Do revision total hip augments provide appropriate modularity?

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Background: Porous metal acetabular augments have become widely used to fill bony defects in patients undergoing revision total hip arthroplasty. The objective of this study was to determine whether the currently offered size range of the augments is appropriate for surgical needs.

Methods: We reviewed the cases of all patients at 1 centre with a porous revision shell, and when an augment was used we recorded the patient and implant characteristics.

Results: We reviewed the cases of 281 patients, and augments were used in 24. Augment diameter was skewed toward the small end ($p < 0.001$), although thickness was not ($p = 0.05$); 21 of 24 augments were those with the smallest 3 diameters and thicknesses.

Conclusion: Given the sizes used, the full range of inventory provided by the manufacturer may be unnecessary, as surgeons will likely attempt a larger shell before a larger augment.

Contexte : Les implants de révision acétabulaire faits de métal poreux sont maintenant largement utilisés pour corriger les anomalies osseuses chez des patients qui doivent subir une révision de leur prothèse totale de la hanche. L'objectif de cette étude était de déterminer si la gamme actuelle des implants offerts répond aux besoins chirurgicaux.

Méthodes : Nous avons passé en revue, dans un seul centre, tous les cas de révision effectuée au moyen d'un revêtement poreux. Lorsqu'un implant avait été utilisé, nous avons consigné les caractéristiques des patients et des implants.

Résultats : Nous avons ainsi examiné 281 cas, dont 24 ont nécessité la pose d'un implant. Le diamètre de l'implant de révision était asymétrique vers l'extrémité fine ($p < 0,001$), mais non son épaisseur ($p = 0,05$); 21 implants sur 24 étaient des 3 diamètres et épaisseurs les plus petits.

Conclusion : Compte tenu des tailles utilisées, la gamme complète offerte par le fabricant n'est peut-être pas nécessaire, puisque les chirurgiens tenteront selon toutes probabilités d'utiliser un revêtement plus volumineux avant d'utiliser un implant plus volumineux.

Revision total hip arthroplasty is substantially more complex than primary arthroplasty, with bone defects surrounding the implant being a common occurrence. Traditionally, segmental bony defects have been filled with bone graft, either in combination with a jumbo cementless cup or, in the case of large defects, with a cage to bridge these defects. However, in the past decade porous metal acetabular augments have been developed as an alternative.¹ These augments integrate (or unitize) with the acetabular component of the implant (the acetabular cup) and are screwed into the surrounding bone, filling the defect (Fig. 1). Although augments were initially marketed by a single implant manufacturer, multiple versions of these porous metal (tantalum or titanium alloys) augments are now available from other manufacturers. Midterm results suggest that the augments are effective for filling the bony defect and provide stable fixation.^{2,3}

The augments, like the implants themselves, follow the principle of modularity, meaning they are available in a range of sizes to fit a variety of patient scenarios. Although the range of implant sizes has been widely studied, particularly with respect to issues such as wear, loosening and dislocation,⁴⁻⁶ the issue of whether the augments are currently offered in an appropriate range of sizes

to fill common defects has not been addressed. Of the papers reviewing authors' experience with acetabular augments, only 1 study⁷ has described the sizes used — only partially — and identified 2 consecutively grouped sizes (size 58, 10- and 20-mm thicknesses) as the most commonly used from a single manufacturer.

The objective of our study was to review acetabular augment usage in patients undergoing revision hip surgery fol-

lowed prospectively at 1 centre to determine whether the currently offered modularity of the augments is appropriate for surgical needs. We hypothesized that the size of augments used would be clustered around a small range at the small to intermediate end of the scale, with few or no augments at the largest end of the scale being used.

