Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

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CORR Insights®: Prediction of Polyethylene Wear Rates from Gait Biomechanics and Implant Positioning in Total Hip Replacement

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Where Are We Now?

Polyethylene wear is a key factor in osteolysis and a determinant for subsequent revisions [6]. To combat polyethylene wear, researchers developed new materials such as highly-crosslinked polyethylene (HXLPE), which in turn, allowed for the use of large femoral heads. It appears that use of this material in practice has lowered the average wear rate. However, it is of particular interest to understand why certain patients have higher than expected wear rates and require revision surgery.

From a mechanical standpoint, wear is a function of the forces on the polyethylene, as well as the distance of travel of the femoral head against the polyethylene, the path of the femoral head, the location of force on the polyethylene, the roughness of the femoral head, and the properties of the polyethylene. In clinical terms, wear is a multifactorial problem that involves patient weight, activity level, gait, implant design, and implant positioning. The clinical and mechanical factors combine to generate wear.

To date, there is no method to predict polyethylene wear in a specific patient. There is not even a method to predict the wear of a previously untested material without the use of a hip wear simulator.

Despite the inability to accurately predict clinical wear, HXLPE has been shown to have wear rates of less than 0.03 mm/year at 14 years [5]. One systematic review [3] found lower wear rates among HXLPE liners (0.042 mm/year) compared to non-HXLPE liners (0.137 mm/year). At this time, there is little doubt that HXLPE wear rates are lower compared to non-HXLPE wear rates. However, there have been reports of osteolysis in low-wear (<.1 mm/year) HXLPE bearings [3, 7].

Where Do We Need to Go?

It is important to monitor polyethylene wear and its consequences. Although it appears that HXLPE wear rates are clearly lower than the traditional non-HXLPE materials, the overall long-term revision rate of hips with HXLPE

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bearings is not known and may be dependent on implant design, implant positioning, and what counterface material is used for the femoral ball.

Total joint replacement makes up the largest Medicare expenditure category for hospitals [4]. In fact, between 1997 and 2003, revision surgery accounted for 19% of the total expenditures for hip replacement [2]. It is critical to note that without accounting for any other factors, the number of THA revisions are projected to increase by 137% by 2030 [4].

Put in this context, there is a major need to improve the performance of total joint replacement. Although polyethylene wear remains a key factor, it may not be the most-critical current factor in hip replacement. Polyethylene wear is one of several main causes of hip revision that needs to be better understood. As we await the results of long-term survivorships of THAs using the different HXLPE materials and their designs, attention should now be directed at reducing the number of revision THAs for all reasons, including polyethylene wear. What other factors lead to hip revisions? An examination of the Medicare database provides some insight to what some of the critical problems might be.

Dislocation has been identified as the largest cause of short-term revisions. For patients with Medicare, the overall incidence rate is estimated to be 2% to 3% (66,000 to 99,000 patients). However, the true incidence of dislocation after primary total hip replacement has been reported as high as 10% [1]. This is an example of how future research should focus on the clinical performance of contemporary materials in current implant designs, with the goal of reducing the overall risk of revision THA. In this regard, topics such as gait patterns as predictors of revision is a relatively unexplored but potentially important avenue of inquiry.

How Do We Get There?

Hip replacement remains one of the most successful interventions we have, but the increasing number of people requiring joint replacement and the economic environment will place an enormous stress on patients and healthcare systems. To reduce the number of revision procedures, we will need to look far beyond polyethylene wear. Although polyethylene wear remains a concern, recent promising results with HXLPE have indicated that a slight shift in priorities should be directed at understanding the outliers in patient groups, particularly those with higher than expected wear rates that lead to revision surgery.

In one sense, a more-practical target would be to develop a methodology to identify when high wear is going to occur. The approach used in this paper was mathematical in nature. As the authors point out, no mechanistic information can be extracted. Understanding the mechanisms is necessary to alter practice, materials, or designs to reduce wear and revisions.

It is likely time for large hip replacement databases to include not only all typical patient information, but also implant placement and gait analysis. The clinical success of hip replacement has been constantly improving since its inception. We are at the envious position of having materials, designs, and surgical knowledge that have resulted in well-fixed, well-functioning, low-polyethylene wear implants. As the performance continues to get better, however, other challenge arise. We appear to have improved polyethylene wear resistance to the point where it may not be the major indication for revision at the 10-year period. The next targets may be the current major causes of both early and late revisions. These targets could include the identification and solutions to revisions done within 90 days of primary surgery and why there always seem to be a small groups of patients who exhibit unexpectedly higher wear or surprisingly low wear. Answering these

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questions, may require different research methods and approaches such as the use of large database analytics and novel measures of performance. However, history strongly suggests that improvements will be continued to be made.

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