1st International Thumb Osteoarthritis Workshop

October 25 - 26, 2013
Hotel Viking | Newport, Rhode Island

Hosted by:

BROWN
Alpert Medical School

STANFORD
School of Medicine
Department of Orthopaedic Surgery
We gratefully acknowledge the support of the following departments, institutions and companies that have made this meeting possible:

BROWN
Alpert Medical School

STANFORD
School of Medicine

DEPARTMENT OF ORTHOPAEDIC SURGERY

Lifespan

Funding for this conference was made possible under Award Number R13 AR065906 from the National Institute Of Arthritis And Musculoskeletal And Skin Diseases of the National Institutes of Health

The views expressed in written conference materials or publications and by speakers and moderators do not necessarily reflect the official policies of the Department of Health and Human Services nor does mention by trade names, commercial practices, or organizations imply endorsement by the US Government.

Exhibitors

3D SYSTEMS
INTEGRA
medartis®
skeletal dynamics™
SBI
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome</td>
<td>2</td>
</tr>
<tr>
<td>Meeting Information</td>
<td>4</td>
</tr>
<tr>
<td>Keynote Speakers</td>
<td>5</td>
</tr>
<tr>
<td>Workshop</td>
<td>6</td>
</tr>
<tr>
<td>Program</td>
<td>7</td>
</tr>
<tr>
<td>Abstracts</td>
<td>9</td>
</tr>
<tr>
<td>About the IYRS</td>
<td>Inside Back Cover</td>
</tr>
<tr>
<td>Program Overview</td>
<td>Back Cover</td>
</tr>
</tbody>
</table>
Welcome to the 1st International Thumb Osteoarthritis Workshop (1st ITOW) which we have the honor of hosting in historic Newport, Rhode Island.

We gratefully thank our respective departments, parent academic institutions, corporate partners, and the National Institutes of Health, whose generous support have made this meeting possible.

The purpose of the 1st ITOW is to bring together clinicians and researchers from multiple disciplines to exchange ideas and disseminate basic science and clinical research regarding the function, pathology and treatment of the CMC joint, with a focus on osteoarthritis and its specific pathophysiology.

The meeting will include 34 podium presentations covering anatomy, imaging, biomechanics, modeling, observational and interventional clinical studies, as well as two keynote presentations by world-class researchers, one of whom will discuss the epidemiology of CMC osteoarthritis, the other thumb and hand evolution.

In keeping with the workshop nature of the meeting, a key goal of the 1st ITOW will be the development of a consensus statement on the critical components of clinical studies on thumb CMC OA treatment and outcomes. The meeting will be kicked off with a session that will include a presentation on elements of study design, and a review of published studies to date, and a available clinical outcome measures. At the close of the meeting a lunch will be hosted at which working groups will identify the most important ‘next-step’ research questions using the Delphi structured decision making process.

We plan to pack a lot into a day and a half. However, the meeting will not be entirely structured. There will be ample time for the informal exchange of ideas at Thursday evening’s opening meeting reception, and at the lobster boil at the International Yacht Restoration School (IYRS) on Friday night.

We hope you have an enjoyable and productive meeting!

Sincerely,

J.J. Trey Crisco, Amy L. Ladd, Arnold-Peter C. Weiss, and Douglas C. Moore
Course Directors

J.J. Trey Crisco, PhD
Henry F. Lippitt Professor of Orthopedics
Warren Alpert Medical School of Brown University
Rhode Island Hospital
Providence, RI

Amy L. Ladd, MD
Professor of Orthopaedic Surgery
Stanford School of Medicine
Stanford Hospital & Clinics
Redwood City, CA

Arnold-Peter C. Weiss, MD
Professor of Orthopaedics
Warren Alpert Medical School of Brown University
Rhode Island Hospital
University Orthopedics, Inc.
Providence, RI

Head Meeting Program

Douglas C. Moore, MS
Senior Research Associate, Orthopaedics
Warren Alpert Medical School of Brown University
Rhode Island Hospital
Providence, RI
Meeting Information at a Glance

Conference Location
Workshops, Presentations, and Keynotes will be held in Salon C, located in the lower level of the Hotel Viking.

Registration
Thursday, October 24th
The registration desk is located in the Tea Room. Registration will be staffed from 5:00–7:00 PM.

Friday, October 25th
The registration desk is located in the Salon C Foyer. The registration desk will be staffed starting at 7:00 AM.

Opening Reception
Thursday, October 24th | 5:30–7:00 pm
Colonnade Room

Attendance is open to all meeting attendees, staff, and exhibitor representatives.

Exhibitor Booths
All exhibitor tables will be held in Salon D/E. For a list of exhibitors, please see inside the front cover.

Internet Access
Free wireless access will be available in the meeting rooms.

Podium Presentations
Speakers are allocated 8 minutes for presentation and 2 minutes for discussion. A 20 minute discussion will be held at the conclusion of each session. Speakers are strongly encouraged to upload their presentations to the conference computers. The speaker ready room (Georgian Room) is available from 5:00–7:00 PM on Thursday, 7:00 AM–5:00 PM on Friday, and 7:00–11:00 AM on Saturday.

Breakfasts
Friday and Saturday | 7:00–8:00 AM
Salon C Foyer

Breaks
All breaks will be held in Salon D/E. Please see back cover for additional details.

Lunches
Friday, October 25th | 1:00–2:00 PM
Saturday, October 26th | 12:50–1:50 PM

Lobster and Clam Bake Banquet
Friday, October 25th
6:30–7:30 PM Reception
7:30–10:00 PM Dinner
International Yacht Restoration School
Restoration Hall
449 Thames St., Newport, RI
The Epidemiology and Functional Impact of Osteoarthritis of the Thumb.

**David Felson, MD, MPH**
Multidisciplinary Clinical Research Center Grant  
Professor of Medicine & Epidemiology Associate  
Boston University School of Medicine  
Boston, MA

Dr. Felson is a Professor of Medicine and Public Health, and Principal Investigator of the NIH-funded Boston University Multipurpose Arthritis and Musculoskeletal Diseases Center and the Boston University Multidisciplinary Research Center. An expert on the epidemiology and pathophysiology of osteoarthritis, Dr. Felson has led numerous large cohort studies in osteoarthritis, with the goal of elucidating risk factors for the disease, as well as its natural history.


**Caley M. Orr, PhD**
Department of Anatomy  
Midwestern University  
Downers Grove, Illinois

The advent of bipedality in our evolutionary lineage has ‘emancipated’ the human hand from locomotor duty. Much can be learned about the origins and evolution of human locomotion and advanced manipulative capabilities and tool behaviors through the comparative study of the hand and wrist in our close extant and extinct primate relatives. Dr. Orr’s lecture will survey the current state of knowledge about human hand and wrist evolution and cover a few “case studies” drawn from the field of paleoanthropology including the anatomy of the earliest hominins (species more closely related to humans than to chimpanzees) and the enigmatic *Homo floresiensis*—the so-called “real-life hobbits” from the late Pleistocene of Flores, Indonesia.

Dr. Orr is a paleoanthropologist and functional anatomist and is an Assistant Professor in the Department of Anatomy at Midwestern University’s Chicago College of Osteopathic Medicine. His primary research interests are focused on understanding the evolutionary history of the human postcranial skeleton (especially the hands and feet) and what this tells us about the intertwined origins of our bipedal locomotion, enhanced manipulative capabilities, and tool use. Much of this work is conducted using a variety of methods in biomedical imaging and morphometrics to study the comparative anatomy of humans, other extant primates, and early fossil human ancestors.
Workshop

What Does An Ideal CMC Research Study Look Like?

Session 1
Friday, October 25, 2013
8:00–9:00 AM

Session 2
Saturday, October 26, 2013
12:00–2:00 PM

Moderators:
Amy L. Ladd, MD and Deborah Kenney, CHT, OTR

Leaders:
Amy Hoang-Kim, PhD and Miriam Marks, cand. PhD

The goal of these sessions are to create a consensus statement on the critical aspects of research specific to thumb CMC pathology. The first session will introduce the goals and review the research studies to date and develop a list of validated clinical outcome measures. In the second session, participants will be divided into working groups with the goal of identifying the most important “next-step” questions in thumb CMC research using the Delphi structured decision-making process.
Friday, October 25, 2013

7:00 - 8:00 AM  Breakfast and Visit Exhibitors
8:00 - 8:10  Opening Remarks
8:10 - 9:00  Workshop Session 1—Amy L. Ladd, MD and Deborah Kenney, CHT, OTR
9:00 - 10:00  Keynote Address—David Felson MD, MPH
10:00 - 10:30  Break and Visit Exhibitors
10:30 - 11:20  Session 1—J.J. Crisco, PhD
1. CMC Biomechanics and OA Progression: An Overview of Our Ongoing Program | J.J. Crisco
2. Radiographic Thumb Osteoarthritis Index (ThOA) Correlating to Clinical Disease Severity | A.L. Ladd
3. Quantifying Potential Biomarkers at the CMC Joint Using Dynamic Imaging | K. Zhao
5. Is Osteoarthritis of the Thumb a Strictly Orthopedic Condition? | F.J. Valero-Cuevas
11:20 - 11:40  Discussion
11:40 - 11:50  Break and Visit Exhibitors
11:50 - 12:40  Session 2—Jennifer Moriatis Wolf, MD
1. Simulated Bennett Fracture and its Relevant Ligamentous Anatomy | H.S. Gong
2. The Distribution of Mechanoreceptors in the Ligaments of the First Carpometacarpal Joint In Surgical Patients with Osteoarthritis | A.L. Ladd
3. A Statistical Shape Model of the Thumb Carpometacarpal Joint | M.T.Y. Schneider
4. The Trapeziometacarpal Joint: A Comparison Between the DRL and AOL | F. Stockmans
5. Activation of the First Dorsal Interosseous Muscle Results in Radiographic Reduction of the Thumb CMC Joint: Implications for Arthritis Intervention | S. Van Nortwick
12:40 - 1:00  Discussion
1:00 - 2:00  Lunch
2:00 - 2:50  Session 3—Arnold-Peter C. Weiss, MD
1. Thumb Basal Joint Hemiarthroplasty for Isolated Trapeziometacarpal Arthritis: A Case Series | J.J. Faillace
2. Salvage Option for Failed Trapeziumectomy and Failed Base of Thumb Arthroplasty: Personal Cases and Discussion of Techniques and Pitfalls | N. Gillham
3. Personal Results for Implants for Base of Thumb Arthroplasty | N. Gillham
4. Save the Trapezium in Thumb CMC Osteoarthritis | J.L. Orbay
5. In Vivo CMC Kinematics | E. Halilaj
2:50 - 3:10  Discussion
3:10 - 3:30  Break and Visit Exhibitors
3:30 - 4:10  Session 4—Scott W. Wolfe, MD
1. Joint Survival of Total Trapeziometacarpal Joint Arthroplasty for Painful, Degenerative Arthritis with Minimum Follow-Up of 5 years | F. Stockmans
2. ARPE Arthroplasty for CMCJ Arthritis: A Review of Cases Over 5 years in Our Unit | A. Siddiqui
3. Denervation of Thumb Basal Joint for CMC arthritis: Preliminary Results of a Prospective Study on 35 Thumbs | A. Siddiqui
4. Procedural and Clinical Outcomes Following Implantation of a New Interpositional Spacer for Treatment of Osteoarthritis of the Carpometacarpal Pometacarpal Joint of the Thumb: One-Year Results | M.J.P.F. Ritt
5. Basal Joint Arthrodesis for the Paralytic Limb: A Case Series | S.W. Wolfe
4:10 - 4:30  Discussion
4:30 - 4:50  Break and Visit Exhibitors
4:50 - 5:30  Session 5—Arnold-Peter C. Weiss, MD
1. Suture Suspension Basal Joint Arthroplasty | J.L. DelSignore
2. Partial Trapezection With Capsular Interposition (PTCI) Arthroplasty for Surgical Treatment of Thumb Carpometacarpal Osteoarthritis | M.S. Moneim
3. Trapezium Excision and Suture Suspensionplasty (TESS) for the Treatment of Thumb Carpometacarpal Arthritis | M.D. Putnam
4. Dynamic CT Scanning of Motion at the Basal Thumb Joint | E.E. Vereecke
5:30 - 5:50  Discussion
5:50 PM  Adjourn
6:30 - 10:00 PM  Banquet
Saturday, October 26, 2013

7:00 - 8:00 AM  Breakfast and Visit Exhibitors

8:00 - 8:50  Session 6—Clark T. Hung, PhD
2. Biomechanical Simulation of Surgical Treatments of Trapeziometacarpal Joint Arthritis | Z-M Li
3. Comparison of Finite Element Modeling and Surface Contact Modeling for In Vivo Thumb Carpometacarpal Joint Mechanics | Q. Zheng
4. Loading Analysis of Thumb Joints While Pipetting | J.Z. Wu
5. Dorsoradial Ligament Imbrication for Thumb Carpometacarpal Joint Instability | M.P. Rosenwasser

