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ORIGINAL STUDY

Hip resurfacing requires larger acetabular cups than conventional hip replacement : A comparative analysis of 100 hips, based on radiographic templating

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Acetabular bone loss is a matter for concern in hip resurfacing arthroplasty (HRA), as preservation of the femoral head and neck might demand a larger acetabular cup than in total hip arthroplasty (THA). Using radiographic templating, the cup size required for either THA or HRA was calculated on 100 pelvic films. First, the cup size was determined based on the dimensions of the acetabulum. Then, the cup size for HRA was evaluated taking into account the dimensions of the femoral head/neck.

The average cup size required for HRA was larger than for THA (Δ + 1.1 mm). The cup size for HRA and THA was similar in 49% of hips ; in 51% of the hips the cup required for HRA was larger : one size larger in 31%, two sizes larger in 18% and three sizes larger in 2% of the cases. The greatest difference and highest bone loss were observed for the large sizes (between 52 and 56 mm) and thus predominantly in men (Δ + 1.5 mm male, Δ + 0.7 mm female).

This study shows that HRA requires a larger acetabular cup in more than 50% of the cases compared to THA. When planning HRA surgeons should remember that cup size is determined by the size of the matching femoral component and that size difference with THA increases with increasing hip sizes.

Keywords : hip resurfacing ; total hip arthroplasty ; hip arthroplasty ; acetabulum ; bone loss.

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INTRODUCTION

Hip Resurfacing arthroplasty (HRA) is predominantly performed in young patients and offers good functional results.

In HRA, stability is enhanced, and force transition is more anatomical than in THR (*10,12,16*). A major advantage is the conservation of femoral bone stock. This is important, as young individuals face a higher risk of early implant failure (*7*). Considering life expectancy, at least one revision of the implant is indeed likely.

It is undisputed that HRA conserves femoral bone stock and usually allows revision with a conventional stem (*1,3,6,16*). However in HRA, the

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acetabular cup size depends not only on acetabular size, but also on the diameter of the femoral head and neck (*2*). Therefore, it has been suspected that HRA requires larger cups than conventional THA (*11,15*).

As only limited data are available and different studies have reported conflicting results, acetabular bone loss in HRA is a matter of controversy (*2,5,14*). Two studies have reported an increased acetabular bone loss in HRA (*11,15*), whereas two other studies suggested a bone loss comparable to THA (*13,17*). These studies compared acetabular cup size in HRA and THA, which is also influenced by the surgeon's preferred technique of reaming and positioning of the components. Most studies evaluated an unmatched study population, although gender, height and hip size have significant impact on the implant size (*15*).

To answer the question whether the size of the femoral component in HRA indeed imposes larger acetabular cups than in THA, we calculated from one hundred pelvic radiographs the smallest acetabular cup size required for a HRA and for a THA.

MATERIAL AND METHODS

Study population

The acetabular cup sizes for HRA and THA were analysed on 100 pelvic radiographs dated from 2004 to 2009 and complying with the following requirements : I) unilateral primary THA, II) cementless acetabular cup, III) pelvic overview, IV) no anatomic deformity.

Analysis of the required cup size

Calibration (femoral head) and measurements were done with the Ein-Bild-Roentgen-Analyse software (EBRA, University of Innsbruck, Austria) (*8*). Analysis was performed on the contralateral hip (no implant) as follows (Figs. 1 & 2) :

- Measurement of cup size (THA/HRA) based on the dimensions of the acetabulum (Fig. 1a).
- Measurement of cup size (only HRA) taking into account the dimensions of the femoral head and neck (Figs. 1b & 2).
- Recorded size of the cup implanted in the contralateral hip and, if available, of the cup subsequently implanted in the ipsilateral hip (both obtained from operative notes)

THA/HRA cup size based on the dimensions of the acetabulum

The acetabular cup size was determined by a method similar to that described by Bono for digital THA templating (*4*). A circle was placed along the rim of the sclerotic acetabulum. Then the distance from the superolateral and infero-lateral lip was taken to determine the smallest cup size (Fig. 1a).

