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SYMPOSIUM: ABJS CARL T. BRIGHTON WORKSHOP ON IMPLANT WEAR AND TRIBOCORROSION OF TOTAL JOINT REPLACEMENTS

How Have Alternative Bearings and Modularity Affected Revision Rates in Total Hip Arthroplasty?

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Abstract

Background Total hip arthroplasty (THA) continues to be one of the most successful surgical procedures in the medical field. However, over the last two decades, the use of modularity and alternative bearings in THA has become routine. Given the known problems associated with hard-on-hard bearing couples, including taper failures with more modular stem designs, local and systemic effects from metal-on-metal bearings, and fractures with ceramic-on-ceramic bearings, it is not known whether in aggregate the survivorship of these implants is better or worse than the metal-on-polyethylene bearings that they sought to replace.

Questions/purposes Have alternative bearings (metal-on-metal and ceramic-on-ceramic) and implant modularity decreased revision rates of primary THAs?

Methods In this systematic review of MEDLINE and EMBASE, we used several Boolean search strings for each topic and surveyed national registry data from English-speaking countries. Clinical research (Level IV or higher) with $\geq$ 5 years of followup was included; retrieval studies and case reports were excluded. We included registry data at $\geq$ 7 years followup. A total of 32 studies (and five registry reports) on metal-on-metal, 19 studies (and five registry reports) on ceramic-on-ceramic, and 20 studies (and one registry report) on modular stem designs met inclusion criteria and were evaluated in detail. Insufficient data were available on metal-on-ceramic and ceramic-on-metal implants, and monoblock acetabular designs were evaluated in another recent systematic review so these were not evaluated here.

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Results There was no evidence in the literature that alternative bearings (either metal-on-metal or ceramic-on-ceramic) in THA have decreased revision rates. Registry data, however, showed that large head metal-on-metal implants have lower 7- to 10-year survivorship than do standard bearings. In THA, modular exchangeable femoral neck implants had a lower 10-year survival rate in both literature reviews and in registry data compared with combined registry primary THA implant survivorship.
Conclusions Despite improvements in implant technology, there is no evidence that alternative bearings or modularity have resulted in decreased THA revision rates after 5 years. In fact, both large head metal-on-metal THA and added modularity may well lower survivorship and should only be used in select cases in which the mission cannot be achieved without it. Based on this experience, followup and/or postmarket surveillance studies should have a duration of at least 5 years before introducing new alternative bearings or modularity on a widespread scale.

Introduction

Over the last decade, the increased activity demands of patients and a younger age at the time of the primary procedure have sparked the development of alternative bearing surfaces in hip arthroplasty (here defined as bearings that replaced the polyethylene counterface) with the goal of addressing lower reported survivorships in younger, more active patient populations [10, 21, 33, 34, 38, 40, 41]. However, some metal-on-metal (MoM) THA designs have been associated with premature revisions related to acute local reactions and high systemic metal ion levels, and reports of ceramic component breakage and squeaking have raised questions about the cost-benefit balance with those implants as well [10, 16, 32, 33, 36, 38, 50, 52, 60, 66, 69, 77].

The use of modular components for THA, available since the late 1970s, has become increasingly popular and has expanded into modular exchangeable femoral necks and proximal implant bodies. These implants seek to improve the fit of the implant to each patient's specific anatomy in hopes of recreating the anatomical center of the hip in all three planes with the goal of improving implant performance and longevity [1, 6, 17, 24, 27, 35]. These implants also seek to allow surgeons to have more options for easier reconstruction of patients with complex deformities and difficult revisions that involve bone loss and/or deformity. These marketed advantages have, however, come with increased risks and complications [4, 15, 27, 44, 70]. Unfortunately, adding another metal taper junction may increase the burden of corrosion debris and the risk of local tissue reactions as well as serve as a possible weak link that can increase the risk of a catastrophic failure [4, 15, 27, 44, 70]. As with any additional technological advancement in implant designs, both alternative bearings and increased modularity add cost to the implants in most cases. It is important to understand whether these cost increases are associated with any results that might affirm the benefit of their use within primary THA.

To determine if alternative bearings or femoral component modularity (using another implant connection other than the head-neck taper connection) have decreased the revision rates after at least 5 years, we undertook a systematic review of clinical research reports and of the national joint registries.

