Impaction Bone Grafting for Acetabular Bone Loss

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Total hip arthroplasty (THA) is increasingly performed in young patients and the number of revisions is estimated to rise over time. Acetabular osteolysis and bone loss are frequently encountered during revision and may be classified and treated in different ways. Impaction bone grafting (IBG) with morselized allograft offers a viable option. IBG was introduced over 40 years ago in combination with cemented cups, and is also used with uncemented cups.

total hip arthroplasty revision acetabular bone loss

1. Introduction

Total hip arthroplasty (THA) is one of the most successful procedures in modern medicine [1]. An increase in the number of THAs performed each year and the longer life expectancy of an ageing population will result in ever more revision procedures in the future [2]. With more and more younger patients undergoing THA, it is estimated that by 2030 more than half of primary THAs will be implanted in patients under 65 years of age [3]. However, these patients are at increased risk of revision procedures over time, with a younger age at primary surgery raising the lifetime risk of revision [4]. The outcomes of revision THA in such patients are worrisome, with re-revision rates of over 25% for any reason at 10 years of follow-up [5]. The selection of biomaterials and a reduction in material wear and wear-induced debris are crucial to improve implant durability [6][7] in both primary and revision THA.

Acetabular osteolysis is one of the reasons for revision and may be accompanied by asymptomatic chronic bone loss. The degree of bone deficiency can be determined by preoperative X-ray (anteroposterior, lateral, cross-table, and Judet views) and computed tomography (CT), the latter being more accurate, whereas magnetic resonance imaging (MRI) is an adjunctive tool to assess soft tissues. Final assessment is made intraoperatively.

The most widely used classifications of acetabular bone defects are the American Academy of Orthopedic Surgeons (AAOS) Classification [8] and the Paprosky Classification [9]. The AAOS system includes the definition of cavitary (volumetric bone loss) and segmental (loss of supporting bone) defects, and grades the defects from I to V. The Paprosky system is based on an assessment of the acetabular rim as a supporting structure for the cup, together with the amount and the direction of cup migration (from grade I to IIIB and a further category of pelvic discontinuity).

Addressing a bone deficient acetabulum is often a challenge for hip surgeons. The goal is to restore hip center and joint biomechanics, while achieving stable fixation of the acetabular component. Though a minor compromise for the first two may be acceptable, firm acetabular fixation is essential for durable reconstruction and less need for revision. Strategies for restoring acetabular bone loss include the use of structural allografts, cementless hemispherical cups, oblong cups, extra-large (or jumbo) cups, modular porous augments, impaction bone grafting (IBG), reinforcement rings, and antiprotrusio cages [10].

Two types of reconstruction for major acetabular bone defects are distinguished: non-biological reconstruction in which a cup is combined with augments and/or cages (or cup-cage constructs). The metal hardware addresses the bone loss and restores the center of the hip. Custom triflanged cups and custom-made implants are reserved for extreme defects. Differently, biological reconstructions with bone grafting offer the added advantage of improving and potentially restoring bone stock for future revisions, which is particularly important in young patients [11]. Some authors do not recommend the latter procedure as the first choice because it may be technically demanding and time-consuming as compared with non-biological techniques, with the risk of graft resorption and infection. Other reasons are the lack of suitable graft material and biologic fixation in cemented IBG [12]. While cementless IBG provides potential biological fixation when combined with a technique that most surgeons may be more familiar with (e.g., hemispherical cups), technical skills remain essential for a successful procedure. Indications for cementless IBG can be extended to major bone defects, in which last generation acetabular implants have redefined the need for pre-existing bone stock and minimum contact between the implant and the host bone to obtain primary fixation.

The most important factor in long-term fixation is bone stock [13]. The use of uncemented cups with adjunct screw fixation is a well-established method for acetabular revision when bone stock is deficient [14]. However, it might not suffice in intermediate and major bone loss, in which the use of uncemented cups can be combined with IBG to fill the defects and achieve better and more durable reconstruction and bone restoration.