HRA cup size taking into account the dimensions of the femoral head/neck

In HRA, the acetabular cup size also depends on the femoral head and neck diameter, the cup size for HRA was therefore calculated taking into account the dimensions of the femoral head and neck. For this purpose the femoral head/neck was mapped by an integrated grid (Fig. 1b). The femoral shaft axis and the implant axis (135°) were drawn on the radiograph and a grid with lines at a right angle to the implant axis (increments of 2.5 mm) was superimposed (Fig. 1b). The diameter of the femoral head/neck was mapped by measuring each orthogonal line to the outlines of the femur (without osteophytes) and transferred into a two-dimensional coordinate system (x-axis : distance from the top of the femoral head, y-axis : diameter of the femoral head at each distance (Figs. 1b & 2)). The opening diameters of all femoral HRA sizes were then plotted into the coordinate system (x-axis : distance from the dome to the opening of the implant, y-axis : diameter of the implant at the open end (Fig 1c)). The first implant size after the intersection of the two graphs determined the smallest possible femoral HRA size without notching the femoral neck. From the size of the femoral component, the smallest matching acetabular cup size was determined.

Acetabular bone loss

The additional acetabular bone loss is defined as the difference in diameter between the cup size determined based on the dimension of the acetabulum (THA/HRA) and the cup size determined taking into account the dimension of the femoral head and neck implant (HRA). This means, for a difference of one cup size (2 mm) a bone loss of 2 mm (acetabular diameter) is reported and corresponds to a radial bone loss of 1 mm in all directions of the acetabulum.

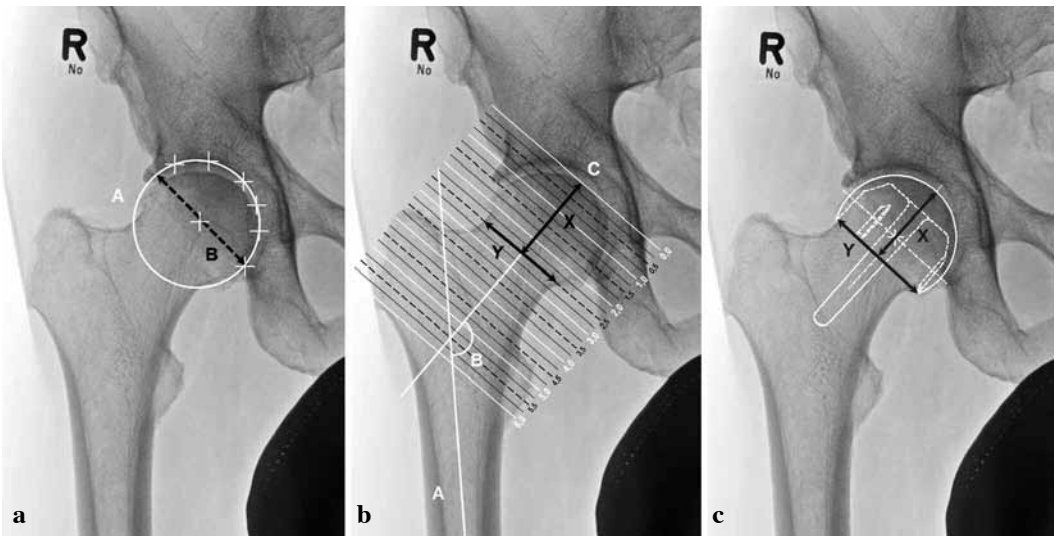

Fig. 1. — a) Acetabular cup size based on the dimension of the acetabulum (THA/HRA). A = circle around the sclerotic rim of the acetabulum, B = diameter of the required cup.
b) Acetabular cup size taking into account the dimension of the femoral head/neck (HRA). Mapping of the femoral head/neck : A = femoral axis, B = 135°, C = implant axis with 2.5 mm grid. To determine the femoral and the corresponding acetabular component, the femoral head/neck is plotted into a coordinate system : X = x-axis : distance from the top of the femoral head, Y = y-axis : diameter of the femoral head at each distance (Figure 2, black line).
c) The opening diameters of all femoral HRA sizes were plotted into a coordinate system : X = x-axis : distance from the dome to the opening of the implant, Y = y-axis : diameter of the implant at the open end (Figure 2, grey line).

