

Use of highly porous shell and variable-angle locking screws for acetabular revision surgery: our experience and medium term results

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SUMMARY

This article presents the clinical outcomes and experiences of our hospital in utilizing highly porous shells with variable-angle locking screws in acetabular revision surgery in patients with total hip arthroplasty (THA). A retrospective analysis was conducted on 16 acetabular revision cases, and patients were followed for an average of 22 months. The postoperative functional outcomes were evaluated with the Harris Hip Score (HHS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC). Complications and radiographic findings were also analyzed. The results demonstrate promising outcomes with improved hip function, pain relief, minimal complications and implant stability. Our findings contribute to the growing evidence supporting the efficacy and safety of high porosity cotyles in revision surgery of THA.

Key words: revision surgery, aseptic mobilization, septic mobilization, total hip arthroplasty

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Introduction

Total hip arthroplasty (THA) is a highly successful surgical procedure for the treatment of end-stage hip osteoarthritis (OA), providing significant pain relief and functional improvement for patients ¹. Even if the clinical success rate of THA is higher than 90%, revision surgery represents about 15% of all hip replacement procedures ². Aseptic loosening is the main factor for revision surgery (55% of all revisions) followed by instability of the implant (14%), osteolysis around a well fixed implant (13%), septic loosening (7%), periprosthetic fractures (5%) and conversion surgery from a hemiarthroplasty (3%) ².

Haynes et al. ² in 2015 published a study in which they analyzed the main indications for THA and for early and late revision surgery. They collected data deriving from their institution's joint database enrolling patients who underwent THA revision surgery between 2004 and 2014 ². They enrolled 870 patients with a mean age of 62.2 years ². These authors found that aseptic loosening was the main cause for revision surgery with a peak between in 5- to 10-years after primary

THA (representing 50% of all revisions), while instability and septic loosening were common indications up to 5 years from the first implant². Moreover, this study showed that the use of new technologies and new materials was responsible for the increase in complications such as metallosis; in fact, metallosis represents the cause of 4.1% of all THA revisions². Another interesting data that emerges from the work of Haynes et al. is that 44.5% of revisions were performed in patients younger than 60 years and 18.9% in patients younger than 50 years as evidence of the increasing demand for primary THA in younger patients².

Achieving stable fixation and ensuring long-term implant survival are crucial in revision THA to restore patient mobility and quality of life. In order for revision of the acetabular cup to be successful, the cup must achieve stable fixation with the remaining bony component of the acetabulum. Treatment options are numerous. The choice of optimal treatment depends on the degree of the discontinuity, amount of available bone tissue and likelihood of achieving stable fixation on the bone. For classification of the bone defect, the Paprosky system is the one that most assists surgeons in managing to improve acetabular revision outcomes. The Paprosky classification describes acetabular defects in accordance with the presence or absence of an intact acetabular rim and if it is able to provide an appropriate initial support to the acetabular component³. Paprosky's classification divides bone defects in three types, each of which is divided in subtypes³. In Type I there is a minimal destruction of the acetabular rim with areas of lytic defects³. In this case X-rays do not show any sign of migration of the component (the dome is intact) and the presence of the teardrop and the absence of ischial bone lysis are signs of lack of involvement of the medial and posterior wall³. Type II defects correspond to destruction of the dome and/or of the medial wall with the integrity of the posterior and anterior columns³. Cancellous bone is replaced with sclerotic bone and, according to different morphological alterations of the acetabulum, three different subtypes are recognized: in Type II A, the acetabulum has an oval shape with superior bone lysis; Type II B is similar to Type II A with the absence of the superior rim; in Type II C there is involvement of the medial wall³. In Type II A defects there is a superior migration of the cup, while in Type II B the cup migrates superolaterally; in both cases the migration is less than 2 cm³. In Type II C, the cup can be medialized because of involvement of the medial wall³. In Type III, there is a severe bone defect with an absence of acetabular rim and involvement of the supporting structures³. Two different subtypes are recognized: in Type III A the defect is localized from 10 o'clock to the 2 o'clock location around the rim; in Type III B the defect does not involve the zone between 9 o'clock and 5 o'clock³. In both subtypes the component is migrated superiorly more than 2 cm. In Type III A, the cup migrates superolaterally because the medial wall is still present (the teardrop is slightly involved,

while in Type III C the cup migrates superomedially because of the disruption of the teardrop³.