Search Strategy and Criteria

A systematic literature search was done in the MEDLINE and EMBASE databases. "Survivorship" was used as the primary search parameter. Only therapeutic studies published in English, Level IV or better, with at least 5 years of followup were included. Case reports, retrieval studies, animal/basic science studies, and in vitro studies, including those on bearing wear, were excluded. Articles reporting on THA revision, hip resurfacing, and corrosion in modular components also were excluded. The search parameters and Boolean strings were modified multiple times to increase the likelihood that all relevant publications were identified. All bibliographies were searched by hand to determine if other studies that might not have been revealed in the search parameters were available for inclusion. Bibliographies from all qualified citations were queried for additional articles that met inclusion criteria. If any other systematic reviews were found for any search, the timeline for citations to be reviewed was started from this point forward.

Country registry reports were also reviewed for comparison of modular THA revision rates and survivorship if implant types were identified. We included registry data at $\geq$ 7 years of followup. The registry reports reviewed were those of England and Wales, Norway, Sweden, Denmark (if an English version was available), Australia, and New Zealand [1, 56, 59, 62, 76]. The Kaiser Permanente publication database also was reviewed for relevant publications.

Insufficient data were available on alternative polymers (eg, polyetheretherketone [PEEK]), metal-on-ceramic and ceramic-on-metal implants, and monoblock acetabular designs, which were evaluated in other recent systematic reviews [31, 83], so these were not evaluated here. Study quality was specified by listing the level of evidence for each of the studies included in the systematic review.

Table 1. Reported survival rates for metal-on-metal THA

Study (year)	Level of evidence	Number of hips (number of patients)	Sex: percent female	Bearing (manufacturer)*	Diameter (mm)	Implantation timeframe	Mean patient age (range) (years)	Mean followup (range) (years)	Survival
Dorr et al. (2000) [23]	IV	56 (56)	43%	Metasul (Zimmer)	28 (66), 32 (4)	1991–1994	70 (35–85)	5.2 (4–6.8)	94% at 7 years
Brown et al. (2002) [11]	IV	123 (101)	62%	McKee-Farrar (Howmedica)		1969–1973	(29–87 F 27–74 M)	12.7 (approximately) (0–28)	84% at 20 years
Long et al. (2004) [51]	IV	161 (154)	38%	Metasul (Zimmer)	28	1995–2002 (clinical evaluation)	55.5 (27–83)	6.5 (2–9)	96% at 7 years followup
Migaud et al. (2004) [54]	IV	30 (39)	13%	Metasul (Zimmer)	28	1995–1998	39.8 (23–49)	> 5	100% at 5 years
Korovessis et al. (2006) [43]	IV	217 (194)	74%	Sikomet SM21 (POA)	28	1994–1999	55 (25–70)	6.4 (5–9.3)	Cup: 97% at 9 years; stem: 92% at 9 years
Milosev et al. (2006) [55]	IV	640 (591)		Sikomet SM21 (POA)	28	1994–2002		7.1	91% at 10 years
Saito et al. (2006) [67]	IV	106 (90)	86%	Metasul (Zimmer)	28	1996–2004	57.8 (42–79)	6.4 (5–8)	99% at 6 years
Grübl et al. (2007) [30]	IV	105 (98)	55%	Metasul (Zimmer)	28	1992–1994	56 (22–79)	(≥ 10)	99% at 10 years
Vassan et al. (2007) [82]	IV	112 (94)	61%	Metasul (Zimmer)	28	1994–2000	56 (21–79)	7 (5–13)	82% at 10 years
Dastane et al. (2008) [18]	III	112 (107)	27%	Metasul (Zimmer)	28	1991–2003	(≤ 60)	5.5 (2.2–11.7)	95% at 5.5 years mean followup
Delaunay et al. (2008) [21]	IV	83 (73)	21%	Metasul (Zimmer)	28	1995–2004	40.7 (23–49)	7.3 (2–10.4)	100% at 10 years
Eswaramoorthy et al. (2008) [26]	IV	85 (82)		Metasul (Zimmer)	28	1995–1997	61.6 (44–84)	10.8 (10.2–12.2)	93% at 10 years
Beldame et al. (2009) [3]	IV	94 (85)	42%	Metasul (Zimmer)	28	1999–2002	59.2	6.4 (4.3–9.3)	Cups: 96% at > 6 years; stems: 95% at > 6 years
Descamps et al. (2009) [22]	IV	107 (101)		Metasul (Zimmer)	28	1997–1999	61.3 (31–89)	5.5 (5–7)	95% at 5 years
Lazennec et al. (2009) [47]	IV	134 (109)		Metasul (Zimmer)	28			9 (7–11)	91% at 9 years for cup
Zijlstra et al. (2009) [86]	I / II	102		Stanmore M2a (Biomet)	28		72 (7 SD)		97% at 5 years
Engh et al. (2010) [25]	IV	1327 (1164)		Pinnacle (96.5%) and ASR (3.5%) Ultamet (DePuy)	36 starting in 2001 40, 44 starting in 2006		55 (17–81)	2.6 (0–8)	94% at 8 years