Validation of the measured THA cup size

To check the accuracy of determining the acetabular component, the measured cup size was compared with the size of the cup implanted in the contralateral hip (operative notes). If patients also underwent THA on the measured side (ipsilateral), the implant cup size was also compared with the measured cup size.

Implants and Surgery

The measured THA cup size was based on a cementless cup (SC, Aesculap, Tuttlingen, Germany) which is available in 2 mm increments (range : 44-62 mm). The HRA cup size was based on the Cormet implant (Corin Group PLC, Cirencester, U.K.), which has a metal-on-metal bearing and is available in 2 mm increments (range : 46-64 mm). As some HRA designs also offer one smaller size (44 mm), this size was included for the measurements. The femoral components (range : 40-56 mm) are available in 4 mm increments and match one cup size which is 6 or 8 mm larger. Calculating the acetabular cup size from the femoral component, the smaller matching size was assumed if possible. All analysed radiographs had a cementless cup (SC, Aesculap, Tuttlingen, Germany) on the contralateral side, which was used as a validation control for the measured cups.

Statistical Analysis

Statistical analysis was performed using the Wilcoxon signed-rank test (SigmaStat 3.1, Systat Software GmbH, Erkrath, Germany). A p-value < 0.05 denoted significance. Graphs were created with Microsoft Office (Microsoft Corporation, Redmond, USA).

RESULTS

Acetabular cup size : HRA versus THA

Total study population

HRA required significant larger acetabular cups than THA, as the size of the femoral components imposed the use of larger acetabular matches (Table I). The mean size for HRA was 52.1 ± 4.6 mm [(50 mm, 50-58 mm (median, 25%-75%

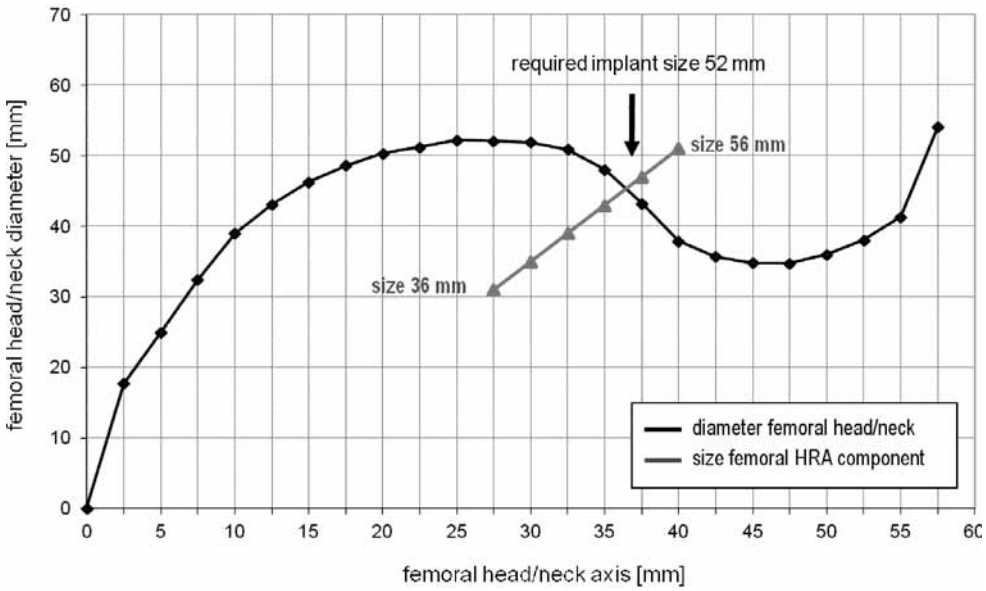

Fig. 2. — Acetabular cup size anticipated taking into account the size of the femoral component (femoral head/neck size). The first size after the intersection represents the required femoral size without notching the femoral neck (femoral component 52 mm, corresponding cup 58/60 mm).