In recent years, the use of highly porous shells has emerged as a promising means to enhance osteointegration and improve clinical outcomes in revision hip surgeries. Highly porous shells are characterized by a porous titanium structure, which facilitates bone ingrowth and implant stability. This innovative design has shown potential advantages over conventional cotyles in promoting osteointegration and reducing the risk of implant failure⁴. Numerous studies have investigated the use of highly porous shells, providing evidence of their effectiveness in enhancing osteointegration and improving clinical outcomes⁴⁻⁶. Furthermore, it is reported that the use of variable-angle (VA) locking screws increases construct rigidity, which may reduce micromotions at the metal-bone interface and in turn promote bone ingrowth⁷. VA is a technology that has been introduced in the last years and allows to place screws in different directions with a tilt angle up to 15°⁸. The characteristics of the VA system provide more freedom for surgeons in placing screws directly in higher bone density areas and avoid osteoporotic bone zones⁸. For these reasons, the VA system represents one of the most important innovations in trauma and arthroplasty surgery⁸. However, it is essential to validate these findings through clinical experiences and patient outcomes in real-world settings.

In this study, we present our hospital's experience with highly porous shells and VA locking screws in acetabular revision cases. We evaluated functional outcomes, complications, and radiographic findings associated with the use of highly porous shells. By sharing our findings, we contribute to the body of knowledge on acetabular revision surgery and provide insights into the efficacy and safety of highly porous shells in enhancing long-term implant survival.

Materials and methods

From January 2016 to December 2021, 46 patients affected by acetabular loosening were treated with a highly porous shell and VA locking screws in the Orthopedic department at San Bortolo Hospital, Vicenza, Italy.

Patients who underwent surgery due to a periprosthetic fracture, those who also presented mobilization of the prosthetic stem, those who died for other causes and those with a follow-up period < 2 years were excluded, for a total of 16 cases remaining. A retrospective analysis was conducted on these patients.

Demographic information, primary diagnosis, and reason for revision were recorded.

The surgical technique utilized for the acetabular revision followed established guidelines⁹.

Postoperative evaluations were performed at regular intervals to assess clinical outcomes and complications: clinical evaluations and X-rays were made at 1, 3, and 6 months, and at 1 and 2 years after surgery.

The follow-up period had an average duration of 22 months. The postoperative Harris Hip Score (HHS) and Western On-



Figure 1. Pre- and post operative x-ray of acetabular revision.

tario and McMaster Universities Arthritis Index (WOMAC) score were utilized as measures of functional outcomes and patient-reported improvements in pain, stiffness, and physical function. The HHS ranges from 0 to 100, with higher scores indicating better hip function^{10,11}. The WOMAC score ranges from 0 to 100, with lower scores indicating less pain, stiffness, and disability¹².

Radiographic evaluations were conducted using the DeLee and Charnley criteria to assess the absence of aseptic loosening or implant migration; during follow-up visits, the new AP and LL radiographs were marked to divide the acetabulum into zones according to DeLee and Charnley's classification: In the AP view, we identified the superior third, middle third, and inferior

third, while in the LL view, we observed the posterior third, middle third, and anterior third zones¹³⁻¹⁵.

The statistical analysis were done using the paired sample t-test.

Data collecting from patients enrolled were compared to data extracted from literature. A comprehensive literature examination was conducted between January 2000 and December 2023 in the PubMed databases in order to demonstrate the validity of our study.

Statistical analysis

Statistical analysis was performed using Microsoft Excel



Figure 2. Pre- and postoperative x-ray of acetabular revision with massive bone defect.

(2017 version). HHS and WOMAC score were calculated for each case by comparing the latest observed postoperative value against the corresponding preoperative value and the significance of the difference was tested using the paired t test.

Results

Among the 16 cases analyzed, 10 were women and 6 men. The mean age at the time of surgery was 65.5 years. The causes of revision were aseptic mobilization of the acetabular component for 10 patients, septic mobilization for 1 patients, and prosthetic liner wear in 5 patients. The mean preoperative HHS was 31.2, while the mean HHS at the last clinical evaluation was 80.1, indicating a statistically significant improvement in hip function and pain relief (p value < 0.001). The mean preoperative WOMAC, which evaluates pain, stiffness, and physical function, was 34.2, instead the WOMAC at the last clinical evaluation was 83.3, reflecting a substantial enhancement in patients' quality of life (p value < 0.001) (Tab. I). In terms of complications, there was one case of re-revision due to a delayed acute periprosthetic infection (after 2 months from revision surgery), which was successfully managed through the Debridement, Antibiotics, and Implant Retention (DAIR) protocol¹⁶. It should be noted that the patient who suffered this complication is not the same as the one who underwent

