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Orthopedic Update

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Highly Porous Metals: A New Class of Materials Leads to Novel Orthopedic Tools and Solutions

Daniel J. Berry, MD
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From abandoned US government plans for an orbiting "spaceplane" to a Mayo Clinic Department of Orthopedic Surgery bone ingrowth laboratory, highly porous metals (HPMs) command attention in select scientific circles. Why all the interest in HPMs, such as porous tantalum, over the past 20 years?

Mayo Clinic orthopedic surgeon David G. Lewallen, MD, cites at least 6 compelling reasons. All relate to HPMs' cellular architecture and ability to form strong, rapid biological fixation of implants that improves spanning of large defects (Figure). From there, many possibilities emerge—such as one day creating "smart" bioactive implants for cancer patients that structurally replace bone after tumor resections, while also delivering chemotherapy to reduce chances of local recurrence.

"This is a real possibility moving forward," Dr Lewallen says. "And while the technology is not quite like what we see in movies yet, there is tremendous potential for new and robust orthopedic solutions from HPM research." Adds his Mayo colleague, orthopedic surgeon and researcher Arlen D. Hanssen, MD: "The work with HPMs is great news for patients, because we do have a need for larger and more complex implants. Our research is very much driven by the underlying patient need." Some of their recent findings, published in the August 2010 issue of *Journal of Arthroplasty*, suggest that in acetabular revision, highly porous tantalum acetabular components provide superior mechanical stability over the traditional cementless implant when tested in hemipelvis specimens with superolateral defects.

6 Ways to Apply HPMs to Orthopedic Problems

Dr Lewallen began researching HPMs' potential orthopedic applications in the early 1990s because of his interest in porous ingrowth implants. The data immediately

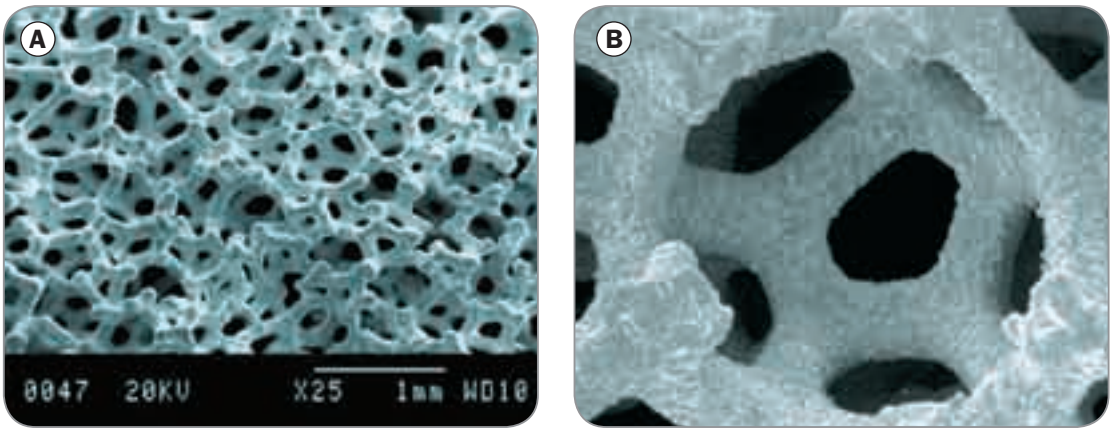

Figure. *A, Scanning electron micrograph of elemental tantalum metal shows close replication by this material of the structure and mechanical properties of cancellous bone. B, Microspikes give the material a high coefficient of friction against cancellous bone.* Used with permission of Zimmer, Inc.

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David G. Lewallen, MD, and Arlen D. Hanssen, MD

got his attention because of the high volume of revision work performed at Mayo that creates a need for reliable fixation and for filling large bone defects around hip and knee joints. "My first look at the data showed impressive evidence in animals of rapid bone ingrowth around HPM joints," Dr Lewallen recalls. "Growth became more and more rapid, in fact, and I was intrigued. It suggested so many possibilities." Among them are these:

- Improving durable fixation of cementless implants through vigorous and strong bone ingrowth.
- Using blocks or shaped segments of HPM to build up defects related to total joint replacements or bone loss from periarticular tumor resection.
- Creating bioimplants loaded with growth factors that can modify the tissue environment to encourage tissue ingrowth or otherwise mediate therapeutic effects.
- Exploiting the spongy nature of HPM by filling it with antibiotics or chemotherapy medicines to deliver therapeutic agents to the implant interface with bone.
- Achieving ligament or tendon ingrowth to a prosthesis. HPM's intricate architecture is like a geodesic dome, Dr Lewallen explains, which not only supports robust bone attachment but also allows for tendon and ligament ingrowth to the implant at near-normal bone attachment strength in animal studies.
- Promoting cartilage growth. In the laboratory, Mayo researchers have grown cartilage derived from periosteal grafts on the top of a rough scaffolding, suggesting the future possibility of combination tissue and prosthetic implants for clinical use.

Next Steps

The versatility and biocompatibility of this new material continue to impress Dr Lewallen. One especially appealing possibility to him is to create clinical devices that allow for tendon attachment to the implant. Another is to cue cartilage growth for the resurfacing of portions of damaged joints.

"Down the line, the prospect exists for development of composite implants of human tissue and artificial materials for the restoration of damaged joints and bone defects, which is a tremendously exciting prospect," he says. "That possibility could open all sorts of therapeutic doors now closed to us."

The Mayo Clinic Total Wrist Implant: A New Era of Restoring Function Through Replacement

In 1972, the Mayo Clinic Department of Orthopedic Surgery opened a new frontier of diagnosis and treatment of wrist injury with the classic paper by Ronald L. Linscheid, MD, and James H. Dobyns, MD. In it, they set forth a pathomechanical framework for understanding carpal instability that influenced many subsequent therapeutic wrist advances, leading ultimately to wrist joint replacement.

Explains William P. Cooney III, MD, Mayo Clinic emeritus hand and wrist surgeon whose team developed the total wrist implant (Figure 1): "Mayo's novel conceptualization of wrist instability related to carpal bone malalignment, ligament laxity, and secondary arthritis helped pave the way for the emergence of advanced prosthetics."

William P. Cooney III, MD

Restoring Anatomic Integrity

Orthopedic surgeons formerly relieved pain and dysfunction from osteoarthritis and

Figure 1. *Advanced rheumatoid arthritis of the wrist (A) treated with total wrist replacement (B), with distal fixation of the carpals and index and long metacarpals, excision of the distal ulna, and press fit fixation of the distal radial component.*

rheumatoid arthritis by modifying bone, such as removing the trapezium or the distal end of the ulna, or by fusing the wrist bones. But the functional outcomes were limited.

Richard A. Berger, MD, PhD

"The important principle that Mayo contributed was the idea that prostheses such as the total wrist, the distal ulna, or the thumb joint, usually can closely restore the normal anatomy—and anatomic correctness and joint integrity optimize function," adds Richard A. Berger, MD, PhD. Says Dr Cooney: "We are now seeing the initial success of this approach, proving that biomechanically and clinically, wrist replacement tends to be a much better solution than just cutting away bone or stiffening of bones (wrist fusion) at the expense of the joint architecture."

The Mayo Method: Engineers and Orthopedists

Specialists across disciplines contributed to Mayo's wrist advances, including earlier work on the lower extremities. "We really benefited from the work of Dr Mark Coventry and his group's 1969 total hip replacement," Dr Cooney says. Mayo's work on the joint replacement of the hip and knee helped to refine the collaborative research method and culture between clinical-surgical care and bioengineering.

At Mayo, the team approach, basing investigative ideas on orthopedic anatomy and biomechanics, originated with Edmund Y. S. Chao, PhD, and continues today with Kai-Nan An, PhD, and his group of biomechanical engineer collaborators. Clinical orthopedic problems are translated into mechanical problems with engineering solutions—and then translated back into the clinical context and applied to patient care. "Joining the 2 cultures enabled us to work more easily with production companies so we could put ideas into practice faster," Dr Cooney says. "Following this model has led to great advances in hand and wrist surgery in the past 10 to 15 years."

20 Years of Funded Hand and Wrist Research

Dr Cooney recalls the collaboration with engineers as an intellectually stimulating and highly productive time. It led to some 20 years of research supported by the National Institutes of Health investigating biomechanical and kinematic forces in the hand and wrist in healthy patients, in those with disease, and in cadavers and anatomic models. The investigations included wear-force characteristics evaluated in a custom-designed wear-testing machine that simulated the loading and motion of the wrist from flexion, extension, radioulnar deviation, and axial rotation (Figure 2).

