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Winner of the Rand Award

Cementless Femoral Components in Young Patients

Review and Meta-Analysis of Total Hip Arthroplasty and Hip Resurfacing

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Abstract: The study purpose was to analyze current results of modern cementless femoral components in young patients having total hip arthroplasty (THA) or hip resurfacing. Twenty-two studies (n = 5907; hips = 6408) evaluating modern cementless THA in young patients and 15 studies evaluating hip resurfacing (n = 3002; hips = 3269) were included. Meta-analysis techniques were used to pool failure rates. The pooled failure rate for THA using femoral revision for mechanical failure as an end point was 1.3% (95% confidence interval [CI], 1.0%-1.7%) at a mean 8.4 years of follow-up. At a mean of 3.9 years of follow-up, the pooled mechanical failure rate of the femoral component for hip resurfacing was 2.6% (95% CI, 2.0-3.4). In conclusion, the enthusiasm for hip resurfacing should be tempered by these data. Longer follow-up and direct comparison trials are required to confirm these findings. **Keywords:** hip resurfacing, cementless, femoral component, total hip arthroplasty, meta-analysis.

There are several perceived advantages to hip resurfacing when compared to total hip arthroplasty (THA). These include improved range of motion with decreased risk of dislocation, more normal proprioception, preserved proximal femoral bone stock, and easy conversion to THA should failure occur [1,2]. Advocates of resurfacing often cite the high rate of failure of THA in young patients as justification for its use. These reports however often contain an older generation of hip arthroplasties with poor design and bearing surfaces that led to high failure rates [3,4].

There has been concern with regard to the short-term and long-term durability of the femoral component in hip resurfacing. Femoral neck fractures and failure of fixation (aseptic loosening) of the femoral component secondary to poor cement technique, avascular necrosis, or aseptic loosening are common modes of failure [5,6]. In addition, the lack of current long-term outcomes, proper patient selection, and technical factors (learning curve) make a widespread adoption of the procedure concerning [7].

The purpose of our study was to analyze failure rates of modern femoral components in young patients having THA or hip resurfacing. Meta-analysis techniques were used to analyze the current available literature with regard to pooled failure rates, the proportion of femoral component failures to overall failures and survival rates. Our hypothesis was that modern cementless femoral components in THA in young patients may in fact be more durable with a lower mechanical failure rate than those associated with hip resurfacing.

Methods

Search Strategy

Medline, PubMed, and Cinahl were systematically searched from their inception date to March 31, 2008, to identify relevant studies. Reference lists from review articles and potentially relevant studies were hand

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Table 1. Baseline Characteristics

Characteristic	HRA Studies	THA Studies
No. of studies	15	22
No. of hips (patients)	3269 (3002)	6408 (5907)
Average age, y (SD; range)	46.6 (6.1; 34.2-56.8)	41.4 (6.1; 32.0-55.4) *
Average of mean length of follow-up, y (SD; range)	3.9 (2.1; 8.7-0.56) †	8.5 (2.4; 13.5-4.8) ‡
Bearing surface (no. of studies)		
MOM	15	2
MOP	0	17
COP	0	1
COM	0	1
Multiple	0	1
Diagnosis §		
Osteoarthritis	1853	3709
Avascular necrosis	207	892
Developmental dysplasia	181	446
Rheumatoid arthritis	24	200
Childhood disorder	42	66
Other	113	130

MOM indicates metal on metal; MOP, metal on poly; COP, ceramic on poly; COM, ceramic on metal; multiple, multiple types of bearing surfaces studied.

* McLaughlin, 2000; Aldinger 2003; and Eskelinen, 2006, did not record a mean age of study participants.

† Treacy 2005 did not provide an average length of follow-up for study participants.

‡ Eskelinen 2006 did not provide an average length of follow-up for study participants.

§ Not all studies listed specific numbers for diagnosis.

searched to identify additional studies. The search was restricted to English language studies.

Selection Criteria

Inclusion criteria for studies were established a priori. Studies were included in the systematic review if they met each of the following: (i) study design was a randomized controlled trial or observational, (ii) study participants were young adults (mean age, <55 years) undergoing THA with modern cementless components or hip resurfacing arthroplasty (HRA), (iii) the study either compared THA and HRA groups or reported on a single cohort of either THA or HRA patients, and (iv) study reported at least one of the predefined primary end points of femoral failure due to any reason, femoral failure due to revision, and femoral failure due to mechanical reasons.