revision surgery due to septic loosening. Additionally, one case presented with ileo-psoas impingement syndrome, which was effectively treated with physiotherapy and physical therapies¹⁷. Importantly, during each follow-up assessment, the new X-rays were evaluated to detect any radiolucent lines around the acetabulum following the DeLee and Charnley zones. What emerged was the absence of signs indicating aseptic loosening or implant migration observed, even after 2 years of follow-up. This indicates the favorable stability and osteointegration of the high porosity cotyles in the revision THA cases analyzed. For what concerns the literature research, a total of 7 studies, which met the inclusion criteria, were analyzed in detail.

Discussion

THA has been defined the "operation of the century" and is currently the most effective treatment for severe OA¹. OA represents one of the main diseases responsible for pain and loss of joint function in people older than 60 years¹. Nowadays due to the ageing population, the incidence of AO and the demand for THA is growing¹. THA has an excellent survival rate of 95%, a good recovery of mobility and physical function and 25-year survival rate up to 80%¹. About 1 million of ankle prostheses are implanted every year and it is estimated that the number of implants will double in the next decade¹.

Table I. Patient score.

	Preoperative HHS	Last HHS	Preoperative WOMAC	Last WOMAC
Patient 1	29.6	90.8	22.7	83.6
Patient 2	52.3	82	68	91.4
Patient 3	20.3	80.9	11.7	86.7
Patient 4	31.3	91	27	91.4
Patient 5	28.6	96	46.7	96.1
Patient 6	16.8	79	18.8	91.4
Patient 7	31.5	90.8	39.8	92.2
Patient 8	33.3	77.8	50	89.1
Patient 9	20	70.7	20	68
Patient 10	31.3	92	39.8	95.4
Patient 11	28.6	96	28.9	96.9
Patient 12	77.2	55.5	56.3	46.9
Patient 13	25.8	67.5	16.4	80.5
Patient 14	20	56.9	20	64.1
Patient 15	26.9	70.3	30.5	67.2
Patient 16	26.3	85	50	92.2
Mean	31.2	80.1	34.2	83.3
St. Dev.	14.7	13	16.4	14.4

The most complex and challenging aspect of THA revision surgery is the revision of the acetabular component¹⁸. The achievement of the suitable muscle tension and of the correct position of the acetabular component is rendered difficult by the status of soft tissues and bone stock¹⁸. The revision of the acetabular component is indicated in cases of symptomatic instability, septic and aseptic loosening and in case of osteolysis and severe bone loss in asymptomatic patients¹⁸. The Paprosky classification is the main classification system used to assess the acetabular bone defect; other classification systems that can be found in literature are the American Academy of Orthopedic Surgeons (AAOS) and Saleh and Gross¹⁸. In the literature there is no gold standard regarding the most suitable surgical technique to use in acetabular revision; several surgical techniques and different devices have been described in the literature to treat acetabular bone loss during a revision: cemented cups, large-sized non cemented acetabular cups (such as trabecular metal cups), reinforcement rings, cages, bone grafts and custom implants¹⁸.

Giaretta et al.¹⁸ published a systematic review with the aim to analyze the different options available for acetabular revision. Using strict criteria, the authors identified relevant studies published between 1991 and 2021; after exclusion of the articles that did not meet the inclusion criteria, data from 43 studies was evaluated¹⁸. What emerged from this study was that trabecular metal cups (made in titanium or tantalum) showed a lower mobilization rate and especially, in case of revision surgery, the combined use of trabecular metal cups and augments allows to fill the bone defects (Paprosky Type III defects) without using bone grafts¹⁸. While in the literature cages represent the most widely used devices in revision surgery, trabecula metal cups and augment, as showed in study by Giaretta and colleagues, represent a valid option in this type of surgery, especially in the elderly and in case of small contained bone defects¹⁸. Highly porous metal surfaces is a new technology that has allowed to enhance osteointegration, to reduce stress shielding and to have a modulus of elasticity equal to bone; the porous surfaces allow bone ingrowth that is responsible for initial stability of the implant and thus for biological fixation (it is a suitable type of fixation in revision surgery)⁴.