"Our solutions did not come right away, but then, the wrist is quite different from other joints," Dr Cooney says. "It's kind of a Rubik's Cube with 8 bones in it, whereas the hip is a ball and socket joint. But eventually our work all came together in this new vision of wrist replacement."

Figure 2. *Wear-testing machine designed by the Mayo Clinic biomechanical orthopedics lab to test wear characteristics.*

Major Mayo Wrist Milestones

- **1970s:** Landmark paper in 1972 by Linscheid and Dobyns revealing new insights into instability
- **1980s:** First Mayo International Wrist Workshop leading to ongoing Mayo wrist course presentation every 3 years
- **1990s:** Continued development and refinement of total wrist implant and related small-joint components of metal and plastic for surface replacement implants of proximal interphalangeal and metacarpophalangeal joints
- **2000s:** Introduction in 2006 of instrumentation to facilitate correct anatomic placement of a total wrist implant; development of a metallic ulnar-head implant for patients with unstable forearms secondary to excision of an arthritic ulnar head
- **2010:** One-stop wrist care with integration of the Department of Physical Medicine and Rehabilitation and new state-of-the-art Musculoskeletal Center

Centennial Year Milestones: Expanding Expertise in Level I Trauma Center, Sports Medicine, PM&R, and Hand Surgery

Mayo Clinic Department of Orthopedic Surgery in Rochester, Minnesota, celebrates its 100th anniversary this fall. Notes department chair Daniel J. Berry, MD, as he surveys a century of orthopedic care at Mayo Clinic in Rochester: "The steady growth and the dedication of a collegial, multidisciplinary staff has enabled Mayo orthopedics to provide the highest-quality orthopedic care on a daily basis for 100 years—that was the original vision, and that remains the vision we work to fulfill everyday."

In 1910, a bold move for the fledgling Mayo orthopedics department was to send its brace maker to New York for training to improve care for polio, tuberculosis, and farm injury patients. "But by 2010, the leadership and presence of the Mayo Clinic Department of Orthopedic Surgery are truly international," explains Dr Berry. "Our presence around the world spans a broad spectrum of clinical, surgical, research, educational, and training initiatives. We focus our care on regularly performed procedures and on complex, less common problems. In most patients, we can achieve excellent recovery of function with a low risk of complications—which is tremendously gratifying for us all."

Growth Areas

Two recent areas of growth stand out. One is the addition of staff to further strengthen Mayo's commitment as a Level I Trauma Center and add depth to the department's subspecialties. The other is the final integration in winter 2010

Figure 1. *Mayo's new PM&R Center services were fully integrated into the Musculoskeletal Center in winter 2010 to optimize patient care, convenience, and education.*

of Mayo's physical medicine and rehabilitation (PM&R) service areas into the W. Hall Wendel, Jr, Musculoskeletal Center, which opened in 2007 (Figure 1). The Department of Physical Medicine and Rehabilitation is celebrating its 75th anniversary year in 2010.

Centennial Milestones: Expanding PM&R

With the centralized design integrating PM&R into the Musculoskeletal Center, patients now have the convenience of 1-stop access to all musculoskeletal specialties, which, in addition to all orthopedic subspecialties and PM&R, includes rheumatology, bone endocrinology, radiology, and anesthesiology.

Explains PM&R department chair Kathryn A. Stolp, MD: "From the point of view of strategic design, integration of PM&R into the Musculoskeletal Center is central to providing the highest-quality service and care." Her colleague Jonathan T. Finnoff, DO, agrees. He sees the integration of PM&R with the Musculoskeletal Center as an ideal platform to assure patients receive state-of-the-art, comprehensive nonsurgical care before progressing to or after surgical solutions: "The Center functions ideally as a gatekeeper," Dr Finnoff says. If a patient does require surgery, that is easily accommodated—often starting as a hallway chat with a colleague in orthopedic surgery. "Seeing professional interactions between specialists gives patients confidence in the quality and continuity of care they receive at Mayo," Dr Finnoff explains.

From Green Screen to Patient Education

In the gym, advanced technology, including the use "green screen" virtual reality motion trainer, is one of the new assets used to guide PM&R exercises. Common in major sports clinics, this training technology gives patients freedom to work on range of motion and other exercises in a simulated setting projected on a wall using green screen technology.