Table 1. continued

Study (year)	Level of evidence	Number of hips (number of patients)	Sex: percent female	Bearing (manufacturer)*	Diameter (mm)	Implantation timeframe	Mean patient age (range) (years)	Mean followup (range) (years)	Survival
Girard et al. (2010) [28]	IV	47 (34)	34%	Metasul (Zimmer)	28 (42), 32 (5)	1995–2003	25 (15–30)	9 (5.2–12.8)	95% at 10 years
Neumann et al. (2010) [58]	IV	100 (99)	44%	Lubrimet (S&N-RS)	32	1995–1996	56.7 (36–75)	10.5 (10–11.9)	93% at 12 years
Zijlstra et al. (2010) [87]	IV	102	79%	Stanmore M2a (Biomet)	28	1998–1999	72 (7 SD)	10.1 (9.1–10.7)	95.5% at 10 years
Bolland et al. (2011) [9]	IV	199*	59%	BHR Cup (S&N-UK) with MMT Head	38–58, 46.0 median	2002–2007	58.1 (29–77)	5.2 (2.7–6.9)	92% at 5 years
Girard et al. (2011) [29]	IV	23 (22)	73%	Metasul (Zimmer)	28	1998–2003	44 (24–56)	6.1 (5–10)	96% at 6 years
Hwang et al. (2011) [34]	IV	78 (70)	19%	Metasul (Zimmer)	28	1994–1997	39.8 (19–50)	12.4 (11–14)	99% at 12 years (inferred using mean followup)
Nikolaou et al. (2011) [61]	IV	193 (166)	46%	Metasul (Zimmer)	26 (1), 28 (177), 36 (15)	1997–2003	50 (18–65)	7 (5–11)	98% at 11 years
Yoon et al. (2011) [85]	IV	37 (36)	56%	Transcend (Wright Medical)	28–36, 32.9 mean	1997–2000	56.9 (25.5–73.5)	8.9 (0.1–12.8)	94% at 10 years
Bernstein et al. (2012) [5]	IV	163		Metasul (Zimmer)	28	1997–2003		8.9 (7–13)	91% at 9 years, 97.5% at 9 years†
Kindsfater et al. (2012) [42]	IV	95 (95)	40%	Pinnacle Ultamet (DePuy)	36 (92), 28 (3)	2001–2003	53.5 (34–70)	6	98% at 7 years
Neuerburg et al. (2012) [57]	IV	1270 (1121)	43%	Metasul (Zimmer)	28	1994–2004	61 (21–83)	6.7 (2–13)	90% at 10 years
Randelli et al. (2012) [64]	IV	149 (111)	74%	Metasul (Zimmer)	28	1993–1996	50 (19–74)	13 (11.2–14.1)	94% at 10 years
Chang et al. (2013) [13]	IV	74 (52)	40%	Metasul (Zimmer)	28	1995–2006	42.1 (25–62)	10.2	97% at 16 years
Liudahl et al. (2013) [49]	IV	169 (148)	43%	Pinnacle Ultamet (DePuy)	< 36 (5), 36 (164)	2002–2006	51.6 (25.4–69.7)	4.7 (3–8.51)	99% at 5 years
Repantis et al. (2013) [65]	IV	203 (181)		Sikomet SM21 (S&N-RS)	28				Cup: 80% at 15 years; stem: 77% at 15 years

