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The midterm and long-term effects of acetabular roof ring and Burch-Schneider anti-protusio cages in acetabular revisions for patients with acetabular bone deficiency

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Objective: The purpose of this study was to investigate the mid-term and long-term effects of the acetabular roof ring (ARR) and Burch-Schneider anti-protrusio cage (BSAPC) in acetabular revision for patients with acetabular bone deficiency and acetabular component loosening.

Methods: Between 1988 and 2007, ARR revisions were performed in 51 patients (25 women; average age: 46.9 years) and BSAPC in 18 patients (16 women; average age: 62.1 years). Grafts were used in all revisions. The patients were evaluated retrospectively. The bone defects were classified according to the classification of the American Academy of Orthopaedic Surgeons (AAOS). Harris Hip Score (HHS) was used for clinical evaluation. Radiolucent lines, implant sizes, osseointegration, and heterotopic ossification in the 3 regions defined by DeLee and Charnley were evaluated radiologically.

Results: The success rate of ARR revisions after an average follow-up of 8.93±4.10 years (range: 4–23 years) was 87.9%, and the cumulative survival rate at year 10 postoperatively was 91%. Average HHS score increased to 83.70±8.98 postoperatively, from 40.10±2.49 preoperatively ($p<0.01$). The success rate of BSAPC revisions after an average follow-up of 7.06±2.39 years (range: 4–12 years) was 83.3%, and the cumulative survival rate was 78%. Average HHS score increased from 42.55 preoperatively to 73.86 postoperatively ($p<0.01$). All failures of ARR revisions occurred in type 3 defects ($p<0.05$). In 40 of the 47 patients in which an allograft was used, osseointegration occurred. No statistically significant difference was found between the increase in HHS scores of patients who underwent femoral component revision with acetabular revision and those who did not ($p=0.06$). Patients who underwent more than 1 revision had statistically significantly higher failure rates in comparison to patients undergoing revision for the first time ($p=0.008$).

Conclusion: The mid-term and long-term results of the use of ARR and BSAPC with allografts in bone deficient acetabular revisions are satisfactory. The implants facilitate graft osseointegration, increase the bone stock, and make future revisions easier. ARR should be preferred in type 1 and type 2 acetabular bone defects, while BSAPC should be preferred in type 3 and 4 defects.

Keywords: Acetabular revisions; acetabular bone deficiency; acetabular roof ring; Burch-Schneider anti-protusio cage.

Level of Evidence: Level III Therapeutic Study

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As the frequency of total hip arthroplasties (THA) has increased in recent years, hip revision surgeries have become more common. The primary purpose of hip revision surgeries is to reorganize the hip center and construct a functional anatomy, a process which requires extensive contact between the implant and the host, as well as adequate mechanical identification. One of the most significant problems that disrupts the contact between the implant and the host bone tissue is acetabular bone defects. These defects pose a challenge for surgeons, and their treatment has not yet been standardized. Acquired acetabular traumas, prior surgeries, inflammatory joint diseases, developmental dysplasia of the hip, and natural aging are causes of acetabular bone defects.

Preoperative evaluation of the acetabular bone defect is one of the most important steps of revision surgeries and affects the success of the revision surgery.[1] The American Academy of Orthopaedic Surgeons (AAOS) classification defined by D'Antonio and colleagues[2] was developed to categorize the bone loss of the femur and acetabulum according to location and pattern, and is the most commonly used classification in the literature (Table 1).[3]

Table 1. AAOS classification of acetabular bone deficiencies.

Type 1	Segmental deficiencies	a) peripheral
		b) superior
		c) anterior
		d) posterior
		e) central (medial wall defect)
Type 2	Cavitary deficiencies	a) peripheral
		b) superior
		c) anterior
		d) posterior
		e) central (medial wall absent)
Type 3	Combined deficiencies	
Type 4	Pelvic discontinuity	
Type 5	Arthrodesis	

AAOS: American Academy of Orthopaedic Surgeons.

