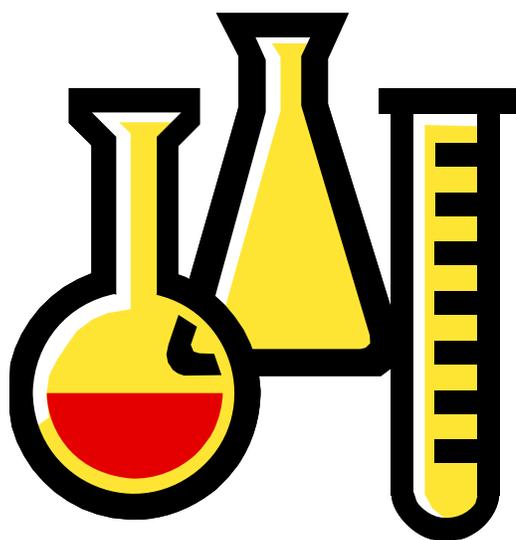


THE OHIO STATE UNIVERSITY

34th Annual
Mallory-Coleman
Resident Research Day



Friday, April 7, 2006
7:30 am

Blackwell Hotel
OSU Campus

PROGRAM

- 7:45 am Welcome and Introduction
- 8:00 am Damon Adamany, M.D.
“Ten To Fourteen Year Follow-Up of the S-Rom Hip Prosthesis”
- 8:15 am Jason Glover, D.P.M.
“Proximal Metatarsal Osteotomy in Hallux Valgus Correction: A Comparison of The Crescentic and Reverse Ludloff (Mau) Procedures”
- 8:30 am Akikazu Ishihara, D.V.M.
“Acceleration of Fracture Healing With Adenovirally Transduced Human BMP-2 and -6 Genes in Horse Metatarsal Osteotomy and Ostectomy Models”
- 8:45 am Bryan Chambers, M.D.
Persistence of Bacteria on Materials Used in Articulating Spacers For Treatment of Infected Total Knee Arthroplasty”
- 9:00 am Isaac Meta, D.D.S.
“Evidence of Genetic Control of Intrinsic Bone Tissue Quality in the Mouse Mandible”
- 9:15 am Maureen Maciel, M.D.
“Management of Stable Type I Open Fractures in Children Without Operative Treatment”
- 9:30 am Break
- 9:45 am Shelly Bowers, D.P.M.
“The Effects of Low-Dye Strapping on the Radiographic Parameters of the Foot”
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- 10:00 am Bret Powers, D.O.
"Tibialis Tendon Allografts in ACL Reconstruction: An Analysis of Failure Rates in Tissue Banks and Patient Demographics"
- 10:15 am Terri Zachos, D.V.M., Ph.D.
"Mesenchymal Stem Cell-Mediated Gene Delivery of Bone Morphogenetic Protein-2 In An Articular Fracture Model"
- 10:30 am Greg Bellisari, M.D.
"Mechanical Evaluation of Crosspins Used for Femoral Fixation of Hamstring Grafts in Anterior Cruciate Ligament Reconstructions"
- 10:45 am David Galluch, M.D.
"Tibialis Anterior Allograft vs. Hamstring Autograft Outcomes for ACL Reconstruction at Two Years Follow-Up"
- 11:00 am Break
- 11:15 am Peter Stern, M.D., Visiting Professor and Moderator
"Current Management of Small Joint Injuries and Arthrosis In The Hand"
- 12:15 Lunch
- 1:00 pm End of Day
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MALLORY-COLEMAN DAY

Mallory-Coleman resident research day was established by Drs. Thomas Mallory and Carl Coleman in 1972 in memory of Katherine Virginia Mallory and Sally Jo Coleman.

This research day was established in order to encourage the development of ideas related to research in orthopaedic surgery and related basic sciences.

Each year, a distinguished visiting professor from an outside institution is invited to moderate and analyze the resident presentations and provide constructive criticism and commentary.

Past Visiting Professors:

- 2005 James Goulet, M.D.
- 2004 Steven Arnoczky, D.V.M.
- 2003 Joseph Buckwalter, M.D.
- 2002 Victor Goldberg, M.D.
- 2001 James Urbaniak, M.D.
- 2000 Douglas Jackson, M.D.
- 1999 Douglas Dennis, MD
- 1998 Thomas Einhorn, MD
- 1997 Larry S. Matthews, MD
- 1996 Gary Friedlander, MD
- 1995 James Herndon, MD
- 1994 Clement B. Sledge, MD
- 1993 Eric L. Radin, MD

2006 MALLORY-COLEMAN VISITING PROFESSOR AND MODERATOR:

PETER STERN, M.D.



Dr. Stern is currently a Professor of Orthopaedic Surgery, Chair of the Department of Orthopaedics, and Surgeon-In-Chief at the University of Cincinnati, where he has been on the faculty since 1979. He also served as the Director of the Division of Hand Surgery for seven years. Dr. Stern graduated from Williams College in Massachusetts in 1966, then went on to Washington University School of Medicine in St.