8:50 - 9:10  Discussion

9:10 - 10:10  Keynote Address—Caley M. Orr, PhD

10:10 - 10:40  Break and Visit Exhibitors

10:40 - 11:30  Session 7—Zong-Ming Li, PhD
2. Forward Simulation of Force Production in Lateral Pinch | S.J. Wohlman
3. Biomechanical Test of Pre-Treatment State VS. Trapezial Excision VS. Suture Suspensionplasty (TESS) VS. LRTI for Treatment of Thumb Carpometacarpal Pometacarpal Arthritis | M.D. Putnam
4. Cadaveric Study Investigating Metacarpal Subsidence in Specimens Treated with Partial Trapeziectomy/Partial Metacarpal Base Resection Versus Those Treated With Total Trapeziectomy | D. Mercer
5. Thumb Carpometacarpal Joint Motion and Bone Shape Differences by Sex | A.J. Chaudhari

11:30 - 11:50  Discussion

11:50 - 12:50 PM  Workshop Session 2—Amy L. Ladd, MD and Deborah Kenney, CHT, OTR

12:50 - 1:50  Working Lunch

1:50 PM  Adjourn
INTRODUCTION. Thumb carpometacarpal (CMC) osteoarthritis (OA) is a widespread, disabling disease of undetermined etiology that is far more prevalent in woman than in men. The disease affects 15% of adults over age 30, and two-thirds of adults over the age of 55. Loss of thumb function alone imparts a 40%-50% impairment to the upper extremity due to its central role in nearly all grasp and handling tasks. Although recent studies suggest genetics, increased BMI and environmental factors (such as hand use) are likely associated with the development of thumb CMC OA, there is strong empirical and experimental data indicating that altered biomechanics plays a central role in the disease, and, importantly in its treatment. CMC OA is far more prevalent in women than men, and women have flatter joint surfaces, smaller areas of cartilage contact, and higher contact pressures.

Our study is designed to generate foundational data on thumb CMC biomechanics in vivo by quantifying and comparing the differences in CMC biomechanics across sex and age using a cross-sectional experimental design (Aim 1), and, using a longitudinal experimental design, to determine if CMC joint laxity is positively associated with CMC OA progression 1.5 and 3 years after initial diagnosis in patients who initially present with CMC pain and minimal radiographic evidence of OA (Aim 2).

METHODS. Aim 1. Determine the in vivo biomechanics and morphometry of the CMC joint in asymptomatic young and old men and women (N = 44; 18 – 25 yrs; and 45-75 yrs.) during functional tasks using well-established methodologies. Hierarchical Linear Models (HLMs) will be used to evaluate differences as a function of age and gender, with task and loading as covariates.

Aim 2. Measure temporal changes in the in vivo biomechanics and morphometry of the CMC joint during functional tasks in women and men (N = 80; 45-75 yrs.) presenting with Early OA at baseline and 1.5 and 3 years follow-up. OA progression will be measured at follow-up primarily via radiographic classification (Eaton) and compared with the baseline CMC joint laxity measure using HLMs.

RESULTS. Our results to date include normal kinematics and shape analyses. Significant motion was identified at the CMC joint during all tasks. Sex did not have an effect on CMC joint kinematics. Motion patterns differed with age group, but these differences were not systematic across the tasks. The curvature of female joints is higher than that of male joints, this difference disappears after adjusting for size. Ageing had a strong effect on the articular shapes of both the trapezium and the metacarpal. The effect of Early OA was also evident in the trapezial surfaces.

DISCUSSION. In this presentation of preliminary findings we have documented the in vivo kinematics of the CMC joint and more fully examined CMC shape. A discussion of our overall approach to studying CMC OA will also be presented.

Acknowledgements. NIH/NIAMS AR059185

COI. No conflict of interests.
INTRODUCTION. The Eaton staging for thumb carpometacarpal (CMC) arthritis has low intra-rater and inter-rater reliability, and clinical symptoms often lack correlation to radiographic (x-ray) disease. These pose challenges for identifying treatment consensus for CMC osteoarthritis (OA). The purpose of this study was to define a reliable x-ray classification that correlates to clinically relevant disease.

METHODS. We evaluated a spectrum of thumb x-rays in 60 subjects: 20 asymptomatic, 20 with mild-advanced OA, and 20 with advanced OA requiring surgery. Standardized AP, lateral, pronated Robert’s (Roberts 1936), and stress views (Wolf 2009) were obtained and randomized for each evaluation. Two senior hand surgeons twice performed Eaton staging (Eaton 1973), and again modified Eaton staging. Stage I was redefined as minimal OA; subluxation was excluded from advanced staging criteria. We created a Thumb Osteoarthritis Index (ThOA) from the Robert’s view alone, based on width (x) and height (y) of the trapezium (Fig. 1). The 2 surgeons, a medical student, and a chief resident (4 total) classified the 60 x-rays twice. ThOA was correlated to Eaton’s and modified Eaton’s staging. The 20 excised trapezia were additionally examined for 1st metacarpal facet wear and osteophytes, then measured and photographed. Twelve cadaveric specimens with preserved saddle joint and minimal wear were similarly analyzed. ThOA was compared among all groups.

RESULTS. The Eaton and modified Eaton classification had high intra- and inter-rater correlation (Eaton ave. ICC 0.90, modified Eaton 0.92) for the 2 hand surgeons, with poorer correlation for the other raters. The ThOA of the 4 investigators highly correlated to both individual intra-rating (ICC ave. 0.95) and inter-rating (ave. 0.85, CI 0.81 < ICC < 0.89). The confidence interval (CI) ranged < 0.14 for all measurements. Both Eaton and modified Eaton correlated to ThOA in disease severity with the surgeons’ rating. ThOA of all asymptomatic subjects was < 1.5, in cadaver specimens < 2.0, and ThOA progressed exponentially with eburnation (full articular wear) > 50% in surgical specimens (Pearson’s correlation = 0.85). ThOA, eburnation, osteophytes, and distal surface area were lower in saddle specimens (6) compared to concave or biconcave articular specimens (14).

DISCUSSION. ThOA using a Robert’s view alone provides a simple, reproducible, and clinically relevant means of quantifying the severity of thumb CMC osteoarthritis. The index offers a tool for more ready diagnosis and treatment options for thumb CMC arthritis.

Acknowledgements. Funding sources include Williams Charitable Foundation (ALL) and NIH/NIAMS 1R01AR059185 - 01A1 (ALL and APCW). We gratefully acknowledge the assistance of statistician Alex Sox-Harris.

References. Listed within.

COI. Research funding listed above.
Quantifying Potential Biomarkers at the CMC Joint Using Dynamic Imaging

K. Zhao¹, A. Goto¹, S. Leng², K. Sugamoto³, W.P. Cooney III¹, S. Kakar¹, K.N. An¹
¹) Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic, Rochester, MN, USA
²) Department of Radiology, Mayo Clinic, Rochester, MN, USA
³) Department of Orthopedic Biomatieral Science, Osaka University, Osaka, Japan

INTRODUCTION. Recent imaging advances allow noninvasive, high-resolution dynamic imaging of the CMC joint during motion. Using 4DCT (3D CT + time) and image processing techniques, it is possible to quantify potential predictive biomarkers, including arthrokinematics, estimated joint contact patterns, and ligament lengths which may have utility in identifying regions of the CMC workspace which present increased risk of promoting joint instability and the eventual cascade to osteoarthritis.

METHODS. 4DCT scans were obtained using a nongated sequential scanning technique. Eighteen image volumes were reconstructed over a 2-second cycle during thumb circumduction and while pipetting with a manual pipette in one healthy volunteer. Using image registration techniques, estimated joint contact areas and ligament lengths were quantified.

RESULTS. During circumduction, the maximum estimated contact area on the trapezium and the metacarpal was in palmar abduction; the minimum was in adduction. Central-volar contact patterns were observed on the trapezium and metacarpal except in adduction (Fig. 1A). Both sides of the anterior oblique ligament (AOL) were slack during the pipetting task (plunging and ejecting). In contrast, all the components of the dorsoradial ligament (DRL) were taut, except for the ulnar portion of the DRL (Fig. 1B).

DISCUSSION. Dynamic imaging metrics (i.e., biomarkers) such as estimated contact patterns and ligament lengths may provide useful information for assessing increased risk for joint instability and eventual arthritis during functional tasks such as circumduction and pipetting.

Acknowledgements. This project was supported by the Mayo Foundation.

COI. No conflict of interests.
Measuring Trapeziometacarpal Mobility Using Stress Radiography and Its Association with Generalized Hypermobility

J.M. Wolf, S. Schreier, S. Tomsick, A.E. Williams, B. Petersen
1) Department of Orthopaedic Surgery, University of Connecticut Health Center, Farmington, CT, USA
2) Departments of Orthopaedic Surgery and Radiology, University of Colorado Denver, Aurora, CO, USA
3) Nursing Service/Research, Bay Pines Veterans Administration Medical Center, St. Petersburg, FL, USA

INTRODUCTION. Increased or abnormal mobility of the trapeziometacarpal (TM) joint is difficult to measure objectively and it is not known whether generalized joint laxity has any effect on TM laxity. We have standardized the stress view radiograph to measure TM mobility using a reproducible technique. We present our evaluation the correlation between generalized joint mobility and increased TM laxity, using the stress view radiograph as an objective measure at the thumb basilar joint in a large group of volunteers.

METHODS. We recruited volunteer subjects of all ages and examined them for generalized laxity using the Beighton-Horan index. A total of 163 subjects, 81 men and 82 women, with an average age of 48 years (range, 20–83 y), were examined. We created a standard hand positioner and modified previously described techniques (1,2) to perform a stress view radiograph, and evaluated measures of radiographic laxity using inter- and intra-observer variability. Each of 163 subjects underwent a stress view radiograph of both TM joints. Different examiners independently measured radial subluxation of the thumb metacarpal over the trapezium and the articular width of the thumb metacarpal and averaged them. The ratio of the radial subluxation to the articular width was calculated as a measure of radiographic TM laxity.

RESULTS. In describing the TM stress view, a total of 69 volunteers (39 women and 30 men) were imaged. Women showed significantly greater radial subluxation compared to men (p < .01). Inter-rater reliability coefficients for radial subluxation and articular width initially and at 2 weeks showed high agreement, as did test-retest reliability coefficients. The average Beighton score was 2 (range, 0–9). A total of 40 subjects had Beighton scores greater than 4. In the total cohort of 163 subjects, the mean stress view ratio was 0.31 (range, 0.06–0.58). For the total sample (n = 163), younger age was correlated with an increased Beighton score (r = −0.256, p = .001) and a higher stress view ratio (r = −0.576, p < .001). Higher generalized laxity on the Beighton measure was significantly correlated with an increased stress view ratio (r = 0.308, p < .001).

DISCUSSION. The TM stress view shows high inter- and intra-observer reliability of radial subluxation and first metacarpal width. The ratio of the 2 measurements provides an accurate measure of the radiographic subluxation of the first metacarpal from the trapezium. This measurement is most specific to radial subluxation under simulated active loading, in the plane of the hand. We showed that greater generalized laxity was significantly correlated with a higher radiographic stress view ratio (p < .001), indicating that laxity was related to a greater amount of uncovered trapezium during stress of the TM joint. These findings suggest that young women with generalized joint hypermobility have greater laxity of the TM joint. The clinical implications of this increased laxity are not known, but TM joint hypermobility may represent a risk factor for the later development of TM osteoarthritis.

Acknowledgements. OREF, American Foundation for Surgery of the Hand.


COI. Elsevier - updates editor, Skeletal Trauma; deputy editor, Journal of Hand Surgery.
Is Osteoarthritis of the Thumb a Strictly Orthopedic Condition?

I. Fassola*, E.L. Lawrence*, S. Dayanidhi, N. Ko, C. Leclercq, F. J. Valero-Cuevas
1) Institut de la Main, Clinique Jouvenet, Paris, France
2) Department of Biomedical Engineering, University of Southern California, Los Angeles, CA, USA
3) Division of Biokinesiology & Physical Therapy, University of Southern California, Los Angeles, CA, USA
*denotes equal contribution

INTRODUCTION. Osteoarthritis (OA) of the carpometacarpal (CMC) is an orthopedic condition that can lead to difficulties gripping objects and limited range of motion, both of which affect activities of daily living (ADLs) including writing, feeding, and dressing [1]. Parkinson’s disease (PD) is a progressive degenerative neurological disorder, characterized by numerous motor features that also impact ADLs [2]. The purpose of this study was to compare deficits in dynamic dexterous manipulation between these conditions.