Table I. — Comparison of acetabular cup size in HRA and THA [mm]

	THA*	HRA**	Bone loss (Δ HRA-THA)	± 0 size	+ 1 size	+ 2 sizes	+ 3 sizes
Total (n = 100)	51.0 ± 4.0	52.1 ± 4.6	+ 1.1***	49	31	18	2
Male (n = 53)	53.7 ± 3.0	55.2 ± 3.5	+ 1.5***	24	14	13	2
Female (n = 47)	47.9 ± 2.5	48.6 ± 2.8	+ 0.7***	25	17	5	0

* THA : cup size determined according to the dimensions of the acetabulum
** HRA : cup size determined according to the femoral neck/head
*** Significantly different $p < 0.05$.

percentile)], which was significantly larger than for THA with 51.0 ± 4.0 mm [50 mm, 48-54 mm] ($p < 0.001$), representing an average difference of + 1.1 mm. In 49% of the hips, a similar cup size was used for HRA and THA. In 51% of the hips a larger cup size was required for HRA, with one size larger in 31%, two sizes larger in 18% and three sizes larger in 2%.

Gender analysis

Gender analysis revealed that men (n = 53) as well as women (n = 47) required significantly larger acetabular cups for HRA than for THA. The difference was more pronounced in men than in women (male : Δ + 1.5 mm ; female : Δ + 0.7 mm) (Table I).

The mean cup size in men was 55.2 ± 3.5 mm (54 mm, 54-58 mm) for HRA, which was significantly larger than for THA with 53.7 ± 3.0 mm (54 mm, 52-56 mm) ($p < 0.001$). In male patients, a similar cup size could be used for HRA and THA in 45% of the hips, whereas in 55% of the hips, a larger cup size was required for HRA, with one size larger in 26%, two sizes larger in 25% and three sizes larger in 4%.

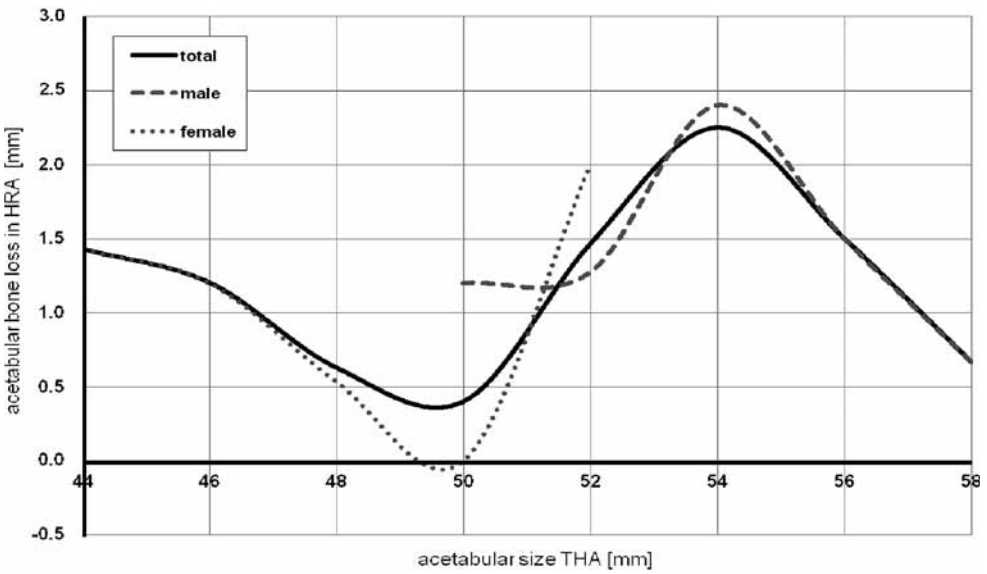

Fig. 3. — Acetabular bone loss in HRA compared to THA. The bone loss was more pronounced for larger cup sizes ranging from 52 to 56 mm.

