MENTORS IN ORTHOPEDICS

A NEW APPROACH FOR PAPROSKY 3 ACETABULAR DEFECTS WITH PATIENT MATCHED 3D PRINTED IMPLANTS BASED ON BONE QUALITY ASSESSMENT

https://doi.org/10.71165/8uxk-w286

AUTHORS

Simon van Laarhoven - Sint Maartenskliniek, Nijmegen, Netherlands
Michiel Baauw - Sint Maartenskliniek, Nijmegen, Netherlands
Gijs G. van Hellemondt - Sint Maartenskliniek, Nijmegen, Netherlands
Maarten Spruit - Sint Maartenskliniek, Nijmegen, Netherlands

SUMMARY

Background: Reconstruction of Paprosky type 3 acetabular defects and pelvic dissociation remains a significant challenge in revision hip arthroplasty. Conventional techniques, including structural allografts and reconstruction cages, often yield inconsistent results due to inadequate primary stability and limited biological ingrowth.

Objective: This study describes the preoperative planning, surgical technique, and preliminary clinical outcomes of a patient-matched, 3D-printed monobloc trabecular titanium acetabular revision system.

Key Points: The system utilizes CT-based software to subtract existing hardware, assess bone quality via Hounsfield units, and determine the native center of rotation. A custom implant with integrated flanges and pre-planned screw trajectories is manufactured via 3D printing. In a cohort of 32 patients (median age 68 years) with a minimum 2-year follow-up, the Oxford Hip Score improved from a preoperative mean of 51 to 29 postoperatively. Visual analog scale scores for activity decreased from 89 to 11. Radiographic analysis confirmed no implant migration or construct breakage, although screw loosening occurred in three cases. Complications included three re-operations for delayed wound healing (9%), one deep infection, and one dislocation. The surgical technique emphasizes a posterolateral approach with extensive exposure of the ilium, ischium, and pubic bone to ensure precise implant seating.

Conclusion: Patient-specific 3D-printed titanium implants provide a viable solution for complex acetabular reconstructions. The technology allows for accurate restoration of hip mechanics and stable primary fixation through bone-quality-guided screw placement, resulting in favorable short-term clinical and radiological outcomes.

KEYWORDS

Arthroplasty, Replacement, Hip; Acetabulum; Reoperation; Printing, Three-Dimensional; Prosthesis Design

INTRODUCTION

Major acetabular defects are most complex and difficult to reconstruct especially if pelvic dissociation is present. Many techniques have been proposed such as bone impaction grafting, structural allografts, anti-protrusio or reconstruction cages, tantalum augments and cup-cage reconstruction. However, in large defects with dissociation the results are inconsistent with high failure rates, because of insufficient primary construct stability, failure of bony ingrowth and the limitations with implants from the shelf. [1 to 3]

One of the latest instruments in the orthopedic surgeon's armamentarium to face these challenges is a patient matched revision system (aMace, Materialise, Leuven, Belgium). This system consists of a 3D-printed monobloc trabecular titanium implant with integrated flanges, augments, cup and holes to guide screw placement (figure 1).

