Addressing Severe Bone Deficiency

What a Cage Will Not Do

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Abstract: Managing severe acetabular bone loss in total hip arthroplasty revision can be a tremendous challenge. Osteolysis and migration of the acetabular component can lead to large uncontained defects. Traditionally, these deficiencies have been treated with allograft with or without the support of a cage. In severe cases, a majority of the cage support is via allograft instead of host bone. Sometimes, with remodeling and resorption of the allograft, the cage can lose structural support, leading to fatigue and failure. In these situations, trabecular metal has become a viable alternative. Deficiencies of acetabular bone can be independently addressed and reconstructed providing initial stability and, we believe, long-term biologic fixation to host bone. **Key words:** revision hip arthroplasty, trabecular metal augments, cage, severe acetabular deficiency, acetabular reconstruction.

Background

As the life expectancy of the population continues to rise and the indications for total hip arthroplasty are broadened, the number and complexity of acetabular revisions will continue to increase. Kurtz et al [1] determined that the rate of primary total hip arthroplasties per 100,000 persons in the United States from 1990 to 2002 increased by approximately 50%. They projected that in the years from 2005 to 2030, the number of total hip revisions would increase 137% [2]. These data underscore the importance of developing new techniques and methods for managing failed total hip arthroplasties. The most challenging aspect of acetabular revision is managing bone loss of variable locations and sizes and consistently creating a stable construct capable of providing long-term stability of an acetabular component. In the revision setting, durable fixation has been most reliably achieved with cementless hemispherical cups. Della Valle et al [3] demonstrated that survivorship of cementless acetabular reconstructions in the revision setting was 96% at 15 years when revision for loosening was considered as the end point. Creating an environment that will lead to stable ingrowth of these prostheses requires rigid initial stability and close contact with a sufficient amount of viable host bone. Often times, this can be accomplished with the use of cementless hemispherical cup at the anatomic hip center or high hip center, a jumbo cup, an oblong cup, or an uncemented cup initially supported by structural allograft until ingrowth is achieved.

Placing components at a high hip center can often provide adequate potential for ingrowth in remaining superior bone stock at a nonanatomic position. This method of acetabular reconstruction alters mechanical forces about the hip and is associated with a higher rate of aseptic loosening [4]. With moderate degrees of bone loss, a jumbo cup can achieve peripheral fixation and intimate contact with the patients' own structures close

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to an anatomic position. Success with this technique often requires an intact posterior column and anterior-inferior or anterior-superior bone to obtain a press-fit. Oblong cups can result in satisfactory stability at midterm for certain types of defects. Disadvantages include the need to remove additional bone to achieve an intimate fit, and intraoperatively, there is a limited range of orientation of the cup and augment, making placement of the device in the correct abduction and anteversion technically difficult. Recently, Herrera et al [5] reported good midterm results with oblong cups placed in American Academy of Orthopaedic Surgery (AAOS) types III and IV acetabular defects. At average follow-up of 6.3 years, 85.8% of the cups were stable. They determined that the cups that failed did not have sufficient contact with the acetabular rim, which led to loosening and subsequent failure. The senior author has had success with the use of distal femoral allografts for reconstruction of a nonsupportive superior dome with intact anterior and posterior columns. The 10-year survival rate with rerevision because of aseptic loosening as the end point was 78% [6].

These devices work perfectly well in most acetabular revisions; however, in severe acetabular deficiencies, they cannot be used alone, and reconstruction of surrounding support must be undertaken. In these situations, bulk allograft is needed to support a cup at an appropriate anatomic position to restore bone stock and leg length, often creating a situation where the allograft is supporting greater than 50% of the cup. Achieving a well-fixed acetabular component in the face of a bone deficiency of this magnitude will require the allograft to be protected by a reinforcement ring or an antiprotrusio cage, a custom triflange cup, or a hemispherical cup in conjunction with trabecular metal augments.

