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Review

The current treatment of hip arthroplasty revision: a systematic review of the literature

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Abstract. *Introduction:* Acetabular revision surgery is the most complex, difficult to treat and challenging aspect in hip prosthetic. In this typer of surgery there is lack of consensus on the optimal method of reconstructing the most severe acetabular defects. The aim of this systematic review is to take stock of the state of the art on the options available in acetabular revisions and highlight which type of construct is the most reliable in usual clinical practice. *Material and methods:* The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 Statement. Electronic search of MEDLINE was performed from 1991 up to April 2021 to identify relevant studies for this review. *Discussion:* various surgical techniques have been adopted and proposed to treat acetabular bone defects: cemented cups, large-sized non-cemented acetabular cups, higher positioned cups, reinforcement rings, cage, oblong cups, custom triflange implants, high porous metal cups and augments. Bone defect defines the type of components to be implanted and among those, outcomes are various depending on the study taken into account, the component used and the degree of initial bone defect. *Conclusions:* In acetabular revision surgerythe use of TM cups and augment is a valid option in presence of major bone loss and pelvic discontinuities. In clinical practice the use of TM components replaced rings, while the cup-cage implant replaced conventional cages. TM augments and cups can be considered as the most promising technique in the reconstruction of wide acetabular defects, while the use of cages can be considered as a valid option in the elderly population and with minor functional demands. (www.actabiomedica.it)

Key words: hip arthroplasty revision, acetabular revision, trabecular metal

Introduction

In revision Total Hip Arthroplasty (THA), there is lack of consensus on the optimal method ofreconstructing the most severe acetabular defects THA is one of the most successful interventions in the orthopaedic field and is the gold standard in the treatment of the end-stage pathology of the coxofemoral joint. In recent years the number of first prosthesis implanted has been steadily increasing. Projection models predict that in the next two decades there will be an increase in the demand for revision procedures (1). Despite the excellent clinical results of the first implant, many patients outlive these and it is estimated that about 17% will need further surgery over their lifetime (2).

Acetabular revision is the most complex, difficult to treat and challenging aspect in hip prosthetic surgery since the achievement of the basic principles of prosthetic replacement, such as the restoration of the correct biomechanical parameters and muscle tensions, are complicated by the loss of bone stock and soft tissue condition. Indications to acetabular revision include in the symptomatic patient septic and aseptic loosening, implant's instability, while in the asymptomatic patient revision THA can be indicated in case of progressive osteolysis, severe components'wear and severe bone loss (3).

Several classification systems are available to quantify the acetabular bone defect. The most widely used are: Paprosky (4), the American Academy of Orthopaedic Surgeons (AAOS) (5), Saleh and Gross (6). In general the wider the defect, the more challenging the surgery will be.

Over the years, various surgical techniques have been adopted and proposed to treat acetabular bone defects such as cemented cups, large-sized non-cemented acetabular cups, higher positioned cups (moving therefore the center of rotation proximally), reinforcement rings and cage anti-displacement, cage with allograft, oblong cups, bone allograft and cement, custom triflange implants: each of these has its own advantages and disadvantages (7–13).

To date, no surgical technique has emerged as the gold standard for acetabular revision. The reason is to be found in the great heterogeneity of cases to be treated with varying degrees of bone loss, the difficulty in measuring outcomes, the low number of available results and the lack of long-term follow-up, especially for the most recently developed and available components in surgical practice (14).

The aim of this systematic review is to take stock of the state of the art on the options available in acetabular revisions and highlight which type of construct is the most reliable in usual clinical practice.

Materials and methods

The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 Statement.

Electronic search of MEDLINE was performed from 1991 up to April 2021 to identify relevant studies for this review. Search terms used included: hip acetabular revision, acetabular augment, revision cups.

Two researchers independently screened titles, abstracts, and full texts according to predetermined inclusion and exclusion criteria (Table 1). The studies selection are reported in the following diagram. Discrepancies were settled by consensus.

Data extraction from the included studies was performed by the principal investigator and was checked by the senior investigator. The data were collected on a prespecified data-extraction form and included first author, title, year of publication, mean follow-up, mean age at revision, sample size, treatment method, associated treatment, classification method, failure, dislocation, survival, clinical outcome, conclusion of the study reported (Table 2).

Pelvic discontinuity

Pelvic discontinuity (PD) is an uncommon and unique form of severe acetabular defect where the upper and lower hemipelvis are separated by loss of bone stock and/or traversed by a fracture through the anterior and posterior columns. Direct signs of this condition can be found directly from a radiolucent line at radiographs or indirectly from a

Table 1. Selection criteria.

