Original Article

Validity of Paprosky and Saleh acetabular bone loss classifications for CLS expansion cup revision surgery

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ABSTRACT

Objectives: To determine the validity of Paprosky and Saleh classifications in predicting bone loss at revision of CementLess Spotorno expansion cups
Design: Prospective
Setting: Istanbul Training and Research Hospital, Orthopaedics and Traumatology Clinic
Subjects: Twenty-one patients who required revision of expansion cup between January 2014 and December 2015 were prospectively evaluated for periacetabular bone loss.
Interventions: Preoperative radiographs were analyzed and bone defects were assessed according to Paprosky and Saleh classification systems. Estimated bone stock loss was compared to the actual deficiency. Cases which required second revision during the follow-up period were considered as failure, whereas arthroplasties that survived this period were deemed successful.
Main outcome measures: Level of agreement between preoperative and intraoperative assessment was calculated using kappa statistics. The relation between the failed implants, the reconstruction method proposed by the classification scheme and the intervention preferred by the surgeon was evaluated.
Results: Paprosky and Saleh classifications showed moderate (Kappa=0.939, *P*<.001) and very good to excellent (Kappa=0.588, *P*<.001) agreement respectively. Acetabular defect was underestimated in seven cases using Paprosky classification. The reconstruction deemed necessary by the senior surgeon was 95% consistent with the treatment proposed according to Saleh classification. With Paprosky classification, there was 29% disagreement between the proposed method of reconstruction for the identified bone defect and the reconstruction performed by the surgeon.
Conclusion: Acetabular bone loss classification systems based on radiographs remain valuable for predicting bone loss. Saleh classification is more advantageous over Paprosky system at predicting the bone loss in revision arthroplasty of expansive cup failures.

KEYWORDS: acetabular osteolysis, hip revision, Paprosky, Saleh, validity

INTRODUCTION

Total hip arthroplasty is described as one of the most successful operations. Approximately 400,000 total hip arthroplasties are performed each year in the USA and this number is increasing[1]. It is estimated that about 0.83% of the total U.S. population has been using hip replacement components by the year 2010[2]. New prosthesis designs are constantly introduced, some of which will stand the test of time while some will fall short of clinical expectations. As life expectancy and number of young patients undergoing total hip arthroplasty increases, more people will outlive their implants[3]. It is no surprise that demand for revision surgeries is also on the rise[4].

A major and perhaps the most important factor for a successful acetabular revision is the management of periacetabular bone loss. There are several classifications to define the severity of periacetabular osteolysis. Paprosky classification is the most widely used one, which focuses on degree and location of bone

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loss and identifies the structures that are deficient[5]. There are 4 anatomical structures that Paprosky system puts emphasis on for classification; anterior column, posterior column, superior dome and medial wall. It relies on integrity of these supporting structures, rather than extent of volumetric bone loss. Paprosky *et al* defined the main theme of their classification as "the presence or absence of an intact acetabular rim and its ability to provide a rigid support for an implanted acetabular component"[5,6]. Despite its common and longtime use, the reproducibility and the ability of this classification system to predict actual bone loss are questioned by several authors[7].

A more recent classification was described by Saleh *et al*, which had promising initial reliability and validity[8]. Both classifications propose the augments and constructs that are likely to be needed during revision surgery based on bone loss severity. Even though initially described to delineate the status of pelvic bone encountered at the surgery, their use is largely confined to predicting bone loss preoperatively using two-dimensional imaging. This guides the surgeon to estimate the complexity of the revision procedure, which may range from a simple cup exchange to pelvic reconstruction in severe cases[9].

In our clinic, CementLess Spotorno expansion shell was extensively used for primary hip arthroplasty during late 1990s and early 2000s. Due to its expansive design, these components have several wide slits devoid of metal back originating from base of the cup reaching to the outer rim[10]. This provides a relatively large passage for the wear particles to reach acetabular bone. Our clinical experience with expansion cups has been that these implants remained well fixed despite extensive periacetabular osteolysis and patients could remain asymptomatic even with shells with broken wings. By the time patients got symptomatic, substantial acetabular defect had already occurred. As we performed numerous revisions of this cup design, we noted that preoperative radiographs underestimated the extent of osteolysis in several cases.