The IBG technique was first described more than 40 years ago. Most studies are focused on cemented IBG, with or without mesh. Though not as well established as the cemented technique [15], IBG has been used in cementless revisions, with promising results in combination with new materials.

2. History of IBG

The conception and the development of IBG are closely related to the use of cemented cups. In 1975, Hastings and Parker first described IBG using cemented cups for protrusio acetabuli in rheumatoid patients [16]. In 1984, almost 10 years later, the technique was popularized for primary and revision THA by Slooff et al. from the Netherlands, who reported the results of 43 hips in which graft union was radiographically confirmed between 2 and 4 months after surgery [17].

In the original procedure, a metal mesh was used to cover the graft and limit cement penetration. This was soon abandoned because it hindered graft incorporation and did not add any relevant mechanical stability, whereas

metal meshes secured with screws remained part of the technique to close the segmental defects of the acetabular wall or on the peripheral rim. Later, the same group reported the outcomes of 88 revisions using aseptic loosening as endpoint, with a 94% survivorship at a mean follow-up of 11.4 years (minimum 10 years) [18]. These results were confirmed also in the long term (20 to 25 years), with an 87% survivorship [19].

Similar results have been reported by other groups [20][21][22], with favorable outcomes in patients under 55 years [23][24][25]. Higher failure rates were associated with larger defects (Paprosky type III) [26][27], however, and less experienced surgeons found the technique difficult to perform, even when assisted by a more experienced colleague [26]. Moderate bone defects (20 mm in depth and without multiple segmental defects) were considered to be predictors for better results [28]. Over time, the original technique has been refined and metal augments and structural allografts are now used in modern reconstructions with cemented components.

3. Rationale of IBG and Cementless Cup

Different from its historical development in combination with cemented cups, IBG and cementless cups offer several advantages. The rationale lies in the biological changes taking place in the graft during the postoperative period. In the treatment of acetabular defects, IBG is a biological void filler and restores bone stock once it is incorporated and substituted by host bone. Theoretically, an autograft, being osteoinductive and nonimmunogenic, ought to be the best biological option for bone restoration [29], but its major limitations in acetabular reconstruction are scarce availability, donor-site morbidity, and time-consuming collection. In contrast, morselized grafts from frozen heads maintain an adequate surface/volume ratio as compared with strut grafts, which means higher remodeling properties with less necrotic residual tissue; they can be used to fill defects in a “personalized” procedure and reach good mechanical properties when properly impacted, as noted for cemented IBG [17].

Histological data show that a creeping substitution takes place, with vascularization and incorporation of the impacted bone graft [30]. A healing scenario partly mimicking bone fracture healing starts from the periphery with partial osteoclastic resorption of graft trabeculae and application of living bone to allograft fragments. The graft fragments are gradually remodeled with progressive vascular ingrowth, until the graft is almost completely incorporated [30][31][32]. This process begins in the first weeks after surgery and continues for years after the operation. The extent of graft incorporation cannot be predicted accurately by postoperative radiographs [31]. Though the fibrous tissue may not be completely replaced by new bone tissue in some cases, the clinical result does not appear to be affected, at least in femoral cemented IBG [33].

An essential point to bear in mind during surgery is that primary stability of the cup is the cornerstone for a successful procedure. Unlike IBG with cemented cups, where cup stability depends on a firm bed of impacted bone, in cementless implants, the cup can migrate and eventually fail if its stability relies only on a graft that is being resorbed [34]. While bone ingrowth is promoted by the bleeding host bone, ingrowth through a morselized graft probably takes years, if ever, to occur [13]. This is why sufficient cup-host bone contact is essential. Though this mean a limitation of the technique, the cup features make the difference; high failure rates in the past were due to inadequate cup design and surface finishing [35]. In the last two decades, tantalum and titanium high-porosity

cup surface finishing by different additive technologies have changed the history of acetabular revision. Primary stability of the cup to the host bone of 50% was initially the cutoff for better results [36], whereas 25–30% cup-host bone contact is now considered to be acceptable for long-term fixation, if primary stability is achieved with a good rim fit and a contact area on the dome and the posterior column with the addition of multiple screws [37][38].