Malahias et al. published a study in 2020 in which they compared the revision rate of primary THA with the use of a highly porous titanium cups with the revision rate of the same cups used in revision surgery with a severe bone loss⁴. With the use of strict inclusion criteria, Malahias et al. collected data from a total 11,282 patients from 16 different studies⁴. 90% of all patients underwent primary THA surgery with the use of highly porous titanium caps, while the remaining are cases of THA revision with the use of the same cups⁴. In both cases highly porous titanium cups showed satisfying clinical outcomes, especially in the short and medium term⁴. Moreover, the reoperation rate in the first group was 0.1%, while it was slightly higher in the second group (0.9%)⁴. This study demonstrates that the highly porous surface represents an effective tool for both primary and revision THA surgery⁴.

The initial mechanical stability provided by the use of cementless porous-coated implants has led to a 10-year survivorship of about 98%⁵. However, the intensive use of this type of device has led to an increase in failure rates; therefore, new types of materials and designs have been introduced in hip surgery to reduce this type of complication⁵. Studies in the literature have shown that micromotions around 150 µm are responsible for fibrous tissue formation between bone and the implant, and thus minimal micromotion (< 40 µm) is required to provide good osteointegration; moreover, bone ingrowth occurs over a period of 6 weeks and this can be delayed in the presence of excessive micromotions^{5,7}. In 2010, Meneghini et al. published a biomechanical study to evaluate the effect of initial stability and to underline the differences in terms of biomechanical property of tantalum devices against traditional titanium implants in THA revision surgery with severe acetabular bone loss⁵. In this study, three different types of implants were tested: the traditional modular porous-coated titanium acetabular component and two types of tantalum acetabular cups with different designs⁵. The biomechanical tests were performed over sawbones and the bone defect was recreated after the reaming of the specimen's acetabulum⁵. The porous tantalum cups showed a high coefficient of friction in the interface bone-implant and a higher modulus of elasticity, unlike the traditional titanium cups⁵. In this study, tantalum cups demonstrated a higher resistance to movements than traditional cups and for this reason the force required for implant failure is higher than that required before traditional acetabular cups failed⁵. Finally, the study by Meneghini et al. indicated that porous-coated tantalum cups ensure a superior biomechanical stability and more effective osteointegration, especially in revision surgery vs traditional titanium cups⁵.

In case of larger bone loss, highly-porous augments are required; these devices have been proposed as an effective addition to porous metal cups in hip revision surgery⁶. The advantage of the use of the augments is to restore the hip's center of rotation to provide better hip biomechanics; this would not be possible without the help of these devices, considering the significant bone loss⁶.

In 2013, Banerjee et al. published a systematic review of the literature with the aim to analyze the outcomes of the combined use of highly porous metal cups with highly porous augment in hip revision surgery⁶. They collected data from 2083 hip revision arthroplasties contained in 25 different studies⁶. What Banerjee et al. found is that a high hip center after placement of the acetabular caps is a better way to achieve a stable initial fixation, but this can affect hip biomechanics⁶. The restoration of the anatomical hip center with the use of augments showed good radiographical and functional outcomes; in fact, patients in which the restoration of the anatomical hip center of rotation demonstrated a reduction in Trendelenburg gate with a better restoration of abductor function⁶. The authors concluded that due to the small sample sizes available in the literature, more studies are required to assess the durable fixation and better

survivorship of these implants in hip revision surgery with larger acetabular bone defects ⁶.

Another way to prevent high forces at the cup-bone interface is the possibility to use VA locking screws through uncemented acetabular metal cups ⁷. Even if locking screws are widely used in fracture osteosynthesis, they have been introduced in hip revision surgery to achieve a better stability in case of severe bone loss ⁷. VA is a technology that has been introduced in the last years and allows to put screws in different directions with a tilt angle up to 15° ⁸. The head of these screws permits to lock them directly in the implant increasing, and in this way, construct rigidity ⁸. The characteristics of the VA system provide more freedom for surgeons in placing screws directly in areas of higher bone density and avoid osteoporotic bone zones; this possibility guarantees an increase in implant stability and a lower risk of implant mobilization ⁸. This technology requires certain precautions in order to unlock its full advantages: the resistance to rotational failure is higher when the screw is perpendicular to the implant, while if the tilt angle increases the resistance to rotation decreases ⁸. Despite this, the VA system represents one of the most important innovations in trauma and arthroplasty surgery ⁸. This system is responsible for an increase in bone-cup interface stiffness; stiffness can be defined as the strength with which an object resists deformation caused by an applied force ⁷.

