

Titanium implants induce expression of matrix metalloproteinases in bone during osseointegration

Veronica I. Shubayev, MD; Rickard Brånemark, MD, PhD;
Joanne Steinauer, BS; Robert R. Myers, PhD

Purpose of the Work. Osseointegration is a surgical and material science that allows for direct attachment of prosthetic devices to the skeleton. Its application in the dental sciences is the state-of-the-art technique for the edentulous jaw. Its current application in orthopedics is focused on the patient with difficult above-knee amputations, where the technique is used to attach a lower-limb prosthetic device to the femur. Patients characterize the use of this prosthesis as life-changing because it is more comfortable than the traditional socket prosthesis and permits increased mobility and perception. **Subjects and Procedures.** In this study, we used a rodent femur model of intramedullary osseointegration to analyze the changes in the immunoreactivity of extracellular matrix (ECM)-controlling matrix metalloproteinases (MMPs), the tissue inhibitor of metalloproteinase-3 (TIMP-3), and the tumor necrosis factor alpha (TNF- α) during osseointegration. **Results.** We observed dramatic increases for MMP-2, MMP-9, MMP-7, TIMP-3, and TNF- α in osteocytes, osteoclasts, haversian canals, and in the interface matrix in bone ipsilateral to the titanium implant. An increase in TIMP-3, MMP-9, and MMP-7 in hypertrophied chondrocytes and the vascular component of the epiphyseal growth plate was also observed in experimental bone. **Relevance to the Veteran Population.** As we bring this technology to the Department of Veterans Affairs patient population from Sweden, we are continuing to study the basic phenomenon of osseointegration at the molecular level to better understand the unique relationship of the titanium implant to living bone. This insight into bone biology will help define the patient selection criteria, and this will enhance the success of the technique. Understanding the role of MMPs in the process of osseointegration is a premier example of the importance of basic science that supports clinical medicine.

Veronica I. Shubayev, MD

Effectiveness of insoles on plantar pressure redistribution

Bonnie Yuk San Tsung, MPhil; Ming Zhang, PhD; Arthur Fuk Tat Mak, PhD; Margaret Wan Nar Wong, FRCS

Purpose of the Work. For this study, we quantified the effects of insole contours on the plantar pressure distribution. **Subjects and Procedures.** Three weight-bearing casting conditions—unloaded, semi-weight-bearing, and full-weight-bearing—were applied to custom-made insoles for both feet of eight normal and six diabetic participants. We measured and compared the plantar pressure distribution of five different support conditions, including shoe-only, flat insole, and three contoured insoles for the whole foot and for selected regions. **Results.** We found significantly different pressure distribution patterns among different support conditions. **Relevance to the Veteran Population.** Knowledge of the effect of insole contours on the pressure distribution pattern can offer guidance for better design and construction of functional insole.

Bonnie Yuk San Tsung, MPhil

Finite-element analysis to determine effect of monolimb flexibility on structural strength and interaction between residual limb and prosthetic socket

Winson C. C. Lee, BSc; Ming Zhang, PhD;
David A. Boone, CP, BS, MPH;
Bill Contoyannis, MEngSc

Purpose of the Work. The monolimb, a monolithic socket-shank endoskeletal prosthesis made of thermoplastic, is an alternative to relatively high-cost prosthetic components to offer flexibility to the prosthesis. This study investigated, using finite-element (FE) analysis, the effect of changes in shank design on the flexibility and structural integrity of monolimbs and the stress distribution at the prosthetic socket-residual limb interface. **Subjects and Procedures.** We developed a three-dimensional FE model to study the structural behavior of monolimbs and interactions between the socket and the residual limb. The FE model was based on the geometries of the bones and residual-limb surface obtained by magnetic resonance imaging on a participating amputee subject and the monolimb obtained from a prosthetic computer-aided design system. Monolimbs with

different shank geometries were analyzed. Loading and boundary conditions were applied according to previous gait analysis. The residual limb and socket were modeled as two separate structures, and their interaction was simulated with the use of automated contact methods. **Results.** The von Mises stress distribution within the monolimbs with different shank designs is reported, and possible failure of the prosthesis is predicted with the use of distortion energy theory. Reducing the anteroposterior dimension of the shank led to an increase in shank flexibility and von Mises stresses. As the shank flexibility increases, socket-limb interface stresses decrease. **Relevance to the Veteran Population.** The von Mises stress distribution within the monolimb and the prediction of possible failure are invaluable for further monolimb design and optimization. The reduction of stresses at the socket-limb interface when a more flexible shank is used suggests that the flexible shank is preferable, giving amputees better comfort.