* Biomet = Biomet, Warsaw, IN, USA; DePuy = DePuy, Inc, Warsaw, IN, USA; Howmedica = Howmedica, Inc, Rutherford, NJ, USA; MMT = Midland Medical Technologies (MMT) Ltd, Birmingham, UK; POA = Plus Orthopedics Ag, Rotkreuz, Switzerland; S&N-UK = Smith & Nephew, Warwick, UK; S&N-RS = Smith & Nephew, Rotkreuz, Switzerland; Wright Medical = Wright Medical Technology, Arlington, TN, USA; Zimmer = Zimmer GMBH, Winterthur, Switzerland; †excluding hips revised for a manufacturer's defect.

Table 2. Reported survival rates for ceramic-on-ceramic THA

Study (year)	Level of evidence	Number of hips (number of patients)	Sex: percent female	Device: cup/stem (manufacturer)*	Diameter (mm)	Implantation timeframe	Mean patient age (range) (years)	Mean followup (range) (years)	Survival
Bizot et al. (2000) [7]	IV	128 (104)	43%	Cerapress, Cerafit/(CO)	32	1978–1994	32 (17–40)	8 (0–19)	84% at 10 years; 80% at 15 years
Hasegawa et al. (2006) [32]	IV	35 (30)	100%	Ti-PE-Alumina/Perfix HA (Kyocera)	28	1999–2000	63 (45–86)	6 (5–6.5)	83% at 6 years
Seyler et al. (2006) [69]	III	79 (70)	23%	ABC, Trident/Omnifit (Stryker)		1996–1999	45 (21–67)	4.2 (0.7–8)	95.5% at 7 years
Seyler et al. (2006) [69]	III	79 (76)	22%	ABC, Trident/Omnifit (Stryker)		1996–1999	46.5 (30–67)	5 (1–8)	89% at 7 years
Boyer et al. (2010) [10]	IV	83 (76)		Cerafit/Ti Osteal, Multicone (CO)	32	1993–2003	(< 50)	10 (7–15)	92% at 10 years
Kim et al. (2010) [41]	IV	93 (64)	14%	Duraloc/IPS (DePuy)	28		38 (24–45)	11 (10–13)	99% at 11 years
Lombardi et al. (2010) [50]	II	65	45%	PPS RingLoc/PPS Mallory-Head (Biomet)	28, 32	2000 onwards	57 (33–76)	6 (2–9)	95% at 6 years
Petsatodis et al. (2010) [63]	IV	109 (100)		Autophor 900-S (Osteo)	38	1985–1989	46 (19–60)	21 (20–24)	84% at 21years
Hsu et al. (2011) [33]	IV	82 (64)	34%	Transcend/Perfecta System (Wright Medical)		1997–2000		10 (10–12)	96% at 10 years
Kusaba et al. (2011) [45]	IV	458 (400)	98%	Spongiosa Metal II (S&N-RS)	28	1998–2009	57 (27–82)	7 (5–11)	100% at 5 years; 98% at 10 years;
Mesko et al. (2011) [53]	I	930 (848)	34%	ABC, Trident (Stryker)	28 (79), 32 (699), 36 (152)	1996–2000 (enrollment)	51 (± 11)	6	97% at 10 years
Steppacher et al. (2011) [72]	IV	350 (305)	40%	Transcend (Wright)/Multiple Brands	28 (102) 32 (240) 36 (8)	1997–2009	42 (17–50)	7 (2–14)	97% at 10 years
D'Antonio et al. (2012) [16]	I	73	33%	ABC Ti Porous Coated/Omnifit (Stryker)	28, 32 (89%)	1996 onwards	55 (30–73)	10 (10–12)	98% at 10 years
D'Antonio et al. (2012) [16]	I	71	28%	ABC Ti Arc-Deposited/ Omnifit (Stryker)	28, 32 (91%)	1996 onwards	55 (26–75)	10 (10–12)	95% at 10 years
Daurka et al. (2012) [19]	III	23		Furlong CSF (JRI), Duraloc (DePuy), Pinnacle (Depuy)/ Furlong HAC (JRI), S-ROM (DePuy)	28 (15), 32 (8)	1995–2005	14 (< 16)	8.5 (6–13)	100% at 8.5 years
Sugano et al. (2012) [74]	IV	100 (87)	87%	AnCa THS (Cremascoli)	28	1996–1998	56 (41–73)	12 (11–14)	96% at 14 years
Synder et al. (2012) [77]	IV	220 (188)	54%	Mittelmeier (S&N)	32	1985–1999	44.5 (20–70)	20 (12–27)	86% at 12 years