Validity Assessment

Methodological quality assessment was performed by a single reviewer by assigning nonrandomized studies a Methodological Index for NonRandomized Studies score.

Data Abstraction

All variables intended for data abstraction were established a priori and included the following: baseline participant demographics, interventions (THA and HRA information), and outcome variables. Two reviewers independently abstracted outcome data from the included studies, and disagreements were solved through consensus. The remaining variables were extracted by a single reviewer.

Analysis

Event and survival rates were respectively calculated and recorded from included studies. Where possible, rates from single-arm THA or HRA studies were pooled, and forest plots were constructed. Pooled rates were displayed with their respective 95% confidence intervals (CIs). For comparison studies, odds ratios (ORs) and 95% CIs were calculated for dichotomous end points. Where possible,

Table 2. Total Hip Arthroplasty Studies Included in Meta-Analysis

Author	Journal (y)	Average Follow-Up	Average age (y)	No. of Hips
Aldinger et al [8]	Acta Orthop Scan (2003)	12 y	47	154
Capello et al [9]	J Bone Joint Surg (2003)	11.2 y	39	111
Chiu et al [10]	J Arthroplasty (2001)	7.6 y	33	61
D'Antonio et al [11]	Clin Orthop (1997)	6.8 y	38.4	155
Dowdy et al [12]	J Arthroplasty (1997)	5.3 y	42	41
Ellison et al [13]	J Arthroplasty (2006)	92.6 mo	34.7	249
Eskelinen et al [14]	Acta Orthop Scan (2006)	10 y	<55	5607
Fye et al [15]	J Arthroplasty (1998)	84 mo	37	72
Giannikas et al [16]	J Arthroplasty (2002)	4.8 y	55	71
Glassman et al [17]	Orth Tran (1996)	8 y	39.1	242
Jacobsen et al [18]	Acta Orthop Scan (2003)	7.6 y	50	97
Kearns et al [19]	Clin Orthop (2006)	8.4 y	41.1	299
Kim et al [20]	J Bone Joint Surg (2004)	7 y	37	68
Kim et al [21]	J Bone Joint Surg (2003)	9.8 y	46.8	118
Kronick et al [22]	Clin Orthop (1997)	8.3 y	37.6	174
McAuley et al [23]	Clin Orthop (2004)	6.92 y	40	561
McLaughlin et al [24]	Clin Ortho (2000)	10.2 y	37	100
Migaud et al [24]	J Arthroplasty (2004)	68.7 mo	39.8	78
Nercessian et al [25]	J Arthroplasty (2001)	10.5 y	48.3	52
Olcott et al [26]	Orth Tran (1996)	12.5 y	48	46
Petsatodes et al [27]	J Arthroplasty (2005)	13.5 y	47.5	205
Piston et al [28]	J Bone Joint Surg (1994)	7.5 y	32	35

Table 3. Hip Resurfacing Studies Included in Meta-analysis

Author	Journal (y)	Average Follow-Up	Average Age	No. of Hips
Amstutz et al [29]	J Bone Joint Surg (2004)	3.5 y	48.2	400
Amstutz et al [30]	Ortho Clin N Am (2005)	4.7 y	38.1	25
Amstutz et al [31]	J Bone Joint Surg (2007)	6 y	43.7	59
Beaule et al [48]	Clin Orthop (2004)	3 y	34.2	94
Beaule et al [32]	J Arthroplasty (2004)	8.7 y	47.5	42
Daniel et al [33]	J Bone Joint Surg (2004)	3.3 y	48.3	446
De Smet et al [34]	Orth Clin N Am (2005)	2.8 y	49.7	252
Hing et al [50]	J Bone Joint Surg (2007)	5 y	52.1	230
Lilikakis et al [35]	Ortho Clin N Am (2005)	28.5 mo	51.5	70
Mont et al [36]	J Bone Joint Surg (2006)	38 mo	40	42
Revell et al [37]	J Bone Joint Surg (2006)	6.1 y	43	73
Schmalzried et al [38]	Clin Orthop (1996)	16 mo	42	21
Siebel et al [39]	J Mech Eng (2006)	202 d	56.8	300
Steffen et al [40]	J Bone Joint Surg (2008)	4.2 y	51.8	610
Treacy et al [41]	J Bone Joint Surg (2005)	24 mo	52.1	144

ORs were summarized using common ORs and their respective 95% CIs.

