporous metal in acetabular reconstruction during complex primary and revision THA has improved survivorship and shown few failures (Table 4) [3–5, 11–13, 15–18, 20, 23–29, 32, 33, 36–42, 48–50, 52, 54, 55, 57, 59, 62, 67–69, 72, 73, 75, 76]. Ultraporous components have been touted to possess optimized ingrowth surfaces that are truly three-dimensional, unlike beaded and plasma-sprayed surfaces. Therefore, one would intuitively believe that biological fixation into these surfaces would be superior. One would also intuitively believe that the percent of biological fixation required for stability of the component would be less than for devices with standard porous coatings. Smoking is a surgical risk factor for delayed wound healing, increased transfusions, infections, and cardiac complications [21, 46, 47, 58, 64–66, 70, 71] as well as increased complications in orthopaedic surgery, including THA [1, 22, 30, 34, 45, 53, 56, 60, 61]. Smoking also impairs fracture repair and osteointegration [2, 10, 14, 31, 43, 63]. The purpose of our study was to retrospectively review our use of ultraporous metal acetabular devices in patients undergoing complex primary and revision THA to determine the incidence and modes of failure and the influence, if any, of smoking status on risk for early failure.

We caution readers of the limitations of our study. First, this was a retrospective review rather than a prospective study with some missing data. In particular we had no smoking data on seven patients, but presume this would not affect the findings. Second, there were demographic differences between the smoking groups, which may have had an influence on implant survival with the current smoking group having more male patients, greater height, younger age, more need for constraint, and higher incidence of diabetes and cardiac disease. While none of these factors differed between failure and nonfailure groups we did not perform a multivariable analysis to control for these potentially confounding variables.

Newer ultraporous metals for acetabular construction in both primary and revision THA have been associated with few failures and survivorship of 86% to 100% at 1.5 to 10.2 years (Table 4). We found a higher risk of failure of ultraporous metal acetabulum reconstruction in current and prior smokers compared with nonsmokers. While smoking has not been reported as a risk factor for early failure in the use of newer ultraporous metal acetabular components, our findings are consistent with other contemporary research of ultraporous metal components and the impact of smoking on surgical outcomes including wound healing, osteointegration, rates of infection, and implant survival. Smoking has a negative impact on surgical outcomes both perioperatively as well as postoperatively [34, 45, 46]. Smoking is associated with decreased survivorship of implants as well as increased surgical complications, delayed wound healing, osteointegration and fracture repair, negatively impacted arthroplasty outcomes, and increased length of stay [1, 2, 10, 14, 21, 30, 34, 43, 45, 46, 53, 56, 60, 61, 63].

In a study of 202 patients undergoing THA or TKA comparing differences in resource consumption and short-term outcomes between current smokers (25 [12%]; average 28.3 pack-years) and nonsmokers (177 [88%]), Lavernia et al. [34] found that despite being younger and having fewer comorbidities, smokers had longer surgical and anesthesia times and higher charges adjusted for age and procedure. Previous smokers had better short-term outcomes than current smokers, indicating a benefit to smoking abstinence before joint replacement. In contrast, our data did not reveal a difference between current and previous smokers in terms of survival of the acetabular component. Møller et al. [45], in a study of the effects of smoking on early complications after elective orthopaedic surgery in 811 patients undergoing THA or TKA, found smoking was the single most important risk factor for development of postoperative complications resulting in delay of discharge, particularly wound-related, cardiopulmonary, and need for intensive care. There were 232 (29%) current smokers with 35 average pack-years (± 17; range, 1–101 pack-years). The 579 (71%) nonsmokers included 125 prior smokers and 454 who never smoked. For patients requiring prolonged hospitalization (> 15 days), there was a greater than twofold proportion of smokers versus nonsmokers with wound complications. Tobacco use reportedly increases the risk of postoperative complications: in a study of 3309 patients undergoing primary THA the risk of postoperative complications was increased by 43% for previous versus nonusers, by 56% for current versus nonusers, and by 121% for heavy users (> 40 pack-years) versus nonusers [56]. AbdelSalam et al. [1] reviewed 22,343 primary and revision THA and TKA cases performed between 1999 through 2008 and examined predictors of intensive care unit (ICU) admission after total joint arthroplasty. One hundred thirty admissions were identified and matched to 260 (two times) control subjects for comparison. The greatest independent risk factor was having ever smoked with an incidence of 38% in those requiring ICU admission versus 5.4% in control subjects for an odds ratio of 65.13. Finally, a study of the effect of