Table 2. continued

Study (year)	Level of evidence	Number of hips (number of patients)	Sex: percent female	Device: cup/stem (manufacturer)*	Diameter (mm)	Implantation timeframe	Mean patient age (range) (years)	Mean followup (range) (years)	Survival
Yeung et al. (2012) [84]	IV	301 (283)	51%	ABC/Secur-Fit (Stryker)	32 (278) 28 (23)	1997–1999	58 (20–76)	11 (10–13)	98% at 10 years
Jack et al. (2013) [36]	IV	165 (161)	53%	Osteonics Metal Shell (Stryker), Trident (Stryker), Trilogy (Zimmer), etc/ABG, S-Rom, etc	28 (4), 32 (131), 36 (30)		65.5 (29–89)	5 (2–12.5)	91% at 8 years
Jameson et al. (2013) [37]	IV	5831		Trident/Exeter V40 (Stryker)		2003–2010	($\leq$ 75)		98 at 5 years followup
Kawano et al. (2013) [39]	IV	270 (229)	92%	ABS/AMS-HA (Kyocera)	28	1998–2000	60 (24–86)	11 (11–13)	68% at 11 years

* Biomet = Biomet, Inc., Warsaw, IN, USA; CO = Ceraver-Osteal, Roissy, France; DePuy = DePuy Orthopaedics, Inc, Warsaw, IN, USA; S&N-US = Smith & Nephew, Memphis, TN, USA; S&N-RS = Smith & Nephew, Rotkreuz, Switzerland; Stryker = Stryker Orthopaedic, Mahwah, NJ, USA; Wright Medical = Wright Medical Technology, Arlington, TN, USA; Z-USA = Zimmer, Inc, Warsaw, IN, USA; Kyocera = Kyocera, Kyoto, Japan; Osteo = Osteo, Selzach, Switzerland; Cremascoli = Cremascoli, Milan, Italy.

Alternative Bearing Search Criteria

The search was performed using a Boolean string containing the following search terms: hip, prosthesis (arthroplasty, replacement), survival (survivorship, longevity, endurance, durability, performance), joint (bearing, articulation), and alternative (metal-on-metal, metal/metal, all-metal, all-ceramic, ceramic-on-ceramic, ceramic/ceramic, ceramic/metal, polyetheretherketone, PEEK, carbon fiber). The principal search terms were connected with "AND", whereas the terms in parentheses were used interchangeably with the principal term and connected with "OR". The search was confined to clinical trial articles published from January 1998 through October 2013, resulting in a total of 776 articles. All of the abstracts for these articles were reviewed and 148 were identified as duplicates between MEDLINE and EMBASE. The remaining 628 abstracts were then filtered according to the inclusion criteria described previously, leading to the elimination of 577 and leaving 51 articles for review. Of these, 32 papers reported on MoM THA and 19 on ceramic-on-ceramic THA. Most of the included articles were of Level IV evidence. In the MoM group, there were only two reports with Level I to II evidence [86, 87] and one report with Level III evidence [18]. In the ceramic-on-ceramic group, there were two reports with Level I evidence [16, 53], one report with Level II evidence [50], and two reports with Level III evidence [19, 69] (Tables 1 and 2).

Modularity Search Criteria

For THA, modularity of the femoral stem was defined as a design that included a second modular junction outside the head-neck taper connection. All combinations of the following terms were searched: hip, arthroplasty (or replacement), modular (resulting in 746 citations when "arthroplasty" was used and 635 when "replacement" was used in the search string) as well as taper (64 citations) and monoblock (29 citations). No study involving retrieval analysis or metal ion levels was included. Twenty reports on dual modular femoral components in the literature met inclusion criteria [4, 6, 8, 12, 17, 19, 20, 24, 35, 40, 44, 48, 68, 71, 73, 75, 78–81]. The levels of evidence for these articles that met inclusion criteria were: Level I (zero), Level II (four), Level III (four), and Level IV (twelve).

