50 Years Ago in CORR

Biomechanics of Hip Prostheses

Duncan C. McKeever, MD CORR 1961;19:187–199

“The fact that a device or a procedure is successful some of the time, most of the time, or even all of the time, does not prove that it is mechanically and physiologically correct.” Thus began Duncan McKeever in his article on, “The Biomechanics of Hip Prostheses,” published in CORR in 1961 [7]. This “axiom” remains true today.

Surgeons have recognized the importance of mechanical conditions, and have attempted to explain why implants work and why they fail since the advent of implants and artificial joints in the 1890s [4, 5]. Haboush [6], in explaining the rationale for what was perhaps the first contemporary arthroplasty using cement (1953), designed his implant using mechanical principles. Charnley [2, 3] performed extensive mechanical experiments while developing his arthroplasty. McKeever outlined four mechanical principles in designing a hip prosthesis (presuming it has a stem): (1) the components of stress should have a constant direction; (2) there must be an optimal relation between the maximal stress and the cross-sectional area; (3) the total stress must be transferred at a single level; (4) the range of stress must be within the range of functional adaptation of the bone (Fig. 6). These are undoubtedly sound principles, but the problem was – and is – determining stress histories in an accurate

comprehensive, and meaningful way. Today, stresses throughout a complex structure, such as a bone-implant construct, can be estimated using increasingly sophisticated finite element analyses, but these analyses do not account for the dynamic nature of the stresses nor the manner in which bone adapts to the constantly changing stresses during function [1]. Further, the precise nature of the stress transfer varies from patient to patient, and more generic estimates of that transfer may not apply.

McKeever did not have the ability to estimate the stresses at his disposal, but he commented, “The stem of the prosthesis should act only as a directional device only, and none of the stress should be transmitted through

it.” He presumed all of the stress would be transferred at the point of maximal contact (Fig. 6). We now know this is not the case. Because of the uncertainties of stress transfer and bone response, empiricism has always played a role in the development of arthroplasties. Implants may be designed on a sound theoretical basis, but may not account for all in vivo conditions or unanticipated responses or reactions; thus, it is hard to predict whether a given arthroplasty will be durable, and much of the advances have occurred through trial and error. McKeever concluded, “Our salvation in many of the more serious problems of bone surgery lies within the field of mechanics and structural design as related to physiology. To

Fig. 6 McKeever's illustration shows the four principles he outlined in his text and the additional point about where the “total stress” is transferred to bone. In fact, stress transfer will occur throughout the interface, depending upon the activity and loading conditions. (Reprinted with permission and © Lippincott Williams & Wilkins, from McKeever DC. Biomechanics of hip prostheses. *Clin Orthop*. 1961;19: 187–199.)

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think along these lines will avoid some of the complications and some of the failures.” In a strict sense, he was correct, but 50 years later, we still do not adequately understand the details of bone adaptation in general or in specific individuals to design an implant that will be durable in all patients.

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