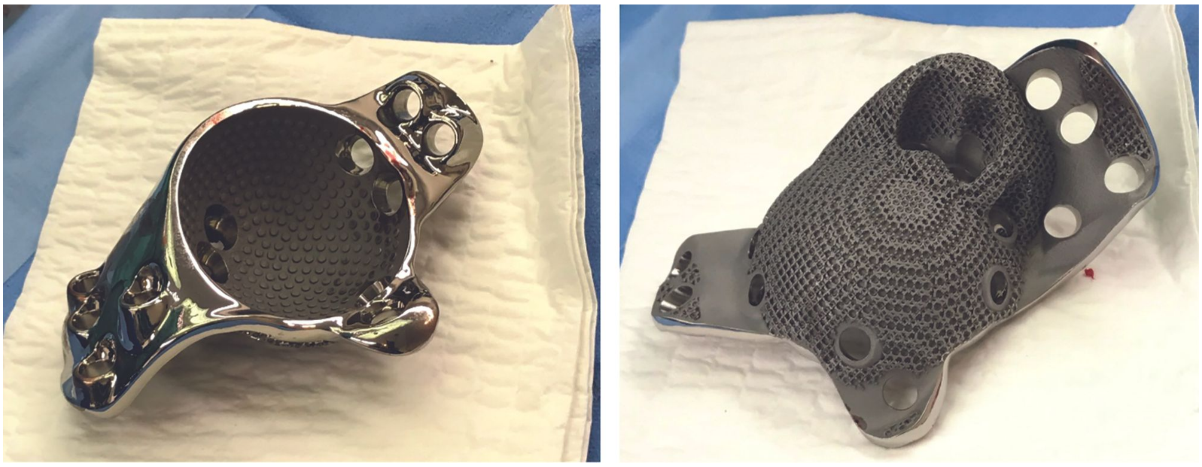

Figure 1: AMace custom-made acetabular revision system with the trabecular titanium backside.

It allows pre-planned screw positioning in good host bone for optimal primary screw fixation and secondary bony ingrowth of the implant for long term survival. We will describe this new technology from planning up to implantation and share our preliminary clinical experience.

PREOPERATIVE PLANNING

A CT scan of the complete pelvis is uploaded to an online platform. Special software is used to subtract all parts of the pre-existing reconstruction (e.g. previous implant, screws, cement, mesh). This allows to assess the ultimate bone defect according to the Paprosky classification (figure 2).

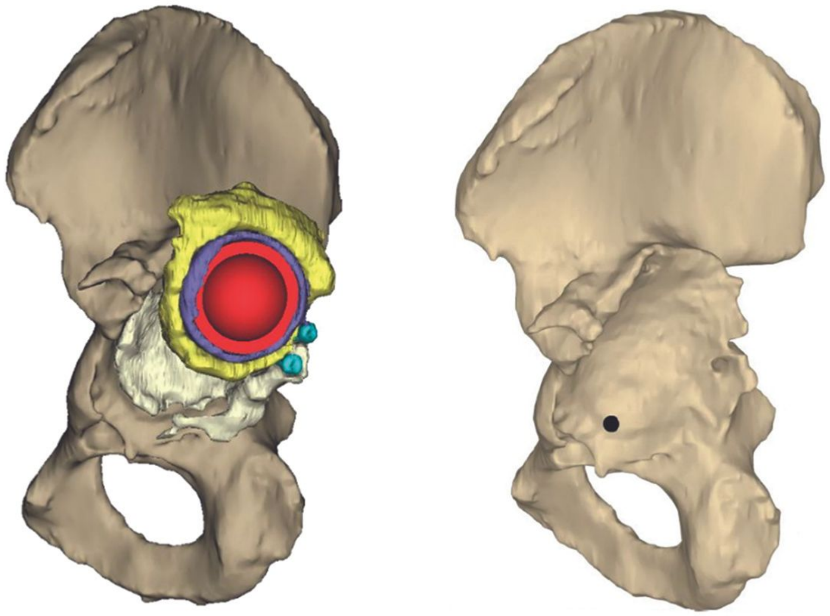

Figure 2: Subtraction of all parts of the existing reconstruction and assessment of the ultimate bone defect and descriptive Paprosky classification. The black dot represents the native centrum of rotation.

Additionally, bone quality is assessed by Hounsfield units and presented with a colour gradient from red (inferior) to green (superior) (figure 3).

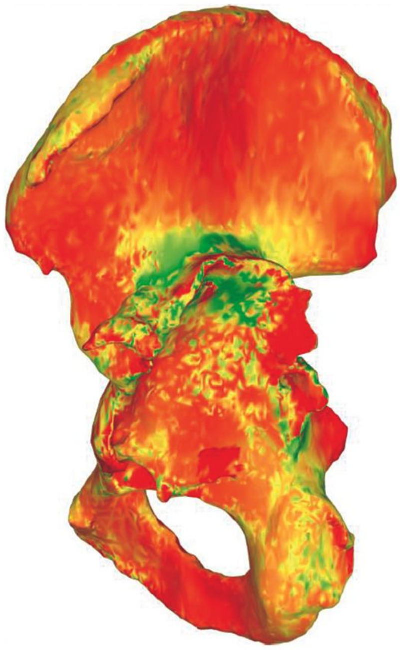

Figure 3: Assessment of the bone quality: red - inferior to green - superior.

By taking into account the bone quality the defect matched acetabular implant is designed restoring the centre of rotation, augmenting the defects and providing optimal screw orientation (figure 4).