METHODS. We measured performance in the Strength-Dexterity (SD) test—a validated instrument for quantifying dynamic dexterous manipulation with pinch forces < 300 grams force [3]—in 33 female patients diagnosed with CMC OA (65.81 ± 9.7 yrs., 42 hands) an average of 40 months post-treatment, 14 patients diagnosed with PD (10M, 4F; 67.6 ± 9.6 years, 27 hands), and a non-clinical control group of 29 healthy, age-matched volunteers (10M, 19F; 65.6 ± 9.7 years, 48 hands) with no history of hand injury or disease or neurological disorder. The SD test consists of compressing a slender spring prone to buckling between thumb and index, where the maximal compression (in gmf) is indicative of the maximal manipulation instabilities the subject can sustain.

RESULTS. We report no significant differences in maximal mean compression force among groups. However, both the CMC OA (p<0.000001) and PD (p=0.019) groups displayed significant differences in the dynamic force variability while maintaining the maximal spring compression (1st and 2nd derivatives of forces and RMSE) compared to the control participants. This indicates significantly reduced stability of manipulation. Furthermore, linear regression shows that individuals with CMC OA (p=0.013) and PD (p=0.026) showed greater rates of decline of maximal spring compression vs. age than control subjects (-1.3 gmf/yr and -1.7 gmf/yr vs. -0.96 gmf/yr, respectively).

DISCUSSION. Both CMC OA (an orthopedic condition) and PD (a neurological condition) are associated with significantly worse neuromuscular control of dynamic manipulation and accelerated losses with age when compared to non-clinical volunteers. These results challenge the notion that CMC OA is a strictly orthopedic condition given that it seems to also produce sensorimotor deficits. We underscore the need to investigate and understand these little known or studied effects of CMC OA on the neuromuscular control of dynamic manipulation at low force levels—which is so critical to ADLs.

Acknowledgements. We thank Veronique Lothon and Alexander Reyes. Funding: NIDRR grant H133E080024; NSF grant EFRI-COPN 0836042 and NIH grants AR050520 and AR052345 to FVC. FVC holds US Patent No. 6,537,075 on some of the technology used, but has no licensing in place.

Simulated Bennett Fracture and Its Relevant Ligamentous Anatomy

J. Messana¹, A. Behn¹, D. Master¹, H.S. Gong¹,², A.L. Ladd¹
1) Department of Orthopaedic Surgery, Stanford University Medical Center, Palo Alto, CA, USA
2) Department of Orthopaedic Surgery, Seoul National University College of Medicine, Seoul, South Korea

INTRODUCTION. The metacarpal shaft displaces from the basilar thumb “Bennett” fracture, an oblique palmar beak intra-articular fragment described as attached to the anterior oblique ligament (AOL). The purpose of this study is to simulate a Bennett fracture in cadaveric wrists and to examine ligamentous structures relevant to this fracture pattern.

METHODS. We tested 4 fresh-frozen cadaveric wrists with preserved radiographic anatomy and minimal thumb carpometacarpal joint osteoarthritis. The radius, ulna, and distal half of the first metacarpal were potted in cement, and the second and third metacarpals were stabilized with two 4 mm threaded rods. The specimens were positioned in 30 degrees wrist extension and maximum ulnar deviation to align the long axis of the first metacarpal with the loading axis of the materials testing system (Figure 1). The flexor carpi radialis and the abductor pollicis longus were counterbalanced with a load of 5N. Testing consisted of ten preconditioning cycles from 10N to 30N compressive load at 0.5 Hz followed by compressive loading at a rate of 0.45 m/s to failure. After confirming the fracture by x-ray, we dissected the thumb carpometacarpal joint to identify ligament and fracture anatomy, and to determine the best joint position to reduce the fracture.

RESULTS. The fracture occurred in all cadaveric wrists, with the palmar beak fragment occupying 25-40% of the articular surface (Figure 2). Two displaced and two non-displaced fractures were created. In all fractures the AOL was partially attached to the fragment and the metacarpal volar beak, with the thicker ulnar collateral ligament (UCL) entirely attached to this fragment (Figure 3). For the two displaced fractures, both radial abduction and pronation of the metacarpal reduced the fracture and tensioned the ulnar collateral ligament. Extension tensioned the AOL, but neither extension nor flexion of the metacarpal reduced the fracture.

DISCUSSION. The Bennett fracture can be reliably created in cadaveric wrists. The UCL is the primary ligamentous structure attached to the fracture fragment and tensions the fracture with reduction in abduction and pronation. The tensioned AOL did not reduce the fracture. This suggests the AOL does not have a stabilizing role in the Bennett fragment or fracture reduction, which supports recent cadaveric evidence that the AOL is thin, variable in its location, and is primarily a capsular structure. This model may be useful for future in-vitro studies for the optimal treatment of the Bennett fracture.

COI. No conflicts of interests.
INTRODUCTION. Intact ligament innervation is essential for joint stability and proprioceptive mechanisms to function properly. In this study we have examined the innervation and distribution of mechanoreceptors in the two principal ligaments of the first carpometacarpal joint (CMC1), the AOL (anterior oblique ligament) and DRL (dorsal radial ligament) in surgical patients with osteoarthritis (OA). We hypothesize that the innervation patterns of these subjects differ from cases without signs of OA.

METHODS. Two ligaments were harvested from the hands of 11 subjects undergoing trapeziectomy with ligament stabilization. Subjects included 10 females and 1 male, 6 right and 5 left hands (mean age 67 years, age range 51-83). The ligaments were divided into their proximal and distal portions (yielding 42 samples total; 2 ligaments were too small to divide) sectioned in paraffin and analyzed using immunofluorescent triple staining microscopy. The results were analyzed using student’s paired t-test, standard linear regression analysis as well as the Pearson correlation coefficient.

RESULTS. Similar to non-OA studies, we found sensory nerve endings predominating in the DRL as compared to the AOL, which was statistically significant (t[10] = 4.903, p = 0.001, a= 0.05; 95% confidence interval, 1.513–4.033). We encountered predominantly unclassifiable nerve endings compared to anticipated nerve endings in the OA subjects, with 74% unclassifiable corpuscles, 14% free nerve endings and 12% Ruffini Endings. While unclassifiable corpuscles were the most abundant mechanoreceptors, found in 11/11 (100%) DRLs and 7/11 (63.6%) AOLs, no significant difference existed between ligament type and location of this sensory receptor type. Similarly, no significant difference existed between ligament type and location of free nerve endings. While significantly more Ruffinis were found in the distal DRL than proximal AOL (p= .039), only one Pacini Corpuscle was found in the distal DRL of one patient.

DISCUSSION. Unclassifiable corpuscles were the most prevalent type of mechanoreceptor found in both DRL and AOLs. There was no difference in the distribution of mechanoreceptors in the proximal or distal portion of the ligaments. The distribution and prevalence of mechanoreceptors in cases with CMC1 OA differs from cases without OA. These findings imply that there may be an alteration of the mechanoreceptor population and distribution due to OA. This provides preliminary evidence to suggest a relationship between inflammation and mechanoreceptor changes in sensory nerve endings, warranting further investigation.

Acknowledgements. This study was supported by the Williams Charitable Foundation, and the Hirsch Foundation (Karolinska Institutet). The funding supported the cost of specimens, supplies, and salaries/stipends.

COI. Research funding listed above.
A Statistical Shape Model of the Thumb Carpometacarpal Joint

M.T.Y. Schneider¹, J.J. Crisco², A-PC Weiss², A.L. Ladd³, P. Nielsen¹, ⁴, T. Besier¹, ⁴, J. Zhang¹

1) Auckland Bioengineering Institute, The University of Auckland, Auckland, New Zealand
2) Department of Orthopaedics, Brown University, RI, USA
3) Department of Orthopaedic Surgery, Stanford, Stanford University, CA, USA
4) Department of Engineering Science, The University of Auckland, Auckland, New Zealand

INTRODUCTION. The first carpometacarpal (CMC) joint performs a range of dexterous movements, all of which are influenced by the morphology and articulation between the first metacarpal and trapezium bones. However, the CMC joint is highly susceptible to osteoarthritis, which is more prevalent with age and 5-7 times more prevalent in women than in men. Here we present a statistical shape model of the CMC joint to investigate age and sex differences in CMC joint morphology.

METHODS. A training set of 50 CMC joints were manually segmented from CT images of the hand with a resolution of 0.4x0.4x0.625mm (age range: 18 yrs to 67 yrs; 24 females and 26 males). A template mesh consisting of parametric surface elements was created for a single segmentation and then fitted to the entire training set (n=50), resulting in a set of correspondent meshes of the metacarpal and trapezium. Principal Component Analysis was performed on these meshes to determine significant modes of shape variation. We then performed linear regression and one-way ANOVA on the mode scores of the meshes against age and sex.

RESULTS. Over 95% of CMC joint morphological variation was described to an accuracy of ~0.2 mm RMS by the first seven modes of the shape model. None of the modes showed significant correlation with age. However, there was a very strong correlation between sex and the 1st mode, which described the size of the CMC joint (Figure 1, p <0.001). The male CMC joints tended to have negative coefficients for the 1st mode, indicating larger size, compared to the females, who had positive coefficients (Figure 2).

DISCUSSION. We have developed a statistical shape model, which accurately described the morphology of the CMC joint. Age did not appear to influence the shape of the CMC joint, nor did sex, with the exception of the first mode, which accounted for overall size of the joint. We will use this shape model to develop an active shape model to automatically segment clinical CT images, which will enable us to investigate a larger cohort and support these findings. Although we did not see much variation in shape between male and female CMC joints, size alone might explain the increased incidence of CMC osteoarthritis, given that a smaller CMC joint will also have a smaller contact area and experience greater cartilage stress for a given force. Further work to investigate the articulating surface and corresponding joint mechanics is required.

Acknowledgements. We would like to thank the Auckland Bioengineering Institute, Stanford Orthopaedics, and the NIH for funding.

COI. No conflicts of interests.
The Trapeziometacarpal Joint: A Comparison Between the DRL and AOL

F. Stockmans1,4, P. D’Agostino1,2, F. Kerkhof1, M. Shahbpour3, M. Jean-Pierre5,6, V. Evie1
1) Anatomy, Biomedical Sciences Kulak, KU Leuven
2) Clinique de la Main, Louise Medical Center, Brussels
3) Department of Radiology, UZ Brussel, Brussels
4) AZ Groeninge, Kortrijk
5) Centre de Chirurgie de la Main, Clinique du Parc Léopold, Brussels
6) HUDERF, ULB

INTRODUCTION. The dorsoradial ligament (DRL) and anterior oblique ligament (AOL) have been proposed to play an important role in stabilizing the trapeziometacarpal joint (TMCJ). The primary objective of our study was to provide comparative anatomical and mechanical data on these ligaments in attempt to understand the relative importance of both ligaments in stabilizing the TMCJ.

METHODS. A training set of 50 CMC joints were manually segmented from CT images of the hand with a resolution of 0.4x0.4x0.625mm (age range: 18 yrs to 67 yrs; 24 females and 26 males). A template mesh consisting of parametric surface elements was created for a single segmentation and then fitted to the entire training set (n=50), resulting in a set of correspondent meshes of the metacarpal and trapezium. Principal Component Analysis was performed on these meshes to determine significant modes of shape variation. We then performed linear regression and one-way ANOVA on the mode scores of the meshes against age and sex.

RESULTS. Over 95% of CMC joint morphological variation was described to an accuracy of ~0.2 mm RMS by the first seven modes of the shape model. None of the modes showed significant correlation with age. However, there was a very strong correlation between sex and the 1st mode, which described the size of the CMC joint (Figure 1, p <0.001). The male CMC joints tended to have negative coefficients for the 1st mode, indicating larger size, compared to the females, who had positive coefficients (Figure 2).

DISCUSSION. Our results show that the DRL is significantly shorter and thicker than the AOL, which is thin and ill-defined. Our results also indicate that the DRL has a higher stiffness than the AOL, making it a more likely candidate to provide joint stability. These results suggest that the DRL can play an at least equal role to the AOL in stabilizing the TMCJ since it has the mechanical potential to withstand higher loads than the AOL. Hence the concept of the AOL as prime stabilizer of the TMCJ should be reconsidered.

COI. No conflicts of interests.
Activation of the First Dorsal Interosseous Muscle Results in Radiographic Reduction of the Thumb CMC Joint: Implications for Arthritis Intervention

J. Adams, MD, S. Van Nortwick, MD, C. McGee, OTR/L, CHT, Virginia O’Brien, OTD, OTR/L, CHT, Ann Van Heest, MD
1) Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, MN 2) Department of Occupational Therapy, University of Minnesota, Minneapolis, MN

INTRODUCTION. Hypermobility of the carpometacarpal (CMC) joint is a major etiological factor in the development of thumb arthritis. Stabilization of the CMC joint with reduction of joint subluxation theoretically reduces the risk of arthritis. The hypothesis of this study is that activation of the first dorsal interosseous (FDI) muscle will reduce CMC subluxation of the metacarpal as measured by fluoroscopy.

