Is there a rationale to use highly cross-linked polyethylene in posterior—stabilized total knee arthroplasty?

Lisa Renner, Martin Faschingbauer, Friedrich Boettner

Hospital for Special Surgery, New York, NY 10021, USA

Correspondence to: Friedrich Boettner, MD. Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA. Email: Boettnerf@hss.edu.

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The use of highly cross-linked polyethylene (HXLPE) in total knee arthroplasty (TKA) is controversial (1).

The concept behind the development of HXPLE in total hip arthroplasty was to reduce wear and to prolong the implant survival. While plastic wear and secondary osteolysis is a main concern in total hip arthroplasty its impact on longevity of total knee arthroplasties is less clear. Aseptic loosening is the main reason for failure of total knee replacement and accounts for around one-third of all revisions (2,3). Other early failure mechanisms are infection, instability and stiffness (2). Wear induced osteolysis is not encountered until more than 15 years after the initial surgery and is not considered a main cause for revision TKA (2).

HXLPE is a modification of standard polyethylene (PE) (4). Irradiation initiates free radicals that promote cross-linking and results in a higher density PE. In a further melting step attempts are made to eliminate remaining free radicals to improve the resistance to oxidation. HXPLE is more resistant to adhesive and abrasive wear (1). However, HXPLE has decreased toughness, ductility and resistance to fatigue and fractures. If residual free radicals are not destroyed by post radiation treatment, HXPLE has an increased propensity to oxidative breakdown (1). Especially the first generation of HXPLE is at increased risk. Therefore manufacturers tried to improve the characteristics of the second-generation HXPLE by sequential irradiation and annealing or by utilizing anti-oxidants like vitamin E.

The benefit of HXLPE has been confirmed for total hip arthroplasty (5). However the PE bearing in hip and knee arthroplasty is exposed to different biomechanical loads. The hip suffers from abrasive and adhesive wear in a highly conformed ball in socket articulation, while, the knee is exposed to shear forces and point contact loads because of its round (femoral condyle) on flat (tibial insert) design. Beside the point loading of the bearing surface there are additional areas with increased mechanical stresses including the tibial post and the insert locking mechanism (6).

Most supporting evidence for HXPLE in knee arthroplasty is derived from *in vitro* wear simulator studies that are showing a reduction of wear up to 60% (7). Although laboratory tests are essential for the development of new materials, *in vitro* studies should only be applied with caution. *In vitro* studies assume an optimal alignment and ligament balance, and primarily test for abrasive and adhesive wear. In addition *in vitro* studies don't include third body wear (cement particle) and wear simulators do not perfectly reflect the kinematics of the normal knee. In the past catastrophic failures of PE that tested well *in vitro* have been encountered and should increase our caution when implementing new materials based on *in vivo* test results alone (8).

Is there any *in vivo* evidence supporting the use of HXPLE? A clinical study about particles in the synovial fluid one year after surgery could not find any difference in number, size and shape of the PE particles between standard PE and HXPLE (9). Kim *et al*. investigated the clinical and radiographic differences between highly cross-linked (XLPE) and conventional PE in 308 patients 5 years after bilateral posterior cruciate substituting TKA—and did not report a difference in outcome nor revision rate (10). There are other short and mid term studies that show no difference in outcome between the two materials (6,11,12).

Since HXPLE reduces the fracture toughness tibial post fracture has been a main concern in posterior stabilized knee arthroplasty. Tibial post fractures have been documented in several studies with standard PE and HXPLE (13-16). Ansari *et al*. (15) reported on two cases of post fractures with inserts made of moderate cross-linked PE. Two failure mechanisms have been suggested: reduced mechanical properties of HXPLE increase the risk of tibial post fracture and oxidation of the HXPLE over time can increase the fracture risk.

Beside the problems of using *in vivo* studies to predict *in vitro* performance there are a number of concerns with the current clinical studies. All reports lack long term follow up beyond 10 years (2). In addition the sample size is rather small suggesting that they might be underpowered to detect certain failure modes like tibial post fracture. Furthermore most studies include a high percentage of normal weight women. Kim *et al*. (10) report on 288 women and only 20 men and did not include patients with a BMI above 40 kg/m^2.

