CEMENTED VERSUS CEMENTLESS FIXATION IN ASEPTIC LOOSENING OF TOTAL HIP ARTHROPLASTY: ASSOCIATION OF OSTEOLYSIS BURDEN WITH HARRIS HIP SCORE

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Abstract: Aseptic loosening remains a leading cause of revision total hip arthroplasty, where periprosthetic osteolysis and bone defects may substantially compromise hip function. The relationship between the burden and distribution of osteolysis and the Harris Hip Score (HHS), particularly when comparing cemented and cementless fixation, is not fully clarified. This retrospective study included 60 patients who underwent revision total hip arthroplasty for aseptic loosening, divided into 30 cemented and 30 cementless implants. Demographic data, body mass index, HHS, Paprosky acetabular defect type, osteolysis volume at the acetabular and femoral sides, and osteolysis distribution according to Gruen femoral zones and DeLee and Charnley acetabular zones were analyzed. Defect types were treated as ordinal categories, and correlations between HHS and osteolysis volume were evaluated separately for cemented and cementless implants. Differences in HHS according to defect type and zonal involvement were also assessed. In both groups, HHS decreased with increasing Paprosky defect severity, with a stronger association in cemented implants. In cemented hips, lower HHS was significantly associated with greater acetabular osteolysis volume, higher total osteolysis volume, and broader DeLee and Charnley zone involvement. In cementless hips, HHS was more strongly related to femoral and total osteolysis volume, while acetabular osteolysis and acetabular zonal distribution showed weaker and less consistent associations. In revision total hip arthroplasty for aseptic loosening, preoperative hip function assessed by HHS is closely related to the severity, volume, and anatomical distribution of osteolysis, with different patterns observed between cemented and cementless fixation. These findings suggest that osteolysis burden, beyond the mere presence of loosening, should be considered in preoperative assessment and planning of revision strategies.
Keywords: Aseptic loosening; Total hip arthroplasty; Harris Hip Score; Osteolysis (bone resorption); Cemented and cementless fixation.

1. INTRODUCTION

Total hip arthroplasty is an effective procedure for end-stage hip disease, but long-term implant survival may be compromised by aseptic loosening and periprosthetic osteolysis. Aseptic loosening remains an important indication for revision surgery and may be influenced by fixation method, implant design, femoral offset, bone quality, mechanical loading, and biological response to wear debris (Chen et al., 2023; Elbardesy et al., 2023; Factor et al., 2023; Finger et al., 2024; Faveere et al., 2025; Giardina et al., 2018; Hameed et al., 2024; Kelly et al., 2021).

Periprosthetic osteolysis is largely driven by biological and immunological reactions to particulate debris, particularly polyethylene wear particles, which stimulate macrophage-mediated inflammation, cytokine release, osteoclast activation, and progressive bone resorption (Gallo et al., 2013; Man et al., 2017). The resulting bone loss may affect the femoral side, acetabular side, or both.

The volume and anatomical distribution of osteolysis are clinically important because they influence implant stability, bone defect classification, surgical reconstruction strategy, and patient function. Implant design, surgical approach, cementing technique, collared or non-collared stem design, offset restoration, and patient factors have all been associated with fixation performance and aseptic loosening risk (Hanif et al., 2023; Janssen et al., 2018; Jud et al., 2024; Kelly et al., 2025; Kuyl et al., 2023; Mannino et al., 2024; Pai et al., 2022). The aim of this study was to

evaluate the association between Harris Hip Score and osteolysis burden in cemented and cementless implants revised for aseptic loosening.

2. MATERIALS AND METHODS

This retrospective study included 60 patients who underwent revision total hip arthroplasty for aseptic loosening. Patients were divided according to fixation type into cemented and cementless groups, with 30 patients in each group. The analyzed variables included age, sex, body mass index, Harris Hip Score, Paprosky acetabular defect type, femoral and acetabular osteolysis volume, Gruen femoral zone involvement, and DeLee and Charnley acetabular zone involvement.

Preoperative CT scans were used to evaluate osteolysis and to quantify the preoperative volume of bone loss. Metal artifact reduction techniques were used to reduce artifacts from prosthetic components and improve visualization of periprosthetic bone defects. Femoral and acetabular osteolysis volumes were segmented and measured using 3D Slicer software, version 5.6.2. Total osteolysis volume was calculated as the sum of femoral and acetabular volumes. Gruen femoral zones and DeLee and Charnley acetabular zones were recorded as involved or not involved. Descriptive statistics were calculated for all variables. Differences in Harris Hip Score across Paprosky defect types were evaluated using non-parametric testing. Spearman correlation was used to assess relationships between Harris Hip Score and osteolysis volume. Statistical significance was set at $p < 0.05$.

3. RESULTS

The cohort included 60 revision cases for aseptic loosening. The cemented group had a mean age of 76.4 years and mean body mass index of 25.38 kg/m². The cementless group had a mean age of 64.03 years and mean body mass index of 27.22 kg/m². Mean Harris Hip Score was 57.95 in the cemented group and 35.47 in the cementless group.