Type 1 segmental defects include the supportive portion or the medial wall of the acetabular hemisphere. Type 2 cavitary defects do not disrupt the supportive portion of the acetabular hemisphere with a volumetric loss in the acetabular cavity or medial wall; integrity is preserved, and the external cortex is intact. In type 3 defects, a combination of segmental and cavitary deficiencies is present. Type 4 defects, known as pelvic discontinuity, is the disruption of the connection between the superior and inferior aspects caused by bone loss. Type 5 defects include those with deformation of the hip anatomy and make the accurate localization of the acetabulum difficult (Figure 1).[3]

In acetabular revisions of acetabular bone damage, the primary objective is to place the implant on the widest possible bone surface. Femur head allografts (FHA), spongious chips allograft (SCA), and autografts are used for this purpose. While SCA is sufficient for cavitary defects, FHA should be used for segmental defects.[4] When the surface between the graft and the implant is larger than the surface between the host bone and the implant, application of these grafts results in failure.[5]

Methods that have been used in acetabular revisions with bone defects are cementing,[6] cementing with grafts,[7,8] cementless cups,[9,10] cementless cups and structural allografts,[11] jumbo cups,[12,13] trabecular metals,[14] rectangular bilobed components, custom prostheses, metal augment modular systems,[15,16] and impaction grafts.[17,18] Because many of these methods did not achieve the anticipated levels of success, the Burch-

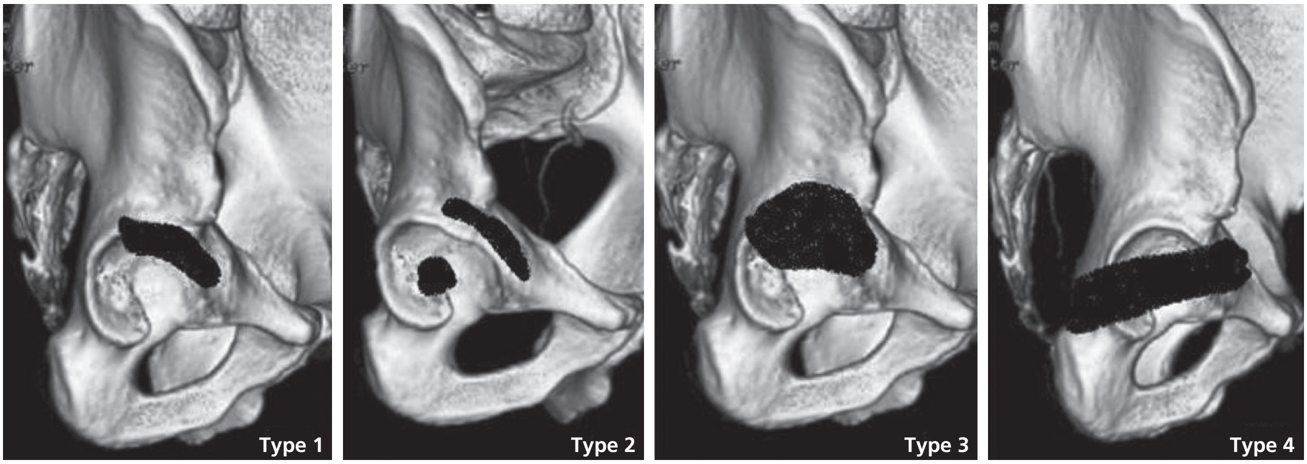

Fig. 1. AAOS classification of acetabular bone deficiencies.

Schneider anti-protrusio cages (BSAPC) and acetabular roof rings (ARR) were developed.

BSAPC was designed by Burch and modified by Schneider. Müller designed the classic ARR, and Ganz added the hook. BSAPC and ARR provide extensive contact between the implant and the bone tissue, optimize the hip center, facilitate graft integration, and increase bone tissue. ARR should be used in peripheral segmental or cavitary defects,[19] while BSAPC should be used in combined segmental and cavitary defects, protrusion, medial segmental bone losses, and pelvic discontinuities.[19,20]

The purpose of this study was to investigate the midterm and long-term results of ARR and BSAPC use in acetabular revision for patients with acetabular bone tissue deficiency and acetabular component loosening.

Patients and methods

BSAPC and ARR were used in 74 hips of 74 patients who developed acetabular loosening after THA between 1988 and 2007. These patients were evaluated retrospectively. Two patients who died during the follow-up period, 1 who underwent disarticulation for infection, 1 who was unwilling to participate in the study, and 19 who failed to complete follow-up were excluded from the study. Of the 51 patients included in the study, ARR was used in 33 and BSAPC in 18 patients.