The mean cup size in women was 48.6 ± 2.8 mm (50 mm, 46-50 mm) for HRA, which was significantly larger than for THA with 47.9 ± 2.5 mm (48 mm, 46-50 mm) ($p < 0.009$). A similar cup size could be used for HRA and THA in 53% of the hips, whereas in 47% of the hips a larger cup size was required for HRA, with one size larger in 36% and two sizes larger in 11%.

Size analysis

Analysis for each acetabular cup size (THA) revealed that HRA required larger cups especially for the sizes 52-56 mm (Fig. 3, Table II). This is also reflected in the larger bone loss observed for men (Δ + 1.5 mm), as they predominantly required cup sizes ranging from 52 to 58 mm, whereas women (Δ + 0.7 mm) usually required cup sizes ranging from 44 to 52 mm.

Validation of the measured THA cup size

Measured versus contralateral implanted THA cup

No significant difference was observed between the measured THA cups (n = 100) and the contralateral implanted THA cups (measured 51.0 ± 4.0 mm ; implanted contralateral 51.2 ± 3.3 mm, $p = 0.264$), indicating that the measurements were representative for the required THA cup size.

Measured versus ipsilateral implanted THA cup

In patients with bilateral hip arthroplasty (n = 33), the measured THA cup size was also comparable with the actually implanted THA cup size (ipsilateral) with no significant difference (measured 50.9 ± 3.7 mm, implanted ipsilateral 51.3 ± 3.3 mm, $p = 0.311$). Similarly, no significant difference was observed between the implanted cups of the ipsilateral and contralateral side (implanted ipsilateral 51.3 ± 3.2 mm, implanted contralateral 51.5 ± 3.2 mm, $p = 0.561$).

DISCUSSION

Acetabular bone loss in HRA is controversial (*2,5*). Previous studies that compared the cup sizes of HRA and THA retrospectively were influenced by the surgeon's implantation technique and the anatomical differences of a non-matched

Table II. — Acetabular determined cups sizes in THA compared to the femoral determined cup sizes in HRA [mm]

THA*	HRA**	Bone loss (Δ HRA-THA)	± 0 size	+ 1 size	+ 2 sizes	+ 3 sizes	Number of patients (male/female)
44	45.4 ± 1.5	+ 1.4	1	6	–	–	7 (0/7)
46	47.2 ± 1.9	+ 1.2	7	2	1	–	10 (0/10)
48	48.6 ± 1.9 +	0.6	6	6	4	–	16 (15/1)
50	50.4 ± 1.8 +	0.4	17	–	3	–	20 (10/10)
52	53.5 ± 2.6 +	1.5	3	–	10	2	15 (11/4)
54	56.3 ± 2.0	+ 2.3	7	–	9	–	16 (15/1)
56	57.5 ± 1.4	+ 1.5	1	–	7	–	8 (8/0)
58	58.7 ± 1.6	+ 0.7	5	–	1	–	6 (6/0)
60	58.0	–	1	–	–	–	1 (1/0)
62	62.0	–	1	–	–	–	1 (1/0)

* THA : cup size determined according to the dimension of the acetabulum
** HRA : cup size determined according to the femoral neck/head.

population (*11,13,15,17*). For those reasons, this study determined the cup size needed respectively in THA and in HRA from one single set of 100 radiographs.

Cup size in the total population

Significantly larger cups were required for HRA than for THA (Δ + 1.1 mm both genders). Moreover, 51% of the HRA cases required at least one cup size larger, as the femoral component imposed a larger acetabular matching cup. Those data are in line with Naal *et al* (Δ + 2.1 mm female, Δ + 2.2 mm male) and Loughead *et al* (Δ + 4.6 mm both genders) (*11,15*). In contrast, Moonot *et al* (Δ -2.0 mm female, Δ + 0.2 mm male) and Vendittoli *et al*. (Δ + 0.2 mm both gender) did not find larger cups in HRA (*13,17*). These conflicting findings may result from different study designs with anatomically different and non-matched populations in some of the studies (*9*). Only two studies have analyzed their population with regard to the genders (*13,15*). As women require smaller cups than men, merging both is very likely to distort the results, especially if an uneven distribution in the population is present (*5*).