METHODS

We queried a clinical database that records all surgical procedures performed at our institution to identify patients who received a Trabecular Metal revision acetabular cup (Zimmer) between 2007 and 2013. For the patients identified in our database search, we reviewed the radiographs to confirm the presence of a Trabecular Metal acetabular augment. Where an augment was present, we recorded patient demographic characteristics, including age, sex, body mass index (BMI), reason for the revision, and whether a further revision occurred. Each case was classified based on the Paprosky and Gross bone defect classification scales. We also recorded implant characteristics, including augment diameter and thickness, cup diameter and the number of screws used to secure the augment and the cup. Our Institutional Research Board approved the study.

Trabecular Metal acetabular augments, shaped as a partial hemisphere, are currently offered in 4 thicknesses: 10 mm, 15 mm, 20 mm and 30 mm. At 10 mm and 15 mm, the sizes (diameters) available are 50, 54, 58, 62, 66 and 70. At 20 mm and 30 mm, the available sizes are 50, 54, 58, 62 and 66 (no size 70). Originally more sizes were available, with 2 mm gaps rather than 4 mm gaps between sizes. For the purposes of our analysis, in cases when the size documented in the patient's chart was no longer available, we recorded the next largest size (i.e., size 48 became size 50, size 52 became 54, and size 56 became size 58). There was no change to the range of thicknesses offered.

Statistical analysis

Standard descriptive statistics were calculated for all categories of patient and implant characteristics. We performed a χ^2 test to measure the augment size usage against a standard even distribution. Linear regression between implant and patient characteristics was performed, including factors such as bone defect class, augment diameter, augment thickness, cup diameter, number of screws used (both in the augment and cup), patient age and patient BMI.

RESULTS

Among 281 patients who received a porous metal revision cup during our study period, 24 also had an augment, for a usage rate of 8.5%. The mean patient age at the time of surgery was 74.3 ± 10.2 (range 52–88) years, and the mean BMI was 27.1 ± 4.2 (range 20.8–33.8). Of the 24 patients, 7 were men and

Fig. 1. Radiograph demonstrating the use of an acetabular augment (arrow).

17 were women. All cases were revised (and a cup with augment implanted) for either aseptic loosening ($n = 19$) or infection ($n = 5$). Ten patients were undergoing a first revision, 8 were having a second revision, 4 were having a third revision and 2 were having a fourth revision. The mean duration of follow-up was 3.2 years. There was no subsequent re-revision in which the cup or augment was removed for any of these patients. There was no use of bulk allograft in any of the cases. Using the Gross classification, there were 2 cases of type III, 18 cases of type IV and 4 cases of type V defects. Using the Paprosky classification, there were 17 cases of type IIIA, 3 cases of type IIIB and 4 discontinuity cases.

The median augment diameter (Table 1) was 54 (range 48–62) mm, and the median thickness was 15 (range 10–30) mm, with 2.2 ± 0.8 (range 0–4) screws used per augment. The majority of augments ($n = 20$) were used in “oblong” mode to fill cavitory defects, with only 4 used in “flying buttress” mode to fill segmental defects. The mean cup diameter was 64 (range 54–76) mm, with 4.0 ± 1.2 (range 2–7) screws used per cup. The augment diameter was skewed toward the small end ($p < 0.001$), but thickness was not ($p = 0.05$). Of the 24 augments used, 21 augments were the 3 smallest diameters and thicknesses, and no augments were the largest diameters (66 mm or 72 mm).

Augment diameter positively correlated with cup diameter ($r^2 = 0.22$, $p = 0.021$; Fig. 2A), while augment thickness negatively correlated (Fig. 2B) with cup diameter ($r^2 = 0.25$, $p =$

0.014). Augment thickness also positively correlated (Fig. 2C) with the number of augment screws used ($r^2 = 0.21$, $p = 0.026$). There were no other significant correlations between implant or patient characteristics. There was no correlation between either the Gross or Paprosky defect classification and augment size or thickness.