Patients were evaluated clinically and radiologically pre- and postoperatively. Harris Hip Score (HHS) was calculated,[21] and subjective patient evaluation was performed. Anterior-posterior and lateral direct radiographs were obtained. The acetabular defects were classified according to the AAOS system, based on preoperative graphs and observations during revisions. The types, localizations, numbers, and sizes of the defects were recorded.

In the cases of no postoperative complications, radiographs were obtained on day 1, month 3, and year 1 after the revisions. Follow-up evaluation was performed at week 2, month 3, and year 1 postoperatively. Patients were seen for annual follow-up, and radiographs were obtained.

The radiolucent lines between the bone tissue and the acetabular component were evaluated according to the 3 regions described by DeLee and Charnley.[22] The integration of allografts with bone tissue was described as complete osseointegration and partial osseointegration, according to the degree of resorption.[23] Heterotopic ossification (HO) was evaluated according to the Brooker classification.[24] Implant migration and screw integrity were evaluated.

Patients who underwent BSAPC and ARR were evaluated independently to determine the adequacy of the indications for use, according to the type of the bone defects. The BSAPC and ARR patients who underwent acetabular component revision, with or without concurrent femoral component revision, were evaluated together to determine the effect of femoral component revision on outcomes, as well as the effect of number of prior revisions on failure rates.

Inclusion criteria were set as clinical and radiological loosening in patients who underwent THA for acetabular components, acetabular bone defects discovered in radiographies, and the need for graft tissues. Exclusion criteria were death, unwillingness to participate, failure to complete follow-up, and amputations during follow-up for any reason. Failure criteria were set as aseptic loosening (a radiolucent line surrounding the implant, a progressive or symptomatic line that does not entirely surround the implant, migration of the implant with clinical findings, significant migration with no clinical findings), dislocation, mechanical dysfunction (broken screw and clinical positivity, broken implant) and infection.

In ARR and BSAPC patients, Kaplan-Meier survival analysis was used in survival analyses, and SPSS Version 15.0 (SPSS Inc., Chicago, IL, USA) was used in statistical analyses. The Fisher-Freeman-Halton test was used in the comparison of qualitative data, and the paired-samples t-test was used in pre- and post-operative evaluation of the parameters. Significance was evaluated using the values $p<0.01$ and $p<0.05$.

All surgeries were performed by the same 2 surgeons, using lateral or posterolateral incisions. Trochanteric osteotomies were not performed. After acetabular debridement, the cartilage tissue was cleaned from the FHA until reaching the subchondral bone. Femoral head grafts were applied to the acetabulum's defective areas and the areas that would support the implant. These areas were shaped to fit the implant and were fixated with 1–2 cancellous screws. Empty spaces were filled with SCA. The ARR and the spongious screws were placed superiorly on the acetabulum. The screws were positioned 20° from the longitudinal axis medially. While applying the BSAPC, the 3-cm area above the ilium and 1–2-cm area of the ischium were exposed. The inferior side of the implant was placed on the ischium. In the case that the inferior support was not present, a nest was made on the ischium. After the cage was placed, it was fixated with spongious screws. The first screw was placed in the ilium from the superior, with an angle of 5–10°, and a maxi-