Reinforcement Rings and Antiprotrusio Cages

Reinforcement rings were designed to place a cemented acetabular component in the anatomic position in patients with severe medial bone loss. This device would allow stress to be distributed to the remaining periphery of the acetabulum. With the increasing availability of hemispherical cups of larger diameters and improved designs, the use of rings has fallen out of favor. Antiprotrusio cages, however, remain a useful device in the face of significant acetabular bone loss. They place the hip center near an anatomic location and restore bone stock, creating the potential for cementless hemispherical cup placement if rerevision is necessary in the future. They also create a stable construct for cementing of a polyethylene component allowing for delivery of antibiotics locally and adjustment of version and abduction independent of cage position. Cages span the acetabular defect, obtaining support from the ilium superior and the pubis and ischium inferiorly. It effectively increases the allograft contact area acting to decrease the forces across the bone graft, allowing time for potential integration. Disadvantages include unacceptable midterm failure if support from allograft or host bone is not adequate. The current designs do not allow for biologic fixation compromising the constructs potential for long-term success. In addition, the placement of the flanges requires greater dissection, potentially leading to compromised soft tissues and increasing the likelihood of dislocation [7]. Comparison of results of cages has historically been difficult because of the mixed patient populations treated with these devices and the variable acetabular deficiencies for which they were used. Several authors have recently reported excellent mid- to long-term results with these devices. At average follow-up of 7.3 years, Winter et al [8] found that none of 38 Burch-Schneider cages with allograft loosened in addition to the finding of incorporation of the bone graft into host bone. They concluded that a close fit between the graft and the acetabulum in addition to mechanical stability was crucial to their successful results [8]. Other studies have also had good results with rates of revision for aseptic loosening from 0% to 12% [9-12]. Most recently, Pieringer et al [13] reported a survival rate of 93.4% at an average follow-up of 50.3 months, with cage removal as an end point. However, drawing conclusions from these studies can be difficult because of the mixed patient populations studied, the length of follow-up, and the varying location and degree of bone loss treated. Some of the patient cohorts included primary arthroplasties in the results. Perka et al had similar success using the Burch-Schneider cage, reporting only 3 cases of aseptic loosening in 62 patients at an average follow-up of 5.45 years [14]. However, all 3 cases were in patients with type IIIb defects. The authors found a direct correlation between migration and posterior column defects and increasing Paprosky stage. Udomkiat et al [7] determined that the amount of superior support from the ilium correlated with migration, and that the chance of loosening

increased as the size of this defect increased. Antiprotrusio cages can have excellent mid- to long-term results in the correct patient populations and with good surgical technique.

Our Experience

We use the classification system of the senior author to evaluate acetabular defects preoperatively and intraoperatively. The classification system was developed to preoperatively identify the location and severity of bone loss and to help determine if the defects will compromise the host bones ability to provide initial stability of a hemispherical cup. Four radiographic parameters are used: component location relative to Kohler's line, superior migration of the hip center of rotation above the superior obturator line, degree of ischial osteolysis, and teardrop osteolysis. In type I and II defects, there is sufficient support from the host bone to provide initial stability for a cementless acetabular component with or without allograft. The difficulty arises in type III defects where the remaining acetabular rim will not provide adequate initial component stability to achieve reliable biologic fixation. Type III defects have more than 3 cm of superior migration. A type IIIA defect is associated with superolateral migration and has less than 15mm of ischial lysis below the level of the superior obturator line. A type IIIB defect has superomedial migration, with the component extending medial to Kohler line and often greater than 15 mm of ischial lysis below the obturator line. In addition, there is often severe teardrop osteolysis with type IIIB defects. As mentioned above, many reports on the use of cages have shown good results in certain situations. We have found an unacceptable rate of failure with IIIA and IIIB defects reconstructed with a cage. In type III defects, the massive bone loss often requires allograft protected by a cage to provide enough support for the acetabular component. If there is a remaining column or the superior dome is structurally intact, this construct will work. If there is not sufficient host bone to support a cage and allograft is necessary to provide the initial support of the cage, our results were poor.

Insufficient bone stock would be suspected preoperatively based on careful examination of the 4 previously mentioned landmarks. Intraoperatively, the lack of sufficient bone stock would preclude intrinsic stability of a trial implant, indicating the need for some type of additional augmentation. When this occurs, one or both of the acetabular columns are likely deficient or missing, or the superior dome is absent and there is insufficient support for ingrowth. We have had good results with the use of structural distal femoral allografts in type IIIa defects. The 10-year survival rate with rerevision because of acetabular loosening as the end point was 78%. However, in IIIb defects, where greater than 50% of the cup is uncovered, Kohler's line is violated, and osteolysis is affecting the teardrop and ischium, the results were far less satisfactory. We had 7 failures in 11 IIIb hips reconstructed in that fashion. In these situations where the defect will leave the cup largely unsupported and allograft is needed to provide initial rigid stability, we have begun using a trabecular metal cup with augments. Trabecular metal augments allow defects to be assessed and reconstructed independently, maximizing ingrowth surface contact with host bone. Biologic fixation potentially allows the bone contacting the material to remain physiologically active and remodel after component implantation, providing long-term fixation.

Technique

The position of trabecular metal augments is dependent upon the acetabular bone loss pattern. In patients with a type IIIa defect, a reamer is placed in the anatomic position, and the size, shape, and location of the bone loss are determined. If the remaining defect is contained, the superior defect is then reamed to match the arch of the trabecular metal augment. The augment is then placed with a press-fit, technique and 3 or 4 screws are added for additional stability. Cement is then placed on the surface of the augment followed by placement of the cup, unitizing the device. The key is to achieve intimate host bone contact with the acetabular component and augment independently. When an augment is used and secured to the acetabular shell, the surface area of the cup available for ingrowth can be increased as much as 30% or 40%. When biologic fixation occurs, it is no different than if that acetabular component had ingrown itself.