For each end point, the results of both the fixed and random effect models were displayed to provide opportunity to interpret the results of both models. Comprehensive Meta-analysis (version 2.0) software (Biostat, Englewood, NJ) was used to perform all statistical analyses.

Results

Baseline summary characteristics of all studies included in the meta-analysis are listed in Table 1. Twenty-two studies evaluating THA with a modern cementless femoral components in young patients were identified using the aforementioned search criteria. There were 5907 patients (6408 hips) with a mean average age of 41.4 years (range, 32-55.4 years). The mean average follow-up across all studies was 8.5 years (range, 4.8-13.5 years). Table 2 lists the studies included in the meta-analysis for THA.

Fifteen studies evaluating hip resurfacing were identified using the aforementioned search criteria. There were 3002 patients (3269 hips) with a mean average age of 46.6 years (range, 34.2-56.8 years). The mean average follow-up across all studies was 3.9 years (range, 0.56-8.7 years). Table 3 lists studies included in the meta-analysis for hip resurfacing. Table 4 lists the components evaluated in the meta-analysis for THA and HRA. All THA femoral components were cementless designs. All hip resurfacing components were of the hybrid type, with a cementless acetabular component and a cemented femoral component.

Table 4. Hip Resurfacing and Femoral Component (THA) Used in Studies

Hip Resurfacing Implant (Manufacturer)	Femoral Implant Hip Arthroplasty (Manufacturer)
ASR (Depuy, Warsaw, IN)	ABG (Stryker)
Birmingham (Smith and Nephew, Memphis, TN)	AML (Depuy)
Conserve (Wright Medical, Arlington, TN)	Autophor 900 (Osteo AG, Selzach, Switzerland)
Corin (Corin Medical, Cirencester, UK)	Bi-Metric (Biomet, Warsaw, IN)
Cormet (Stryker, Malwah, NJ)	CLS (Sulzer)
Durom (Zimmer, Warsaw, IN)	Mallory-Head (Biomet)
McMinn (Corin Medical)	Omnifit (Stryker)
Wagner (Sulzer, Hampshire, UK)	Profile (Depuy)
	SROM (Depuy)
	Taperloc (Biomet)
	Zweymuller (Sulzer)

Pooled Failure Rates

Table 5 lists the pooled failure rates for those studies reporting overall failure for any reason (revision + radiographic failure) for modern cementless THA (n = 19) and HRA (n = 13). Table 6 lists the acetabular failure rate for those studies reporting overall acetabular failure rate using failure for any reason (revision + radiographic failure) for modern cementless THA (n = 21) and HRA (n = 15).

The pooled failure rates of the femoral component in both THA and hip resurfacing with various end points are listed in Table 7. The pooled failure rate of the femoral component in THA using revision of the femoral component for any reason (aseptic loosening, infection, dislocation, fracture, osteolysis, and others) was 3.1% (95% CI, 2.7%-3.7%) at a mean average follow-up of 8.4 years. The pooled failure rate of the femoral component in hip resurfacing using revision of the femoral component for any reason (aseptic loosening, infection, dislocation, fracture, and others) was 2.7% (95% CI, 2.1%-3.5%) at a mean average follow-up of 3.9 years.

Table 5. Overall Failure Rates

		HRA		THA	
End point	MA Model	n	% (95% CI)	n	% (95% CI)
Overall failure rate	Fixed	15	4.6 (3.7-5.6)	19	16.1 (14.9-17.3)
	Random	15	3.7 (2.0-6.5)	19	11.6 (7.5-17.4)

MA indicates meta-analysis.

Table 6. Acetabular Failure Rates

End point	MA Model	HRA n	HRA % (95% CI)	THA n	THA % (95% CI)
Cup failure rate due to any reason	Fixed	15	2.8 (2.0-3.9)	21	14.1 (13.1-15.2)
	Random	15	1.4 (0.5-3.4)	21	10.5 (7.0-15.4)

The *mechanical failure rate of the femoral component in THA*, defined as femoral revision for aseptic loosening, was 1.3% (95% CI, 1.0-1.7) at a mean average follow-up of 8.4 years. The *mechanical failure rate of the femoral component in HRA*, defined as femoral revision for aseptic loosening or femoral neck fracture, was 2.6% (95% CI, 2.0-3.4) at a mean average follow-up of 3.9 years.