For exclusion criteria, no metal ion or retrieval studies or case reports were included. Dual mobility acetabular components were not included in the analysis because their second articulating junction may increase wear but are associated with other complications not specific to fixed-bearing acetabular components. After applying these search parameters and inclusion/exclusion criteria, we ended up with 20 publications and one registry report.

Results

Alternative Bearings: Metal-on-metal

For all combined THA types of implants, cumulative revision rate at 10 years listed in the Australian registry had a 95% confidence interval that ranged from 2% to 14% for femoral stems, from 3% to 100% for acetabular components, and from 2% to 10% for combinations with an overall THA revision rate of 6%. Values for the overall THA revision at 10 years ranged from 4% to 6% for all registries reviewed [1, 56, 59, 62, 76]. These combined results are used for comparison of the alternative bearing and modularity data subsequently.

The reported survival rates at 5 years ranged from 92.4% to 100%, whereas the 10-year survival rates ranged from 82% to 100% (Table 1). Because all but one [86, 87] of the studies were retrospective (Table 1), no meta-analysis or any other type of statistical analysis that pooled the data was performed, and therefore no trends could be established. In the only reported randomized controlled trial [86, 87], cemented Stanmore 28 mm MoM THAs (Biomet Inc, Warsaw, IN, USA) were not found to be superior to their metal-on-polyethylene counterparts with 10-year survival rates of 95.5% (Table 1) and 96.8%, respectively ($p = 0.402$) [87].

By contrast, the Australian registry documented a cumulative MoM revision rate of 9.6% (lower and upper boundary of 95% confidence interval [CI], 9.2%–10.1%) at 5 years and 15.5% (14.8–16.3) at 10 years for prostheses with fixed femoral necks [1]. This was the highest rate of revision of all investigated bearing types in the registry. Such data are mirrored in the UK registry, in which MoM performed much worse than any other bearing type [56]. Revision rates of uncemented MoM THAs were reported as high as 7.7% (7.3–8.0) at 5 years and 17.7% (15.9–19.6) at 9 years and were only marginally better with hybrid fixation [56]. The New Zealand registry differs in that it reported unsatisfactory results for only 36-mm diameter bearings and larger [59]. Thus, for uncemented cups with a liner having a small bearing diameter ($\leq$ 28 mm), MoM couples had lower revision rates per 100 component years than ceramic-on-ceramic, ceramic-on-polyethylene, and metal-on-polyethylene couples ($p \leq 0.05$). The influence of MoM head size on revision rate has also been documented in a recent supplementary report of the Australian registry, where head sizes of $\leq$ 28 mm produced smaller cumulative revision rates of 3.7% (3.1%–4.5%) and 5.7% (4.8%–6.6%) at 5 and 10 years, respectively [2]. These revision rates are better than those for conventional polyethylene bearings (7.7% [7.2%–8.3%] at 10 years) but slightly worse than those paired with crosslinked polyethylene (4.5% [4.3%–4.8%] at 10 years).

Alternative Bearings: Ceramic-on-ceramic

The reported survival rates at 5 years ranged from 98.3% [37] to 100% [45] and at 10 years from 83.9% [7] to 100% [45] (Table 2). Of the three prospective comparative studies (Level I or II) that were retrieved, one found the ceramic-on-ceramic (CoC) and control hard-on-polyethylene THA had comparable survivorship, whereas two found the CoC had greater survivorship. Thus, Lombardi et al. [50] determined a survivorship at 6 years of 95% for CoC bearing versus 93% for the ceramic-on-polyethylene bearing ($p = 0.44$). The CoC bearing couple entailed a Biolox Delta head articulating against a Biolox Forte cup (CeramTec GmbH, Plochingen, Germany), whereas the control couples consisted of a zirconia head articulating against a highly crosslinked polyethylene liner (ArCom; Biomet Inc, Warsaw, IN, USA). On the other hand, Mesko et al. [53] recorded survival rates at 10 years of 96.8% for the alumina-alumina bearing THA (ABC and Trident; Stryker Orthopaedic, Mahwah, NJ, USA) versus 92.1% for the control CoCrMo-polyethylene, which were significantly different ($p = 0.0017$). D'Antonio et al. [16] found survivorships at 10 years of 97.9% and 95.2% for two alumina-on-alumina THAs ("System I" and "System II") versus 91.3% for the control conventional polyethylene (gamma-sterilized in an inert atmosphere) articulating against a CoCrMo head ("System III"). The difference among the three systems was significantly different ($p = 0.027$, no pairwise comparison of the groups was provided). The authors determined that the risk of revision relative to the metal-on-polyethylene control THA was 0.183 for System I and 0.394 for System II [16].