In more severe situations where the anterior and posterior wall is missing and a discontinuity is present, trabecular metal can potentially restore the integrity of the hemipelvis. First, an inferior augment can be used to restore the posterior inferior wall as a sort of inferior footing. The superior defect is then sized to decrease the acetabular volume. Both augments are press-fit

and secured with screws. The cup is then press-fit against host bone and/or acetabular augments. Allograft bone can be used to fill any remaining cavitary defects before cement is applied to the superior and inferior augments and the acetabular component is inserted. Multiple screws are placed into both the superior and inferior hemipelvis to provide rigid fixation. If initial rigid fixation can be achieved both superiorly and inferiorly, the construct can potentially function as an internal plate stabilizing the discontinuity. The trabecular metal has greater surface roughness than other current material increasing the intraoperative scratch fit, and the biocompatibility of tantalum appears to create an excellent environment for ingrowth. Other advantages of the technique are the lack of soft tissue stripping of the ilium protecting the integrity of the already attenuated abductors. In addition, the great variability in the amount and location of bone loss encountered in revision surgery can be accommodated by the modularity of the system.

Conclusion

The goals of acetabular reconstruction are to restore normal hip mechanics and provide durable long-term stability of an acetabular component. The quality, amount, and location of bone loss affect surgical decision making. The most difficult situations are those where host bone will not support at least 50% of a cementless hemispherical cup, necessitating reconstruction of surrounding supporting structures. Custom triflange cups can provide lasting fixation of an acetabular component in an anatomic position [15,16]. Disadvantages are delay in surgery for manufacturing, expense, and the possibility of unexpected findings at the time of surgery that may jeopardize the fit of the implant and ultimately the stability. Structural allograft with cages has resulted in satisfactory outcomes as well. They restore bone stock by buttressing bone graft while it remodels as well as provide a stable scaffold to cement a polyethylene liner in a relatively independent position. However, in more severe defects where they are not relatively contained, their results are discouraging at mid- and long-term follow-up. If sufficient host bone is not stabilizing the cage, the construct will toggle or migrate and eventually fail. The variable nature of bone loss demands a procedure that can be adapted intraoperatively when defects of different locations and sizes are encountered. Trabecular metal augments provide the surgeon with the ability to reconstruct each absent supporting structure independently with the possibility of biologic fixation. Many orthopedic surgeons have differing opinions as far as to which device is most successful, but one point everyone can agree upon is that acetabular deficiency in revision total hip arthroplasty is a problem that will only increase in severity and incidence.

References

1. Kurtz S, Mowat F, Ong K, et al. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. J Bone Joint Surg Am 2005;87:1487.
2. Kurtz S, Mowat F, Ong K, et al. The Future Burden of Hip and Knee Revisions: US Projections from 2005 to 2030. Paper No. PAPR403 accepted, 73rd Annual Meeting of the American Academy of Orthopaedic Surgeons, Chicago, IL, March 22-26, 2006.
3. Della Valle CJ, Berger RA, Rosenberg AG, et al. Cementless acetabular reconstruction in revision total hip arthroplasty. Clin Orthop 2004;420:96.
4. Kelly SS. High hip center in revision arthroplasty. J Arthroplasty 1994;9:503.
5. Herrera A, Antonio Martínez Á, Cuenca J, et al. Management of types III and IV acetabular deficiencies with the longitudinal oblong revision cup. J Arthroplasty 2006;21:857.
6. Sporer SM, O'Rourke M, Chong P, et al. The use of structural distal femoral allografts for acetabular reconstruction. J Bone Joint Surg Am 2005; 87:760.
7. Udomkiat P, Dorr LD, Won Y, et al. Technical factors for success with metal ring acetabular reconstruction. J Arthroplasty 2001;16:961.
8. Winter E, Piert M, Volkmann R, et al. Allogenic cancellous bone graft and a Burch-Schneider ring for acetabular reconstruction in revision hip arthroplasty. J Bone Joint Surg 2001;83A:862.
9. Gill TJ, Sledge JB, Muller ME. The Burch-Schneider anti-protrusion cage in revision total hip arthroplasty: indications, principles and long-term results. J Bone Joint Surg 1998;80B:946.
10. Gill TJ, Sledge JB, Muller ME. The management of severe acetabular bone loss using structural allograft and acetabular reinforcement devices. J Arthroplasty 2000;15:1.
11. Berry DJ, Muller ME. Revision arthroplasty using an anti-protrusio cage for massive acetabular bone deficiency. J Bone Joint Surg 1992;74B:711.
12. Peters CL, Curtain M, Samuelson K. Acetabular revision with the Burch-Schneider antiprotrusio cage and cancellous allograft bone. J Arthroplasty 1995;10:307.
13. Pieringer H, Auersperg V, Bohler N. Reconstruction of severe acetabular bone-deficiency: the Burch-

Schneider antiprotrusio cage in primary and revision total hip arthroplasty. J Arthroplasty 2006;21:489.
14. Perka C, Ludwig R. Reconstruction of segmental defects during revision procedures of the acetabulum with the Burch-Schneider antiprotrusio cage. J Arthroplasty 2001;16:568.
15. Christie MJ, Barrington SA, Brinson MF, et al. Bridging massive acetabular defects with the triflange cup: 2-9 year results. Clin Orthop Relat Res 2001;216.
16. Dennis DA. Management of massive acetabular defects in revision total hip arthroplasty. J Arthroplasty 2003;18(Suppl):121.