References

1. Learmonth, I.D.; Young, C.; Rorabeck, C. The Operation of the Century: Total Hip Replacement. Lancet 2007, 370, 1508–1519.
2. Ibrahim, M.S.; Raja, S.; Haddad, F.S. Acetabular Impaction Bone Grafting in Total Hip Replacement. Bone Jt. J. 2013, 95-B, 98–102.
3. Kurtz, S.M.; Lau, E.; Ong, K.; Zhao, K.; Kelly, M.; Bozic, K.J. Future Young Patient Demand for Primary and Revision Joint Replacement: National Projections from 2010 to 2030. Clin. Orthop. Relat. Res. 2009, 467, 2606–2612.
4. Bayliss, L.E.; Culliford, D.; Monk, A.P.; Glyn-Jones, S.; Prieto-Alhambra, D.; Judge, A.; Cooper, C.; Carr, A.J.; Arden, N.K.; Beard, D.J.; et al. The Effect of Patient Age at Intervention on Risk of Implant Revision after Total Replacement of the Hip or Knee: A Population-Based Cohort Study. Lancet 2017, 389, 1424–1430.
5. Kuijpers, M.F.L.; Hannink, G.; van Steenbergen, L.N.; Schreurs, B.W. Outcome of Revision Hip Arthroplasty in Patients Younger than 55 Years: An Analysis of 1037 Revisions in the Dutch Arthroplasty Register. Acta Orthop. 2020, 91, 165–170.
6. Ammarullah, M.I.; Afif, I.Y.; Maula, M.I.; Winarni, T.I.; Tauviqirrahman, M.; Akbar, I.; Basri, H.; van der Heide, E.; Jamari, J. Tresca Stress Simulation of Metal-On-Metal Total Hip Arthroplasty during Normal Walking Activity. Materials 2021, 14, 7554.
7. Jamari, J.; Ammarullah, M.I.; Saad, A.P.M.; Syahrom, A.; Uddin, M.; van der Heide, E.; Basri, H. The Effect of Bottom Profile Dimples on the Femoral Head on Wear in Metal-On-Metal Total Hip Arthroplasty. J. Funct. Biomater. 2021, 12, 38.
8. D'Antonio, J.A.; Capello, W.N.; Borden, L.S.; Bargar, W.L.; Bierbaum, B.F.; Boettcher, W.G.; Steinberg, M.E.; Stulberg, S.D.; Wedge, J.H. Classification and Management of Acetabular Abnormalities in Total Hip Arthroplasty. Clin. Orthop. Relat. Res. 1989, 243, 126–137.
9. Paprosky, W.G.; Perona, P.G.; Lawrence, J.M. Acetabular Defect Classification and Surgical Reconstruction in Revision Arthroplasty. A 6-Year Follow-up Evaluation. J. Arthroplasty 1994, 9, 33–44.