Based on the registry data, CoC bearings performed as well as or better than conventional polyethylene-on-metal and as well as highly crosslinked polyethylene against metal or ceramics. For prostheses with a fixed femoral neck, the Australian registry documented a cumulative revision rate of 2.9% (2.8%–3.1%) and 4.8% (4.5%–5.2%) at 5 and 10 years, respectively [1]. This is similar to a bearing with crosslinked polyethylene (4.5% [4.3%–4.8%] when paired with metal and 5.1% [4.5%–5.8%] when paired with ceramic at 10 years). The UK registry [56] documents low revision rates for CoC, which in the case of hybrid fixation (2.3% [1.8%–3.0%] at 9 years) rival those of the front runner: all cemented/ceramic versus polyethylene (1.8% [1.5%–2.2%] at 9 years). The New Zealand registry [59] also reported overall low

Table 3. Registry data concerning modular and nonmodular total hip revision rates

Source	Implant type	Average followup (years)	Cumulative revision rate (%)
Australian Orthopaedic Association National Joint Replacement Registry [1]	All THA	10	6
	EXN THA	7	8.9
	FN THA	7	4
Swedish Hip Register [76]	All THA	10	7
New Zealand Joint Registry [59]	All THA	10	7
National Joint Registry for England, Wales and Northern Ireland [56]	All THA	8	4
Norwegian Arthroplasty Registry [62]	All THA	10	5.5
Literature	Modular femoral stem	10	0–9
Literature	SROM	12	0–6.7

EXN = exchangeable modular femoral neck; FN = fixed femoral neck; MBA = monoblock acetabulum; XX = New Zealand reported on three monoblock cups paired with three different femoral components with 238 cases and 12 reported revisions over an average of 371 observed component years and a 0.98 revision rate/100 component years (the Danish hip registry was not available in English).

revision rates for CoC, except for head sizes ≤ 28 mm, in which the CoC articulation showed significantly ($p \leq 0.05$) higher revision rates when compared with bearing types with polyethylene.

Modular Femoral Components in THA

In the literature, the survivorship for exchangeable modular necks was similar to overall reported survivorship from registry data but one registry reported a higher revision rate for all exchangeable modular femoral neck prostheses [1]. This increased frequency of revision with exchangeable neck prostheses occurred with all bearing surfaces in the Australian Registry (Table 3). Twelve studies reported on various types of modular femoral neck and stem components with a range of survivorship from 91% to 100% with a range of followup of 8.6 and 5 years, respectively [4, 8, 17, 19, 20, 35, 44, 68, 73, 79–81]. Eight reports dealing specifically with the S-ROM modular stem/body (DePuy Orthopaedics Inc, Warsaw, IN, USA) reported a range of survivorships for aseptic loosening of 93.3% to 100% with a range of followup of 19 years and 10 years, respectively [6, 12, 24, 40, 48, 71, 75, 78]. One report for an SROM type of stem reported an 84% survivorship when revision for any reason was considered at an average of 17 years [48].

The Australian registry compared 6659 THAs performed with femoral stems with exchangeable necks with 166,932 THAs performed with fixed-neck stems and found a cumulative percent revision at 7 years of 8.9% (95% CI, 7.9%–10.1%) for exchangeable neck prostheses compared with 4.2% (95% CI, 4.1%–4.3%) for fixed stems [1].