Proportion of Femoral Component Failures

Femoral component failures requiring revision surgery for any reason accounted for 70.7% (95% CI, 57.9-80.9) of all failures in HRA. In contrast, modern cementless femoral component failures requiring revision surgery for any reason in THA accounted for 14.7% (95% CI, 10.3-20.6) of all failures.

Discussion

The concept of hip resurfacing is not new. In fact, the procedure was first introduced in the 1930s and has spanned several decades of technological advancement [42]. Early results however were poor with unacceptably high rates of wear, osteolysis, and component loosening [43,44]. With the rising success of THA, the use of hip resurfacing diminished substantially in the United States. The advent of newer bearing surfaces, better fixation options, and improved surgical techniques have led to a resurgence of hip resurfacing. In Australia, hip resurfacing now represents 7.9% of all hip arthroplasties, and 46% of patients younger than 55 years undergoing arthroplasty in the United Kingdom had a resurfacing [45,46].

Proponents of hip resurfacing often cite poor results of THA in the young patient as justification for hip resurfacing. Many of these studies commonly cited, however, include an older generation of cementless stems, cemented stems, and the use of suboptimal bearing surfaces resulting in high rates of osteolysis and aseptic loosening [3,4]. Callaghan et al [3] reported the result of cemented and hybrid fixation in a group of patient younger than 50 years. The hybrid group had an 18% failure rate of the femoral component and 24% prevalence of radiographic loosening at 5-year to 10-year follow-up. This femoral component was ultimately abandoned due to concerns with surface finish and distal geometry. Interestingly, the cemented Charnley femoral stems in this group had a femoral component failure rate of only 5% at 20 years. Joshi et al [4], however, reported a 51% survivorship at 20 years in young patients (age, <40) with osteoarthritis. Both acetabular and femoral components were cemented.

The results of modern cementless THA in young patients are quite encouraging [8-28,47]. A meta-analysis of cementless femoral component survivorship in young patients (9 studies) in our study was 95% at 12 years. In addition, the mechanical failure rate of the femoral stem is extremely low, 1.3% at a mean average follow-up of 8.4 years. Petsatodes et al [27] reported on the results of 205 hips (195 patients) with an average age of 47 years. Survivorship at 17 years using a fully porous-coated stem was 98% using femoral revision for any reason as an end point. Only 2 stems were revised at 10 years for aseptic loosening. Ellison et al [13] reported on the results of 249 hips (201 patients) with an average age of 34.7 years using a proximally coated femoral component. The survivorship at 15 years using revision of the femoral component for aseptic loosening was 99.2%.

Presently, there are no long-term data available on the current designs of hip resurfacing. The short to intermediate-term data that are available, while as whole show acceptable results, is concerning the femoral component. In reviewing 15 current studies available on hip resurfacing, the overall pooled failure rate is low (4.6%) [29-41,48,49]. The femoral component failure rate was 2.7% at 3.9 years; however, it accounted for 70% of all the failures in resurfacing arthroplasty. The most common reasons are femoral neck fracture and aseptic loosening of the femoral component.

The 2007 Australian registry reports a cumulative percentage of revision rate for hip resurfacing of 3.8% [46]. For patients younger than 55 years, this 5-year cumulative revision rate was 2.8%. In comparison, the

Table 7. Femoral Failure Rates

End point	MA Model	HRA n	HRA % (95% CI)	THA n	THA % (95% CI)
Femoral failure rate due to revision surgery	Fixed	15	2.7 (2.1-3.5)	22	3.1* (2.7-3.7)
	Random	15	2.7 (1.8-4.0)	22	2.7* (2.1-3.5)
Femoral failure rate due to any reason (including radiographic failure)	Fixed	15	2.8 (2.1-3.5)	22	3.4* (2.9-4.0)
	Random	15	2.8 (2.0-4.0)	22	3.2* (2.4-4.2)
Femoral failure due to mechanical failure requiring revision surgery	Fixed	15	2.6 (2.0-3.4)	20	1.3* (1.0-1.7)
	Random	15	2.4 (1.5-3.8)	20	1.3* (1.0-1.7)

* Eskelinen et al [14] recorded femoral failure rates for modern and nonmodern femoral stems. In this analysis, outcomes associated with nonmodern femoral stems were excluded from the pooled femoral failure rate.

cumulative percentage of revision rate for THA (all components, all ages) was 2.8%. For cementless THA in patients younger than 55 years, the 5-year cumulative percentage of revision rate was 3.1%.