Harris Hip Score decreased with increasing Paprosky defect severity in both implant groups. In cemented implants, mean Harris Hip Score decreased from 76.1 in type 1 defects to 43.5 in type 3B defects. In cementless implants, mean Harris Hip Score decreased from 63.0 in type 1 defects to 28.7 in type 3B defects. Differences across defect types were significant in cemented implants ($p = 0.0002$) and cementless implants ($p = 0.0011$).

Table 1. Harris Hip Score according to Paprosky defect type and fixation group.

Group	Paprosky	n	Mean HHS	SD	Median
Cemented	1	3	76.1	2.71	77.3
Cemented	2A	4	66.4	3.59	67.0
Cemented	2B	6	58.95	4.54	57.35
Cemented	2C	9	56.67	3.16	56.0
Cemented	3A	6	49.0	3.03	49.0
Cemented	3B	2	43.5	0.71	43.5
Cementless	1	1	63.0	-	63.0
Cementless	2A	4	51.58	2.88	50.5
Cementless	2B	8	38.67	4.98	39.5
Cementless	2C	4	32.02	4.33	31.4
Cementless	3A	6	25.7	11.24	29.7
Cementless	3B	7	28.73	3.59	28.0

Source: Authors' own elaboration

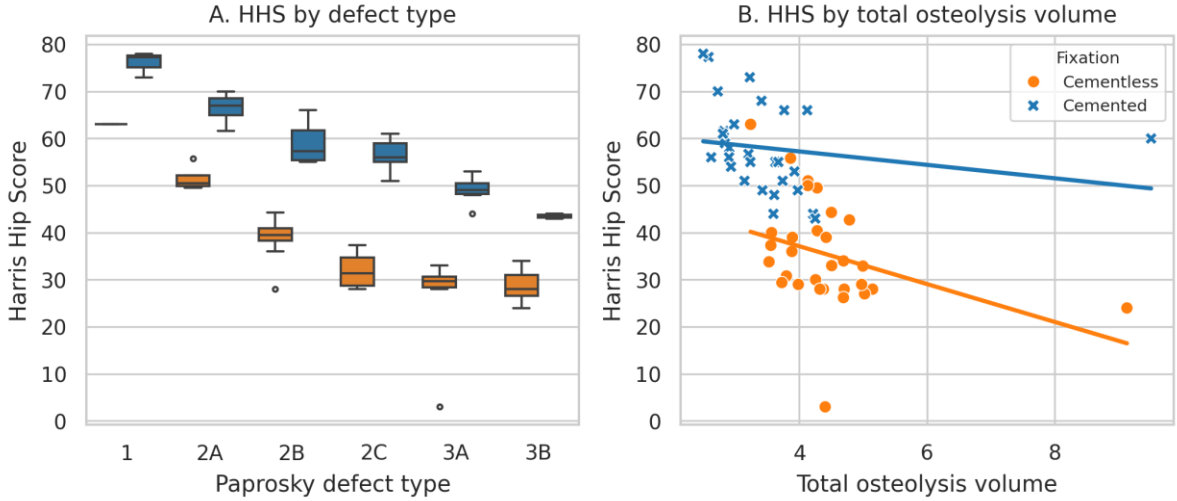
In cemented implants, Harris Hip Score correlated negatively with acetabular osteolysis volume (Spearman rho = -0.569, $p = 0.001$) and total osteolysis volume (Spearman rho = -0.515, $p = 0.0036$). In cementless implants, Harris Hip Score correlated negatively with femoral osteolysis volume (Spearman rho = -0.555, $p = 0.0015$) and total osteolysis volume (Spearman rho = -0.493, $p = 0.0056$).

Table 2. Correlation between Harris Hip Score and osteolysis volume.

Group	Variable	Spearman rho	p value
Cemented	Femoral volume	-0.1964	0.2982
Cemented	Acetabular volume	-0.5693	0.001
Cemented	Total volume	-0.5151	0.0036
Cementless	Femoral volume	-0.5549	0.0015
Cementless	Acetabular volume	-0.2179	0.2475
Cementless	Total volume	-0.4934	0.0056

Source: Authors' own elaboration

Figure 1. Association of Harris Hip Score with Paprosky defect type and total osteolysis volume.



Source: Authors' own elaboration

DeLee and Charnley zone involvement showed different patterns according to fixation type. In cemented implants, zone 1 involvement was associated with lower Harris Hip Score (54.38 vs. 60.69, p = 0.031), and zone 2 involvement was also associated with lower Harris Hip Score (55.66 vs. 64.25, p = 0.044). Zone 3 involvement was not significant. In cementless implants, DeLee and Charnley zone involvement did not show a consistent negative association with Harris Hip Score.

