Clinical Research Award goes to Donald D. Anderson, PhD

OREF recognizes research on posttraumatic osteoarthritis

▲ Donald D. Anderson, PhD

By Terry Stanton

The development of osteoarthritis (OA) in the years following intra-articular fracture is one of the unsolved puzzles of orthopaedic surgery. Approximately 12 percent of patients with OA of the hip, knee, or ankle have a history of prior joint trauma. Osteoarthritis develops in as many as 25 percent of hip fracture patients, up to 44 percent of those with knee fractures, and in more than half of patients with fractures of the ankle (tibial plafond). Despite continued refinement of surgical reconstruction techniques, patient outcomes have not substantially improved over the past 30 years.

For his efforts to delineate the relationship between trauma and osteoarthritis, **Donald D. Anderson, PhD**, of the University of Iowa, and colleagues have been awarded the 2011 Orthopaedic Research and Education Foundation Clinical Research Award.

Their novel objective measurement technologies, developed over a decade of study, provide a better understanding of the relative roles and pathomechanisms of both the original joint injury and the subsequent elevation in contact stress resulting from residual incongruity. These objective biomechanical indices may lead to clinical studies assessing the development of new approaches—including biologic and pharmaceutical treatment paradigms—to prevent posttraumatic osteoarthritis (PTOA) following intra-articular fractures.

THE CLINICAL PROBLEM

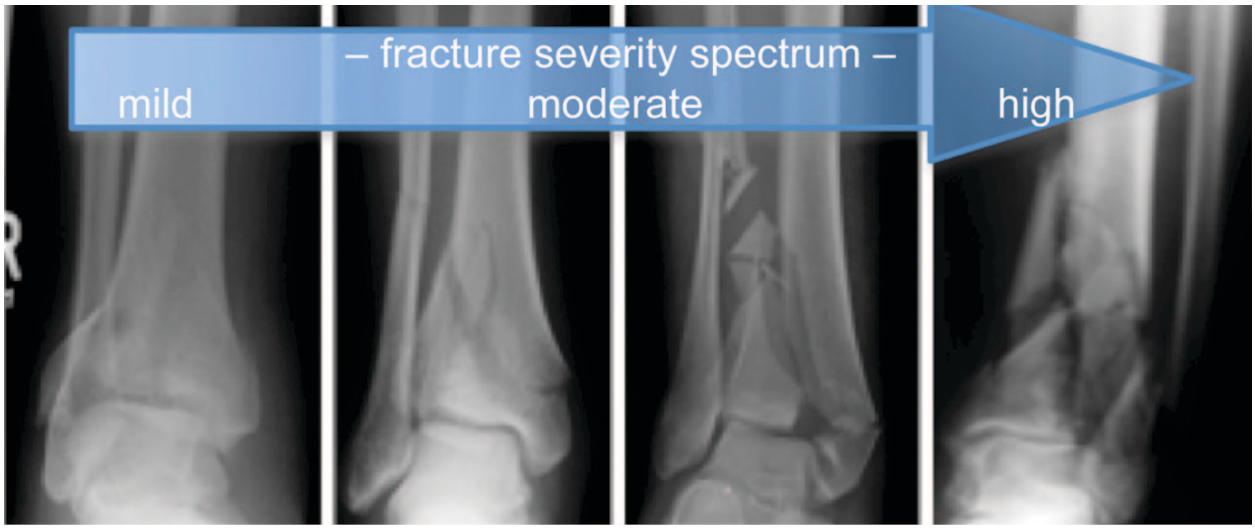
In tibial plafond fractures (Fig. 1), for example, 30 percent of affected ankles develop radiographic evidence of significant OA within 2 to 4 years after fracture, and that incidence increases to 74 percent by 11 years after fracture. Although reduction of displaced articular fragments is the most important factor in achieving a good outcome, a reliable prognosis for a specific injury has proved elusive.

The studies combined expertise in clinical investigation and bioengineering to develop a way to index both the severity of initial joint injury (based on the mechanical energy released in bony fracture, as obtained from digital image analysis of computed tomography [CT] scans) and chronic stress elevations (based on finite element [FE] stress analysis).

THE ROLE OF ACUTE FRACTURE SEVERITY

To measure the energy imparted in an injury, the researchers hypothesized that the mechanical energy absorbed in a fracture "is converted to de novo surface energy of the fracture fragments." CT scans enabled them to measure the de novo interfragmentary fracture surface area and thus to quantify surface energy. This provides a metric of the energy that must have crossed the articular surface, injured the cartilage, and created the bony fracture.

Using a polymer bone surrogate and bovine cortical bone segments, Dr. Anderson found that the de novo surface area in the specimens that absorbed greater energy was significantly higher ($p < 0.0001$) than that in the lower



▲ Fig. 1 Simple intra-articular fractures result from low-energy impacts (left). As energy increases, the fractures become more complex, with greater comminution. *Photo courtesy of the Iowa Orthopaedic Journal*

energy groups. When the assessment technique was extended to humans, the algorithm was adjusted to accommodate relevant differences, such as those related to patient age and bone density.

An expedited method of fracture severity assessment was subsequently developed, so an objective fracture severity assessment can be obtained in about 10 minutes.

CHRONIC CONTACT STRESS ELEVATION

Without a way to reliably measure injury severity and without treatments to enhance cartilage survival, management of intra-articular fractures has largely concentrated on fracture reduction. Measuring joint incongruity on radiographs, however, "is a weak surrogate for … contact stress abnormality," wrote Dr. Anderson.

When residual stress incongruity is present, joint loads that are normally well tolerated generate local areas of elevated contact stress. Because the degree to which injured articular joints can tolerate elevated contact stress and the precise degree of articular reduction needed to prevent clinically significant PTOA are unknown, FE stress analysis techniques were used to address these gaps in knowledge.

The FE formulation developed automatically generates patient-specific meshes suitable for contact stress analysis and implements whole-duty-cycle functional loading. The researchers studied contact stress differences in fractured versus intact ankles from the same patients. In general, the intact ankles had lower peak contact stress exposure values and more uniform and centrally positioned exposure regions than the reduced fractured ankles.

CLINICAL INVESTIGATIONS

To investigate the hypothesis that elevated contact stress exposure results in cartilage thinning, double-contrast (radiopaque contrast agent followed by air) CTs were obtained for 11 patients, at 6 months and 2 years after the injury. Localized areas of cartilage thinning generally corresponded to areas exposed to elevated contact stresses. The most severely comminuted fractures experienced the greatest cartilage loss, in addition to having the greatest FE-predicted contact stress exposures.

"Given the experience of the past several decades, further mechanical refinements of fracture stabilization techniques alone seem unlikely to advance the treatment of patients with articular fractures," wrote Dr. Anderson and his coauthors. "Future investigation probably needs to focus on bio/pharmaceutical interventions designed to preserve the damaged articular surfaces."

As increasing evidence that biologic interventions can decrease chondrocyte damage induced by mechanical stress, it may be possible to limit progressive chondrocyte damage after joint injury. Dr. Anderson's efforts to date are important steps in making this type of clinical research possible.

The coauthors of "The Pathomechanical Etiology of Post-traumatic Osteoarthritis Following Intra-articular Fractures" are **J. Lawrence Marsh, MD**, and **Thomas D. Brown, PhD**. Disclosure information: The authors report no conflicts.