Ming Zhang, PhD

Effects of stimulation pattern on electrical stimulation-induced leg cycling performance

Thomas W. J. Janssen, PhD, FACSM;
Maaïke Bakker, MSc; Annick Wyngaert, MSc;
Karin (H. L.) Gerrits, PhD; Arnold de Haan, PhD

Purpose of the Work. This study evaluated whether an electrical stimulation-induced leg cycling (ES-LC) pattern with a catchlike-inducing pulse train increased force production and hence cycling performance. **Subjects and Procedures.** Five men with complete spinal cord injury (SCI) performed several cycling sessions on a computer-controlled cycle ergometer using different stimulation patterns: (1) the standard pattern with ramp modulation, (2) a similar pattern but without ramp modulation, (3) a pattern without ramp modulation but with an initial doublet, and (4) a pattern with a middle doublet. **Results.** None of the experimental stimulation patterns resulted in a significantly improved cycling performance compared with the standard pattern. The only advantageous effect was that during the first 3 min of cycling, the current amplitude was significantly higher with the standard stimulation, suggesting that stimulation without ramp modulation, either with or without a doublet, produces more force at the same submaximal current amplitude. The results do not indicate that stimulation with catchlike-inducing trains with the current parameter settings can improve ES-LC performance. However, the lower

current amplitude during the first few minutes of exercise suggests that further research may be more successful in finding stimulation patterns that can improve cycling performance. **Relevance to the Veteran Population.** ES-LC can benefit individuals with SCI, but cycling performance is often limited because of rapid fatigue of the stimulated muscles. A need exists to improve the cycling technique to enhance exercise effects and optimize health benefits.

Thomas W. J. Janssen, PhD, FACSM

Using wavelet analysis to characterize the thermoregulatory mechanisms of sacral skin blood flow

Mary Jo Geyer, PhD, PT; Yih-Kuen Jan, PhD, PT;
David M. Brienza, PhD; Michael L. Boninger, MD

Purpose of the Work. Our long-term aim is to gain a more complete understanding of the physiological mechanisms controlling skin blood flow responses to tissue loading. For a determination of loading parameters that enhance perfusion and improve tissue viability in tissue at risk for injury, the physiological, biomechanical, and biochemical responses to mechanical deformation must be quantified and their relative significance determined. Wavelet analysis of blood flow has potential for use in quantifying such control mechanisms. **Subjects and Procedures.** The skin over the sacrum, the most common site for pressure ulcer development, was heated from 35 °C to 45 °C at a rate of 1 °C per minute in 10 unimpaired subjects. We used time-frequency analysis (wavelet transform method) to decompose the blood flow signal recorded during baseline, heating and recovery periods into five characteristic frequency bands associated with specific physiological control mechanisms. The transforms were then normalized to the total power for each period to reveal the relative contributions of each characteristic frequency band to the increase in total blood flow. **Results.** Compared to baseline, the relative contribution of the metabolic frequency band increased while the myogenic frequency band decreased. Thus, wavelet transform analysis successfully differentiated the effects of heating from baseline and recovery conditions. **Relevance to the Veteran Population.** The veteran population has a high prevalence of pressure ulcers (spinal cord injured and elderly), and a more complete understanding of skin blood flow control mechanisms could be used to improve pressure ulcer prevention and treatment interventions.

Mary Jo Geyer, PhD, PT

Response of sagittal plane gait kinematics to weight-supported treadmill training and functional neuromuscular stimulation following stroke

Janis J. Daly, PhD, MS; Kristen L. Roenigk, BME; Kristen M. Butler, MSPT; Jennifer L. Gansen, MSPT; Eric Fredrickson, MD; E. Byron Marsolais, MD, PhD; Jean Rogers, PT; Robert L. Ruff, MD, PhD

Purpose of the Work. Conventional rehabilitation fails to restore normal walking and mobility to many veterans following stroke. Persistent swing phase limb flexion deficits after stroke can cause falls and compromised walking endurance. The long-term goal of the work is to restore voluntary motor control and voluntary gait. This research study tested the benefits of two promising treatments: (1) body-weight-supported treadmill training (BWSTT) and (2) a combination of functional neuromuscular stimulation (FNS) with intramuscular (IM) electrodes (FNS-IM). **Subjects and Procedures.** Sixteen subjects (>12 months poststroke) were enrolled in the study and assigned to one of the two treatment groups. Both groups received 90 min of exercise and gait training four times per week for 12 weeks. Both groups received the following treatment procedures: strengthening and coordination training, over-ground gait training, and BWSTT. Group 2 also used FNS-IM-assisted knee and ankle flexor exercise and gait training. Benefits were assessed with measurements of gait kinematics for the swing phase of gait. **Results.** Group 1 (no FNS) had no improvements. Group 2 (FNS-IM) had significant improvements in peak swing knee flexion and mid-swing ankle dorsiflexion. **Relevance to the Veteran Population.** Improvement in sagittal plane gait kinematics can mean a safer gait with fewer falls and greater walking endurance with more functional mobility.