4. DISCUSSION

This retrospective study demonstrates a clinically relevant association between osteolysis burden and Harris Hip Score in patients undergoing revision total hip arthroplasty for aseptic loosening. The most consistent finding was the progressive decline in Harris Hip Score with increasing Paprosky acetabular defect severity in both fixation groups. This relationship was particularly strong in cemented implants, where defect severity explained a large proportion of functional variation. These findings indicate that radiological bone defect severity is not only important for surgical planning but is also closely related to the patient's pre-revision clinical function.

The observed difference between cemented and cementless implants is important. In cemented hips, lower Harris Hip Score was more closely associated with acetabular osteolysis volume, total osteolysis volume, and involvement of DeLee and Charnley zones. This may reflect the mechanical consequences of acetabular bone loss in cemented constructs, where progressive loss of periacetabular bone stock may compromise implant support, increase pain, and reduce functional capacity. In contrast, in cementless hips, Harris Hip Score was more strongly related to femoral osteolysis volume and total osteolysis volume. This suggests that femoral bone loss may have greater clinical impact

in cementless loosening, possibly because fixation depends on biological integration and mechanical stability along the femoral component.

The use of preoperative CT scans and 3D Slicer software allowed volumetric assessment of osteolysis rather than relying only on plain radiographic interpretation. Metal artifact reduction techniques were used to reduce the influence of prosthetic components on CT interpretation; however, residual artifacts may still affect segmentation precision. Therefore, future improvement of existing software or development of dedicated software should be considered, especially tools designed to directly identify, segment, and measure osteolytic zones around hip implants. Such software could improve reproducibility, reduce observer-dependent segmentation, and support more accurate preoperative planning.

Osteolysis is not only a mechanical phenomenon but also a biological process driven by the host response to wear particles. Polyethylene wear particles may activate macrophages and other immune cells, stimulate inflammatory cytokine pathways, and promote osteoclast-mediated bone resorption (Gallo et al., 2013; Man et al., 2017). This biological mechanism helps explain why osteolysis can progress silently before clinical loosening becomes obvious and why volumetric assessment may be useful even before severe implant migration is present.

The anatomical distribution of osteolysis also provided clinically meaningful information. In cemented implants, involvement of DeLee and Charnley zones 1 and 2 was associated with significantly lower Harris Hip Score. This suggests that the location of acetabular osteolysis may be as important as the total volume of bone loss. Zone involvement may indicate weakening of specific structural regions of the acetabulum and may contribute to pain, migration, or instability. In cementless implants, acetabular zone involvement did not show a consistent negative relationship with Harris Hip Score, further supporting the idea that the functional consequences of osteolysis differ according to fixation type.

These findings should be interpreted in relation to previous literature comparing cemented and cementless fixation. Existing studies have largely focused on survivorship, revision risk, complications, implant design, offset, stem geometry, or registry-based outcomes (Chen et al., 2023; Elbardesy et al., 2023; Factor et al., 2023; Finger et al., 2024; Faveere et al., 2025; Hameed et al., 2024; Kelly et al., 2021; Kelly et al., 2025). The present study adds a functional perspective by evaluating how the burden and distribution of osteolysis are associated with Harris Hip Score at the time of revision. The results support the concept that similar clinical diagnoses, such as aseptic loosening, may have different structural and functional patterns depending on fixation type.

From a clinical perspective, these results highlight the importance of detailed preoperative evaluation in revision total hip arthroplasty. In cemented implants, careful assessment of acetabular bone stock, Paprosky defect type, and DeLee and Charnley zone involvement may help anticipate functional impairment and plan acetabular reconstruction. In cementless implants, femoral osteolysis volume may deserve particular attention during preoperative planning, especially when choosing revision stem fixation strategy and estimating the complexity of femoral reconstruction.

This study has limitations. The retrospective design limits causal interpretation, and the sample size was relatively small, with 30 cases in each fixation group. Some Paprosky defect subgroups contained few patients, which may reduce the stability of subgroup comparisons. Osteolysis segmentation may be influenced by CT quality, metal artifact, slice thickness, and observer-dependent segmentation decisions. The study also evaluated preoperative Harris Hip Score and did not include postoperative functional recovery, implant survival after revision, or longitudinal change in osteolysis. One cemented case had an extremely high acetabular osteolysis volume compared with the rest of the dataset; however, sensitivity analysis did not change the main interpretation of the relationship between acetabular osteolysis burden and Harris Hip Score.

Despite these limitations, the study supports the value of combining clinical scoring, defect classification, CT-based volumetric measurement, and anatomical zone mapping. This integrated approach may improve understanding of the functional impact of osteolysis and may assist surgeons in preoperative risk assessment, patient counselling, and revision strategy selection.

5. CONCLUSION

In revision total hip arthroplasty for aseptic loosening, Harris Hip Score is strongly associated with Paprosky defect severity in both cemented and cementless implants. Cemented implants showed a stronger relationship between functional impairment and acetabular osteolysis burden, including DeLee and Charnley zone involvement. Cementless implants showed a stronger relationship between Harris Hip Score and femoral osteolysis volume. Quantitative CT-based measurement and anatomical mapping of osteolysis may improve preoperative evaluation and surgical planning in revision hip arthroplasty.

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