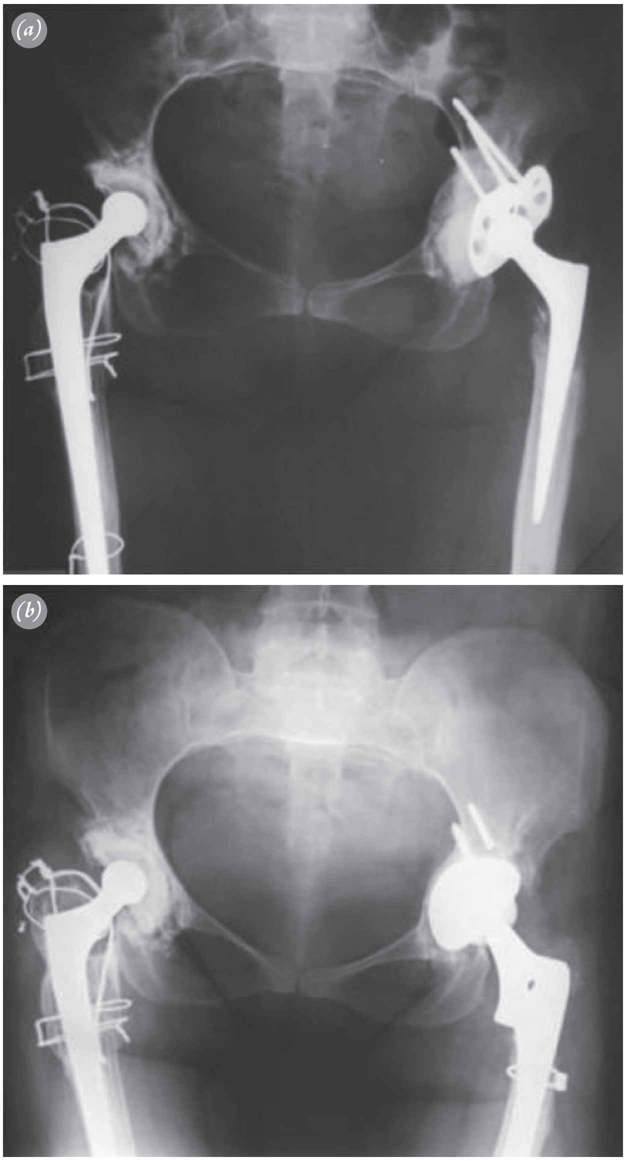

Fig. 2. **(a)** Posterior-anterior direct radiograph showing that the bone tissue reserve is sufficient and that 1 screw had broke at Year 5 postoperatively after revision using ARR. **(b)** Posterior-anterior direct radiograph after revision was performed using porous coated components without requiring the use of ARR or BSAPC.

mal number of screws were positioned towards the ilium posterior column. Short screws were placed transversely to the ilium from the superior side. The polyethylene cup was fixated to the ARR with cement and placed at an angle of 45° inclination and 10–15° anteversion, according to the normal pelvis and not the ARR or BSAPC. All patients were administered low molecular heparin for an average of 3 weeks postoperatively. Patients sat bedside on the first postoperative day. On the second day, they were lifted, and light weight-bearing on the toes was allowed. Partial weight-bearing was allowed after an average of 6–8 weeks, and full weight-bearing was allowed after an average of 14–16 weeks.

Results

Of the 33 ARR patients (25 women, 8 men), mean age was 64.9 years (range: 48–83 years). Twenty-five patients (75.7%) underwent their first revision, 4 (12.1%) their second, and 4 (12.1%) their third (including the last ARR revision). According to AAOS classification, 5 patients (15.1%) were classified as type 1, 16 (48.4%) were type 2, and 12 (36.3%) were type 3.

In 1 ARR patient, luxation occurred within 3 months postoperatively. One patient was treated for THA infection, which had relapsed by year 1 follow-up. In 1 patient who had 2 prior revisions for developmental dysplasia of the hip (DDH), the screw broke, and aseptic loosening had developed at year 5 (Figure 2). Aseptic loosening occurred in 1 patient at year 6. In one patient who had a broken screw, loosening did not occur (Figure 3). Sciatic nerve neuropraxia was identified in 1 patient at month 5; however, the patient's complaints resolved. It was observed that all cases that failed were type 3.

Mean pre- and postoperative HHS values of ARR patients were 40.10±2.49 and 83.70±8.98, respectively. The average improvement of 43.61±8.84 in HHS values was found to be statistically significant ($p<0.01$). Patient satisfaction was very good in 48%, good in 36%, moderate in 6%, and poor in 6% of patients. According to DeLee and Charnley, radiolucent lines were observed in zones 2 and 3 in 2 patients and in all 3 zones in 2 patients. According to the Brooker classification, type 1 HO was identified preoperatively in 4 patients and postoperatively in 5 patients; type 2 HO was identified postoperatively in 1 patient.

In the 33 ARR patients, a total success rate of 87.9% was observed. The follow-up period was 8.93±4.10 years (range: 4–23 years). The Kaplan-Meier cumulative survival rate (CSR) was 96% at year 5 postoperatively, 91% at year 10, and 69% at year 15 (Figure 4a).