Inclusion criteria
• Human studies
• Sample size > 15 patients
• Average follow-up > 1.5 years
• Written in English
Exclusion criteria
• Only investigation of femoral side of hip revision
• Case-report
• No full text available
• Oncology

Table 2. Data extraction.

Initial search
N = 7647

- Publication before 1991 and after 2021 N = 734
- Duplication removed N = 3365

Titles and abstract screened
N = 3548

- Record excluded N = 3505

Studies meeting the inclusion criteria
N = 43

medialization or rotation of the lower hemipelvis with respect to the upper hemipelvis, visible as an interruption of the Köhler line and an asymmetry of the obturator foramen.

Such condition is the most difficult challenge in THA revision surgery since involves the treatment of a pelvic fracture and a prosthetic revision in presence of major bone loss and severe lack of bone stock. The reconstruction alternatives for PD depend on the remaining bone stock. Treatment options vary from plaques, structural and non-structural bone grafts, uncemented cups and cages.

Cemented revision

The use of cemented acetabular cups has been present in the clinical practice for many years. This has encouraged the publication of many studies with long follow-up providing us information about the survival of the implant. Depending on the study considered, conflicting results are present in the literature: for example, according to Schreurs (12) the 20 years survival of a cemented cup is reported to be 79%, while for Katz (15) the failure at 10 years reaches 65%. The use of cemented acetabular cups for revision surgery is associated with very high mobilization rates. The probability of a cemented revision cup being revised again is 25-50% (16). The high failure rate is mostly due to the lack of cement interdigitation in the patient's sclerotic bone, and for this reason this revision method has been abandoned by many surgeons who tend to prefer the use of non-cemented components (17). The use of this type of surgical method it is still used in centres with considerable experience in cementation techniques and in some special cases.

Cementless acetabular design

The high failure rate of cemented cups has encouraged the evolution of the non-cemented ones, which has become the method of choice in both first implants and revision surgery. Porous coat implants were introduced about 30 years ago in attempt to increase implants' survival. Initially metallurgy included: cobalt-chrome sintered beads, diffusion bonded fibers metal mesh, cancellous-structured titanium, and titanium plasma spray. The biological fixation of these implants included bone ingrowth/ongrowth and remodeling at the bone-metal interface to achieve a more durable and solid fixation, but the physical characteristics of such implants were limiting especially in the presence of poor bone stock. These limitations have encouraged the development of further implants, fixation methods, alternative techniques and dedicated implants for revision surgery

Highly porous metals (HPM) have been developed to answer these questions and thus to improve biomechanical properties and implant survival. The open-cell structure of these HPM is ideal for revision surgery due to the high volume of porosity (increased early osteointegration), low modulus of elasticity (lower risk of bone loss from stress shielding) and high friction characteristics (best cup-bone interface).

Jumbo cups

The use of extra-large cups or non-cemented jumbo cups in revision surgery has shown favorable results in patients with moderate bone loss, but in the presence of severe defects, different components should be used.

Among the advantages of this type of cup we find the hemisphere preparation of the acetabulum as it happens in the case of the first implant. In fact, the minor bone defects are uniformed and filled by the cup obviating the need for extensive bone-grafting. The disadvantages are the non-recovery of the missed bone stock and the inability to fill large inferior-superior bone defects without reaching very high diameters and thus affecting the residual bone stock. The use of very large diameter cups also leads to a compromise between the positioning of the cup itself and the determination of the centre of rotation, which is often raised and anteriorised compared to the optimum, with a potential reduction in muscular efficacy and the creation of unfavourable forces on the implat at long-term. A large acetabular cup provides adequate biological fixation and can be combined with larger femoral heads thus increasing implant stability. For this type of cup it is reported a mobilization rate of 1.5%, with implant survival of 98% at 4 years and of 96% at 16 years (18).

Oblong – bilobate cups

Bilobed cups have the supero-inferior diameter greater than the antero-posterior one. These type of impants constitutes an alternative to restore the center of rotation and increase the implant-bone contact area in presence of superior segmental acetabular defects (Paprosky III A). The disadvantages include technical difficulties to determine a complete bone-implant contact such as to make the same stable with the risk of further affecting the bone stock.

In the light of modern revision surgery, the use of oblong cups is not practical. Again, the results reported in the literature are discordant and depend on the series taken into account, mainly because of the small number of patients included in the studies. In a recent review this type of cup obtained the lowest revision rate and the lowest dislocation rate among those considered. (14) This could be determined by the ability of the cup to restore the center of rotation of the hip and to obtain sufficient bone-cup contact for increased osseointegration (19).