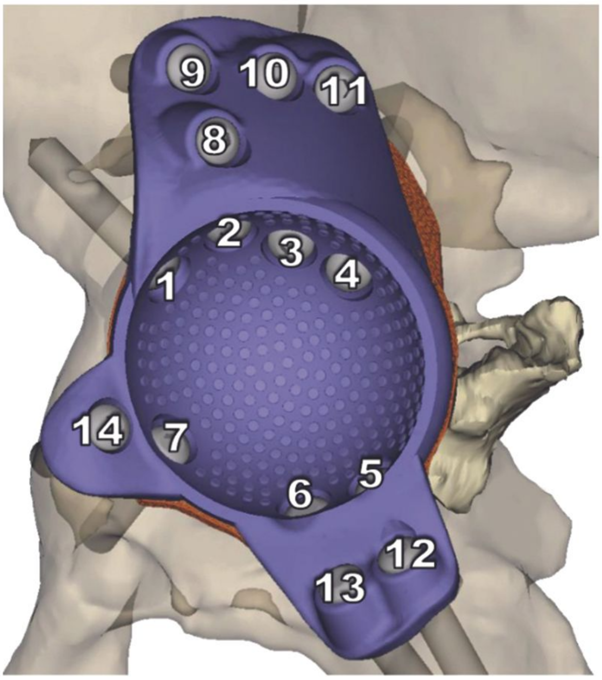

Figure 4: Implant design and screw position proposal.

The process from uploading the CT scan to the final design of the implant will take one week. During the entire process, the surgeon is able to give feedback on the defect classification, design and orientation of the implant for anteversion and inclination on the online platform. Changes will be made on request in collaboration with the engineer.

Once the design of the implant has been approved, the 3D printing process of the patient matched implant can be started and delivery occurs within 4 weeks. The delivered package consists of the implant, an anatomical plastic model of the hemipelvis, trial implant, drill guides, the case report, surgical technique, and sterilization instructions (figure 5). The plastic model helps to identify landmarks and expose the defect during surgery.

Figure 5: The delivered package consists of the implant, an anatomical plastic model of the hemipelvis, trial implant, drill guides, the case report, surgical technique, and sterilization instructions.

SURGICAL TECHNIQUE

In our clinic all operations with patient matched implants are performed by two senior orthopaedic surgeons only. They use a posterolateral approach and removal of a fixed femoral component is not mandatory but can be helpful for optimal exposure in selected cases. The femur is moved and held anteriorly with a large Hohmann retractor. A posterior soft tissue envelope is created by carefully releasing the posterior capsule form the posterior wall and ischium protecting the ischial nerve. A Cobb elevator can be helpful for exposure. Steinmann pins or threaded Kirschner wires are inserted maintaining the exposure. Afterwards the anterior structures are released starting superior with the caput reflexum of the rectus toward the pubic bone inferiorly. The gluteus maximus insertion is often released. Now the entire acetabular defect including the surface for flanges on the ilium, ischium, and pubic bone is exposed through a moveable window (figure 6). This window can be moved anterior, posteriorly, superiorly and inferiorly wherever exposure is needed during surgery.

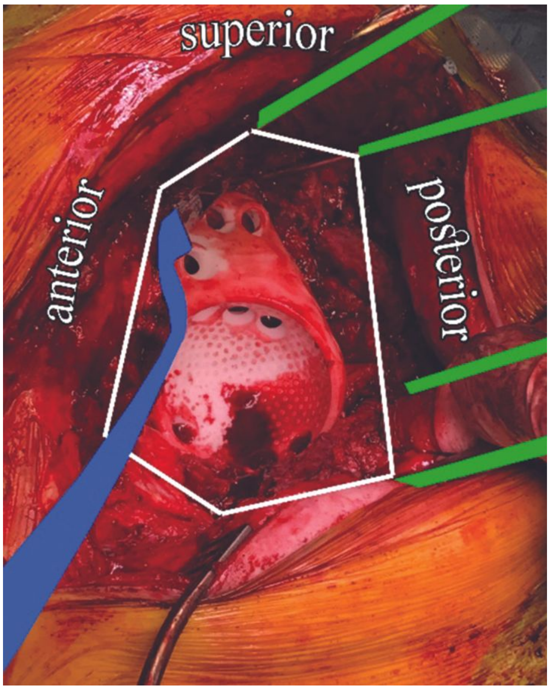

Figure 6: Exposure through the moveable window (white) and positioning of the plastic 'trail' model; The femur is moved and held anteriorly by a large Hohmann retractor (blue). Steinmann pins (green) are placed in the ilium, posterior wall and ischium.