Milne et al. published in 2013 a biomechanical study with the aim to test the VA system in osteoporotic cancellous bone models ⁷. Although it was difficult to replicate the natural forces that act *in vivo*, Milne et al. succeeded in demonstrating the advantages of VA locking screws in bone models ⁷. In fact, when a coronal or axial torque force is applied, the VA system provides a higher stiffness (3 times higher) than standard cancellous non-locking screws ⁷. On the other hand, both VA locking screws and non-locking screws provide the same compression force in the bone-cup interface ⁷. These findings have been compared to data derived from our study.

This study aimed to evaluate the clinical outcomes and complications associated with the use of highly porous shells in acetabular revision surgeries. Our results demonstrate significant improvements in hip function, pain relief, and patients' quality of life, as indicated by the postoperative HHS and WOMAC score. All the revisions followed a standardized procedure without any deviations ⁹.

During follow-up visits, HHS and WOMAC were administered to all patients.

The observed increase in HHS from an average preoperative score of 31.2 to 80.1 at the last clinical evaluation highlights the substantial improvement in hip function achieved with the use of highly porous shells and VA locking screws. Similarly, the WOMAC score showed a notable enhancement, with an mean preoperative score of 34.2 improving to 83.3 at the last clinical evaluation. These findings are consistent with previous studies reporting improved functional outcomes following revision surgeries with highly porous shells ^{4-6,18,19}.

In fact, in comparison with others publications such as the study by Shaarani et al. ¹⁹, the clinical outcomes obtained in our patients show similar results.

In 2023, Shaarani et al. published a retrospective review in which they analyzed data from 59 revisions of hip arthroplasties treated with metal acetabular shells with VA locking screws ¹⁹. After a mean follow-up of 25.7 ± 13.9 months, clinical scores such as WOMAC have showed good results (WOMAC: 85) ¹⁹. Regarding complications, the study by Shaarani reported a higher rate of reoperation that could be linked to a longer follow-up period compared to our study ¹⁹.

On the other hand, in our comprehensive analysis, a low rate of complications was observed. Specifically, only one case required re-revision due to a delayed acute periprosthetic infection, a challenge effectively addressed through the implementation of the Debridement, Antibiotics, and Implant Retention (DAIR) protocol. This successful management underscores the importance of prompt and targeted intervention strategies in mitigating potentially serious complications. Additionally, another case presented with ileo-psoas impingement syndrome, a condition effectively alleviated through the application of physiotherapy and physical therapies. These findings collectively indicate that the utilization of highly porous shells is associated with a relatively low risk of complications, thereby contributing significantly to enhanced patient outcomes. The ability to effectively manage and address complications further underscores the safety and efficacy of highly porous shells in acetabular revision surgeries, thereby promoting improved overall patient well-being and functional outcomes.

Radiographic evaluations utilizing the DeLee and Charnley criteria revealed a consistent absence of indicators suggesting aseptic loosening or implant migration across all cases analyzed. These findings underscores the favorable stability and successful osteointegration of the highly porous acetabular components, reaffirming their efficacy in facilitating long-term implant survival. The ability of the porous titanium structure to promote bone ingrowth and enhance implant stability aligns seamlessly with findings from prior studies, thus providing further validation of the reliability and durability of these implants in daily clinical practice. This collective evidence highlights the integral role of highly porous shells in achieving enduring stability and optimal functional outcomes for patients undergoing acetabular revision surgeries ⁴⁻⁷.

Our study has several limitations. First of all, the retrospective nature of the analysis may introduce bias and limit the generalizability of the findings. Additionally, the relatively small sample size and single center experience affects the statistical power and external validity of the results. Future studies with larger sample sizes and longer follow-up periods are warranted to validate our findings.

Conclusions

The utilization of highly porous shells in acetabular revision surgeries has demonstrated favorable clinical outcomes, including improved hip function, pain relief, and patients' quality of life. Complication rates were low in the first 2 years after surgery, and there were no signs of aseptic loosening or implant migration in radiographic evaluations. These findings highlight the potential of highly porous shells to enhance long-term implant survival and restore mobility for patients undergoing revision THA. Further research with larger sample sizes and longer follow-up periods is necessary to validate these findings and optimize the use of highly porous shells in revision hip surgeries.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

All the authors contributed equally to this work; SG, JA,CZ, PS: designed the research; GV, GS, SG: analysed the data; CB, JA, PS, CZ: wrote the paper; GV, AM: contributed to manuscript revision; all authors approved the final version of the manuscript.

Ethical consideration

All procedures in the study and involving humans were implemented in accordance with the ethical standards established by the Helsinki Clarification of 1975 and subsequent amendments. Informed consent was obtained from all patients included in the study.

The article does not contain any studies performed on humans and animals by the Authors.

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