Trabecular metal cups and augment

The use of trabecular metal acetabular cups and augment is a valid option both in simple acetabular revisions and in more complex ones, where bone biology is poor, the bone stock is affected and even in particular cases of pelvic discontinuity. As mentioned above, HPM offer an optimal biological environment for bone ingrowth (up to 3 fold compared to conventional porous cups)(20), and for the remodelling of the bone graft used thus ensuring better initial stability and biological fixation resulting structurally ideal for acetabular revision surgery. (21)

Multiple studies have reported low failure rates and increased survival in implants revised with such components, although they are lacking with long-term follow-up outcomes (17,22,23).

Thanks to its physical characteristics, the porous metal guarantees in the immediate post-surgery a stable bone-implant interface which determines a reliable primary mechanical stability and the subsequent osteointergation that promotes secondary biological stability (24). Since osteointegration occurs at the metal-bone interface, the relative movement between the metal components (cup and augment) could affect the overall stability of the construct, also hesitating in the production of metal fragments, causing the adverse rection to metal debris, ARMD (25,26).

A revision system that involves the use of modular augment and screws to support an hemispherical acetabular cup, ensures stable support even in presence of critical bone segmental defect, increases the bone-components contact area and allows biological fixation as well as mechanical fixation (27,28). To achieve this type of stability between components, the best method described was achieved by placing multiple screws between these and the patient's bone and cement between the components themself (29,30).

The production process of such metal surfaces involves the formation of a reticular skeleton with metal deposition on the surface. Polyurethane foam, reticulated vitreous carbon and other organic substrates can be designed into various shapes and sizes for use in orthopaedics. Once a scaffold is created, a metallic coating can be applied using a chemical or arc vapour deposition process.

Different manufacturers have introduced their HPM products for prosthetic surgery including Trabecular Metal (Tantalum, Zimmer, Warsaw, IN), Tritanium (Titanium, Stryker, Mahwah, NJ), Regenerex (Titanium, Biomet, Warsaw, IN), Stiktite (Titanium, Smith and Nephew, Memphis, TN) and Gription (Titanium, depuy, Warsaw, IN). The largest clinical data available is on Trabecular Metal (TM) which has established itself as leader in the development of this technology.

Possible disadvantages related to the use of TM components could be the lack of knowledge of long-term survival, the potential production of debris and periarticular soft tissue damage, liner wear, mechanical failure, inability to restore bone stock for any subsequent revisions.

In the series described by Nehme et al. (30), none of the implants showed signs of mobilization at 32 month. Similar results were found by Spoorer and Paprosky (31) where at 37 months of follow-up, only 1 patient out of 28 was reviewed for recurrent instability. Fernandez et al. (32) revised 263 implants using a cup with TM cup and augment, in 49 cases there was a type III defect. Such coupling has been used in 12.9% of cases, while the graft with morcellized bone has been used in 48% of cases. At the last follow-up (average 73.6 months), all cups were stable at the rx and none required revision for loosening. Medium-term follow-up studies have shown good results with the use of these components in acetabular reconstruction. In the Weeden and Schmidt's study, a 98% success rate was reported considering radiographic mobilization as endpoint. (33) Del Gaizo et al reported a 97.3% success considering as endpoint at 5 years of follow up the aseptic loosening (34). TM components show promising results and the present literature supports and suggests their use in patients with severe acetabular bone loss (35).

Antiprotrusio cage

Antiprotrusio cages have been used in the past in the more complex acetabular reconstructions. The cage allows the use of bone grafting and ideally bridging areas of bone loss. This type of implants are composed of titanium alloys and transfer the load from the acetabular cup to the periacetabular bone through the ileal and ischial flanges, fixed with screws to the patient's bone, protecting the bone graft from lysis and allowing it to reshape with the native bone (36,37,38).

In the literature the data are once again discordant, in fact for Paprosky et al. (39) at 46 months of followup the 31% of the patients revised with this implant were again revised for aseptic loosening, for Peters et al. (40) the new revision rate for the same reason was 5%, 8% for mechanical failure of the implant and 12.7% for dislocation, while for Goldmann et al. (41) success was achieved in 76% of cases at 46 months of followup. In the latter series, PD was found in 10 patients, and on these the use of an antiprotruse cage led to success in 50% of cases.

The need for extended surgical exposure is one of the major drawbacks to the use of this type of component due to the increased risk of damage to soft tissues and neurovascular structures. The lack of biological fixation and the dependence of mechanical stability to the screws'fixation leads to failure. This occurs in most cases due to the lack of incorporation of the bone graft with the native bone due to the lack of the cage surface porosity which makes ingrowth problematic (36).