METHODS. Subjects at least 18 years old were recruited. Exclusion criteria included a history of hand arthritis, positive grind test, pregnancy, and major conditions of ligamentous laxity. A certified hand therapist performed a grind test, measured grip and pinch strength, and maximal voluntary contraction of the FDI using the Rotterdam Intrinsic Hand Myometer. Fluoroscopy was used to obtain true AP radiographs of the CMC joint at 1) rest, 2) while stressed without activation of the FDI and 3) while stressed with activation of the FDI. Radial subluxation of the first metacarpal and metacarpal width were measured by 3 blinded surgeons as described by Wolf (2011).

RESULTS. Seventeen subjects with 34 thumbs (5 male and 12 female) participated. Average age was 25.9(21-59). Thirteen right handed, one left handed, and 3 ambidextrous subjects were included. Two thumbs were excluded for a positive grind. Thirty-two thumbs were evaluated. Average maximal voluntary contraction of the FDI was 27N, lateral pinch 81N, and grip strength 347N.

Twenty-seven thumbs demonstrated subluxation when stressed with reduction after activation of the FDI. Three thumbs were not subluxed at rest and did not sublux with stress or reduce with firing of the FDI, consistent with stiff CMC joints. Two thumbs were subluxed at rest but did not further sublux with stress. Inter-rater reliability of this categorization was high(ICC>.74).

In the 27 thumbs that demonstrated increased subluxation with stress, subluxation while stressed averaged 0.6 cm(0.0-0.9) or 48%(29-75) of articular width. FDI activation reduced subluxation by an average of 0.5 cm(0.1-0.9) or 80%(20-120). The two thumbs with the same degree of subluxation at rest and with stress had subluxation of 0.5 cm and 0.7 cm corresponding to 43% and 63% of articular width, respectively. Reduction with FDI activation was by 0.3 cm and 0.2 cm or 67% and 28%, respectively. When the CMC joint was stressed and FDI activated, maximum FDI strength explained 32.3% of the variability in subluxation.

DISCUSSION. The FDI radiographically reduces subluxation of the thumb CMC joint. Strengthening the FDI may be an effective intervention in preventing arthritis.


COI. No conflicts of interests.
Thumb Basal Joint Hemiarthroplasty for Isolated Trapeziometacarpal Arthritis: A Case Series

J.J. Faillace
Waco Hand, Elbow & Wrist, Waco, TX, USA

INTRODUCTION. Trapeziometacarpal osteoarthritis (Thumb CMC OA) is a common condition affecting both genders and is likely increasing in prevalence as the “Baby Boomers” age. Numerous different procedures have been performed including several different types of implants. Problems associated with earlier implants have been addressed in the design of a newer, modular hemiarthroplasty. A single surgeon case series is reported.

METHODS. From October 2007 to March 2013, 72 thumb CMC hemiarthroplasties were performed in 65 patients by a single surgeon in several facilities. The mean age was 60 (Range 41 to 79,) 72% were women. Minimum follow up was 3 months. Follow up evaluations included clinical examination and periodic radiographs, grip and pinch testing and two validated patient questionnaires (QuickDash, Michigan.)

RESULTS. At latest follow up, pain in 65 thumbs was absent or improved, function improved in 66 thumbs. Implant survivorship is 92%.

DISCUSSION. In general, implant arthroplasty is widely accepted in the treatment of arthritis and is available for the thumb CMC joint as well. This implant is well tolerated, has improved function and yields pleasing cosmetic results. There were no dislocations with the improved design. Patient satisfaction was high overall. There were a few revisions due to metal allergy.

Acknowledgements. The author would like to thank Donna Faillace for her work in collecting patient data and contacting patients for follow up.

COI. The author receives royalties for a different implant made by the same company which manufactures the thumb implant in this study and is also a paid consultant.
Salvage Options For Failed Trapeziumectomy and Failed Base of Thumb Arthroplasty:
Personal Cases and Discussion of Techniques and Pitfalls

N. Gillham, MA FRCS Ed Orth,
Oxford University Hospitals, Horton Hospital, Banbury. UK

Introduction. A personal series of implant arthroplasty for failed trapeziumectomy and failed implant arthroplasty is presented. A variety of prostheses and techniques and the treatment rationale is presented.

Case examples:
Failed trapeziumectomy with metacarpal trapezial impaction; salvaged with a Pi2 pyrocarbon spacer.

Failed trapeziumectomy with Dacron interposition and MCPJ hyper extension; salvaged with Pi2 interposition and MCPJ release and temporary stabilisation.

Failed trapeziumectomy; salvaged with long stem ball and socket prosthesis with cup in scaphoid.

Loose Elektra ball and socket prosthesis; salvaged with CMI pyrocarbon hemi-arthroplasty.

Loose MAIA ball and socket prosthesis; salvaged with trapeziumectomy and Pi2 pyrocarbon interposition arthroplasty.

The options and decision making process and surgical techniques and results are discussed.
Introduction. A personal series of implant arthroplasty for base of thumb arthritis is presented. A variety of prostheses have been used for a variety of conditions. Case examples and a diagnostic and treatment algorithm are presented.

Results.

21 patients with the MAIA ball and socket replacement for isolated MCTrap OA were reviewed. Full recovery was achieved by six weeks in all cases. Complications were recorded with two dislocations managed with a closed reduction. One patient required revision for cup loosening.

11 cases of CMI pyrocarbon hemiarthroplasty for isolated MCTrap OA were reviewed. All had returned to full function by six week, a third took three months to achieve a pain free thumb. One patient developed a CRPS which resolved with physiotherapy. One patient required revision for instability.

18 cases of STPi pyrocarbon interposition arthroplasty for STT OA were reviewed. 50% of these patients did have involvement of other joint in the operated hand. 50% of the patients recovered in six weeks and all within three months. Two patients required additional bone resection and in one patient the implant was removed for instability.

21 cases of Pi2 pyrocarbon trapezial replacement were reviewed. This is a much more mixed series with all patients having significant additional pathology in the hand and some with previous procedures. The majority returned to full function in six weeks from surgery and all were satisfied with the procedure. Two patients developed instability after trauma, one requiring re-operation.
INTRODUCTION. Motion preserving reconstructive procedures commonly used for osteoarthritis of the trapezio-metacarpal joint involve excision of the trapezium and invariably result in a weak pinch. We present our clinical results with two new motion preserving procedures that do not require excision of the trapezium.

METHODS. We performed a retrospective review of all the cases treated between November 1st 2011 and June 31st 2012 with these procedures. The indications were severe pain due to trapezio-metacarpal arthritis that did not respond to conservative treatment. Through a Wagner approach, a constant palmar trapezial osteophyte was removed (trapezioplasty), which allowed reduction of the joint subluxation. The underlying instability was corrected either with a 1st MC osteotomy or a hemiarthroplasty with a stabilized saddle surface. Temporary pinning of the TM joint and splinting for four weeks was used in the case of osteotomy and splinting alone for four weeks for the hemiarthroplasty. Useful thumb function was allowed after four weeks and pin removal and no further support was provided. During the last follow-up visit results were evaluated by assessing pain, ROM and pinch strength.

RESULTS. Twenty-two osteotomy and thirteen hemiarthroplasty patients were followed for an average of 8 months (range: 6-13 months). There were 6 males and 28 females and one patient was lost to follow up. At final follow-up all patients were satisfied with their degree of pain relief; eighteen patients reported no pain, fourteen mild and two moderate pain. All patients could reach the flexion crease at the base of the small finger, adduct their thumb to the 2nd metacarpal, flatten their hand and oppose their thumb to the pulp of their extended index finger. Pinch strength averaged 12lbs. The twelve employed patients were able to return to work in an average period of six weeks. Complications were four neuropathies of a branch of the radial sensory nerve. There were no non-unions, loss of correction or subluxation.

DISCUSSION. Trapezial preserving procedures provide satisfactory pain relief, useful motion at the TM joint and a strong pinch. They are technically involved and attention to surgical detail is important.

COI. Skeletal Dynamics, LLC
In Vivo Kinematics of the Thumb Carpometacarpal Joint During Three Isometric Functional Tasks

E. Halilaj¹, M.J. Rainbow², C. Got¹, J.B. Schwartz¹, J.C. Tarrant¹, D.C. Moore¹, A-PC. Weiss¹, A.L. Ladd³, J.J. Crisco¹
1) Department of Orthopaedics, The Warren Alpert Medical School of Brown University and Rhode Island Hospital, Providence, RI USA
2) Department of Physical Medicine and Rehabilitation, Harvard Medical School, Cambridge, MA
3) Robert A. Chase Hand & Upper Limb Center, Department of Orthopaedic Surgery, Stanford University School of Medicine, Stanford, CA, USA

INTRODUCTION. Carpometacarpal (CMC) joint osteoarthritis (OA) is a mechanically mediated disease, however its kinematics is not thoroughly understood due to paucity of in vivo data. Improved understanding of the normal function of the CMC joint should provide insight into the effect of mechanics on the pathogenesis of CMC OA and, ultimately, influence its diagnosis and treatment. The aim of this study was to document normal, in vivo CMC joint kinematics during three isometric functional tasks. We hypothesized that there would be motion of the CMC joint during these tasks and that this motion would differ with sex and age group. We also sought to determine if the rotations at the CMC joint were coupled and if the trapezium moved with respect to the third metacarpal.

METHODS. 46 asymptomatic subjects were CT-scanned in a neutral braced position and during three functional tasks (key pinch, jar grasp, and jar twist), in an unloaded and a loaded position. The wrist, hand, and forearm bones were segmented from the neutral CT volumes using Mimics® v.13.1 (Materialise, Leuven, Belgium) and exported as meshed surfaces. Bone kinematics from the neutral position to each of the other positions were then computed with a markerless registration algorithm [1]. Using a previously reported joint coordinate system [2], rotations and translations of the metacarpal with respect to the trapezium from an unloaded to a loaded position and from the neutral position to the unloaded position of each task were computed. Rigidity of the trapezium with respect to the third metacarpal was examined by computing their relative posture in each position.

RESULTS. Significant motion was identified in the CMC joint with loading, during all the tasks, but on average these motions were small (< 10º and < 5mm in each direction). Sex did not have an effect on CMC joint kinematics, but age did. Rotation at the CMC joint was generally coupled: flexion/extension was coupled with adduction/abduction. Changes in the posture of the trapezium with respect to the third metacarpal during the tasks were small in magnitude (< 5º in each direction), but statistically significant.

DISCUSSION. The healthy CMC joint is relatively stable during key pinch, jar grasp, and jar twist tasks, despite gender and age group. Our findings indicate that directionally coupled motion patterns in the CMC joint, which lead to a specific loading profile, are similar in men and women. These patterns, in addition to other, non-kinematic, influences, especially in the female population, may contribute to the pathomechanics of the osteoarthritic joint. Our finding that motion of the trapezium with respect to the third metacarpal changes with thumb motion suggests that assumptions of trapezium-third metacarpal rigidity may be appropriate when answering questions regarding larger operational motion patterns at the thumb, rather than interactions at the CMC joint level, for which CT-based methods seem necessary.

Acknowledgements. The project described was supported by Grant Number AR059185 from NIAMS/NIH and the American Foundation for Surgery of the Hand (AFSH). We thank Arlene Garcia, BA, Jason T Machan, PhD, and Bethany J Wilcox, BS, for their help.


COI. No conflict of interests.
Joint Survival of Total Trapeziometacarpal Joint Arthroplasty for Painful, Degenerative Arthritis With Minimum Follow-Up of 5 Years

F. Stockmans1, J. Barth2, J. Van Haecke1, M. Dizillie1
1) Consultant Handsurgery AZ Groeninge, Kortrijk, Belgium
2) Resident Orthopedics and Traumatology AZ Groeninge, Kortrijk, Belgium

INTRODUCTION. The purpose of this study was to review our outcome in the treatment of trapezio-metacarpal osteoarthritis with a total joint replacement (ARPE-Biomet) in patients with a minimum follow up of 5 years.

METHODS. 81 consecutive ARPE-prosthesis for osteoarthritis of the thumb carpometacarpal joint were prospectively followed and reviewed for the study. All patients were operated on by a single surgeon. Radiological evaluation was performed with bilateral standard AP en lateral X-rays, as well as a Robert's view. X-rays were compared to preoperative radiological studies if available. We screened for stem or cup loosening, subsidence of the stem and whether or not patients developed ipsilateral STT-arthrosis. Clinical assessment consisted of VAS for pain, VAS for subjective satisfaction and Quick-Dash questionnaire. Strength was quantified using a hand dynamometer and a pinch gauge to measure the lateral pinch.