Table 4. Results of ultraporous acetabular reconstruction

Study	Year	Number of hips	Specific selection	Implants used	Mean followup (years)	Failures (number of cups revised)	Survival (%)	Mean postoperative score
Baad-Hansen et al. [3]	2011	24	Primary, noninflammatory, unilateral	TM	2	0	100%	HHS 92
Ballester Alfaro and Sueiro Fernández [4]	2010	19	Revision for massive bone loss; Paprosky 68% IIIA, 32% IIIB	TM, cup-cage in 100%	2.2	0	100%	MMP 9.1
Blumenfeld and Bargar [5]	2012	8	Revision; severe protrusio defects; Paprosky 38% IIC, 50% IIIA, 13% IIIB	TM cup-in-cup technique	2.3	0	100%	HHS 78
Davies et al. [11]	2011	46	Revision with severe bone loss; Paprosky 22% IIC, 46% IIIA, 24% IIIB; 9% pelvic discontinuity	TM, augments in 30%	4.2	1	97.8%	HHS 78.2
Del Gaizo et al. [12]	2012	37	Revision; 100% Paprosky IIIA; 4 pelvic discontinuity	TM, augments in 100%	5.0	2	94.6%	HHS 81.5
Fernández-Fairen et al. [13]	2010	263	Revision: excluded infection, irradiated, antitumor drugs; Paprosky 8% I, 28% IIA, 31% IIB, 19% IIC, 15% IIIA, 3% IIIC	TM, augments in 13%	6.1	2	99.2%	HHS 80.4
Flecher et al. [16]	2008	23	Revision with major bone loss; Paprosky 74% IIIA, 26% IIIB	TM, augments in 61%	2.9	0	100%	MMP 10.6
Flecher et al. [15]	2010	72	Revision; Paprosky 18% I, 20% IIA, 20% IIB, 32% IIIA, 11% IIIB	TM, augments in 19%, cup-cage in 1%	4	0	100%	MMP 15.8
Gross and Goodman [17]	2005	61	Revision with large bone defects	TM, bone graft, screws, cage	4.6	8	86.9%	NA
Gruen et al. [18]	2005	574	Primary; excluded segmental and rim defects, severe dysplasia, severe deformity from acetabular fracture, advanced osteoarthritis	TM monoblock	2.8	10	98.3%	HHS 90
Hasart et al. [20]	2010	38	Revision with bone loss; Paprosky IIB-IIIB; excluded infection, pelvic discontinuity	TM	2.1	2	94.7%	MMP 13; HHS 78
Jafari et al. [23]	2010	81	Revision; Paprosky 51% I, 10% IIA, 7% IIB, 17% IIC, 11% IIIA, 4% IIIB	TM	3.0	3	96.3%	NA
Joglekar et al. [24]	2012	34	Primary after pelvic irradiation for malignancy	TM, cup-cage in 9%, augments in 6%	6.5	0	100%	HHS 80
Kim et al. [25]	2008	46	Revision; Paprosky 43% IIA, 9% IIB, 20% IIC, 13% IIIA, 9% IIIB; 7% unknown	TM, 15% constrained	3.3	1	97.8%	NA
Komarasamy et al. [26]	2006	113	Primary	TM	2.7	0	100%	OHS 14
Koshashvili et al. [27]	2009	26	Revision in pelvic discontinuity	TM, cup-cage construct	3.7	2	92.3%	HHS 76.6
Koshashvili et al. [28]	2010	15	Revision after failed antiprotrusion cage (67%) or roof ring (33%)	TM	2.0	2	86.7%	HHS 69
Kostakos et al. [29]	2010	51	Primary; excluded dysplasia, avascular necrosis, inflammatory disease	TM monoblock	2.0	0	100%	HHS 92
Lachiewicz and Soileau [32]	2010	39	Revision; Paprosky 5% I, 28% II, 21% IIIA, 46% IIIB	TM, augments in 10%	3.3	1	97.4%	HHS 86