The original acetabular implant has to be extracted completely with all hardware and cement. 6 cultures are obtained from multiple locations in every revision. Osteophytes have to be removed according to the preoperative plan before insertion of the trial implant. Sclerotic bone surface should be cleared by an acetabular reamer, curette or drilling small drill holes. Morselized allograft bone may be used to fill remaining contained defects between implant and host bone. With the included plastic trail implant a good fitting and orientation can be controlled before insertion of the definitive implant (figure 6).

According to the preoperative plan on the 3-D model primary fixation is achieved with multiple screws in the ilium, ischium, and pubic bone using the drill guides (figure 7).

Figure 7: Screw placement using the drill guide.

Screw length is also predetermined and can be double checked with the surgical guide. In case of a pelvic dissociation we start the fixation inferiorly in order to prevent pushing the ischium and pubic away during the insertion of the flange and screws. After inferior fixation the implant is fixed to the ilium together with the reduction of the dissociation (figure 8).

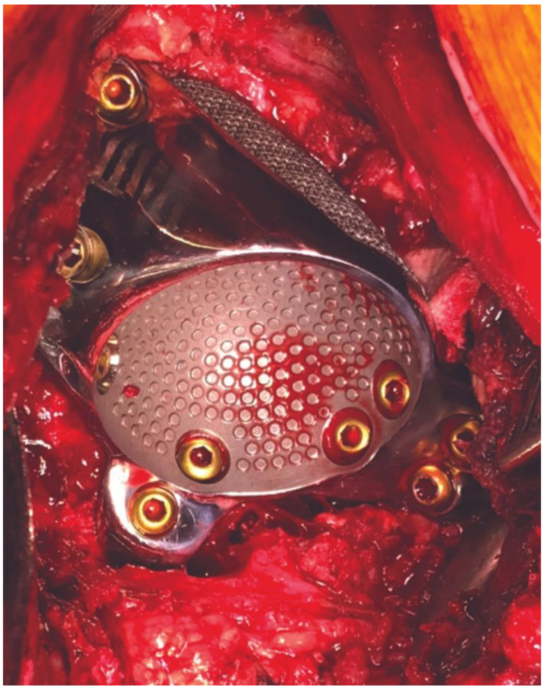

Figure 8: Definitive position and fixation of the implant.

Finally, a dual mobility cup is cemented into the implant and reduction of the femoral head is performed (figure 9). In case of severe abductor deficiency, we prefer the use of a constrained cup.