RESULTS. Seventy prosthesis were implanted in women, 11 in male patients. Forty-six cases were performed on the left side, 35 on the right side. Five patients had bilateral procedures. Mean age at surgery was 57 years with a mean follow-up of 74,5 months (range: 60-105) Five patients were lost to follow up, 12 patients could not come to the hospital for X-ray and clinical examination. For these patients a questionnaire was taken by phone. The remaining 64 patients were reviewed clinically and radiologically by one of the authors (JB). Survivalship analysis according to Kaplan Meiers showed 4 failures (failure defined as any reason for arthroplasty revision) which means a survivalship of 94,91 % at 5 years. Two dislocated prostheses were revised to a retentive cup and evolved uneventfully afterwards. In 2 cases with symptomatic STT-arthrosis a trapeziectomy was performed. Radiological evaluation at the final follow-up did not show any signs of stem subsidence. Stem loosening was detected in 1 case, loosening of the cup in 2 cases. Six patients developed ipsilateral STT-arthrosis of whom 2 were operated. After a mean follow-up of 74,5 months patients reported a mean VAS pain: 0 (range 0 – 9) , a mean VAS satisfaction: 10 (range 4 -10) and a mean Quick-Dash-score: 4,55 (range 0 – 86,36). Range of motion evaluation showed a mean Postop Kapadji-score of 10 (range 8-10),a mean postoperatively JAMAR-score: 26 kg vs 26 kg on the contralateral side and a mean postop K-pinchn: 4 kg ipsilateral vs 3,5 kg contralateral.

DISCUSSION. We believe that our data demonstrate that total joint arthroplasty is a reliable alternative to trapeziectomy with good joint survival, high patient satisfaction and an acceptable complication rate.

COI. No conflict of interests.
ARPE Arthroplasty for CMCJ Arthritis: A Review of Cases Over 5 years in Our Unit

A. Siddiqui¹, L. Onwordi², G.J. Packer²
1) St. Andrew’s Centre for Plastic Surgery, Chelmsford, Essex, UK
2) Southend University Hospital, Southend-on-sea, Essex, UK

INTRODUCTION. Osteoarthritis of the thumb basal joint (CMCJ) is the most common presentation for degenerative joint disease of the hand. CMCJ arthritis of thumb has been treated surgically using a variety of techniques and more recently prosthetic arthroplasty for isolated CMCJ arthritis has been introduced as an ideal surgical solution. Therefore, we reviewed our surgical outcomes following 241 ARPE prosthetic arthroplasty procedures over five years (2007 - 2011).

METHODS. We used a cement-less total prosthetic arthroplasty using ARPE prosthesis in our series. A retrospective study of case notes with details of demographics, operations, complications and further surgery has been recorded. Indications for surgery after failure of conservative treatment were severe pain, loss of pinch strength, and diminished thumb motion. The outcome measure has been done using DASH questionnaire. The follow-up period ranges from 18 months to 66 months.

RESULTS. In our series patients had APRE prosthetic arthroplasty and 92% patients went on to have pain free hand function. There was a 6.2% (n=15) dislocation rate. 1.2 % (n=3) patients needed revision surgery (periprosthetic fracture, exchange of head for stiffness and excision of osteophytes at metacarpal base for continued pain). 1.6%(n=4) patients presented with post-operative periprosthetic fractures of which 3 were managed conservatively. 1 patient developed CRPS and 1.6 % (n=4) had hypertrophic scars. There was an infection rate of 2.9% (n=6) all managed conservatively with antibiotics. Mean DASH score was 23.4.

DISCUSSION. In our series, ARPE total joint arthroplasty of the thumb CMC joint has proven to be an effective treatment with good range of motion, strength and a high degree of pain relief. In our series of 241 prosthetic arthroplasty procedures for CMCJ arthritis to date, we report a low complication rate and a low revision rate.

Acknowledgements. No external funding


COI. No conflict of interests.
INTRODUCTION. Denervation of the CMC joint of the thumb is an attractive alternative for the treatment of CMC arthritis. Only one previous series has been published. We present the preliminary results at 6 months of a prospective study on 35 thumbs in 34 patients.

METHODS. From August 2012 to February 2013, 62 patients with clinical and radiological diagnosis of Thumb Carpo-Metacarpal (CMC) arthritis were seen at our Hospital. After presenting to the patients the different possibilities of treatment, 34 patients decided to undergo CMC Denervation using the technique described by de Lorea.

There were 32 women and 2 men. For a total of 35 hands, 20 patients were operated to the dominant hand. There were other pathologies to the same hand associated with CMC Arthritis in 16 cases. All patients x-rays were staged for CMC arthritis before surgery. All the patients underwent a prospective assessment protocol before surgery and after 2, 6, 12 weeks and at 6 months. The assessment included the following: VAS for pain at rest, on light duties and on heavy duties. Kapandji score for thumb opposition. Hand grip strength measurement with Jamar dynamometer (position 2) and K-pinch strength with K-pinch dynamometer.

RESULTS. At 6 months pain at rest and on light duties was resolved (VAS<2) in 91.4% of the patients. In the rest of the patient the pain improved by a mean of 2 points at rest and 3.3 points on light duties with the value never being higher than 4. Pain on heavy duties was resolved in 78% of the patients. In all patients but one with residual pain on heavy duties the pain being in all cases but one with intermittent spikes. The K-pinch strength improved in all patients by a mean value of +82% (range +9%/+250%). The hand grip strength did not significantly change in most of the patients (94%). Kapandji score for opposition remained the same in all but 2 cases. Most of the improvement were observed between week 2 and 6 post-operative. None of the patients required further procedure. The quality of results did not seem to correlate with the radiological stage of arthritis.

DISCUSSION. CMC joint denervation for CMC Arthritis seems to represent a valid option in the treatment of CMC arthritis. It is a relatively simple operation that does not require post-operative immobilization and specific hand therapy. Further investigation with longer follow up is needed in order to determine the lasting of the effects of this operation.

Acknowledgements. No external funding.

COI. No conflict of interests.
Procedural and Clinical Outcomes Following Implantation of a New Interpositional Space for Treatment of Osteoarthritis of the Carpometacarpal Joint of the Thumb: One-Year Results

F.J.C. van der Veen, MD, J.P.W. Don Griot, MD, PhD, M.J.P.F. Ritt, MD, PhD
Department of Plastic, Reconstructive and Hand Surgery, VU University Medical Center, Amsterdam, The Netherlands

Introduction. Trapeziectomy is the most commonly performed surgical procedure for the treatment of osteoarthritis (OA) of the carpometacarpal joint of the thumb (CMC-I). However, minimally invasive trapeziem-sparing options are increasingly recognized by surgeons as desirable for the preservation of thumb length, grip and pinch strength. Currently available alternatives such as CMC arthroscopy with or without interpositional arthroplasty are technically demanding and typically involve at least partial tissue and/or bony removal. The Articulinx Intercarpometacarpal Cushion (ICMC) is a newly developed, unconstrained interpositional spacer that is implanted into the CMC-1 joint using a simple, minimally invasive technique without the need for resection of any tissue or bone. The aim of this prospective study was to evaluate ease of use of the Articulinx ICMC and clinical outcomes in patients with early- to mid-stage CMC OA.

Methods. Twenty patients (20 joints) with a mean age of 54.8 (42 - 66) years and suffering from painful Eaton-Littler Stage I or II CMC-I osteoarthritis were included in this observational postmarket study. Patients with extreme joint laxity and radiographic abnormalities such as free-floating bodies, large osteophytes, and cystic/sclerotic changes consistent with Stage III/IV disease, were excluded. Perceived pain (primary outcome parameter) was recorded on a visual analog scale (VAS) before treatment and after 3, 6, 12 months. Additionally, radiographic findings and joint function were recorded pre- and postoperatively using quick-Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Canadian Occupational Performance Measure (COPM) questionnaires, and measurements of pinch, tripod and grip strength.

Results. The surgical technique proved successful in 100% (20/20) of devices implanted with no intraoperative complications reported. Only local anesthesia was used and the average procedure time was 25 (SD 12.1) minutes. Within the first year, the spacer was removed without complication in 3 patients because of 1) unresolved pain, 2) incomplete capsule closure causing device extrusion, and 3) a preexisting bone cyst that aggravated the patient’s pain symptoms; two of these patients had no other surgical procedure at time of device removal. Among all implanted subjects, mean pain VAS, QuickDASH and COPM change scores showed statistically significant improvement (p < 0.05) at the 1-year visit compared to baseline: average VAS pain (-2.42, SD 3.23), QuickDASH symptom disability ( 12, SD 20), COPM-performance (2.19, SD 2.32) and COPM-satisfaction (2.79, SD 2.74) respectively. Average pinch and grip strength measurements showed improvement compared to baseline though the results were not statistically significant (lateral key pinch: 5.04 (SD 3.40) to 5.49 (SD 2.59) kg; tripod pinch: 4.66 (SD 3.80) to 4.77 kg (SD 2.68); grip: 18.03 (SD 13.41) to 22.57 kg (SD 10.96)).

Discussion. The study results clearly demonstrate the surgical technique is safe and effective in preserving the native bone and tissue in the CMC-1 joint. Should the device require removal, the procedure is completely reversible thereby leaving other treatment options available. In this study population, pain measurements showed clinically and statistically significant improvement as early as 3 months, which persisted through 1 year (Figure 1). Significant functional improvement was also observed, and pinch and grip strength was preserved. An unconstrained interpositional spacer is a valid treatment option for patients with early to mid-stage CMC OA.

COI. This study was sponsored by Articulinx, Inc., Cupertino, CA. The sponsor monitored the study, and collected and analyzed the data. F.J.C van der Veen, MD and M.J.P.F. Ritt, MD, PhD report a consulting arrangement with the sponsor.
Basal Joint Arthrodesis for the Paralytic Limb: A Case Series

S.W. Wolfe, MD, P. Johnson, BA
Hospital for Special Surgery, New York, NY 10021, USA

INTRODUCTION: Basal joint arthrodesis provides a stable platform for reconstruction of the thumb in paralytic disorders of the upper extremity. We report the outcome of ten patients who underwent basal joint fusion and tendon transfers to restore functional use of the hand.

METHODS: Ten patients with an average age of 42 (15-63) underwent basal joint fusion as the foundation of a tendon transfer strategy to reconstruct intrinsic function and restore digital balance. The diagnosis in 7 patients was lower plexus palsy, spinal cord injury in 2, and transverse myelitis in one. The same bony preparation and positioning technique was utilized in each patient, while fixation varied: 5 patients had locked screw fixation, 4 patients had mini-blade plate fixation, and one had K-wire fixation. Local bone graft was used in all, and cast immobilization averaged 5.5 weeks.

RESULTS: All but one arthrodesis demonstrated clinical and radiographic union at an average of 8.6 weeks (6-11). An average of 3.2 (range 2-6) tendon transfer procedures were performed in each patient. Though not significantly different, those with locked screw fixation healed at an average of 16d earlier than blade plate and K-wire fixation. Complications included one nonunion in a patient with blade plate fixation; no other hardware related complications occurred.

DISCUSSION: Basal joint arthrodesis is a simple and durable solution for patients with severe combined intrinsic deficiencies of the hand secondary to paralytic disorders of the upper limb. A stable and abducted thumb metacarpal enables tendon transfer for pinch and grasp and improves functional use of the upper extremity. Locked screw fixation provides simple, rigid fixation that may enable earlier removal of cast immobilization and tendon transfer training.

Acknowledgements. None.

COI. The author discloses a consulting agreement with Extremity Medical, Inc., Parsippany NJ.
INTRODUCTION. Many surgical techniques have been developed to address basal joint arthritis, which include reconstructive procedures involving tendon harvest and interposition, and simple trapeziectomy with or without some form of fixation or suspension method. To date, none has proven to be clearly superior to others. The suture suspension arthroplasty was developed as a technique to simplify a potentially technically demanding procedure, yet achieve results of pain relief and restoration of function of the thumb. The purpose of this study is to evaluate a minimum of one-year follow up results of patients who have undergone the suture suspension arthroplasty for basal joint arthritis and determine if results are comparable to results of other techniques found in the literature.

METHODS. This simple surgical technique involves complete trapeziectomy with creation of an intra-articular suture suspension sling, which devises an intra-articular hammock with firm soft tissue anchoring points into the insertion points of the flexor carpi radialis and the abductor pollicis longus. A retrospective chart review and patient examination was performed on 112 patients, 126 hands, to obtain intermediate term (12-56 months) follow-up. Measurements included pre-operative and post-operative grip, key, and tip pinch, radiographic subsidence/proximal migration of the thumb metacarpal, and QuickDASH questionnaire.

RESULTS. 126 hands were available for follow-up analysis, with a minimum of 12 months to a maximum of 56 months. The mean age of patients was 61 years. There were 105 females (83%) and 21 males (17%). Clinical and radiographic assessments were obtained for all patients preoperatively, at 4 weeks and 12 weeks postoperatively. Objective and subjective data were obtained at final follow-up ranging from 12-56 months. Longer-term follow up Xrays were available on 65% of hands. The research protocol was designed to obtain objective data (pinch and grip strength) and subjective data, using the mini DASH questionnaire. Average grip, key, and pinch strength increased significantly after the surgical procedure. Average radiographic subsidence was 17% on final follow-up. QuickDASH scores indicated good to excellent patient satisfaction at final follow up.