Steffen [40] recently reported on the results of 610 hip resurfacings done at an independent center. Overall survivorship at 7 years was 95%. There were 23 failures (3.7%) requiring revision. Of the 23 failures, 13 occurred in the first year after surgery and 57% of failures were on the femoral side. In addition, 30% of patients had radiographic evidence of femoral neck narrowing of uncertain clinical significance. Interestingly, the older age group had improved survivorship compared to a younger cohort of patients. Hing [49] also reported an independent review of their first 230 hip resurfacing. Survivorship for worst case scenario was 97.8% at 5 years. Radiographic review however revealed 6 patients with progressive radiolucent lines around the femoral component, and 18 femoral components (8%) had migrated into varus.

Young patients often require arthroplasty for disease other than primary osteoarthritis. Secondary arthritis due to avascular necrosis and dysplasia are common in this age group. Revell et al [37] and Mont et al [36] in separate studies reported survivorship of 93.2% at 6 years and 94.5% at 41 months, respectively, in group of young patients with avascular necrosis. Amstutz [31] reported a 10% failure rate of hip resurfacing in 59 patients with a diagnosis of dysplasia at 6 years.

With no long-term data available, it is difficult to predict what if any failure mechanisms may develop. Narrowing of the femoral neck has been reported but is of unknown clinical consequence at this point [50]. Beck et al [51] has reported that men lose 18% and women 25% of their bone mineral density in the femoral neck from age 30 to 70. Ritter et al [52] evaluated failure modes of an older generation resurfacing and found that the average time to failure was 9.7 years. All late femoral failures (>10 years) had shown evidence of narrowing of the femoral neck.

Most surgeons would agree that hip resurfacing is technically more demanding than primary THA. The surgeon's learning curve has been shown to be substantial and may require up to 55 to 60 cases to diminish the complications related to surgical technique [7]. The first 537 cases monitored in the Food and Drug Administration post market analysis of the Birmingham hip resurfacing in the United States shows a 7.4% adverse event rate and includes 9 nerve palsies and 9 dislocations. There were 14 reoperations (7.4%) within the first year and 10 for femoral neck fracture [53].

As with any procedure, patient selection is critical to the success of any procedure, and hip resurfacing may be particularly sensitive to patient selection [54]. Beaule et al [48] demonstrated a 12 times greater relative risk of early complications in hip resurfacing in patients in patients with a Surface Arthroplasty Index Score greater than 3. In addition, the ability to alter the biomechanics of the hip joint with regard to leg length and offset are limited with hip resurfacing [55,56]. In such instances, patients may be better optimized with THA.

We have shown in this meta-analysis of modern cementless femoral components a low rate of mechanical failure (1.3% at 8 years) of the femoral component in young patients undergoing THA. The femoral component in hip resurfacing likewise shows a low failure rate (2.7%) but only at short-term follow-up. In addition, many of the total hip studies analyzed implement poor bearing surfaces (non–cross-linked polyethylene) with high rates of osteolysis. The advent of modern bearing surfaces combined with these cementless stem designs is to be hoped to improve on the current results. The strength of this study includes the large number of patients analyzed with surgery performed by multiple surgeons and a variety of implants. Potential limitations are the retrospective review of the study, the limitations of each individual study, and the potential overlap of included patients who could be potentially reported twice in articles by the same author.

There is little doubt that hip resurfacing has an appropriate role in the arthroplasty arena, and the perceived benefits are appealing to both surgeons and patients. The preservation of proximal femoral bone stock in a young patient is advantageous and may yield to a potentially easy conversion to THA when failure occurs [57]. Surgeons and patients however should feel comfortable with the durability of modern cementless femoral component in this patient population. Our meta-analysis data show twice the mechanical failure rate of the femoral component in hip resurfacing with half the follow-up compared to modern cementless femoral components in THA. We believe that modern cementless femoral components should be used as the benchmark for comparison in hip resurfacing. Longer follow-up of resurfacing and prospective direct comparison trials are required to confirm these findings.

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