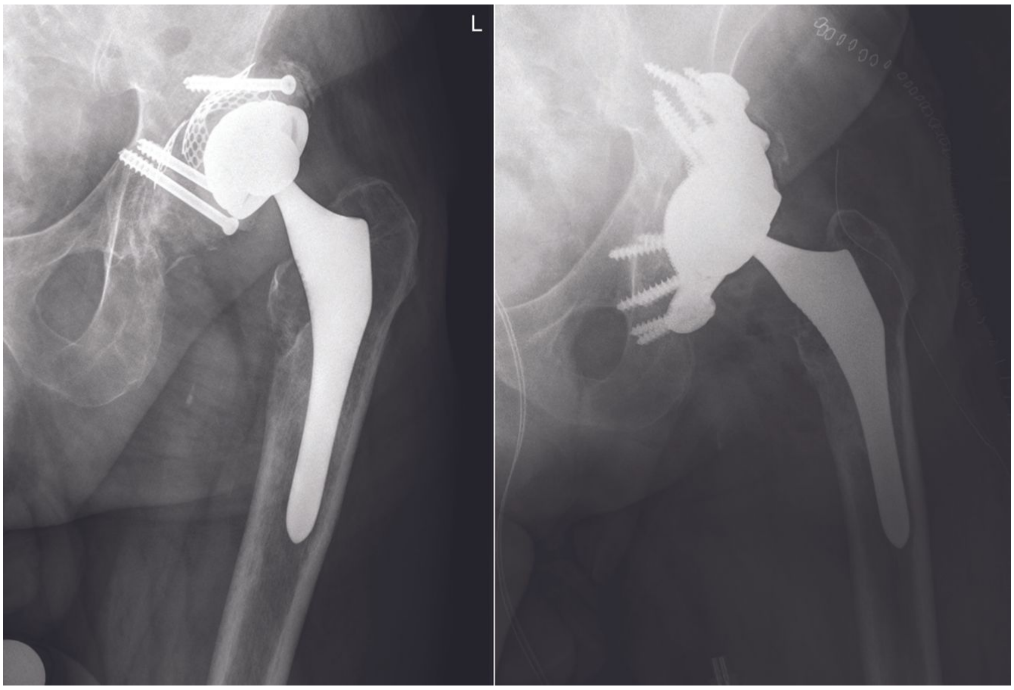

Figure 9: Pre- and postoperative X-ray.

TIPS & TRICKS

- Product design and specifications can be changed after surgeon's input. For instance, flanges and rows of screws can be reduced to allow easier implantation.

- Exposure and creating the moveable window as mentioned above is essential for good positioning of the implant (figure 6).

- A large Hohmann retractor facilitates exposure by keeping the femoral component anterior. Exact positioning of this device can be assessed using the 3D printed hemipelvis model during surgery, especially with anterior wall defects.

- Steinmann pins or threaded Kirschner wires are helpful for holding the posterior structures away and safe (figure 6).

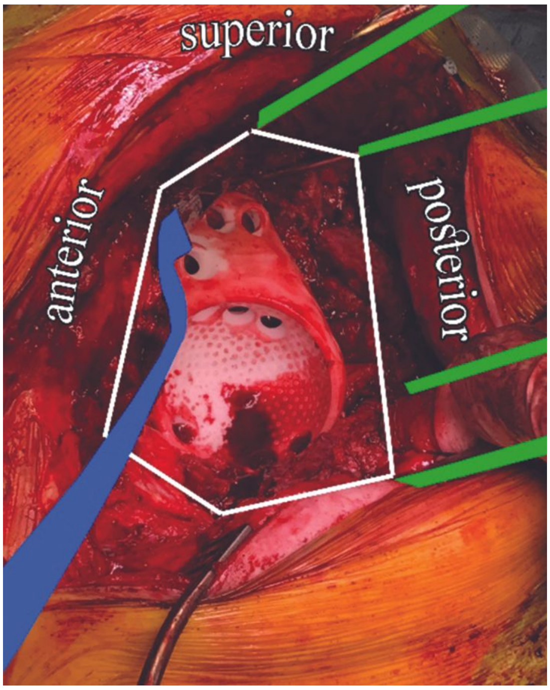

Figure 6: Exposure through the moveable window (white) and positioning of the plastic 'trail' model; The femur is moved and held anteriorly by a large Hohmann retractor (blue). Steinmann pins (green) are placed in the ilium, posterior wall and ischium.

- Inferior screws will prevent pull-out and early failure. Be careful with screws in the pubic area as vascular structures are at risk. We recommend using the drill guides to avoid this.

- We use bone wax for secure screw attachment to the screwdriver. This is helpful for screws inserted with the angular screwdriver.

- To minimize infection rate, we regulatory rinse the wound with diluted betadine solution and pulsatile lavage. Before closure we recommend painting the skin with betadine again.

POST-OPERATIVE CARE

Patients will be mobilised with 2 crutches under standard thrombosis prophylaxis for six weeks postoperatively. All patients receive empirical antibiotic therapy until perioperative cultures are negative. If the cultures will be positive the AB therapy is adapted to the pathogen sensitivity and continued for 6 weeks. In order to assess the final position of the implant and screws a CT scan is made postoperatively. A previous study from our group could show good accuracy for positioning of the implant according to the preoperative plan. [4]

OUR EXPERIENCE AND OUTCOME

Between 2011 and 2019 we have reconstructed over 100 Paprosky type 3 defects with the aMace patient matched implant. A cohort of 32 consecutive patients with a minimum follow up of 2 years were included for clinical analysis and radiologic outcome parameters. Median age was 68 years (range 48-89), male to female ratio was 12:20 and median BMI was 28 kg/m3 (range 20-44).