Table 4. continued

Study	Year	Number of hips	Specific selection	Implants used	Mean followup (years)	Failures (number of cups revised)	Survival (%)	Mean postoperative score
Lakstein et al. [33]	2009	53	Revision with 50% host bone contact, 100% Saleh type II; excluded those requiring structural allograft, augment, cup-cage	TM	3.8	2	96.2%	MMP 10.6
Lingaraj et al. [36]	2009	23	Revision with major bone loss; Paprosky 70% IIIA, 30% IIIB	TM, augments in 91%, cup-cage in 4%	3.4	0	100%	HHS 75.7; MMP 13.7
Macheras et al. [39]	2006	86	Primary	TM monoblock	7.3	0	100%	HHS 94
Macheras et al. [37]	2009	156	Primary	TM monoblock	8–10	3	98.1%	HHS 97; OHS 13.9
Macheras et al. [38]	2010	27	Primary; high congenital dislocation; all female	TM monoblock	10.2	0	100%	HHS 89.5; OHS 21.2
Malizos et al. [40]	2008	245	Primary	TM monoblock	5.0	1	99.6%	HHS 94; OHS 16.4
Malkani et al. [41]	2009	22	Revision; Paprosky 73% II, 27% III	TM	3.3	1	95.5%	HHS 81
Markuszewski et al. [42]	2011	21	Revisions	TM	1.7	0	100%	HHS 78.8
Nakashima et al. [48]	2012	82	Primary	TM modular	5.1	0	100%	MMP 16.4
Nehme et al. [49]	2004	16	Revision; Paprosky 6% IIA, 19% IIB, 6% IIC, 31% IIIA, 38% IIIB	TM, augments in 100%	2.7	1	93.8%	HHS 75
Paprosky et al. [50]	2005	12	Revision with pelvic discontinuity; Paprosky IIIA and IIIB	TM with or without augments	2.1	0	100%	NA
Pierannunzii et al. [52]	2011	21	Revision with severe bone loss; 71% GIR-III, 29% GIR-IV	TM multihole without augments	1.8	3	85.7%	HHS 82
Ramappa et al. [54]	2009	43	Revision; AAOS 17% Type 1, 49% Type 2, 24% Type 3, 5% Type 4, 5% none	Tritanium, augment in 2%	1.5	1	97.7%	HHS 86
Rose et al. [55]	2006	12	Primary after pelvic irradiation for malignancy	TM revision	2.6	0	100%	HHS 88
Siegmeth et al. [57]	2009	34	3% primary (avascular necrosis); 97% revision → Paprosky 12% IIA, 6% IIB, 3% IIC, 58% IIIA, 24% IIIB	TM, augments in 100%	2.8	2	94.1%	NA
Simon and Bellemans [59]	2009	64	17% complex primary → 45% dysplasia, 18% SCFE, 27% posttraumatic, 9% Paget's; 83% revision → Paprosky 28% I, 28% IIA, 26% IIB, 9% IIC, 8% IIIA	TM modular	2.1	1	98.4%	MMP 16
Skyttä et al. [62]	2011	827	Revision	TM revision	3	40	95.2%	NA
Sporer and Paprosky [68]	2006	28	Revision; Paprosky IIIA	TM, augments in 100%	3.1	1	96.4%	MMP 10.6

Table 4. continued

Study	Year	Number of hips	Specific selection	Implants used	Mean followup (years)	Failures (number of cups revised)	Survival (%)	Mean postoperative score
Sporer and Paprosky [67]	2006	13	Revision; Paprosky IIIB	TM, 1 augment in 31%; 2 augments in 31%	2.6	0	100%	MMP 10.3
Sternheim et al. [69]	2012	102	Revision; Gross 52% IIA, 48% IIB	TM revision	6	8	92.2%	HHS 74.2
Unger et al. [72]	2005	60	Revision; Paprosky 2% I, 27% IIA, 42% IIB, 17% IIC, 12% IIIA, 2% IIIB	TM	3.5	4	93.3%	HHS 94.4
Van Kleunen et al. [73]	2009	97	Revision; Paprosky 25% IIA, 20% IIB, 20% IIC, 20% IIIA, 16% IIIB	TM, augments in 24%, cup-cage in 2%	3.8	8	91.8%	HHS 76
Weeden and Schmidt [75]	2007	43	Revision with severe defects; Paprosky 77% IIIA, 23% IIIB	TM, augments in 60%, cup-cage in 5%, plating in 2%	2.8	1	97.7%	HHS 84; MMP 9.2
Xenakis et al. [76]	2000	253	Primary	TM monoblock	5–8	1	99.6%	HHS 97; OHS 13.9
Current study	2012	534	37% primary, 3% conversion, 58% revision; 12% reimplantation, 0.4% total femur; Paprosky 17% I, 29% IIA; 21% IIB, 16% IIC, 16% IIIA, 1% IIIB	35% TM, 52% Regenerex, 13% Tritanium; augments in 8%	2.6	34	93.6%	HHS 71.8