The aim of this study is to assess the validity of two acetabular bone deficiency classifications, Paprosky and Saleh, in predicting bone loss at revision of CementLess Spotorno expansion cups. Our second objective was to evaluate which type of defects could be managed with cementless cups and morselized autograft alone and which types would require more complex reconstruction procedures.

SUBJECTS AND METHODS

Following approval from Institutional Ethics Committee of Istanbul Training and Research Hospital (Registration no: 356), 21 patients who required revision of expansion cup between January 2014 and December 2015 were prospectively evaluated for functional outcome and loss of bone stock during a two year period. Sixteen patients were female and 5 patients were male. The average time from index operation was 15.1 years (13-24 years). Mean age at the time of revision surgery was 64.1 years (47-78 years). Patient radiographs were evaluated preoperatively by one surgeon blinded to patient names. Acetabular bone loss was classified according to Paprosky *et al* and Saleh *et al* using antero-posterior and lateral radiographs. Results were compared to actual bone defect noted intraoperatively.

Table 1: Levels of agreement according to two different criteria using Kappa statistics

Landis and Koch		Svanholm *et al*	
Kappa	**Level of agreement**	**Kappa**	**Level of agreement**
0-0.20	Poor	0-0.50	Poor
0.21-0.40	Fair	0.51-0.75	Moderate
0.41-0.60	Moderate	0.76-1.00	Excellent
0.61-0.80	Good		
0.81-1.00	Very good		

All the revision surgeries were done by the same senior surgeon. Actual bone loss was defined by visualization and palpation once metal back and fibrous tissue were removed[11]. Intraoperative findings and used implants and grafts were noted. Validity measured by percentage agreement for classification subgroups was calculated. Cumulative agreement was assessed using the weighted Kappa statistics in order to eliminate the agreement that would occur by chance. A Kappa score of 1 represents perfect agreement; whereas a score of 0 indicates agreement that would be expected by pure chance. Levels of agreement were evaluated using the criteria of both Landis and Koch and Svanholm *et al*, as outlined on Table 1. Of these two Kappa statistics interpretation models, Landis and Koch is the widely used one whereas Svanholm *et al*'s is more stringent[7].

Table 2: Percentage agreement of subgroups between the preoperative radiographs and intraoperative findings using the Paprosky classification

Preop Classification	Actual Defect					Agreement in percentages
	2A	2B	2C	3A	3B	
2A	2	1	1			50
2B		4	1	4		44
2C			1			100
3A				6		100
3B					1	100
Total						67

RESULTS

Mean follow-up after revision surgery was 20.4 months (12-31 months). Mean Harris score at the time of last follow-up was 71.8 (60-90). Reason for revision surgery was acetabular component breakage in three cases, repeating prosthesis dislocations in two cases and symptomatic acetabular loosening in 16 cases. Of these 18 cases with preoperative radiographs with intact acetabular component, metal shell was found to be broken during surgery in six cases. Revision arthroplasty was performed with cementless cup in 16 cases and cemented cups and cages in five cases. Three patients required additional revision surgeries because of acetabular cup protrusion. A mean volume of 75 cc (range 20-150 cc) morselized allograft was used in 17 cases.

Table 3: Percentage agreement of subgroups between the preoperative radiographs and intraoperative findings using the Saleh classification

Preop Classification	Actual Defect				Agreement in percentages
	2	3	4	5	
2	4				100
3		11	1		92
4			4		100
5				1	100
Total					95

Using the Paprosky classification, actual bone loss could be predicted successfully in 15 cases using the preoperative radiographs. The bone defects were underestimated in the remaining six cases. Hundred percent of Type 3A defects classified preoperatively were able to accurately reflect intraoperative findings, whereas group 2A and 2B showed the least accurate estimations (50%) (Table 2). Using the Saleh classification, actual bone loss was successfully predicted in 20 cases. Only one actual Type 4 defect was underestimated as Type 3 during preoperative evaluation of pelvis radiographs (Table 3). Paprosky classification showed moderate agreement (Kappa=0.588, *P*<.001) between the predicted and actual bone loss according to both criteria, whereas Saleh classification yielded very good and excellent agreement (Kappa = 0.939, *P*<.001) (Table 4).