DISCUSSION. One-year minimum follow-up of the suture suspension arthroplasty suggests that this method is a reliable alternative for basal joint reconstruction. Data analysis shows improvement in strength and thumb function, and high levels of patient satisfaction, similar to those reported on studies of other techniques. Advantages of this method are that it is simple to perform, offers low morbidity, a faster early stage recovery, a relatively short surgical time, and is easily reproducible.

Acknowledgements. No funding was received

Partial Trapeziectomy with Capsular Interposition (PTCI) Arthroplasty for Surgical Treatment of Thumb Carpometacarpal Osteoarthritis.

M.S. Moneim, MD, D. Mercer MD, Cc Salas, MS.UNMHSC Albuquerque, NM, USA

INTRODUCTION. Osteoarthritis of the thumb CMC joint is a common problem affecting both women and men in the sixth decade and older. There are many surgical procedures described to treat this condition. Our hypotheses is that limited excision of the base of the first metacarpal and partial Trapeziectomy, using the joint capsule as interposition may provide a viable alternative to more extensive surgical procedures and result in a stable thumb.

METHODS. Between January 2003 and December 2009 62 patients had surgery following failed non operative treatment. Of these, 25 patients were excluded because of inadequate preoperative documentation. This left 37 patients for follow up.

Technique—

1. ELEVATION OF THE PERIOSTEUM, INCLUDING THE ABDUCTOR POLLCIS LONGUS TENDON, OFF THE BASE OF THE FIRST METACARPAL
2. RESECTION OF 2 MM OFF THE BASE OF THE FIRST METACARPAL AND 2 MM OFF THE DISTAL TRAPEZIUM, LEAVING THE CAPSULE ATTACHED TO THE TRAPEZIUM.
3. CAPSULAR INTERPOSITION IN THE JOINT.
4. REEFING THE ELEVATED PERIOSTEAL FLAPS, INCLUDING THE ABDUCTOR TENDON, ON THE DORSAL SURFACE OF THE FIRST METACARPAL TO STABILIZE THE JOINT. NO K-WIRES USED. SPLINT FOR 4 WEEKS TO BE FOLLOWED BY HOME THERAPY PROGRAM. C- BAR FOR THE FIRST WEB CAN BE USED FOR ADDITIONAL 2 WEEKS. UNPROTECTED ACTIVITY AT 8 WEEKS.

RESULTS. Of the 37 patients 22 had a chart review at a mean follow up of 6 months that showed no significant improvement of grip and pinch strength. Fifteen patients (42% of qualifying patients) were evaluated clinically at a follow up examination with a mean follow up of 51 months. A statistically significant difference was found comparing the preoperative to postoperative grip strength (23.3+-10.1 and 32.0+-12.8 kg respectively) Grip strength averaged 69.9% preoperatively and 88.2% postoperatively of contralateral side. Pinch strength averaged 61.3% preoperatively and increased to 77.1% postoperatively of contralateral side. Excellent DASH scores were reported (median 4.17). Future plans are to evaluate a larger number of patients that had this procedure recently.

DISCUSSION. Our results indicate that our procedure results in improved grip and pinch strength at long term follow up. Pain relief and excellent DASH scores were achieved. Further follow up on a larger number of patients is needed. This procedure is simpler to perform, provides a stable thumb without the need for tendon suspension or prosthetic replacement.

IRB OBTAINED.

COI. No conflicts of interest.
Trapezium Excision and Suture Suspensionplasty (TESS) for the Treatment of Thumb Carpometacarpal Arthritis

M.D. Putnam, MD\textsuperscript{1}, J. Brehmar, MD\textsuperscript{2}, N.J. Meyer, MD\textsuperscript{3}

1) Orthopaedics, University of MN, Minneapolis, MN, USA
2) Orthopaedics, University of MN, Minneapolis, MN, USA
3) St. Croix Orthopaedics, Stillwater, MN, USA

INTRODUCTION. Basilar thumb arthritis, or first carpometacarpal arthritis, is a common condition affecting older women and some men. It is estimated that as many as one-third of postmenopausal woman are affected. Surgical treatment of this condition includes options ranging from arthrodesis to prosthetic arthroplasty. Intermediate options include complete or partial trapezial excision with or without interposition of a cushioning/stabilizing material (auto source, allo source, synthetic source). This project examines one simpler method to see if it offers clinical benefits equivalent to more complex methods.

METHODS. Through retrospective evaluation of a cohort of patients who underwent suture suspensionplasty (see Figure 1 insert), we determined the post-operative effect on strength, motion, patient satisfaction, complications, and radiographic maintenance of the scaphoid-metacarpal distance. This review shows the method to be clinically effective and, by comparison to a more traditional ligament reconstruction trapezial interposition (LRTI) arthroplasty, the method does not require use of autograft or allograft tendon, thus it has fewer surgical steps. Forty-four patients were included in this retrospective study.

RESULTS. The results showed that 91\% of patients were satisfied with the procedure (Between 12-92 months (Avg. 47 mos.)). Pinch and grip strength remained the same pre- and post-operatively. DASH scores averaged 30 at final follow-up. Three patients developed a late complication requiring further surgical intervention.

DISCUSSION. In summary, this technique appears to be technically reproducible, requires no additional tendon material, and achieves objectively and subjectively similar results to other reported procedures used to manage 1\textsuperscript{st} CMC Arthritis.

Acknowledgements. All funding used to support this project was provided by the senior author.

COI. No conflicts of interest.
INTRODUCTION. Visualization and quantification of motion occurring at the basal thumb joint during functional tasks (e.g. opposition, pinch, full grip) is particularly difficult due to the complex 3D arrangement of the small bones with multi-planar range of motion and skin motion artifacts. Because of the limited applicability of standard motion capture techniques, we investigated the feasibility and clinical workability of dynamic CT scanning to visualize and quantify the basal thumb joint kinematics.

METHODS. Dynamic CT scanning was performed during thumb opposition of a cadaveric human hand positioned in a custom-build motion simulator. Acquisition was done using the following settings: FOV: 150 mm, 80 kV, 72 mA, voxel size: 0.054 mm³. This resulted in a sequence of 10 seconds consisting of a time series of 26 image stacks. Each image stack was manually segmented using Mimics 16.0 software (Materialise, Belgium) and 3D bone models of the radius, scaphoid, trapezium and first metatarsal were exported as STL-files. Bone motion was calculated using Matlab code, based on rigid body dynamics and icp algorithm. The resulting translation vectors and rotation matrices were used to calculate helical axes at the radiocarpal (RC), scaphotrapezial (ST) and trapeziometacarpal (TMC) joints. Validation of the method was performed by comparing the distance between radio-opaque (SiN) beads obtained via dynamic CT, static CT and manually.

RESULTS. During passive thumb opposition, movement in the RC, SC and TMC joints was confirmed, with largest motion occurring at the MTC joint and smallest motion at ST joint. The 4D CT images were of high quality, showing minor motion blurring and no banding artifacts. Results of the validation process point to a high precision (RSD < 0.80%) and high accuracy (%error < 3.5%).

DISCUSSION. Dynamic CT scanning appears to be a valuable method to visualize and quantify complex bone motion in situ, and offers great opportunities for obtaining a better understanding of the function of the native and diseased basal thumb joint. The wide availability of CT scanners and relative low radiation dosage gives the method a high potential for use in a clinical setting. Challenges related to this method do, however, remain and are specifically linked to the limited field of view and manual segmentation process. Further validation of this technique will open possibilities to investigate pathological joint function in the presence of degenerative joint disease or total endoprosthesis.

Acknowledgements. This study is partially funded by Materialise (Belgium). Special thanks go to Jasper Callemeyn for help in the segmentation process and Donald Samyn and Ivan De Pauw for technical support.

COI. No conflicts of interest.
Strategies for Engineering Functional Articular Cartilage Grafts

C.T. Hung¹, T.N. Kelly¹, B.L. Roach¹, E.G. Estell¹, G.A. Ateshian¹,²
1) Department of Biomedical Engineering, Columbia University, New York, NY, USA
2) Department of Mechanical Engineering, Columbia University, New York, NY, USA

INTRODUCTION. The unique load-bearing properties of articular cartilage stem from the underlying structure-function relationships associated with the interplay of the collagen and proteoglycan rich extracellular matrix. A significant challenge to engineering cartilage with functional mechanical properties is growing tissues with native collagen levels. In this study, we aim to increase collagen content in engineered cell-seeded agarose hydrogel constructs through application of controlled enzymatic digestion of tissues using chondroitinase-ABC and dynamic deformational loading.

METHODS. Juvenile bovine chondrocytes were cultured in agarose hydrogel and cultured in serum-free chondrogenic media. After 2 weeks of culture, a subset of constructs was digested for 3 days with chondroitinase-ABC (cABC). At day 17, constructs were cultured under free-swelling (FS) or dynamic deformational loading (DL, 1 Hz, 10% deformation, 3 hours/day, Figure 1) conditions. On day 42 of culture, mechanical testing, assays for biochemical content and histology were performed.

RESULTS. Application of dynamic loading (16.4±1.9 %dw) or enzymatic digestion (16.7±3.5 %dw), or their combination (16.7±3.2 %dw) significantly increased collagen levels over free-swelling control (14.8 ± 3.6 %dw). Increased collagen levels corresponded to more prominent picrosirius red staining as well as to significantly greater mechanical properties, Figure 1.

DISCUSSION. Application of controlled enzymatic digestion to growing engineered cartilage constructs followed by dynamic deformational loading is an effective strategy for increasing collagen content as well as functional properties of chondrocyte-seeded hydrogel constructs.

Acknowledgements. This work was supported in part by NIH grants AR46568, AR60361, AR59038.

COI. No conflicts of interest.
Biomechanical Simulation of Surgical Treatments of Trapeziometacarpal Joint Arthritis

M. Domalain, P.J. Evans, W.H. Seitz, Z.-M. Li  
Departments of Biomedical Engineering Orthopedic Surgery, and Physical Medicine and Rehabilitation  
Cleveland Clinic, Cleveland, OH 44195, USA

INTRODUCTION. Osteoarthritis of the trapeziometacarpal (TMC) joint is treated by arthrodesis and arthroplasty, which potentially decreases and increases the degrees of freedom (DoFs) of the joint, respectively. The aim of this study was to bring novel biomechanical insights into these joint surgery procedures by investigating the influence of DoFs at the TMC joint on muscle and joint forces in the thumb.

METHODS. A musculoskeletal model of the thumb was developed to equilibrate a 1 N external force in various directions while the thumb assumed key and pulp pinch postures. Muscle and joint forces were computed with an optimization method.

RESULTS. In comparison to that of the intact joint (2 DoFs), muscle forces slightly decreased (-0.8 N) in the 0 DoF (arthrodesis) condition, and increased (+9.0 N) in the 3 DoFs (arthroplasty) condition. The 3 DoFs condition resulted in overall higher TMC joint forces with also a greater percentage of shear to normal forces (64.6% in 3 DoFs vs. 26.0% in 2 DoFs). The 3 DoFs condition was also more sensitive to external force direction and thumb posture.

DISCUSSION. For the 0 DoF condition, muscle and joint forces decreased in comparison to that of the intact joint (2 DoFs) condition as, in contrast, the 3 DoFs condition resulted in excessive increases in muscle and joint forces and changes in muscle force patterns. This indicates that TMC arthroplasty (especially with a ball-and-socket implant) without any tendon transfer may lead to a less stable joint and overload some muscles. This study contributes to a further understanding of the biomechanics of the intact and surgically repaired TMC joint and addresses the biomechanical consequences of changing a joint's DoFs by surgery.
Comparison of Finite Element Modeling and Surface Contact Modeling for In Vivo Thumb Carpometacarpal Joint Mechanics

Q. Zheng¹, P. Lee², T.E. McIff³, E.B. Toby³, K.J. Fischer¹, ², ³, ⁴
¹) Bioengineering, The University of Kansas, Lawrence, KS, USA
²) Hoglund Brain Imaging Center, The University of Kansas Medical Center, Kansas City, KS, USA
³) Department of Orthopedic Surgery, The University of Kansas Medical Center, Kansas City, KS, USA
⁴) Department of Mechanical Engineering, The University of Kansas, Lawrence, KS, USA

INTRODUCTION. The thumb carpometacarpal (CMC) joint is frequently affected by osteoarthritis (OA). Contact pressure distribution on the articular cartilage can be an important factor for OA development but no data has been published on the in vivo thumb CMC joint contact pressure. The objective of this study was to obtain preliminary in vivo thumb CMC contact pressure data and compare finite element modeling (FEM) and surface-based contact modeling (SCM).