AAOS = American Academy of Orthopaedic Surgeons classification of acetabular defects; SCFE = slipped capital femoral epiphysis; TM = trabecular metal; HHS = Harris hip score (0–100 possible with 100 being best); MMP = Modified Merle d'Aubigné-Postel rating scale (0–18 with 18 being best); NA = not available; OHS = Oxford hip score (12–60 possible with 12 being best); GIR = Italian Society for Revision Arthroplasty.

smoking on short-term outcomes in 33,336 veterans undergoing primary THA or TKA [61] found current smokers were more likely than nonsmokers to have surgical site infection (odd ratio, 1.41), pneumonia (odds ratio, 1.53), stroke (odds ratio, 2.61), and 1-year mortality (odds ratio, 1.63). Prior smokers were more likely than never smokers to have pneumonia (odds ratio, 1.34), stroke (odds ratio, 2.14), and urinary tract infection (odds ratio, 1.26). The primary author [60] also performed a meta-analysis of smoking and outcomes after hip and knee arthroplasty, reviewing 21 studies. Both current and former smokers had an increased risk of postoperative complications and perioperative death after arthroplasty.

Osteointegration of orthopaedic implants involves a coordinated, complex cascade of events similar to those that occur during fracture repair and likewise adversely affected by smoking [2, 10, 14, 63, 65]. One study specifically reported a link between smoking and increased risk for aseptic loosening after primary THA with uncemented porous cups in all cases and cemented stems in 61% [43]. In 147 patients (165 hips), 21% were current smokers and 79% were nonsmokers. There were eight of 68 (12%) cups or stems revised for aseptic loosening in smokers compared with only five of 262 (2%) in nonsmokers for a 4.5-fold greater risk in smokers ($p = 0.0012$). In our study, a higher rate of aseptic loosening was observed in prior smokers ($p = 0.015$), whereas current smokers had a higher rate of failure secondary to infection ($p = 0.003$).

Several studies have reported that smoking leads to higher rates of wound infection after surgery [2, 22, 30, 64–66] with both transient and prolonged effects. The leading cause of failure in our study was SSI (3% overall) with an 8% incidence in current smokers compared with 4% in prior smokers and 2% in nonsmokers. Similarly, in a systematic review across surgical specialties to clarify evidence on smoking and postoperative healing complications, analysis of 140 studies involving 479,150 patients revealed an odds ratio of 1.8 for SSI for smokers compared with nonsmokers [64]. The same study also reviewed four randomized controlled trials of smoking cessation intervention and observed a reduction in SSIs (odds ratio, 0.4) with cessation but not in other healing complications. We found the incidence of infection was lower for patients who never smoked compared with prior and current smokers but the difference between prior and current smokers was not significant with the numbers available.

Ultraporous metal technology offers the advantages of improved mechanical stability, enhanced fixation, osteoconductivity, and the ability to allow vascularized bone ingrowth [3, 6–8, 59, 72]. Despite these benefits, smoking, both current and prior, appears to be a risk factor for early failure in complex primary and revision THA using ultraporous metal acetabular components. Long-term followup is recommended in addition to well-documented radiographic evaluation of patient status. Quitting smoking can effectively reduce some inherent risks following THA but not eliminate them. While we continue to recommend preoperative discussion of smoking cessation to decrease incidence of complications and improve recovery and overall quality of life, we found no improvement in implant survival for prior smokers compared with current smokers. This suggests earlier efforts to further educate and discourage young people from taking up the harmful and addictive habit of smoking tobacco would be ideal.

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