Janis J. Daly, PhD, MS

Comparison of interface pressures with pin and suction suspension systems

Tracy L. Beil, MS; Glenn M. Street, PhD

Purpose of the Work. Clinicians are questioning the use of pin liner systems because of the high incidence of skin problems seen at the distal end of the residual limb. This is sometimes referred to as the “pin liner effect.” We wanted to compare the pressures applied to the residual limb with pin and suction suspension systems to gain insight as to what is causing these skin issues. **Subjects**

and Procedures. Eight transtibial amputees walked while interface pressures were recorded. Each subject performed three walking trials with the pin and suction suspension systems. **Results.** During the swing phase of walking, the pin system compressed (avg.: 6.7 kPa) the residual limb proximally to a greater extent than the suction system (avg.: 1.1 kPa). The pin system also had significantly higher peak suction at the distal end (−39.5 vs. −26.1 kPa), as compared to the suction system. The combination of simultaneous proximal squeezing and distal suctioning of the limb is likely due to the elongation of the pin liner. **Relevance to the Veteran Population.** A large proportion of amputees use the pin liner for suspension of the prosthetic limb. Walking with the pin liner likely causes a disturbance in circulation within the residual limb, which results in daily and chronic skin changes. Despite its ease of use, a pin suspension system might not be appropriate for an active amputee or those with circulatory complications.

Tracy L. Beil, MS

The effect of walking speed on center of mass displacement

Michael S. Orendurff, MS; Ava D. Segal, BAS; Glenn K. Klute, PhD; Jocelyn S. Berge, MS; Eric S. Rohr, MS; Nancy J. Kadel, MD

Purpose of the Work. Physicians are often taught to examine whole-body movements to evaluate the impact of a specific limb or joint limitation on overall functional mobility. Center of mass (COM) motion may help connect technical clinical outcomes, such as improved joint range of motion to functional mobility outcomes such as reduced falls, faster gait speed, or increased independence. This paper describes the effect of walking speed on COM excursion in both the vertical and lateral directions. **Subjects and Procedures.** Ten normal subjects walked at their self-selected speed and then at 0.7, 1.0, 1.2, and 1.6 m/s in random order. COM location was calculated from a 15-segment, full-body kinematic model with the use of segmental analysis. **Results.** Mediolateral COM displacement was 6.99 ± 1.34 cm at the slowest walking speed and decreased to 3.85 ± 1.41 cm at the fastest speed ($p < 0.05$). Vertical COM excursion increased from 2.74 ± 0.52 at the slowest speed to 4.83 ± 0.92 at the fastest speed ($p < 0.05$). The data suggest that the relationship between the vertical and mediolateral COM excursions changes substantially with walking speed. **Relevance to**

the Veteran Population. Veterans with gait pathologies often walk slower than normal and understanding the lateral stability challenges may improve assessment and treatment choices.

Michael S. Orendurff, MS

Qualitative profiles of disability

Roberta Annicchiarico, MD, PhD;
Karina Gibert, PhD, Associate Professor;
Ulises Cortés, PhD, Associate Professor;
Fabio Campana, MD, PhD;
Carlo Caltagirone, MD, Professor

Purpose of the Work. This study identifies profiles of disability on the basis of functional problems, paralleled by increasing levels of disability. **Subjects and Procedures.** We used the World Health Organization Disability Assessment Schedule II (WHODAS II) to assess 96 subjects. Seventy-six were neurological patients, aged 18 to 80 yr, recovering at the IRCCS (Istituto di Ricovero e Cura a Carattere Scientifico) S. Lucia rehabilitation hospital in Rome, Italy. They included 20 spinal cord injury patients (aged 47.20 ± 17.6 standard deviation [SD]), 20 Parkinson disease patients (69.25 ± 6.53), 20 stroke patients (63.40 ± 15.96), and 16 depressed patients (46.56 ± 11.15). The control group included 20 subjects. Clustering Based on Rules (CIBR) (a hybrid technique of Statistics and Artificial Intelligence) was used in the analysis. **Results.** Four groups of subjects with different profiles of functional disability, were ordered according to an increasing degree of disability: "Low," self-dependent subjects, with no physical or emotional problems; "Intermediate I," subjects with low/moderate physical and emotional disability, with high perception of disability; "Intermediate II," subjects with moderate/severe disability concerning only physical problems related to self-dependency, without emotional problems; "High," subjects with highest degree of disability, both physical and emotional. The order of the four classes is paralleled by a significant difference (<0.001) in the standardized global score. **Relevance to the Veteran Population.** The use of CIBR, allowing the integration of clinical knowledge in the analysis, proposes a new taxonomy to improve the knowledge of functional disability. This result represents a significant step in the definition of a qualitatively homogeneous group of disabled patients (neurological patients and older adults) who can be treated by standardized rehabilitative procedures.