Cup size with respect to gender

Analysis with regard to gender revealed that the average additional bone loss in HRA was less in women (Δ + 0.7 mm female) than in men (Δ + 1.5 mm). This is also reflected by the fact that 29% of the male hips required two or three cup sizes larger in HRA, compared to only 11% of the hips in women. Naal *et al* already described a positive correlation between the cup size and the height, weight and BMI, but did not report impact on acetabular bone loss (*15*). Loughead *et al* reported that irrespective of gender, an increasing diameter of the femoral head goes along with a larger acetabular bone loss (*11*).

Cup size with respect to the acetabular size

To further assess this correlation, we evaluated the bone loss in our population with respect to the acetabular size (THA cup size). We found, similar to Loughead *et al,* that especially the larger THA acetabular cup sizes of 52-56 mm were associated with bigger HRA cups (*11*). As those sizes are predominantly used in men, this also explains the greater bone loss in the male compared to the

female population. It may also explain the different results of previous studies, as they had varying gender distributions and thus different acetabular sizes in their populations.

Nevertheless, the huge variations in cup sizes of the different studies remain notable. The cup sizes, measured in this study based on a German population matched best with the data of Naal *et al* from Switzerland (*15*). Studies from England and Canada reported larger cups (*11,13,17*) which might be related to differing populations and patient demographics. Moonot *et al* suggested that differences in implant size also can be ascribed to varying operative techniques, especially in reaming and positioning of the femoral implant (*13*).

Clinical relevance of acetabular bone loss

Naal *et al* reported in a large study of 491 HRA implants similar additional acetabular bone loss for HRA ($\Delta + 2.2$ mm male, $\Delta + 2.1$ mm female) as in our study ($\Delta + 1.5$ mm male, $\Delta + 0.7$ mm female) (*15*). This bone loss corresponds to an increase of about one acetabular cup size (2 mm) and might appear to be moderate. It is unknown whether this statistical difference will have a significant influence on the clinical long term-outcome or not (*15*). In particular, it is unclear if these larger cups lead to more or earlier failures, and if eventual revision procedures are really aggravated by the larger cup sizes. It also remains unknown if these larger cup sizes influence the quality and longevity of acetabular revision procedures. Therefore, further research is required that addresses the long-term outcome of those larger cups and especially their outcome after acetabular revision procedures.

The reported bone loss represents an average value and is not representative for the bone loss of each individual. In this study, we could demonstrate, that although a similar acetabular cup size could be used in 49% of the patients, 31% would have required one size larger and 20% would have required two or even three cup sizes larger compared to THA. As a consequence, for 20% of the cases, a considerably larger reamer would have been required, resulting in a bone loss of 2-3 mm in all directions of the acetabulum (4-6 mm in diameter). This demonstrates that these individuals have a high risk for a distinctive bone loss at the acetabulum when undergoing HRA. A careful preoperative planning seems to be necessary to identify those patients in advance.

Study limitations

We are aware that this study has certain limitations. First, the cup size calculated from radiographs can differ from the size of the cup actually implanted. However, we have demonstrated that our measurements are representative for the really inserted cup sizes and even if an error might have occurred, it would probably be comparable in both groups. Second, analysis of the cup size was performed on the contralateral, mainly unaffected hip, which may result in a different cup size than used in a destroyed hip. Third, various types of implants with different designs, sizes and matching components are available which potentially can affect the results ; although Naal *et al* could only find an marginal difference for two different HRA designs, we cannot exclude an influence on the final results (*15*).

CONCLUSIONS

This study showed that in about 50% of cases of HRA, the size of the femoral head/neck imposes larger acetabular cups than in THA and greater bone loss, predominantly so for larger hip sizes and thus particularly in men, a fact to be taken into account in planning HRA.

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