Discussion

Every year, healthcare costs are increasing in the United States and, therefore, a critical evaluation of their impact on patient care should be routine. Although THA continues to be one of the most successful operations in orthopaedic surgery, we continue to introduce new technologies with the aim to further improve survivorship and implant performance, especially in younger patients, who are having the procedure in increasing numbers. In general, the use of both modularity and alternative bearings increases implant costs. With questions being raised concerning corrosion of modular taper junctions and use of some hard-on-hard bearings increasing the risk of complications, we sought to answer the question of whether either of these implant design features has produced improvements in the survivorship or risk of revision at 5 years or longer after the index procedure [9, 10, 15, 16, 22, 25, 27, 32, 33, 36, 42, 46, 50, 52, 60, 69, 77]. In general, both alternative bearings and modularity showed no evidence of improvements in survivorship in either the literature or registry reports.

This study had a number of limitations. First, the study quality was low but this was strengthened by including registry data where available. It must be realized that many other variables are considered within registry data and within the literature reports that were reviewed. The reporting within many retrospective studies does not take into account patient demographics and risk factors or surgical technique. The literature reviewed also mixes multiple design variables, especially when modularity issues are compared (femoral neck modular connections may be of a different metallic alloy as well as different designs). There also have been unanticipated adverse events that have occurred both with alternative bearings and implants using increased modularity; these were not evaluated in this review, because sufficient detail about reasons for revision often is not provided in published reports nor included in registry data.

The systematic review concerning alternative bearings revealed that small head MoM had similar but large head MoM had inferior results compared with both standard and highly crosslinked polyethylene mated with any hard material. This evidence is solely based on registry data, because there are insufficient data to make such comparisons fairly in the nonregistry study populations. MoM revision rates at 10 years ranged from 0% to 12% in the clinical series studies that we surveyed, whereas in the registries, they ranged from 5.7% (Australian registry [1], small MoM heads) to 17.7% (National Joint Registry of England [56]; aggregate for uncemented prostheses). The fact that we found only one randomized controlled trial that compared MoM with metal-on-polyethylene barred us from performing a meta-analysis between both bearing types. For reference, in a meta-analysis by Clement et al. [14], revision rates for conventional polyethylene bearings ranged from 8% to 18%. The dearth of long-term clinical trials in the literature points to the power of registry data. Because the United States accounts for such a large percentage of the THAs performed, a proper registry with annual reports may have alerted surgeons to the higher revision rates earlier in the case of large head MoM instead of relying on reports from experts and tertiary care centers that reported no differences in survivorship.

In our analysis, CoC had better results than MoM. Our review also found that CoC bearings in general were found to perform better than conventional polyethylene-on-metal but not as well as metal on highly crosslinked polyethylene at 10 years. The benefits of these bearings may be justified but according to the survivorship review we made in this report, its cost may not be justified; this would need to be the focus of future studies, because we did not specifically evaluate costs here.

According to all registry reports, THA modular necks had lower survivorship as did the clinical series that we reviewed for this aspect of modularity [1, 4, 6, 8, 12, 17, 19, 20, 24, 35, 40, 44, 48, 68, 71, 73, 75, 78–81]. Similar survivorships and revision rates were found for modular stem/body and body/neck femoral components, whereas registry data revealed similar results except when these types of stems were paired with a MoM articulating bearing, which was reported to increase revision rates even further [1]. This further begs the question whether a modular taper in a femoral stem that is added along the axis of the diaphysis (ie, a solid stem with a modular body or a solid stem neck with a modular body) creates less fretting and local tissue reactions than a second modular taper added to the neck (ie, exchangeable modular femoral neck implants) resulting from the loading conditions and added bony stability afforded to the modular connection.

In summary, increased modularity of the femoral component appears to have not improved implant revision rates. Registry data show an increase in revision rate for exchangeable femoral neck modular stems. Whether this is the result of implant taper mismatch in the assembly of the added taper junction, implant material or design, or surgical technical errors remains to be established. Based on the experiences reported in this review, there should be a 5-year followup and/or postmarket surveillance studies of at least 5 years before introducing new alternative bearings or modularity in THA on a widespread scale. Surgeons need to consider all aspects of alternative bearings and modularity before using them on a widespread fashion within their practice.

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