10. Mancino, F.; Cacciola, G.; Di Matteo, V.; De Marco, D.; Greenberg, A.; Perisano, C.; MA, M.; Sculco, P.K.; Maccauro, G.; De Martino, I. Reconstruction Options and Outcomes for Acetabular Bone Loss in Revision Hip Arthroplasty. Orthop. Rev. 2020, 12, 8655.
11. De la Torre-Escuredo, B.; Gómez-García, E.; Álvarez-Villar, S.; Bujan, J.; Ortega, M.A. Bone Impaction Grafting with Trabecular Metal Augments in Large Defects in Young Patients: Unravelling a New Perspective in Surgical Technique. BMC Musculoskelet. Disord. 2020, 21, 581.
12. Fryhofer, G.W.; Ramesh, S.; Sheth, N.P. Acetabular Reconstruction in Revision Total Hip Arthroplasty. J. Clin. Orthop. Trauma 2020, 11, 22–28.
13. Lee, J.-M.; Nam, H.-T. Acetabular Revision Total Hip Arthroplasty Using an Impacted Morselized Allograft and a Cementless Cup: Minimum 10-Year Follow-up. J. Arthroplasty 2011, 26, 1057–1060.
14. Palm, L.; Jacobsson, S.-A.; Kvist, J.; Lindholm, A.; Ojersjö, A.; Ivarsson, I. Acetabular Revision with Extensive Allograft Impaction and Uncemented Hydroxyapatite-Coated Implants. Results after 9 (7–11) Years Follow-up. J. Arthroplasty 2007, 22, 1083–1091.
15. Perlbach, R.; Palm, L.; Mohaddes, M.; Ivarsson, I.; Schilcher, J. Good Implant Survival after Acetabular Revision with Extensive Impaction Bone Grafting and Uncemented Components. Bone Jt. J. 2020, 102-B, 198–204.
16. Hastings, D.E.; Parker, S.M. Protrusio Acetabuli in Rheumatoid Arthritis. Clin. Orthop. Relat. Res. 1975, 108, 76–83.
17. Slooff, T.J.; Huiskes, R.; van Horn, J.; Lemmens, A.J. Bone Grafting in Total Hip Replacement for Acetabular Protrusion. Acta Orthop. Scand. 1984, 55, 593–596.
18. Schreurs, B.W.; Slooff, T.J.; Buma, P.; Gardeniers, J.W.; Huiskes, R. Acetabular Reconstruction with Impacted Morsellised Cancellous Bone Graft and Cement. A 10- To 15-Year Follow-up of 60 Revision Arthroplasties. J. Bone Jt. Surg. Br. 1998, 80, 391–395.
19. Schreurs, B.W.; Keurentjes, J.C.; Gardeniers, J.W.M.; Verdonschot, N.; Slooff, T.J.J.H.; Veth, R.P.H. Acetabular Revision with Impacted Morsellised Cancellous Bone Grafting and a Cemented Acetabular Component: A 20- To 25-Year Follow-up. J. Bone Jt. Surg. Br. 2009, 91, 1148–1153.
20. Gilbody, J.; Taylor, C.; Bartlett, G.E.; Whitehouse, S.L.; Hubble, M.J.W.; Timperley, A.J.; Howell, J.R.; Wilson, M.J. Clinical and Radiographic Outcomes of Acetabular Impaction Grafting without Cage Reinforcement for Revision Hip Replacement: A Minimum Ten-Year Follow-up Study. Bone Jt. J. 2014, 96-B, 188–194.
21. Comba, F.; Buttaro, M.; Pusso, R.; Piccaluga, F. Acetabular Reconstruction with Impacted Bone Allografts and Cemented Acetabular Components: A 2- To 13-Year Follow-up Study of 142 Aseptic Revisions. J. Bone Jt. Surg. Br. 2006, 88, 865–869.

