Retrieval analysis of failed constrained acetabular liners
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INTRODUCTION
Constrained acetabular liners are viable treatment options for selected unstable total hip arthroplasties. However, these components are subjected to high loads, resulting in mechanical failure rates as high as 29%.1,2 The liner manufactured by Stryker Orthopedics has had the best clinical results, with 96% success at 10 years1,2. However, an increasing number of failures have occurred with longer follow-up. Several studies reported on the role of impingement as a mechanical cause of failure using retrieved conventional total hip acetabular components, but, to our knowledge, no similar study exists in which failure modes were investigated in retrieved constrained liners. Our goals were to assess the damage in a sample of constrained liners and determine the effects of clinical, radiographic, and design variables on the damage incurred.

MATERIALS & METHODS
70 Stryker constrained liners with a 20° elevation were retrieved at revision surgery from our institution. Implants were cleaned, cataloged, and stored as part of an IRB-approved, institutional retrieval system. Liners were analyzed by sectioning the titanium locking ring and dissassembling the inner bearing. Evaluation was performed via visual and stereomicroscopic examination (10-31X). The rims were graded for the location and severity of impingement and for the mode of wear. The bearing surfaces were graded for the location, mode, and severity of wear (Fig. 1). Outer rim impingement location was defined by 4 quadrants, with quadrant 1 centered over the 20° elevated rim. Inner rim impingement location was not subdivided into quadrants. Outer and inner rim impingement severity was graded on a 4-point scale based upon depth of impingement into the rim. Wear mode was described as: surface deformation, burning, pitting, embedded third-body debris, scratching, abrasion, and delamination; each mode was graded on a 0-3 scale according to the percentage of bearing surface area affected.

Demographic data were collected, including age, sex, and body-mass index (BMI). Clinical data included indication for the constrained liner, failure mechanism (revision diagnosis), and length of implantation. Design variables included cup, liner, head, and neck size. Radiographs were examined to assess cup and/or liner abduction angle and offset.

RESULTS
There were 32 males and 38 females (average age = 65.2 yrs, avg. BMI = 26, and average length of implantation = 26 mos, range 0 to 125 mos). Radiographs were available for 59 implants. Avg. cup abduction angle, liner abduction angle, and offset were 44.1° (range 28-64°), 42.3° (range 20-66°), and 37.6 mm (range 25-53 mm), respectively.

Failure mechanisms requiring removal were bearing surface failure (25%), liner dissociation (25%), cup/cage failure (17%), infection (18%), femoral stem failure (10%), and biomat erial failure (5%).

The frequency of outer rim impingement (80.0%) was significantly higher (Table 1) than that for the inner rim (15.7%), as was the average impingement severity score (2.8 versus 1.4) (p<0.05). The 20° elevation on the outer rim (quadrant 1) was involved in 76.9% of the liners with impingement, a significantly higher percentage than that for quadrants 3 and 4 (p<0.05), but not for quadrant 2. Inner rim impingement was more likely to occur with 22 mm heads (p<0.05).

The frequency of embedded third-body debris was significantly higher (p<0.05) in the outer bearing surface (Table 2). The average outer bearing surface wear score (27.2) was also significantly higher (p<0.05) than that for the inner surface (24.6). Outer and inner bearing surface wear scores were positively correlated with implantation time (p<0.05).

No significant associations were found between liner damage and sex, BMI, surgical indication, failure mechanism, cup or liner abduction angle, offset, neck size, head to neck ratio, inner to outer bearing surface diameter ratio, or cup size. Well-functioning liners removed for infection or stem failure had similar damage compared to other groups.

DISCUSSION
More than a fourth (28.2%) of the liners were clinically well-functioning when retrieved for infection or femoral component failure. This group served as an internal control for comparison to liners removed for mechanical failure. Damage incurred by the two groups was similar, demonstrating the complex relationship of impingement and wear with clinical performance.

The frequency of outer rim impingement (80%) was higher than that reported for unconstrained liners in primary hip replacement (56%)1, whereas involvement of the inner rim was relatively rare. Impingement often involved the elevated rim, suggesting that liners without elevation should be used preferentially. Impingement of the inner rim was less common for larger heads, suggesting use of such heads when possible.

The prevalence of wear on the four evaluated surfaces was high. Scratching, burning, and pitting were ubiquitous. The high frequency of embedded third-body debris in both the outer (60.0%) and inner (31.4%) bearing surfaces demonstrates the ease with which debris can become entrapped in these closely conforming surfaces. Wear and subsequent osteolysis with component loosening is a potential late mechanism of failure for liners with longer implantation times.

Our study has limitations. Implants were retrieved at re-operation and thus might not represent well-functioning implants. Lack of adequate radiographs made cup version assessment impossible. Finally, in vivo liner orientation could not be determined exactly, limiting our ability to examine relations between orientation and wear.

Despite these limitations, this study provides valuable information about constrained liners that could potentially aid future implant usage and design. This particular constrained liner has had excellent clinical results at 10 year follow-up, but our retrieval experience suggests a high incidence of impingement and wear that may lead to implant failure.

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REFERENCES