Roberta Annicchiarico, MD, PhD

Analyses of male residents in community nursing facilities: Comparisons of Veterans Health Administration residents to other residents

Robert J. Buchanan, PhD; Christopher Johnson, PhD;
Suojin Wang, PhD; Diane C. Cowper, MA;
Myung Suk Kim, MS; Dean Reker, PhD, RN

Purpose of the Work. This study describes health conditions, the use of health services, and personal characteristics of veterans in community nursing homes. It compares male Veterans Health Administration (VHA) residents admitted to community nursing homes to other male residents admitted to these facilities during the year 2000. **Subjects and Procedures.** All male VHA residents (7,926) in community nursing facilities were compared to all other male residents (159,203) in community nursing facilities who had admission assessments recorded in the Minimum Data Set during 2000. **Results.** Significant differences were found in the demographic and clinical characteristics of male VHA residents when compared to other male residents in community nursing homes. In particular, male VHA residents received much less physical, occupational, respiratory, speech, and psychological therapies in community nursing homes compared to their other male counterparts. **Relevance to the Veteran Population.** The differences in demographic and clinical characteristics described in this study provide important preliminary research to more accurately analyze the quality of nursing home care provided to veterans in the future.

Robert J. Buchanan, PhD

Predicting oxygen uptake in older adults using lower-limb accelerometer measures

L. Jerome Brandon, PhD; David A. Ross, MSEE, MEd;
Jon A. Sanford, MArch; Adrienne Lloyd, MEd

Purpose of the Work. This study developed prediction equations to estimate oxygen uptake and, subsequently, physical activity participation by older adults based on lower-limb movements as measured by an accelerometer. These equations will be the basis for development of a physical activity monitor for this cohort. **Subjects and Procedures.** Sixty-eight older community-dwelling ambulatory adults (37 males and 31 females) between 61 and 89 years old completed a protocol that included a 7-minute walk on a treadmill and a climbing test on a Stairmaster ergometer. The older adults were measured for volume of oxygen uptake, heart rate, and ventilation while performing

the exercises. **Results.** Physical activity levels can be effectively predicted in older adults with the use of accelerometers on lower-limb sites. Prediction equations for older adults, based on lower-limb placements, are better when task-specific equations are developed. Better predictions are obtained for walking when the accelerometer is placed on either the heel or mid-ankle and the vertical axis is selected. The best prediction equation for climbing is obtained on the lateral ankle from the horizontal axis. **Relevance to the Veteran Population.** Devices can be developed that effectively monitor the physical activity of older veterans. This is important because physical activity has been shown to help prolong independence, reduce the risks of developing cardiovascular diseases, and extend the retention of functional skills. Additionally, physically active persons over 40 years old reported fewer functional limitations than unfit or sedentary individuals. Participation in physical activity can greatly increase the quality of life for older veterans.

L. Jerome Brandon, PhD

**Computer-automated tinnitus assessment
using patient control of stimulus parameters**

James A. Henry, PhD; Betsy Rheinsburg, MS;
Roger M. Ellingson, MSCSE

Purpose of the Work. Although tinnitus is increasing as a major health problem, techniques to quantify the percep-

tual aspects of the disorder are nonstandardized. Our overall objective is to develop and document clinical methodology for accurate and reliable quantification of tinnitus. This study describes new automated testing procedures for rapidly evaluating tinnitus loudness and pitch. **Subjects and Procedures.** We developed hardware and software to enable subject control of the loudness and pitch of pure tones presented during tinnitus loudness- and pitch-matching. Forty subjects with chronic tinnitus were each tested repeatedly over two sessions with the new automated system. **Results.** Results of testing were compared to results obtained with previous versions of the system. Only slight decrements in response reliability were noted with the new system, in spite of the new protocol that was designed primarily to reduce testing time. Obtaining measures of hearing thresholds and loudness matches at 13 test frequencies and 5 repeated pitch matches requires an average of 19 minutes with the new system. **Relevance to the Veteran Population.** Whether a veteran is claiming tinnitus as a disability or is seeking treatment at 1 of the 132 Department of Veterans Affairs (VA) audiology clinics, standardized assessment of tinnitus is essential so that the perceptual attributes of the disorder can be quantified. Further development of the automated system is ongoing with the primary objective of providing a standardized tinnitus measurement technique to all VA audiology clinics.

James A. Henry, PhD