Cup-cage technique

The cup-cage construct is an additional alternative to correct large acetabular defects and in the presence of PD. In the early post-surgery period, the cage aims to protect the cup by removing the load forces, optimizing the patient's bone ingrowth and therefore the osseointegration of this with bone grafting (42). The combination of TM cup and cage for treating very large defects or PD was first described by Lewallen at the 2008 AAOS meeting. This construct showed encouraging short-term results where no clinical or radiological signs of mobilization were observed in 88.5% of the cases analysed at 44.6 months (43).

Despite the concern that the cage may face wear and mechanical failure due to loads, combining it with the characteristics of a biologically compatible porous cup can lower this complication, but further data are needed to understand the actual use of this construct (44).

Acetabular distraction with porous cup

The technique is a further new approach for the treatment of PD that bases its principle in approaching the non-union by applying a distraction to expand the bone defect and thus create an elastic force to compress the acetabular cup once removed the distraction (45). Before implanting the cup, a careful debridment is carried out at the PD level to remove the interposed tissue, while the reaming process prepares for fixation with augmenation (46).

No long term studies are available on the technique just described. In the afore mentioned study of Sporer et al. (47) it was reported at 9 months only 1 case of revision by aseptic loosening on 20 implants, while at 4 years of follow-up 4 additional implants showed radiological signs of migration but remained clinically stable (46).

Custom triflange cages

Triflange implants are custom-made implants based on patient's pelvis CT, made of porous coated titanium alloys and are used as a rescue option in patients with PD or severe bone stock damage not reconstructable with traditional techniques or with the use of metal augments. This solution entails the need for a careful pre-operational planning, the technical manufacturing time that can reach even 5-6 weeks in addition to a considerable increase in the production's costs (42). Compared to other methods, the triflange cages have shown the highest failure rate in terms of reintervention, but it must be remembered that this plant is indicated in the presence of PD and severe bone loss, where Girldestone pseurdoarthrosis is the only other surgical option (47).

Discussion

The bone defect defines the type of components to be implanted, and among those described outcomes are alternate depending on the study taken into account, the component used and the degree of initial bone defect. (4,23,48) Preoperative planning is a fundamental tool in dealing with this type of surgery, it is essential to choose the most appropriate implant, and it is therefore mandatory to objectify the nature of the defect to determine which is the remaining acetabular bone stock. The planning shall use both conventional pelvic and femoral x-rays and CT imaging to target areas of bone loss (49). The choice of the implant to be used depends on several variables: the type of bone defect, the availability of the implants, and the preferences of the operator surgeon.

In presence of a cup-bone contact area greater than 50%, therefore where the bone bears more than 50% of the load, it is possible to proceed with the use of a porous metal hemispherical acetabular cup, screws and possible bone graft. In presence of major bone defects and poor bone stock, where component-bone contact is less than 50% and insufficient to ensure implant stability, more complex surgical options will be needed. In such cases the use of porous cups and augments in trabecular metal, oblong cups, roof reinforcement rings, anti-protrusio cage, cup-cage, plate fixation of the rear column, bone distraction, structural bone grafts or combinations of these as explained below (17). For a long time the cup-cage and bone allograft has been the gold standard, with high failure rates reported at the long term follow-ups, especially in case of severe acetabular roof defects and pelvic discontinuity (50). For these latter conditions, metallic materials have been developed and proposed in the recent years to achieve a better primary fixation, and a secondary osseointegration so as to allow an early post-operative mobilization and to avoid components' loosening due to bone reabsorption (51). These include HPM that ensure better primary stability, optimize the distribution of stress forces and thus promote osteointegration. The use of this kind of augment has been proposed as an alternative to the use of structural bone allografts and could also have the additional advantage of bringing joint rotation's center closer to the physiological one, improving articular biomechanics (4,10).

In the literature, among the preferred methods for severe acetabular defects' treatment are the use of massive bone transplantation with protective cages. Reported outcomes are not good, as reported by Garbutz et al.(52) where there has been a success in only 55% of plants to 7 years of followup. Udomakiat et al. (53) reported a 17% failure in patients with a Müller or Burch-Schneider ring at a 54-month follow-up. Cages do not guarantee biological fixation and do not obtain sufficient bone ongrowth to stabilize the construct, leading to long-term loosening, even when morcellized bone graft is used (40,54,55). The use of XL cups - un-cemented jumbo cups, bilobed cups or smaller cups placed more proximally, have shown variable results depending on the study considered (56,57). Jumbo cups may require the bore of the front column, since most of the upper defects are elliptical with the AP's largest supero-inferior size, further affecting the stock bone. Placing a cup more proximally can alter the biomechanics of the hip and contribute to a higher rate of dislocation (11%) and loosening (6%) (13,58). Custom triflange cups are a promising option reaching a survival of 88% at 54 months, but presenting a high rate of dislocation and higher times and costs for production (59,60).