Table 4: Levels of agreement

Classification	Kappa	*P*	Landis and Koch	Svanholm *et al*
Paprosky	0.59	<.001	Moderate	Moderate
Saleh	0.94	<.001	Very Good	Excellent

All the acetabular defects which were classified preoperatively as Paprosky Type 2 (A, B, or C) (14 cases) were managed with morselized allograft and cementless cups. Two of these cases were complicated with acetabular protrusion in the early period and required second revision with cage construct. Five of the seven cases which were classified preoperatively as Paprosky Type 3 required cage construct and cemented cups, whereas remaining two were managed with allograft and cementless cups. One of these two cases was complicated with acetabular protrusion in the early period and required a second revision with cage construct (Figure 1).

Fifteen out of 16 acetabular defects which were classified preoperatively as Saleh type 2 or 3 were

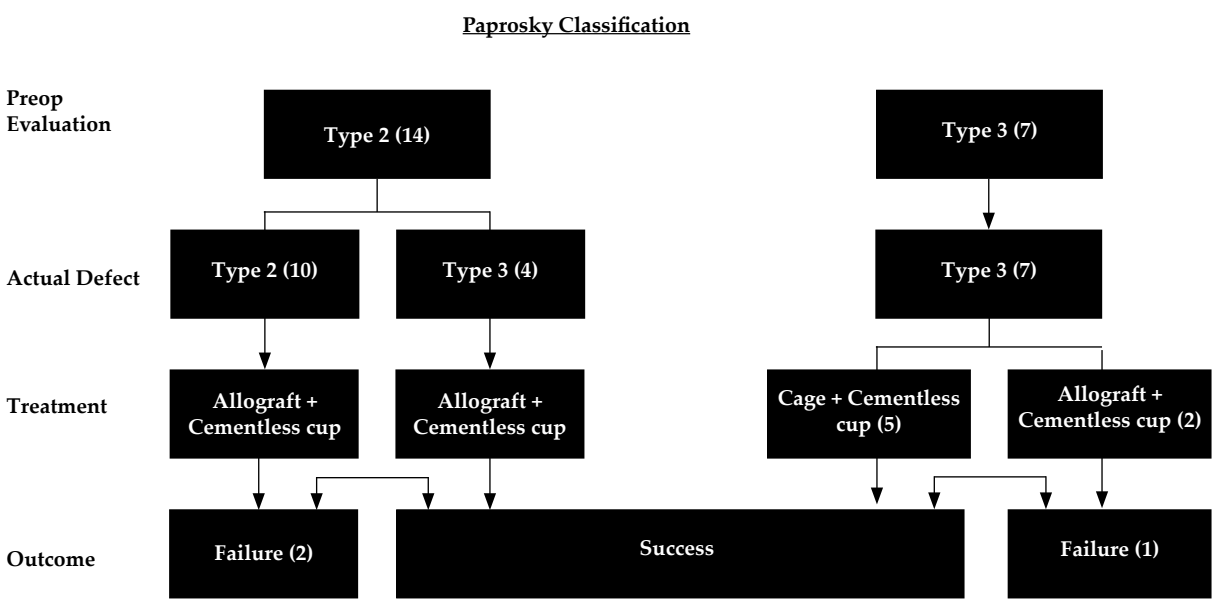

Fig 1: Flow-chart diagram of revision procedures with acetabular defect described according to Paprosky classification.