DISCUSSION

The majority of augments were clustered at the smallest size combinations available; the majority of augments used were the thinnest (10 mm) model available. Interestingly, the single most frequent size combination (size 58, 10 mm thickness) was consistent with the only other mention of augment size available in the literature.⁷ Also of interest was that the manufacturer had already decreased the range of sizes of acetabular augments available since the implants were first introduced at our institution, grouping together multiple sizes such that there are 4 mm increments rather than 2 mm increments between diameters. Although more women than men (17 v. 7) received augments, this did not appear to have an effect on size; the largest augments were used only in women, and some of the men received the smallest augments (size 50, 10 mm thickness).

While we found a seemingly low overall augment usage rate of 8.5% (24 of 281 patients), this too was consistent with the literature. One study⁸ reported an augment usage

Table 1. Number of augments used by size (diameter and thickness).

Size	Thickness				Total
	10 mm	15 mm	20 mm	30 mm	
50	2	1	3	0	6
54	2	2	3	0	7
58	7	0	1	2	10
62	0	1	0	0	1
66	0	0	0	0	0
70	0	0	0	0	0
Total	11	4	7	2	24

Fig. 2. Regression between (A) augment and cup diameter, (B) augment thickness and cup diameter and (C) augment thickness and number of screws.

rate of 7.6% (34 of 448 patients), and other centres have reported on augment usage samples ranging from 23 to 46 patients.^{2,3,9,10} This low augment usage rate means that in 91.5% of cases, the revision acetabular cup on its own is sufficient. Based on the defect classification, the patients whose cases we reviewed all had the most severe types of defects. At our institution, augments are generally not used outside of these worst case scenarios owing to cost. Instead, surgeons prefer to use as large a cup as possible before the addition of an augment. This is supported by the inverse association found between cup diameter and augment thickness; surgeons appeared to select the largest possible cup before adding an augment. The advantages of so-called “jumbo cups” have been described as a simple procedure that maximizes cup–bone contact and potentially restores the centre of hip rotation. Such cups have been reported to last as long as 15 years.^{11,12} The use of jumbo cups and augments has replaced the use of bulk allografts at our institution.

Other correlations included increasing augment diameter with increasing cup diameter and increasing screw usage with increasing augment thickness. A wider cup will naturally be more suitable than a narrower cup for a wider augment. Increased screw usage with thicker augments could suggest that surgeons felt less sure of the augment’s bony fixation with thicker dimensions. Interestingly, screw usage did not correlate with augment diameter or cup diameter, so it was not the case that more screws were used simply because there was more room to use them.

As technology advances in additive manufacturing (also known as 3-dimensional printing), there may be a greater role for custom, patient-specific acetabular revision cups (and augments) that incorporate and ideally improve upon the stability of the cup–augment combination. These would be designed to better fill the bony defect and attach with appropriate fixation based on the bone remaining, regardless of what the defect looks like. Such structures are already being designed to have mechanical strength and porosity that more closely mimics bones and can be manufactured using selective laser melting or electron beam melting technologies.^{13,14}

Limitations

Limitations of this study are that it represents a single centre and that only 1 acetabular augment product was examined. However, the sample size in this study is consistent with that in other studies reviewing these augments, and while other manufacturers now have similar product offerings, the augment used in our study was the first available and is the most widely used to date. The principles of sizing are likely consistent with other similar products.

CONCLUSION

Given the small range of acetabular augment sizes used, the full range of inventory provided by the manufacturer

may not need to be routinely stocked in the same amounts, as surgeons will likely attempt a larger cup before a larger augment. There may also be a role for introducing additional augment shapes to better fill bony defects, perhaps involving custom designs rather than maintaining a wide augment size range, many of which are never used.

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Contributors: M. Teeter, R. McCalden and S. MacDonald designed the study. M. Teeter, D. Naudie and J. Howard acquired the data, which D. Naudie, J. Howard, R. McCalden and S. MacDonald analyzed. M. Teeter wrote the article, which all authors reviewed and approved for publication.

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