Clinical outcome measurements were the Oxford Hip Score (OHS), Euroqol-5-dimensions 3 level (EQ5D-3L), visual analog scale (VAS) for pain at rest, during activity and patient satisfaction. All outcome parameters (mean/ median, [SD/range]) improved over time; OHS (pre-op 51 [12]; 2yrFU 29 [10]), EQ5D utility (pre-op 0.216 [-0.128-0.920]; 2yrFU 0.747 [0.216-1]); VAS rest (pre-op 53 [0-100]; 2yr FU 20 [0-65]) and VAS activity (pre-op 89 [1-100]; 2yrFU 11 [0-65]) (table 1). At 2 years follow-up 93% of the patients were satisfied with the result. In total 9 complications occurred in 8 patients (table 2).

Outcome measurements	Pre-operative	2yr post-operative
	mean or median (SD)/[range]	
OHS	51 (21)	29 (10)
EQ5D utility	0.216 [-0.128-0.920]	0.747 [0.216-1]
VAS rest	53 [0-100]	20 [0-65]
VAS activity	89 [1-100]	11 [0-65]
Satisfied		93%

SD: standard deviation

Table 1: Clinical outcome measurements.

Complications	Number
re-operations	3 (9%)
DAIR	3
deep infection	1
dislocation	1 (3%)
screw loosening	3 (9%)
other	2 (6%)
total	9 (28%)

DAIR: debridement antibiotics implant retention

Table 2: Complications

Radiologic follow up showed no signs of migration of the implant or breakage of the screws. Screw loosening occurred in 3 patients without signs of implant loosening or tilting. No revisions of the implants were necessary but 3 re-operations for debridement of delayed wound healing had to be performed (9%). One of these cases had a culture proven deep infection which was treated with additional antibiotics successfully. One patient had a hip dislocation and closed reduction was performed, one patient had a cerebral vascular incident and one had a stress fracture of the ramus inferior (table 2). Existing literature of other patient matched acetabular systems reported re-operation rates up to 35% and revision of the implant in 0-11% of the cases. [5 to 7]

This a Mace reconstruction system has proven to be a solution for (re-)revision of difficult large acetabular defects with consistent clinical and radiological results. Patient matched implants for reconstruction of large acetabular defects are not new but the unique features of trabecular titanium, perfect fit of augments with flanges and bone quality assessment for screw fixation makes it in our opinion superior to other systems. Especially fixation to the ischium and pubic bone is of vital importance to prevent pull-out and consequently early mechanical failure. The revision system might be further improved by locking screws especially for the ischium flange. In poor bone quality this will have it advantages for primary fixation and might prevent screw loosening as described above. The disadvantage for this new technique are the high costs for the production of the 3-D printed implant.

CONCLUSION

Patient matched 3D printed implants are a safe and reliable solution in large acetabular Paprosky type 3 defects with evidence for surgical accuracy and consistent results. Complication rates are low considering the case mix and the complexity of the surgery. The major advantage seems to be the adequate primary fixation by the preop planned screw and implant fixation including the assessment of the bone quality. Long term follow-up is needed to demonstrate good secondary fixation and long-term survival. All our patients are included in a prospective database.

REFERENCES

1. **Baauw M, Van Hooff ML, Spruit M.** Current construct options for revision of large acetabular defects: A systematic review. JBJS Reviews 2016; 4: e2.

2. **Ahmad AQ, Schwarzkopf R.** Clinical evaluation and surgical options in acetabular reconstruction: A literature review. J Orthop 2015; 12: S238-43.

3. **Kosashvili Y, Backstein D, Safir O, et al.** Acetabular revision using an anti-protrusion (ilio-ischial) cage and trabecular metal acetabular component for severe acetabular bone loss associated with pelvic discontinuity. J Bone Joint Surg Br 2009; 91-B: 870–876.

4. **Baauw M, van Hellemondt GG, van Hooff ML, et al.** The accuracy of positioning of a custom-made implant within a large acetabular defect at revision arthroplasty of the hip. Bone Joint J 2015; 97-B: 780–785.

5. **Wind MA, Swank ML, Sorger JI.** Short-term Results of a Custom Triflange Acetabular Component for Massive Acetabular Bone Loss in Revision THA. Orthopedics 2013; 36: e260–e265.

6. **Taunton MJ, Fehring TK, Edwards P, et al.** Pelvic Discontinuity Treated With Custom Triflange Component: A Reliable Option. Clin Orthop Relat Res 2012; 470: 428–434.

7. **DeBoer DK, Christie MJ, Brinson MF, et al.** Revision Total Hip Arthroplasty for Pelvic Discontinuity. J Bone Jt Surg 2007; 89: 835.