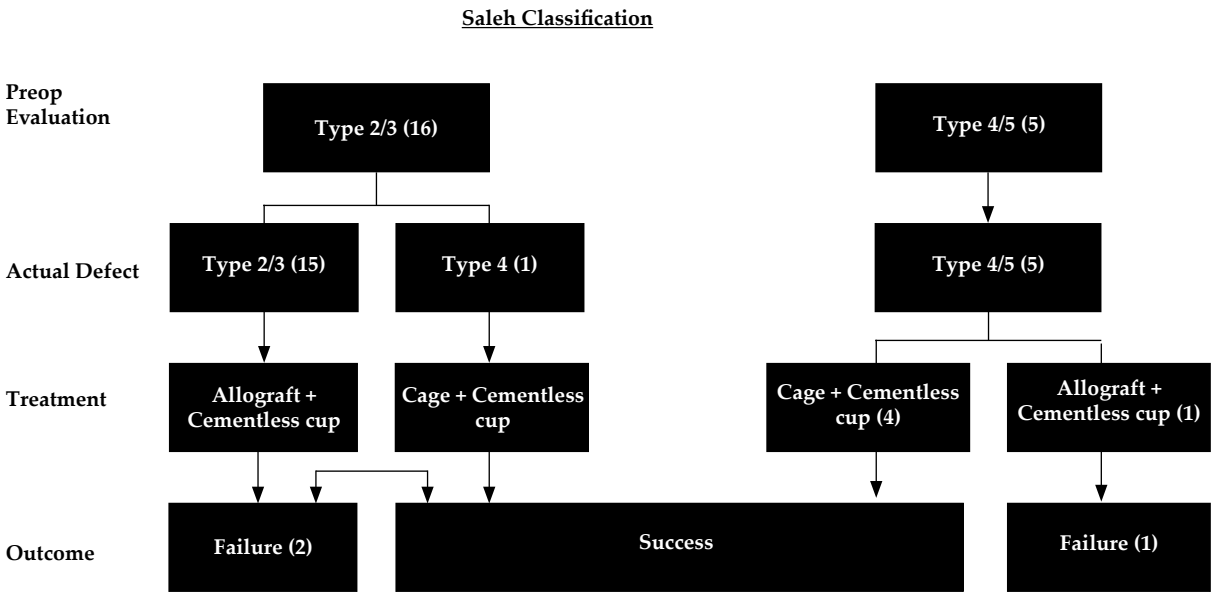

Fig 2: Flow-chart diagram of revision procedures with acetabular defect described according to Saleh classification.

managed with morselized allograft and cementless cups. Two of these 15 cases were complicated with acetabular protrusion in the early period and required second revision with cage construct. One patient who was thought to have type 3 defect turned out to be type 4 intra-operatively and cage-cemented cup construct was used. Four of the 5 cases which were classified preoperatively as Saleh type 4 or 5 required cage construct and cemented cups, whereas the remaining one was managed with allograft and cementless cup. This case was complicated with acetabular protrusion in the early period and required a second revision with cage construct (Figure 2).

Based on the actual bone loss encountered in the operating theater, all the Paprosky type 2 defects and Saleh type 2 and 3 defects could be initially treated with allograft and cementless cups. Of these, two cases did not survive during the follow-up period and developed early protrusion, requiring second revision with cage construct. Five of the 11 cases with Paprosky type 3 (A or B) defect required cage augmentation, and one of the remaining 6 cases which were managed with allograft alone developed acetabular protrusion during follow-ups and underwent second revision. Five of the six cases with Saleh type 4 or 5 defect required cage augmentation, and the remaining case which was managed with allograft alone developed acetabular protrusion during follow-ups and underwent second revision. Details of cases which required second revision are outlined in Table 5.

DISCUSSION

Revision hip arthroplasty has several technical difficulties, among which periacetabular bone stock loss is one which requires meticulous preoperative evaluation and preparation[3,12]. Periacetabular bone loss may lie anywhere from small osteolytic lesions around the acetabular rim to pelvic discontinuity. Several authors have proposed different classifications to define either the degree or location of the acetabular bone loss to assist the surgeon during preoperative planning[6,12,13].

While plain radiography still remains the most practical and important method for assessing periacetabular bone loss, many defects in the complex architecture of the acetabulum are obscured by the radiopaque components[14]. This creates a tendency for preoperative radiographs to underestimate the extent of actual bone loss[15,16]. This was also evident in our study, where acetabular defect was underestimated in seven cases using Paprosky classification. No defect was overestimated. The validity study by Gozzard

Table 5: Cases that required second revision

Cases	Preop Paprosky	Perop Paprosky	Preop Saleh	Perop Saleh	1st revision
1	2A	2A	2	2	20 cc Allograft + cementless cup
2	2B	2B	3	3	60 cc Allograft + cementless cup
3	3A	3A	4	4	120cc allograft + cementless cup

et al stands out as an exception, in which 20% of the cases were overestimated as opposed to 4% of underestimation using the Paprosky classification[3].