METHODS. Three female subjects were enrolled for this study (approved by IRB). For each thumb CMC joint, a high resolution MRI image set was obtained while relaxed (unloaded) and a low resolution set was obtained during light grasp. Joint kinematics during functional loading were determined using unloaded-to-loaded image registration. From unloaded image set, trapezium and metacarpal bones with cartilage were segmented (ScanIP) to create SCM bilinear surfaces and spatially varying cartilage thickness was computed. Cartilage only 4-node tetrahedral volume meshes were created for FEM. Cartilage for the FEM analysis (Abaqus 6.9) was modeled as homogeneous, isotropic, elastic solid (Young’s modulus = 4 MPa, Poisson’s ratio = 0.2). SCM analysis (Joint_Model Windows) was performed using both uniform (1mm) and variable cartilage thickness; local strain was estimated based on cartilage surface interpenetration and local pressure was proportional to strain. For all 3 subjects, contact pressure distribution was compared between FEM, SCM with uniform thickness (SCMU) and SCM with variable thickness (SCMV).

RESULTS. Although all subjects reported asymptomatic, the MRI image of Subject 3 showed substantial cartilage degeneration and osteophyte formation. No significant abnormality was observed for Subject 1 and 2. Subject 3 had much higher peak pressure (PP), shifted contact location and larger contact area compared with the first two subjects. For all 3 subjects, PP from FEM was higher than SCMU and SCMV. PP from SCMV was higher than SCMU for Subject 2 and 3, but slightly lower for Subject 1 (Figure 1 bottom). Although varying among subjects, pressure distribution was similar from SCMU, SCMV and FEM (FEM displayed) within each subject.

DISCUSSION. Contact pressure distribution can be directly related to cartilage degeneration and OA development. FEM and SCM have been previously applied in the radiocarpal joints and are presumed to be accurate for in vivo thumb CMC joint contact mechanics. SCM is much more computationally efficient than FEM and thus may be feasible for future clinical evaluation, but the accuracy of SCM can be a major concern due to the linear contact rule assumption. Substantial reduction in cartilage thickness is consistently observed in advanced stages of thumb CMC OA, leading to increased contact pressure and altered pressure distribution. Therefore, incorporating cartilage thickness into SCM analysis is important for accuracy in evaluating changes of thumb CMC contact mechanics during OA development. Future analyses with more subjects with additional functional tasks such as tip pinch and key pinch will provide further insights into thumb CMC joint mechanics and degeneration.

Acknowledgements. Supported by NIBIB of the NIH award R01EB008709. Allan Schmitt for MRI technical assistance. Columbia University and Leendert Blankevoort for providing Joint_Model software and support.

COI. No conflicts of interest.
Loading Analysis of Thumb Joints While Pipetting

J.Z. Wu and F.L. Buczek
Health Effects Laboratory Division
National Institute for Occupational Safety and Health
Morgantown, West Virginia, USA

INTRODUCTION. A thumb-push pipette is a tool commonly used in biological and chemical laboratories worldwide. Nearly 90% of pipette users, who continuously used pipettes for more than an hour on a daily basis, reported hand and/or elbow disorders [1]. Despite compelling evidence that operation of a thumb-push manual pipette is related to musculoskeletal disorders in the thumb, joint loads during pipetting have not been quantified. It is not known if the operation of the thumb-push pipette would induce excessive joint moments (torques) in the carpometacarpal (CMC) joint, a factor that may potentially cause degeneration of the articulation [2].

METHODS. A typical thumb-activated pipette (P200, Pipetman, Gilson, Inc, Middleton, WI, USA) was used in the study. Subjects were instructed to repeat the same procedure 15-20 times in a test session: extract the sample fluid from one container on the left and dispense it to another container on the right. The hand was modeled as a multi-body linkage system [3,4] and includes four fingers (index, long, ring, and little finger), thumb, and a palm segment. We analyzed only the biomechanics of the thumb because it is the focus of the current study. The time-histories of joint angles and the interface contact force between the thumb and plunger while pipetting were determined experimentally, and the joint loads and joint power in the thumb were calculated via an inverse dynamic approach. The force, moment, power, and energy absorption in each joint of the thumb during the extraction and dispensing actions were analyzed.

RESULTS. Our calculations showed that the maximal joint moments in the thumb occurred at approximately 60% of the cycle for the dispensing action. The magnitude of the maximal moment in the CMC joint was found to reach 4.0 N-m at the peak, which is approximately 1.9 and 5.7 times that in the metacarpophalangeal (MP) and interphalangeal (IP) joints, respectively. Furthermore, the results of the energy analysis of the joints showed that the peak power generated by the joints reaches approximately 0.90 W at 50% of the cycle for the dispensing action; the power generated in the CMC joint represents about 68% of the total joint power at the peak.

DISCUSSION. Our results indicate that the CMC joint is loaded more than other joints in the thumb while pipetting. Our theoretical analysis is consistent with clinical observations [5] that the CMC joint may be susceptible to developing osteoarthritis during occupational activities, especially pipetting.


COI. No conflict of interests.

Disclaimer: Findings are those of the authors, and may not represent views of NIOSH.
Dorsoradial Ligament Imbrication for Thumb Carpometacarpal Joint Instability

M.V. Birman1, J.P. Danoff2, J. Lombardi2, M.P. Rosenwasser2
2) Department of Orthopaedic Surgery, Columbia University Medical Center, New York, New York

INTRODUCTION. The thumb carpometacarpal (CMC) joint has unique anatomy comprised of an unstable biconcavoconvex bony articulation supported by numerous ligaments. CMC instability and ligamentous laxity can be caused by many factors, including prior trauma, circulating estrogen, and connective disorders such as Ehlers-Danlos syndrome. A significant source of debate remains around which of the CMC ligaments serves as the primary stabilizer of the joint. Initially, it was thought that the anterior oblique ligament was the primary stabilizer, however more recent biomechanical and histopathologic studies have proven this incorrect and demonstrate that the dorsoradial ligament is the primary stabilizer.

Since its description by Eaton and Littler in 1973, the Eaton-Littler procedure has been the classic treatment of thumb CMC joint instability, and utilizes half the FCR tendon passed volar to dorsal though the base of the first metacarpal. Although intended to reconstruct the anterior oblique ligament, authors have noted that this in fact reinforces the dorsoradial ligament as well. Additionally, metacarpal osteotomy, which has been shown to relieve pain and improve function in early stage basal joint arthritis, is thought to work by tightening the dorsal ligaments and unloading degenerated contact areas.

Based on the importance of the dorsoradial ligament in thumb CMC joint stability, the senior author has developed and performed a technique in which the dorsoradial ligament is imbricated with the use of a suture anchor in order to stabilize the joint. We present our technique along with an anatomical dissection to demonstrate the ligament and surgical procedure on an anatomical specimen. We also present results from three patients who underwent our technique with photographs and clinical results in three patients with follow-up.

METHODS. Although not required, arthroscopy of the thumb CMC joint may be performed prior to the imbrication procedure to inspect the joint surfaces and debride synovitic tissue. After arthroscopic evaluation, a longitudinal dorsal incision is made over the thumb trapeziometacarpal joint. The first and second compartment extensor tendons are identified and retracted to expose the dorsal capsule. The thickened portion of the dorsal capsule corresponding to the dorsal radial ligament is identified. Either the trapezial or metacarpal insertion of the dorsal radial ligament can be elevated. This decision is made intraoperatively based on the appearance of the soft tissue. Once the ligament is elevated, the thumb metacarpal is brought up into a reduced and more extended palmar abduction position. A 2.5 mm suture anchor is drilled into either the metacarpal base or trapezium and attached to a 2-0 Biosyn suture, which is then used in an interlocking ligament repair to advance the dorsoradial ligament and stabilize the joint. Additional sutures may be used to stabilize the advanced ligament to the adjacent periosteum. The tensioning can be tested to ensure that the dorsal radial ligament has been advanced adequately to stabilize the joint. The skin is then closed and sterile dressings applied, followed by immobilization in a plaster forearm-based thumb spica splint maintaining the thumb metacarpal in an abducted and extended posture to protect the dorsal radial ligament imbrication and repair.

RESULTS. Three cases were reviewed at follow up of 1 year (1 patient) and 10 years (2 patients). Patients suffered from CMC laxity due to the following problems: hyperlaxity collagen condition, hyperextension trauma and CMC OA. In each case, pre-operative examination showed localized pain at CMC joint and laxity with lateral pinch. Conservative treatment failed in all patients. Each patient underwent a diagnostic arthroscopy to evaluate cartilaginous eburnation and degree of subluxation after which they received a dorsoradial ligament imbrication. At one year follow-up, patient 1 reported no difficulty with daily activities and was satisfied with the results of surgery. The patient reported CMC extension to 0 degrees and flexion to 55 degrees (contralateral 65 degrees). Pinch strength was identical to the contralateral thumb. At 10 years post-op, patient 2 reported satisfaction with outcomes and reduction in pre-operative pain. Patient 3 also had follow-up at the 10 year mark with a long period of symptomatic relief and baseline VAS of 2. However, the patient began to experience MCP hyperextension to 65 degrees.

DISCUSSION. The dorsoradial ligament imbrication procedure can be used to tighten the dorsoradial ligament complex and stabilize the CMC joint in patients with painful CMC joint instability. In our follow-up with three patients at 1 year, 10 years, and 10 years, patients reported overall improvement in symptoms. The advantage of this procedure is the achievement of dorsoradial ligament tightening and CMC joint stability without the use of complex tendon graft or osteotomy procedures. Moreover, dorsoradial ligament imbrication preserves the option of additional interventions, including ligament reconstruction, metacarpal osteotomy, and trapeziectomy. This technique for treatment of thumb carpometacarpal joint instability may be an effective alternative to ligament reconstruction or metacarpal osteotomy in patients with painful thumb CMC joint instability.

COI. No conflicts of interest.
INTRODUCTION. Patients with advanced basal joint arthritis may suffer from a characteristic hyperextension deformity of their thumb metacarpophalangeal (MCP) joints. Correcting the thumb metacarpal adduction deformity of basal joint arthritis without addressing thumb MCP laxity can decrease pinch strength and function when the hyperextension deformity is greater than 10-15˚ and the thumb assumes a zigzag collapse deformity. The purpose of this study is to provide long-term follow-up on a group of patients who were treated with a novel technique of thumb MCP joint capsulodesis as an adjunct to basal joint arthroplasty.

METHODS. We retrospectively evaluated 14 patients who had received basal joint interposition arthroplasty with concomitant MCP capsulodesis. MCP capsulodesis was performed through a volar approach using a step-cut between sesamoid bones and allowing proportionate imbrication of the volar plate (Figure 1). Objective evaluation included thumb range of motion, grip strength and key pinch strength. Subjective evaluation included patient-based scores on the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, visual analog scale (VAS) pain scores, and a study-specific questionnaire.

RESULTS. At an average of 4.74 years after surgery (range, 0.9 – 11.5 years), average MCP hyperextension was 15.0˚ (range, 0˚-30˚), with all but three patients hyperextending to less than 20˚. Thirteen of 14 patients were able to oppose their thumbs against the distal end of the fifth metacarpal. Average grip and pinch strength were 24.7 kg and 3.7 kg, respectively. The average DASH score was 11.8. Patients reported minimal pain and were all satisfied with the procedure. No complications or revision procedures were reported.

DISCUSSION. Basal joint arthroplasty combined with the described volar plate step-cut technique for thumb MCP joint capsulodesis provides excellent long-term results for patients with basal joint arthritis and severe MCP hyperextension, although precise indications for the procedure are evolving. This new procedure is safe, reproducible, and without complications, and does not alter the post-operative management of patients undergoing basal joint arthroplasty.
Introduction. Static biomechanical models have been used to simulate the thumb-tip forces produced during maximum isometric effort by human subjects [1, 2]. The methods implemented in these studies assumed thumb posture was constant during force development. Under these conditions, there is a linear relationship between the force each muscle produces and the thumb-tip force that results. Previous experimental work demonstrated that non-linear changes in thumb-tip forces resulted from linear increases in the forces applied to cadaveric muscles [3]. Simulation work suggests that the nonlinearities observed experimentally were consistent with changes in thumb posture during muscle loading [4]. The aim of this study was to simulate both lateral pinch force production and thumb posture simultaneously during EMG-driven forward dynamic simulation.

Methods. We developed a dynamic thumb model, augmenting previous work [2, 5]. Lateral pinch force production was simulated using forward dynamics; constant activations, derived from EMG data [1], served as inputs to nine muscles. The positions of the thumb-tip and trapezium were constant; both the posture of the thumb joints and the force produced at the thumb-tip were determined by the forces calculated via simulation. The simulation ran for 4 seconds; initial and equilibrium postures of the thumb were compared. Lateral pinch force was evaluated in equilibrium.

Results. The experimental muscle activations generated a palmar force of 65 N; a substantial distal force (14 N) was also produced. Relative to the initial, lateral pinch posture (Fig. 1a), the final, equilibrium posture of the thumb changed substantially (Fig. 1b).