The lobby area is designed to support patient education. Anatomic models help patients visualize their injuries. Electronic education kiosks answer questions about postprocedure safety and independent living.

Dedicated to Restoring Function

Through its many expanded services, the full integration of PM&R within the Musculoskeletal Center provides comprehensive care for maximal healing and recovery of function. Says Dr Stolp: "Our job is to restore patients to their fullest mental, emotional, physical, vocational, and avocational function. While most of medicine is organized along organ systems, we like to think that the organ systems we address are 'function' and 'quality of life.' We never say to a patient, 'We can't help you.' There is always something we can do to improve function and thereby enhance quality of life."

Kathryn A. Stolp, MD, and Jonathan T. Finnoff, DO

Adding Expertise in Level I Trauma, Subspecialties

With the arrival of orthopedic surgeon William W. Cross III, MD, Mayo's orthopedics department now has 4 full-time staff trauma surgeons—a reflection of the practice's ongoing commitment to providing Level I Trauma Center care. Dr Cross is particularly interested in acetabular fractures in the elderly, which tend to be the result of low-energy falls from standing height in patients with poor bone quality (Figure 2). Says Dr Cross:

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William W. Cross III, MD

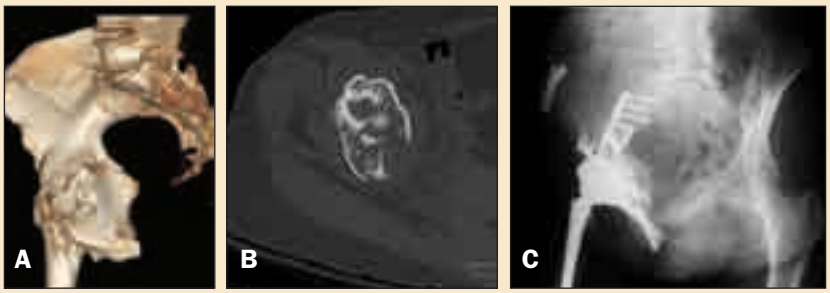

Figure 2. *In select cases of elderly acetabular fracture, Mayo orthopedic surgeons perform an innovative early total hip arthroplasty (ETHA). In ETHA, 2 surgical procedures are completed in a single operation, which is less disruptive to quality of life and reduces the deconditioning seen in serial procedures. These 3 images are from a 79-year-old woman who underwent ETHA at Mayo for injury to the right hip sustained when she fell off a step. A, Preoperative 3-dimensional reconstruction. B, Preoperative CT of impaction of the articular surface and involvement of the ilium. C, Postoperative follow-up radiograph revealing healed fractures and a well-seated cup with no loosening.*

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"A great strength of Mayo orthopedics that I highly value is its commitment to innovation in improving the treatment of the elderly with these types of fractures."

Dr Cross's research interests include studying outcomes, epidemiology, and mortality of traumatic conditions. The addition to the staff of epidemiologist Hilal Maradit Kremers, MD, will be helpful in developing comprehensive outcome reports. Other additions to the staff also deepen the department's expertise and ability to contribute outcome data. They include Debra A. Zillmer, MD, in the Musculoskeletal and Sports Medicine Centers; Michael J. Taunton, MD, in adult reconstruction (hip and knee); and Sanjeev Kakar, MD, in hand surgery.

Mayo Clinic Leadership

International Participation Grows in International Hip Society Under Mayo Leadership

When the International Hip Society (IHS) was founded in 1966 in Paris by a group of surgeons, including Mayo Clinic hip surgeon Mark Coventry, MD, it had an invited membership of approximately 100 hip surgeons worldwide—but nearly all practiced in the United States.

Miguel E. Cabanela, MD

Elected to the Society's 3-year presidency in 2008, Mayo Clinic's Miguel E. Cabanela, MD, has helped change that. With a renewed emphasis on growth through diversity of membership, he has used his post to encourage membership from beyond North America. "This has been my No. 1 goal as president, and it is gratifying to see. Internationalism brings new ideas and experience and stimulates growth, which is always a good thing," Dr Cabanela says.

The Society's membership roster now includes hip surgeons from Asia, Europe, Australia and New Zealand, and North and South America. Next year's meeting will be in Prague.