Of the 18 BSAPC patients (16 women, 2 men), mean age was 62.1 years (range: 39–82). Seven patients (38.8%) underwent their first revision, 2 (11%) their second, 8 (44%) their third, and 1 (5%) their fourth (including the last BSAPC revision). According to AAOS classification, the acetabular defects were identified as type 1 in 1 patient (5.5%), type 2 in 3 (16.6%), type 3 in 12 (66.6%), and type 4 in 2 (11.1%).

In 1 BSAPC patient, dislocation occurred 1.5 months postoperatively. Aseptic loosening occurred after 3 years in 1 patient who underwent 4 revisions for

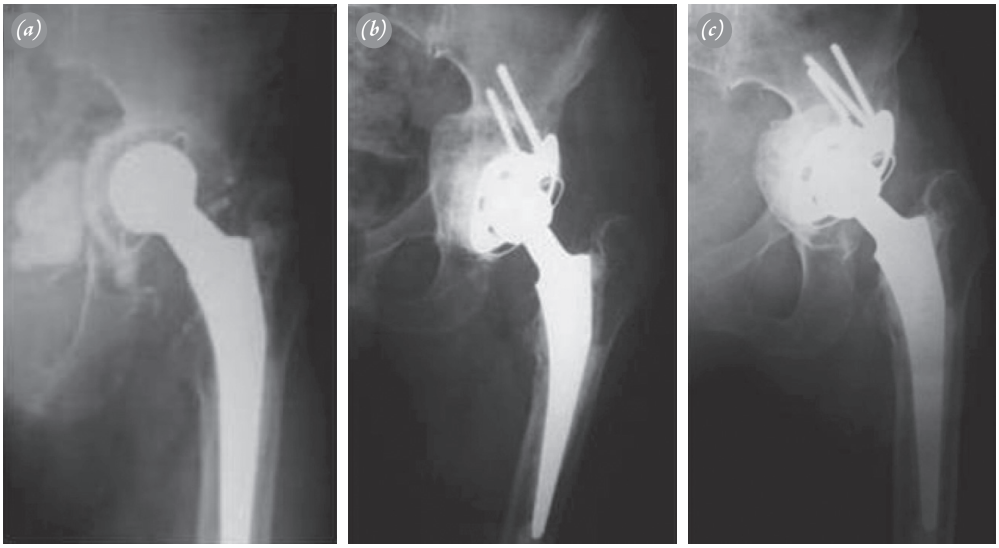

Fig. 3. **(a)** Medial migration of the acetabular component and acetabular component loosening, **(b)** direct radiograph at Month 6 postoperatively after reconstruction with ARR and allografts, **(c)** breakage of 1 screw without loosening at Year 5.

DDH. In 1 patient who had visible radiolucent lines in all 3 zones, screw breakage and aseptic loosening occurred. In 2 patients, screw breakage occurred without any clinical findings of loosening. In 1 patient, sciatic nerve neuropraxia was identified at month 12; however, the patient's complaints resolved.

In the BSAPC patients, the average pre- and postoperative HHS values were 42.55±4.78 and 73.86±19.06, respectively. The mean improvement in HHS values of 31.30±18.68 was found to be statistically significant ($p<0.01$). Patient satisfaction was very good in 33%, good in 33%, moderate in 16%, and poor in 16% of patients. According to DeLee and Charnley, in 2 patients radiolucent lines were present only in zone 3. These patients had no clinical complaints. Radiolucent lines were present in all 3 zones in 2 patients. According the Brooker classification, HO type 1 was identified preoperatively in 3, type 2 in 3, and type 3 in 2 patients; HO type 1 was postoperatively identified in 7, type 2 in 2, and type 3 in 3 patients.

In 18 BSAPC patients, total success rate of 83.3% was obtained. Mean follow-up period was 7.06±2.39 years (range: 4–12 years). The Kaplan-Meier CSR was 88% at year 5 postoperatively and 78% at year 10 (Figure 4b).

Of 51 patients who underwent revision and BSAPC or ARR, 32 underwent their first revision, and 19 had undergone more than 1 revision. The failure rate of patients who had undergone more than one revision was statistically significantly higher than the failure rate of patients who underwent their first revision ($p=0.008$).