Discussion. Forward simulation predicted lateral pinch force magnitude comparable to experimental data. However, the substantial distal component of the force indicates a direction error much larger than existed in the experiments from which the EMGs were measured [1]. We expect the misdirection arose from the change in thumb posture with force production [4]. Forward simulation enables us to analyze muscle contributions to both force production and maintenance of thumb posture. We expect this capability will improve our understanding of basic thumb mechanics and provide new insights into how impairments, such as carpometacarpal osteoarthritis, influence the ability to use the thumb.

Acknowledgements. This work is funded by NIH R01 EB011615 and NSF DGE-090363.


COI. No conflict of interests.
Biomechanical Test of Pre-treatment State vs. Trapezial Excision vs. Suture Suspensionplasty (TESS) vs. LRTI for Treatment of Thumb Carpometacarpal Arthritis

M.D. Putnam, MD, R. Ratay, MD, F. Wentdorf, MS
Orthopaedics, University of MN, Minneapolis, MN, USA

INTRODUCTION. Basilar thumb arthritis, or first carpometacarpal (CMC) arthritis, is a common condition. Surgical treatment of this condition is highly varied. One common method consists of trapezium excision and a concomitant procedure for treatment of the “floating” thumb metacarpal. That a variety of concomitant procedures are used suggests that these procedures offer no clear advantage of one method over another. We speculated that in-vitro testing might identify a difference that has been difficult to measure in vivo.

METHODS. A 2 degrees of freedom biomechanical cadaver study was completed looking at simulated pinch strength and prevention of metacarpal subsidence during pinch. Three methods (1 trapezial excision alone, 2 trapezial excision and suture suspensionplasty (TESS), 3 trapezial excision followed by a ligament reconstruction using ½ of the FCR) were compared to each other and against the normal pre-treatment state.

RESULTS. After suture suspensionplasty (TESS) the loaded mean height was 1.24 cm (std. dev. = 0.5). However, the height maintained after LRTI (1.07 cm (std. dev. = 0.45)) was statistically less than the pre-treatment state. The mean key pinch measured after suture suspensionplasty (6.68 lbs) was similar to the intact specimens pinch strength of 7.34 lbs and statistically different from LRTI.

<table>
<thead>
<tr>
<th>Height State</th>
<th>Mean</th>
<th>n</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>1.500</td>
<td>8</td>
<td>0.123</td>
</tr>
<tr>
<td>Exc</td>
<td>0.100</td>
<td>8</td>
<td>0.123</td>
</tr>
<tr>
<td>SS</td>
<td>1.199</td>
<td>8</td>
<td>0.117</td>
</tr>
<tr>
<td>LRTI</td>
<td>1.000</td>
<td>8</td>
<td>0.123</td>
</tr>
</tbody>
</table>

ANOVA model: Height by State
Variances are homogeneous by Levene's, Brown & Forsythe's, and Bartlett's tests
Model p < 0.0001, strongly significant

DISCUSSION. In summary, the tested technique of TESS appears to be biomechanically sound and technically reproducible. Mechanically, in in vitro testing it is superior to excision alone and at least equal to the ligament reconstruction method tested.

Acknowledgements. This study was funded using internal departmental financial support.

COI. No conflict of interests.
Cadaveric Study Investigating Metacarpal Subsidence in Specimens Treated with Partial Trapeziectomy/Partial Metacarpal Base Resection Versus Those Treated with Total Trapeziectomy

D. Mercer, C. Salas, M. Moneim
Department of Orthopaedics and Rehabilitation, The University of New Mexico, Albuquerque, NM, USA

INTRODUCTION. A modified technique of partial trapeziectomy and partial metacarpal base resection with local soft tissue interposition for treatment of early trapeziometacarpal osteoarthritis (OA) is biomechanically investigated. We examine the metacarpal to scaphoid distance after partial and total resection of the trapezium with soft tissue interposition as a measure of thumb subsidence. We hypothesize that partial trapeziectomy with joint capsule interposition will result in less thumb subsidence which may lead to a more functional thumb.

METHODS. Nine matched pairs of fresh-frozen human cadaveric forearms were randomized into two groups – total trapeziectomy (TTCI) or partial trapeziectomy (PTCI). Capsular tissue was used as interposition for both techniques. Specimens were mounted in a custom-built testing device and weighted suture was attached to 6 tendons (flexor pollicis longus, abductor pollicis longus, adductor pollicis, abductor pollicis brevis, and combined flexor pollicis brevis/opponens) that allowed the hand to form a lateral pinch position. As a reference for relative metacarpal motion and metacarpal to scaphoid distance, we utilized two K-wires which we securely embedded into the bone of the first metacarpal base and distal scaphoid. We loaded all thumb joints prior to performing the surgical procedure to evaluate group similarity prior to bone resection. Group I specimens were treated with the partial trapeziectomy technique characterized by removal of the arthritic articular surfaces of the trapezium and base of the first metacarpal (~2mm of each surface removed). Group II specimens were treated with the total trapeziectomy technique characterized by total trapezium removal. Antero-posterior radiographs were taken of the untreated and treated wrists in three loaded positions. Custom designed software was developed to allow analysis of all images and relative distance measurements between the inserted ends of the K-wires. A paired t-test (a=0.05) was used to compare relative metacarpal to scaphoid distance between treated and untreated specimens in each group.

RESULTS. Relative metacarpal to scaphoid distance was significantly different between the TTCI (34% reduction) and PTCI (17% reduction) groups (p=0.05; 7.75+-3.09mm and 4.28+-3.25mm, respectively) indicating greater metacarpal subsidence with the TTCI group.

DISCUSSION. We have demonstrated in a cadaveric model that the PTCI treatment, when compared to complete trapezium excision, results in less proximal translation of the first metacarpal under simulated physiological load. The maintenance of overall thumb length may be important as it may lead to a more stable and biomechanically sound thumb. Clinically, it has been shown that metacarpal subsidence correlates with decreased thumb strength due to a reduction in the length of the lever arm.

COI. No conflicts of interests.
INTRODUCTION. We hypothesize that thumb carpometacarpal (CMC) joint motion and bone shape will differ by sex and this may be along the causal pathway for the development of Hand Osteoarthritis (HOA). Our objectives were to develop two imaging approaches, (1) real-time MRI during active hand motion and (2) morphometric analysis, to determine if there are the sex-specific motion-related and shape variations for the thumb CMC joint.

METHODS. For real-time MRI during active motion, the data acquisition protocol was based on balanced steady-state free precession. Magnetic susceptibility artifacts that are usually introduced during motion were mitigated by the use of a wrist harness and susceptibility pads attached to the carpal region of the hand. Two healthy men and two healthy women were scanned using the imaging protocol, demonstrating feasibility. Measurement of the point-wise Euclidean distance for the bones during motion was used to generate displacement and velocity maps for the individual bones. For morphometric analysis, the shapes of the bones of the thumb CMC joint were obtained from a publicly-available database [2] for women (n=10) and men (n=10) without HOA and were analyzed using spectral theory and registration-based morphometry. The shape analysis approach was made independent of scale and bone orientation.

RESULTS. The displacement and velocity maps enabled a comparison of thumb CMC joint motion based on sex. Comparisons based on morphometric analysis for the 10 healthy men and 10 healthy women showed statistically significant shape differences (p<0.05) between the sexes for the trapezium and the first metacarpal bones.

DISCUSSION. The imaging approaches developed here showed promise for enabling comparisons of thumb CMC joint motion and bone shape based on sex. Our future work will validate the imaging approaches and start to determine if the derived imaging metrics correlate with HOA risk.

Acknowledgements. This work was funded by the NIH K12HD051958 grant.


COI. No conflicts of interests.

Note. Some contents of this abstract will be presented at the Annual BIRCWH Scholars Meeting at the NIH, Bethesda, MA on Wednesday, October 23, 2013.
The IYRS School of Technology & Trades is a world-class experiential school with a core education model dedicated to teaching highly technical and deeply craft-oriented career skills. IYRS currently has three accredited schools: School of Boatbuilding & Restoration, School of Marine Systems, and School of Composites Technology. With campuses in Newport and Bristol, RI, IYRS offers an extraordinarily attractive location to study.

Located in a coastal region with a history of forward thinking, innovation, and educational institutions, the school has not only become known for training fine craftsmen and technicians, but it has also become a destination stop, enjoyed by the public. Its doors are open to all who want to see how craftsmen train and how the history of making and building things has evolved. IYRS is home to an important array of projects—from the cutting edge to restoration, many accompanied by exhibits and tours.

IYRS is a registered 501 (c) (3) non-profit educational organization with federal tax identification of 05-0470320. There are many ways to support IYRS and the education of an IYRS student. IYRS accepts gifts online, by mail, or via alternate arrangements coordinated through the Development Department. Learn more about the IYRS School of Technology & Trades at http://www.iyrs.edu/.
<table>
<thead>
<tr>
<th>Time</th>
<th>Thursday, Oct 24</th>
<th>Friday, Oct 25</th>
<th>Saturday, Oct 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00–6:00 PM</td>
<td>Registration</td>
<td>Registration &amp; Breakfast</td>
<td>Breakfast</td>
</tr>
<tr>
<td>(Tea Room)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:30–7:00 PM</td>
<td>Welcome Reception</td>
<td>Opening Remarks</td>
<td></td>
</tr>
<tr>
<td>(Colonnade Room)</td>
<td></td>
<td>Workshop Session 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A. Hoang-Kim</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M. Marks</td>
<td></td>
</tr>
<tr>
<td>8:00–8:10 PM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Salon C)</td>
<td></td>
<td>Keynote</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>David Felson, MD, MPH</td>
<td></td>
</tr>
<tr>
<td>8:10–9:00 PM</td>
<td></td>
<td>Session I</td>
<td></td>
</tr>
<tr>
<td>(Salon C)</td>
<td></td>
<td>P1 - J.J. Crisco</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - A.L. Ladd</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - K. Zhao</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - J.M. Wolf</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P5 - F.J. Valero-Cuevas</td>
<td></td>
</tr>
<tr>
<td>9:00–10:00 PM</td>
<td></td>
<td>Session I</td>
<td></td>
</tr>
<tr>
<td>(Salon C)</td>
<td></td>
<td>P1 - H.S. Gong</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - A.L. Ladd</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - M.T.Y. Schneider</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - F. Stockmans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P5 - S. Van Nortwick</td>
<td></td>
</tr>
<tr>
<td>10:00–10:30 PM</td>
<td></td>
<td>Break &amp; Visit Exhibitors</td>
<td></td>
</tr>
<tr>
<td>(Salon D/E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Keynote</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calley Orr, PhD</td>
<td></td>
</tr>
<tr>
<td>10:30–11:20 PM</td>
<td></td>
<td>Session I</td>
<td></td>
</tr>
<tr>
<td>(Salon C)</td>
<td></td>
<td>P1 - J.J. Faillace</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - N. Gillham</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - N. Gillham</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - J.L. Orbay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P5 - E. Halilaj</td>
<td></td>
</tr>
<tr>
<td>11:20–11:40 PM</td>
<td></td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11:40–11:50 PM</td>
<td></td>
<td>Break &amp; Visit Exhibitors</td>
<td></td>
</tr>
<tr>
<td>(Salon D/E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00–1:00 PM</td>
<td></td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>1:00–2:00 PM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Bellevue Room)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:00–2:50 PM</td>
<td></td>
<td>Session III</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1 - F. Stockmans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - A. Siddiqui</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - A. Siddiqui</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - M.J.P.F. Ritt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P5 - S.W. Wolfe</td>
<td></td>
</tr>
<tr>
<td>2:50–3:10 PM</td>
<td></td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>3:10–3:30 PM</td>
<td></td>
<td>Break &amp; Visit Exhibitors</td>
<td></td>
</tr>
<tr>
<td>3:30–4:10 PM</td>
<td></td>
<td>Session IV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1 - J. L. DelSignore</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - M.S. Moneim</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - M.D. Putnam</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - E.E. Vereecke</td>
<td></td>
</tr>
<tr>
<td>4:10–4:30 PM</td>
<td></td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>4:30–4:50 PM</td>
<td></td>
<td>Break &amp; Visit Exhibitors</td>
<td></td>
</tr>
<tr>
<td>4:50–5:30 PM</td>
<td></td>
<td>Session V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1 - J. L. DelSignore</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 - M.S. Moneim</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 - M.D. Putnam</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P4 - E.E. Vereecke</td>
<td></td>
</tr>
<tr>
<td>5:30–5:50 PM</td>
<td></td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjourn</td>
<td></td>
</tr>
<tr>
<td>6:30–10:00 PM</td>
<td></td>
<td>Lobster and Clam Bake Banquet</td>
<td></td>
</tr>
<tr>
<td>(IYRS*)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*See Inside Cover</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>