22. Garcia-Cimbrelo, E.; Cordero, J. Impacted Morsellised Allograft and Cemented Cup in Acetabular Revision Surgery. A Five to Nine Year Follow-up Study. Hip Int. 2002, 12, 281–288.
23. Busch, V.J.J.F.; Gardeniers, J.W.M.; Verdonschot, N.; Slooff, T.J.J.H.; Schreurs, B.W. Acetabular Reconstruction with Impaction Bone-Grafting and a Cemented Cup in Patients Younger than Fifty Years Old: A Concise Follow-Up, at Twenty to Twenty-Eight Years, of a Previous Report. J. Bone Jt. Surg. Am. 2011, 93, 367–371.
24. Schmitz, M.W.J.L.; Hannink, G.; Gardeniers, J.W.M.; Verdonschot, N.; Slooff, T.J.J.H.; Schreurs, B.W. Acetabular Reconstructions with Impaction Bone-Grafting and a Cemented Cup in Patients Younger than 50 Years of Age: A Concise Follow-Up, at 27 to 35 Years, of a Previous Report. J. Bone Jt. Surg. Am. 2017, 99, 1640–1646.
25. Comba, F.; Buttaro, M.; Pusso, R.; Piccaluga, F. Acetabular Revision Surgery with Impacted Bone Allografts and Cemented Cups in Patients Younger than 55 Years. Int. Orthop. 2009, 33, 611–616.
26. van Haaren, E.H.; Heyligers, I.C.; Alexander, F.G.M.; Wuisman, P.I.J.M. High Rate of Failure of Impaction Grafting in Large Acetabular Defects. J. Bone Jt. Surg. Br. 2007, 89, 296–300.
27. Rigby, M.; Kenny, P.J.; Sharp, R.; Whitehouse, S.L.; Gie, G.A.; Timperley, J.A. Acetabular Impaction Grafting in Total Hip Replacement. Hip Int. 2011, 21, 399–408.
28. Iwase, T.; Ito, T.; Morita, D. Massive Bone Defect Compromises Postoperative Cup Survivorship of Acetabular Revision Hip Arthroplasty with Impaction Bone Grafting. J. Arthroplasty 2014, 29, 2424–2429.
29. Pierannunzii, L.; Zagra, L. Bone Grafts, Bone Graft Extenders, Substitutes and Enhancers for Acetabular Reconstruction in Revision Total Hip Arthroplasty. EFORT Open Rev. 2016, 1, 431–439.
30. Ullmark, G.; Obrant, K.J. Histology of Impacted Bone-Graft Incorporation. J. Arthroplasty 2002, 17, 150–157.
31. Heekin, R.D.; Engh, C.A.; Vinh, T. Morselized Allograft in Acetabular Reconstruction. A Postmortem Retrieval Analysis. Clin. Orthop. Relat. Res. 1995, 319, 184–190.
32. Buma, P.; Lamerigts, N.; Schreurs, B.W.; Gardeniers, J.; Versleyen, D.; Slooff, T.J. Impacted Graft Incorporation after Cemented Acetabular Revision. Histological Evaluation in 8 Patients. Acta Orthop. Scand. 1996, 67, 536–540.
33. Linder, L. Cancellous Impaction Grafting in the Human Femur: Histological and Radiographic Observations in 6 Autopsy Femurs and 8 Biopsies. Acta Orthop. Scand. 2000, 71, 543–552.
34. Jones, S.A. Impaction Grafting Made Easy. J. Arthroplasty 2017, 32, S54–S58.

35. Jeffery, M.; Scott, G.; Freeman, M. Failure of an Uncemented Non-porous Metal-Backed Prosthesis with Augmentation Using Impacted Allograft for Acetabular Revision 12- To 17-Year Results. J. Bone Jt. Surg. Br. 2003, 85, 182–186.
36. Sternheim, A.; Backstein, D.; Kuzyk, P.R.T.; Goshua, G.; Berkovich, Y.; Safir, O.; Gross, A.E. Porous Metal Revision Shells for Management of Contained Acetabular Bone Defects at a Mean Follow-up of Six Years: A Comparison between up to 50% Bleeding Host Bone Contact and More than 50% Contact. J. Bone Jt. Surg. Br. 2012, 94, 158–162.
37. Konan, S.; Duncan, C.P.; Masri, B.A.; Garbuz, D.S. Porous Tantalum Uncemented Acetabular Components in Revision Total Hip Arthroplasty: A Minimum Ten-Year Clinical, Radiological and Quality of Life Outcome Study. Bone Jt. J. 2016, 98-B, 767–771.
38. Patel, S.; Sukeik, M.; Haddad, F.S. Initial Implant Stability Predicts Migration but Not Failure in Cementless Acetabular Revision with Bone Grafting. J. Arthroplasty 2013, 28, 832–837.

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