While interobserver and intraobserver reliability studies of classification systems are numerous, studies focusing on the ability to depict the actual bone loss noted during the operation are relatively rare. Among the two classification systems we have evaluated, the one proposed by Paprosky *et al* is used more frequently. Validity and interobserver and intraobserver reliability studies of this classification have reported generally moderate agreement, although results are dispersed in a spectrum ranging from poor to good agreement. In their study where they compared the validity of American Academy of Orthopaedic Surgeons and Paprosky classification systems, Gozzard *et al*[3] reported good agreement using Paprosky classification (k=0.65). We have noted moderate agreement (Kappa=0.588, $P<.001$) between the predicted and actual bone loss according to both criteria. Even though our results were inferior to the ones reported by Gozzard *et al*, kappa values were relatively close. Saleh classification is a relatively new system, and the only validity study to date is performed by its developers, where they reported good to excellent agreement with weighted and unweighted kappa values ranging from 0.73 to 0.9[13]. Similarly, in our study, we achieved very good and excellent agreement (Kappa = 0.939, $P<0.001$) using Saleh classification.

These classification systems guide the surgeon on the extent of reconstruction necessary for the defined bone defect. Typically, Paprosky type 3 and Saleh type 4 defects are advised to be managed with cage constructs or augmentation with structural graft and/or plate-screws by the developers of the classification systems[13]. In our study, the reconstruction deemed necessary by the senior surgeon was 95% consistent with the bone loss identified according to Saleh classification and the proposed treatment. With Paprosky classification, there was 29% disagreement between the proposed method of reconstruction for the identified bone defect and the reconstruction performed by the surgeon. The superiority of Saleh classification may be expected, since groups are divided according to the ability of the remaining bone stock to host acetabular component firmly. On the other hand, Paprosky system focuses on integrity of certain anatomical landmarks.

Overall, all cases which required second revision were the ones who were treated with morselized allograft and cementless cup. These 3 cases were classified as Paprosky type 2A/Saleh type 2, Paprosky type 2B/Saleh type 3, and Paprosky type 3A/Saleh type 4, with complete preoperative and intraoperative agreement. None of the cases with cage-cement construct failed during the follow-up. It is expected that the defects that required more extensive reconstruction would be more prone to failure. Our results indicate the opposite, with failed components occurring in group of patients with milder bone defect. One possible explanation is that cage-cement reconstruction provides superior initial mechanical stability than cementless cups and allograft which require incorporation of the graft and biological fixation of the cup for optimum stability. Another possibility is that the senior surgeon who performed the operations failed to accurately identify the bone defects and performed a less extensive reconstruction than was necessary.

CONCLUSION

Acetabular bone loss classification systems based on radiographs remain valuable for predicting bone loss. Categorizing the morphology of bone defect helps the surgeon to perform the appropriate reconstruction procedure. Saleh classification is more advantageous over Paprosky system at predicting the bone loss in revision arthroplasty of expansive cup failures.

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Author Contributions

Specific contributions made by each author are listed below.

Cenk Ermutlu: Design of the work, drafting the work, approval of the version to be published, agreement to be accountable for all aspects of the work

Tolga Tuzuner: Conception of the work, revising it critically for important intellectual content, approval of the version to be published, agreement to be accountable for all aspects of the work

Emrah Kovalak: Interpretation of data for the work, revising the work critically for important intellectual content, approval of the version to be published, agreement to be accountable for all aspects of the work

Abdullah Obut, Atakan Telatar: Interpretation of data for the work, drafting the work, approval of the version to be published, agreement to be accountable for all aspects of the work

Alican Baris: Interpretation of data for the work, revising the work critically for important intellectual

content, approval of the version to be published, agreement to be accountable for all aspects of the work

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