Research Briefs

From January 1-June 30, 2010, Mayo Clinic consultants in the Department of Orthopedic Surgery published more than 120 journal articles. Two highlights appear below.

Postoperative Falls on an Orthopedic Inpatient Unit

Journal of Arthroplasty 2010;25:10-1.
Duncan B. Ackerman, MD; Robert T. Trousdale, MD; Patti Bieber, MS, RN; Joan Henely, MS; Mark W. Pagnano, MD; and Daniel J. Berry MD

Falling events among hospitalized patients are not uncommon, affecting approximately 2% to 17% of patients. But the specific risk for patients in the orthopedics ward had not been studied. These investigators reviewed all orthopedic inpatient records from January 1, 2003, through May 31, 2005, from a 50-bed postoperative unit at Mayo Clinic in Rochester, Minnesota. They found that of the 6,912 patients admitted, 70 (1%) fell while recovering in the orthopedic ward.

Most falls were related to getting to and from the bathroom or using it and walking without assistance, and most occurred during the evening or night shift. The risk of falling was significantly higher in patients who were older (>65 years), were female, had a prolonged admission (>4 days), and were admitted for primary or revision knee arthroplasty.

Of those who fell, 19% sustained some type of injury in the fall. Researchers concluded that a successful fall prevention program should focus on creating prevention strategies for postoperative orthopedic patients.

Survivorship of the Humeral Component in Shoulder Arthroplasty

Journal of Shoulder and Elbow Surgery 2010;19:143-50.
Akin Cil, MD; Christian J. H. Veillette, MD; Joaquin Sanchez-Sotelo, MD; John W. Sperling, MD, MBA; Cathy D. Schleck, BS; Robert H. Cofield, MD

A central factor in the success of shoulder replacement surgery is the durability of the implant. Now this large-sample, 20-year-long study helps illuminate durability by identifying humeral component survivorship factors. These investigators' analysis of the impact of age, sex, disease etiology, surgery type, and humeral component design on survivorship is based on 1,584 primary Neer and Cofield shoulder arthroplasties performed at a single institution. The results showed the following:

- Estimated survivorship free of revision or removal of the humeral component of the implant was approximately 95% at 5 years.
- Need for revision of the humeral component was commonly related to glenoid or glenoid component issues.
- Risk factors for humeral component failure are young age, male sex, replacement due to posttraumatic arthritis, an uncemented component, and use of a metal-backed glenoid component.
- Implant type and method of fixation are less important to component survival than patient and diagnostic factors.

To learn more about Mayo Clinic's ongoing orthopedic research, visit mayoresearch.mayo.edu/mayo/research/ortho/index.cfm

Mayo Clinic Orthopedic Update

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www.mayoclinic.org/medicalprofs

Education Opportunities

Mayo Clinic Orthopedic Alumni and 100th Anniversary Symposium

Sept 16-18, 2010, Rochester, MN

While learning the most advanced surgical and nonsurgical management of orthopedic injuries and conditions, Mayo orthopedic alumni also gather to honor the Mayo surgeons, clinicians, researchers, and educators who came before them.

For registration information, call 507-284-4051 or e-mail garmers.rose@mayo.edu.

20th Annual Mayo Clinic Symposium on Sports Medicine

Nov 12-13, 2010, Rochester, MN

This case-oriented program provides an integrated approach to the injured athlete. Case presentations, lectures, and video demonstrations make this course valuable to all sports medicine practitioners. Developed for health care professionals with an interest in sports medicine, the course also is valuable for athletic trainers involved with various athletic specialties and levels of participation, from entry-level fitness clients to elite competitors.

For registration information, call 800-323-2688 or e-mail cme@mayo.edu.

Minnesota Memorial Pediatric Orthopedic Trauma Course

Nov 19, 2010, Rochester, MN

Pediatric orthopedic surgeons, general orthopedic surgeons, and allied health professionals in the field of pediatric orthopedics will all benefit from this multiplatform learning experience. Through lectures, case presentations, and interactive sessions, participants will be exposed to the latest trends and treatments in the field to gain a better understanding of new techniques in the diagnosis and treatment of pediatric orthopedic disorders.

For registration information, call 800-323-2688 or e-mail cme@mayo.edu.

To view all Mayo Clinic CME offerings visit www.mayo.edu/cme/

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