Is there a good reason to consider HXPLE in primary total knee arthroplasty? There is little doubt that today's patients are younger and request a more active life style and it can be argued that conventional PE might not be the optimal bearing for these patients. However, the history of orthopedics has its fair share of disastrous failures of well-meant implant "improvements". Especially considering our recent experience with metal on metal bearings in total hip arthroplasty I recommend applying caution when using HXPLE in knee arthroplasty. HXPLE has not shown any clinical benefits, is more expensive and has not been adequately tested in obese and young active male patients (1,17). Its unrestricted use cannot be encouraged.

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References

1. Sakellariou VI, Sculco P, Poultsides L, et al. Highly cross-linked polyethylene may not have an advantage in total knee arthroplasty. HSS J 2013;9:264-9.
2. Lombardi AV Jr, Berend KR, Adams JB. Why knee replacements fail in 2013: patient, surgeon, or implant? Bone Joint J 2014;96-B:101-4.
3. Register SK. Annual Report 2013. 2013: Lund, Sweden.
4. Jasty M, Rubash HE, Muratoglu O. Highly cross-linked polyethylene: the debate is over--in the affirmative. J Arthroplasty 2005;20:55-8.
5. Digas G, Kärrholm J, Thanner J, et al. The Otto Aufranc Award. Highly cross-linked polyethylene in total hip arthroplasty: randomized evaluation of penetration rate in cemented and uncemented sockets using radiostereometric analysis. Clin Orthop Relat Res 2004;429:6-16.
6. Inacio MC, Cafri G, Paxton EW, et al. Alternative bearings in total knee arthroplasty: risk of early revision compared to traditional bearings: an analysis of 62,177 primary cases. Acta Orthop 2013;84:145-52.
7. Stoller AP, Johnson TS, Popoola OO, et al. Highly crosslinked polyethylene in posterior-stabilized total knee arthroplasty: in vitro performance evaluation of wear, delamination, and tibial post durability. J Arthroplasty 2011;26:483-91.
8. Ahn NU, Nallamshetty L, Ahn UM, et al. Early failure associated with the use of Hylamer-M spacers in three primary AMK total knee arthroplasties. J Arthroplasty 2001;16:136-9.
9. Hinarejos P, Piñol I, Torres A, et al. Highly crosslinked polyethylene does not reduce the wear in total knee arthroplasty: in vivo study of particles in synovial fluid. J Arthroplasty 2013;28:1333-7.
10. Kim YH, Park JW. Comparison of highly cross-linked and conventional polyethylene in posterior cruciate-substituting total knee arthroplasty in the same patients. J Bone Joint Surg Am 2014;96:1807-13.
11. Minoda Y, Aihara M, Sakawa A, et al. Comparison between highly cross-linked and conventional polyethylene in total knee arthroplasty. Knee 2009;16:348-51.
12. Hodrick JT, Severson EP, McAlister DS, et al. Highly crosslinked polyethylene is safe for use in total knee arthroplasty. Clin Orthop Relat Res 2008;466:2806-12.
13. Lee CS, Chen WM, Kou HC, et al. Early nontraumatic fracture of the polyethylene tibial post in a NexGen LPS-Flex posterior stabilized knee prosthesis. J Arthroplasty 2009;24:1292.e5-9.
14. Mauerhan DR. Fracture of the polyethylene tibial post in a posterior cruciate-substituting total knee arthroplasty mimicking patellar clunk syndrome: a report of 5 cases. J Arthroplasty 2003;18:942-5.
15. Ansari F, Chang J, Huddleston J, et al. Fractography and oxidative analysis of gamma inert sterilized posterior-stabilized tibial insert post fractures: report of two cases.

Knee 2013;20:609-13.

16. Jung KA, Lee SC, Hwang SH, et al. Fracture of a second-generation highly cross-linked UHMWPE tibial post in a posterior-stabilized scorpio knee system. Orthopedics 2008;31:1137.
17. Bozic KJ, Morshed S, Silverstein MD, et al. Use of cost-effectiveness analysis to evaluate new technologies in orthopaedics. The case of alternative bearing surfaces in total hip arthroplasty. J Bone Joint Surg Am 2006;88:706-14.

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