The use of TM augment to reduce the acetabular defect and provide cup support is indicated when the use of a revision cup alone would not be stable. The type, placement and orientation of the augment depends on the bone loss pattern. Structural allografts have been shown to produce good results if a bone-cupping surface of more than 50% is present, whereas in presence of a component-bone contact of less than 50%, long-term results are poorer and more complicated. The implant survival rate is 80.6% in the first case and 55-74% in the second (40,52,61,62).

It has been suggested that the most desirable fixation method in acetabular revision is the biological one, and the characteristics of TM cup-augment system achieve this purpose. The greatest advantage in the use of TM augment is that these can also fill the bone defect without the need to use bone allografts, developing a greater bone-component surface.

Although it is difficult to compare the results of all the literature's studies due to their non homogeneity, the TM has a statistically significant lower mobilization rate than the use of rings for the treatment of any degree of bone defect (including PD) (60). The characteristics of the TM are optimal for revision surgery, the presence of a modular cup-augment system ensures better management of the acetabular anatomy, requires less soft tissue damage, less mobilization of the abductors, and due to the very nature of the material, the construct cannot undergo structural changes over time as could happen in the presence of bone allograft. This type of construct maximizes the potential for a biological fixation, and the reconstruction of the anatomy could bring the center of rotation closer to the physiological one ensuring greater survival to the implant and better results in the long term.

In the study of Jafari et al. (63) at a 4-year follow-up, in the presence of major bone defects, it was reported a mobilization rate of 12% for tantalum cups and 24% for porous-coated cups.

In the comparative study of Sternheim et al. (64) on highly porous cups, at 6years of followups, it was observed that in presence of less than 50% contact surface the 7.5% of the cups needed revision, in contrast to the 0% where more than 50% of bone-component was present, however this difference is not statistically significant. When compared with previous reports, these data were found to be significant in aseptic mobilization in the presence of major and minor bone defects (2.9% and 0.4% respectively)(65).

There is no agreement in the literature if the restoration of the center of rotation optimizes the outcome. In fact an option involves placing the cup in the healthy bone more proximally, to obtain a valid primary fixation and promote bone ingrowth for secondary stabilization. Dearborn et al. (58) reviewing 46 revised THA with an average follow up of 10.4 years, reported a 96% survival for this type of implant, no functionality changing of the abductors, with a reduction of the Trendelembug sign from 98 to 44% at the final visit. Similar to Dearborn, Schutzer et al. (66) also reported excellent results in the revised hips with the upper placement of the acetabular cup, with 100% survival at 3.3 years, moving the center of rotation on average 29mm.

A recent review (67) analysed the many options available for the major bone defects treatment, showing the best outcomes in terms of re-revision and radiographic mobilization are reported using TM cup and augments. With regard to the use of anti-protusio cages, the re-revision and radiographic mobilization rate was reported to be slightly higher than the one reported in the TM studies. Many of these implants, however, did not need revision due to satisfactory clinical results in a population with low functional demands. This suggests that such implant can be considered when treating an acetabular defect in the elderly population, while in younger population with higher functional demands, a mechanical failure of the implant caused by lack of stability and physiological fixation may result in lower clinical outocome (67).

Conclusions

In the setting of acetabular revision, based on the results available in the literature (and at a short term follow-up), the use of TM cups and augment is a valid option if in presence of Paprosky type III defects and pelvic discontinuities. In clinical practice, the use of TM components replaced rings, while the cup-cage implant replaced conventional cages. TM augments and cups can be considered as the most promising technique in the reconstruction of wide acetabular defects, while the use of cages is the most frequently reported technique in the literature. This last type of component can be considered a valid option in the elderly population and with minor functional demands

Bone stock restoration is the goal of the use of morcellized allograft, but this method has shown lower results for III B defects especially when associated with PD. Further data and studies with longer follow-ups are needed to determine which is the gold-standard technique in acetabular revision surgery that guarantees durable fixation and improved survival in the presence of significant bone loss.

Conflicts of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Ethics Approval and Consent to Participate: Authors state that, since it is a Literature Review, Ethics committee approval was not required. The work was undertaken according to the provisions of the Declaration of Helsinki.

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