Grafts were used in all BSAPC and ARR patients. For 6 type 1 patients, 6 SCA were used; for 19 type

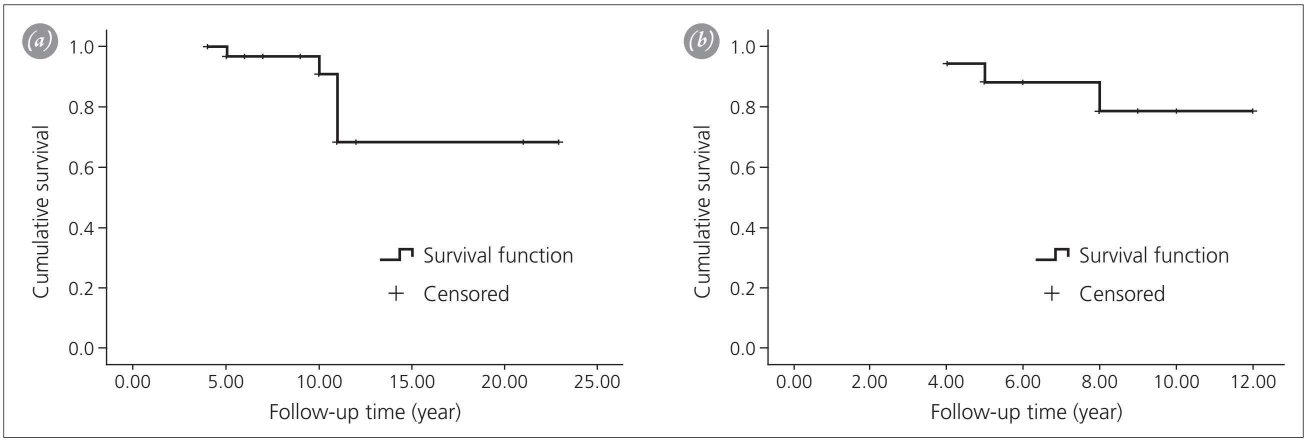

Fig. 4. **(a)** Kaplan-Meier survival chart for ARR patients. **(b)** Kaplan-Meier survival chart for BSAPC patients.

2 patients, 17 SCA and 2 autografts were used; for 24 type 3 patients, 8 SCA, 6 FHA, 8 FHA-SCA, and 2 autografts were used; and for 2 type 4 patients, 2 FHA-SCA were used.

The radiological evaluation of bone graft maturation is very challenging. It may take up to 7 years for the graft tissue to mature.[25] Apart from the 4 patients to whom autografts were applied, the osseointegration duration varied between 6 months and 7 years in the 29 patients in whom complete osseointegration was achieved. In the 11 patients where partial osseointegration was achieved, it took between 6 months and 7 years for the osseointegration to be radiologically present. Allograft osseointegration did not occur in 7 patients.

Femoral component revision was performed in 32 of the BSAPC and ARR patients. The HHS value improvement of patients who underwent femoral component revision was 37.44±6.9, while the HHS value improvement of the 19 patients who did not undergo femoral component revision was 43.71±6.25. Although the HHS value improvement was higher in patients who did not undergo femoral component revision, the improvement was not statistically significant ($p=0.06$).

Deep vein thrombosis (DVT) did not occur in any of the BSAPC or ARR patients.

Discussion

It is not precisely known which method is most effective for acetabular bone defect revision, which is a complicated topic for orthopedic surgeons. Initially, only cement was used, and failure was observed at 2.1 years postoperatively.[6] In studies that used grafts in combination with cement, 11.4%[7] failure was observed at year 5 and 15% at year 14[8] postoperatively. In revisions with cementless components, in cases where baseline stability and adequate component bone contact can be achieved, successful long-term results can be obtained.[9,10] While large cups can be used for extensive defects, they may increase bone loss.[12,13] Cementless cups with allografts may provide biological fixation in extensive defects and may facilitate ideal revisions for extensive acetabular defects.[14] Rectangular bilobed components designed for advanced bone loss have failed to provide the anticipated adaptation to the acetabular surface. Although custom prosthetics have solved this adaptation issue, they are not advantageous due to their high cost, the difficulty of preoperative planning, and prolonged procedures. Studies of modular metal augment systems that were developed as an alternative for these implants have shown favorable results.[15,16] Impaction bone grafting facilitates restoration but is a technically challenging method. Successful results have been reported, but recent studies show that this technique is less successful in cases of massive bone loss.[17,18] Successful results have been obtained in the use of BSAPC and ARR since they were first implemented. Gurtner et al.[26] reported an 87% success rate in their study, which included 150 ARR patients with a mean follow-up period of 7 years. Schatzker et al.[19] reported an 87.5% success rate at a mean follow-up of 8.3 years and Kaplan-Meier survival rates as 92.3% at year 10 and 75.5% at year 12 postoperatively. Schlegel et al.[25] reported a 90% survival rate of 122 ARR patients at a mean 6-year follow-up. Berry et al.[27] reported a 75% success rate in 42 BSAPC patients at a mean follow-up of 5 years. Schatzker et al.[19] reported a 5.4% failure rate in 83 BSAPC patients at a mean follow-up of 6.6 years and 91.7% Kaplan-Meier 10-year survival rates. Symeonides et al.[28] reported success rates of 89.5% at a mean follow-up of 11.5 years in 54 BSAPC patients. Coscujuela-Mana et al.[29] reported Kaplan-Meier survival rates at year 13 postoperatively as 92.4% in 91 BSAPC patients, with a mean follow-up of 8.1 years. Regis D. et al.[20] reported the CSR at 18.9 years postoperatively of type 3A and type 3B groups according to the Paprosky classification[30] as 80% and 84.6%, respectively. In our study, in the 33 ARR patients, the success rate at a mean follow-up of 8.9 years was 87.9, Kaplan-Meier CSR at Year 5 postoperatively was 96%, survival rate at year 10 was 91%, and survival rate at year 15 was 69%. In the 18 BSAPC patients, the success rate at a mean follow-up of 7 years was 83.3%, Kaplan-Meier CSR at year 5 postoperatively was 88%, and CSR at Year 10 was 78%. The results obtained in our study are in accordance with other studies conducted in the same field. These findings demonstrate that BSAPC and ARR are more successful than other methods used in the treatment of acetabular bone defects.

According to AAOS, 5 of the ARR patients (15.1%) were type 1, 16 (48.4%) were type 2, and 12 were (36.6%) type 3. Of the BSAPC patients, 1 (5.5%) was type 1, 3 (16.6%) were type 2, 12 (66.6%) were type 3, and 2 (11.1%) were type 4. In the ARR patients, the 2 aseptic loosenings, 1 septic loosening, and 1 dislocation that occurred were classified as type 3, and statistically significant difference was present ($p<0.05$). No statistically significant difference was identified in the success rates according to types in BSAPC patients ($p>0.05$). As the defect type grows, the success of ARR decreases, while the frequency of complications increases. Survival rate at 12 years postoperatively decreased to 75.5%, and the 12.5% negative outcomes reported by Schatzker et al.[19] were attributed to inadequate implant selection.

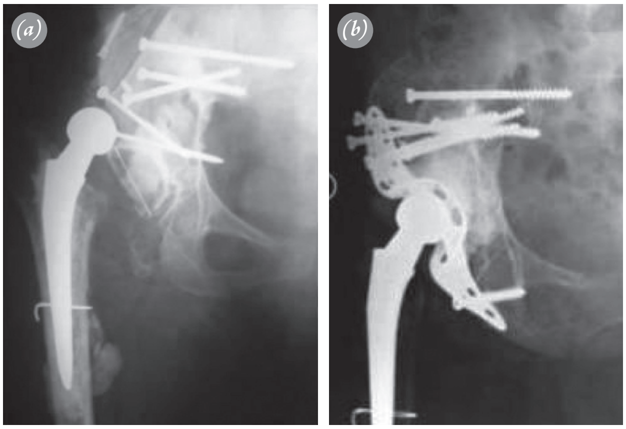

Fig. 5. **(a)** Implant luxation and acetabular component loosening. **(b)** No signs of loosening are present after BSAPC use at Year 12 postoperatively.

We recommend BSAPC use for large medial segmental and cavitary defects, and the development of protrusio acetabuli and pelvic discontinuity (Figure 5). Although our ARR patients had longer follow-up periods, the success rates were higher than in the BSAPC patients because they were selected for smaller defects.

BSAPC and ARR restore the hip center, protect bone grafts, and facilitate the construction of bone reserves.[31] The restoration of bone stock was evaluated in 50 ARR and BSAPC patients with allografts that required subsequent revision, and it was observed that bone structure restoration occurred in 31 hips. It was reported that 17 of these patients underwent revision using simple acetabular components without allografts, ARR, or BSAPC.[32] In 1 of our patients to whom ARR was applied during the third revision, screw breakage after a forceful move occurred at 5 years postoperatively. Revision was performed because the clinical findings were consistent with loosening. The graft osseointegration was good, so porous coated AC was used (Figure 2). BSAPC and ARR provide short-term stabilization until long-term ossification is achieved and simplify future revisions.

Screws provide strong and secure fixation initially, but this is a temporary effect. Screws contribute to the adaptation process, but long-term fixation is provided by graft integration.[19,31] Screw breakage does not always cause loosening and require revision. In a study including 52 BSAPC patients, screw breakage occurred in 4 patients, with only 1 patient requiring revision.[28] Screw breakage occurred in 3 of our ARR patients, 1 of who underwent revision with porous coated AC. In 1 case, aseptic loosening occurred 6 years postoperatively. In the third patient, it was not regarded as loosening, as no clinical findings were present, and the patient was monitored. Screw breakage was observed in 3 BSAPC patients. Aseptic loosening occurred in 1 patient with radiolucent lines visible in all 3 zones. The clinical and radiological evaluation of the other 2 cases with screw breakage was inconsistent with loosening.

Radiolucent lines were present only in zones 2 and 3 in 2 ARR patients, and radiolucent lines were observed only in zone 3 in 2 BSAPC patients. These patients were monitored, and no clinical complaints were reported. Radiolucent lines were present in all 3 zones in 2 ARR patients and 2 BSAPC patients; all 4 of these cases underwent revision. In some patients, it was observed that no osteolytic areas were present, although screw breakage had occurred. If radiolucent lines 2 mm or wider are visible in all 3 zones, it can be regarded as loosening.[33] The revision decision must be made in patients who are symptomatic, even when radiolucent lines are not visible in all zones, and in asymptomatic patients who manifest radiolucent line progression.[3] Radiolucencies that are unlikely to progress early should not be regarded as implant loosening.[34]

In 95 patients with bone defects, revisions were performed with allografts and ARR. The patients were reviewed retrospectively, and it was observed that graft integration was good in 60% of them.[35] In a study that evaluated 45 patients, it was reported that graft integration was good in 40 ARR and allograft patients.[36] In a study of 65 cases, patients with acetabular bone defects underwent reconstruction using BSAPC and allografts, and graft union occurred in 48 patients.[20] Of the 47 of our patients treated with allografts, allograft host bone tissue osseointegration occurred in 40. This is a substantially acceptable result when compared to other results. In patients with bone defects undergoing acetabular reconstructions, the use of allografts with BSAPC and ARR implants facilitates the successful construction of bone tissue reserves.

In all BSAPC and ARR patients, the failure rate of patients who underwent more than 1 revision was statistically significantly higher than that of patients undergoing revision for the first time ($p=0.008$). No data on this topic was found in the literature.

Among all BSAPC and ARR patients, although HHS value improvement in patients who did not undergo femoral component revision was higher than those who did, this improvement was not statistically significant ($p=0.06$).

In ARR patients, no type 3 HO was observed. In 3 BSAPC patients, type 3 HO was observed postoperatively. The higher number of revisions and requirement for wider surgical openings increases the incidence of type 3 HO in BSAPC patients. Additionally, history of HO, soft tissue damage during surgery, and history of surgery increase the risk for HO.[37]

We primarily preferred using the posterolateral incision because it increases the ease of dissection in the internerval plane, preserves the abductor mechanism, and can be extended or used for trochanteric osteotomies when needed. The number of dislocations is higher with this incision than with lateral incisions.[38] Some studies suggest that the modified Harding midlateral approach can decrease the risk of dislocation.[39] The superior gluteal nerve may be damaged in this approach, causing Trendelenburg positivity.[40] The posterolateral incision was preferred in our 2 cases of dislocation. The rate of total sciatic neuropraxia was 3.9%, which can be reduced by trochanteric osteotomy.[19]

The results obtained in the mid-term and long-term use of BSAPC and ARR are satisfactory and acceptable when compared to the results of other studies in the literature. We recommend the use of BSAPC and ARR because they have favorable results when used with appropriate techniques in cases with suitable indications.

Conflicts of Interest: No conflicts declared.

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