Louis, where he received his medical degree. He completed a straight surgical internship and one year residency in surgery at Beth Israel Hospital in Boston and a residency in orthopaedics at the Harvard combined program. He then completed a fellowship in hand surgery with Dr. Harold Kleinert in Louisville, Kentucky.

He currently serves on the Orthopaedic Residency Review Committee of the ACGME as well as the nominating committee of the AAOS. Other positions in organizations include membership in the examination committee of the American Board of Orthopaedic Surgery, the journal committee of the American Society for Surgery of the Hand, and the secretarial position of the American Foundation for Surgery of the Hand. Past positions include President of the ABOS, Vice Chairman for the Orthopaedic RRC, president of the American Society for Surgery of the Hand, Research Grant Committee Chairman for the American Association for Hand Surgery, Chairman of the American Society for Surgery of the Hand, and Board of Trustees member of the Orthopaedic Research and Education Foundation.

Dr. Stern has published over one hundred articles in peer reviewed scientific journals and over twenty book chapters. He has also been an invited visiting professor over forty times at various orthopaedic programs around the world and has given over twenty endowed lectureships. He has also served numerous times as a national course chairman and co-chairman and has been a Presidential Guest Lecturer.

Dr. Stern is also very active in resident and fellow education. He is actively involved in Mary S. Stern hand fellowship at the University of Cincinnati which has trained thirty-two residents since its inception. He is also a five time recipient of the University of Cincinnati Resident Appreciation Award.



*Damon Adamany,
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TEN TO FOURTEEN YEAR FOLLOW-UP OF THE S-ROM HIP PROSTHESIS

Authors: Damon Adamany, M.D., Joel Politi, M.D., Walter Hauser, M.D.
Presenter: Damon Adamany, M.D.

Introduction: Many of the early cementless femoral hip prostheses showed disappointing results. Because of this, implant designers attempted to match the various anatomic shapes of femora and designed modular implants. The purpose of this study was to retrospectively evaluate the clinical and radiographic results of the S-ROM modular femoral component at 10 to 14 year follow-up.

Methods: A total of 55 SROM femoral components were placed in 45 patients by the senior author between 1990 and 1995. Twelve patients (15 hips) were lost to follow-up. Survivorship of the hip prosthesis was determined in the remaining 33 patients (40 hips). Two of the patients were deceased, but their next of kin provided survivorship information. Failure was defined as revision surgery of the hip for any reason. The remaining 31 patients were available for clinical examinations by an independent evaluator. Harris hip scores and radiographic analyses were performed for these patients.

Results: Thirty-four hips were performed in a primary fashion. For primary total hip arthroplasty, there was 100% survivorship for aseptic loosening. The average duration of follow-up was 12 years and 3 months. Six hips were performed in a revision fashion. One of the 6 hips in this group underwent revision surgery. The average Harris Hip score was 87.

Conclusions: The results of this study show excellent long term follow-up of the S-ROM cementless hip prosthesis at 10 to 14 years.



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PROXIMAL METATARSAL OSTEOTOMY IN HALLUX VALGUS CORRECTION: A COMPARISON OF THE CRESCENTIC AND REVERSE LUDLOFF (MAU) PROCEDURES

Authors: Jason Glover, DPM, Christopher Hyer, DPM, Gregory Berlet, MD, Terrence Philbin, MD, Thomas Lee, M.D
Presenter: Jason Glover, DPM

In our retrospective study, we compared the results of the crescentic and Mau (reverse Ludloff) osteotomies of the first metatarsal in the treatment of hallux valgus. Historically, the crescentic osteotomy has been associated with dorsiflexion and shortening of the metatarsal which pre-disposes the patient to new transfer lesions or persistence of existing lesions. The Mau and Ludloff osteotomies have superior stability when compared to other proximal procedures in sawbones. **Methods:** We reviewed the results of thirty-four total cases of moderate to severe hallux valgus deformities corrected with the crescentic and Mau osteotomies of the first metatarsal combined with a distal soft-tissue procedure. **Results:** Follow-up was possible in thirty-four cases. There were ten cases in the crescentic group with an average follow-up 104.6 days and twenty-four cases in the Mau group with an average follow-up of 118 days. Pre-operatively, the mean first intermetatarsal and hallux valgus angles in the crescentic group were 17.5° and 35.4° respectively and 15.8° and 31.3° respectively in the Mau group. Post-operatively, the average change of the IM and HV angles were 5.80 ± 3.99° and 16.50 ± 8.77° in the crescentic group and 5.83 ± 2.58° and 16.79 ± 8.66° in the Mau group with no statistical significance. Complications included elevation (7,2), non-union (5,1), revision surgery (0,2), hallux varus (0,1), hardware into the tarso-metatarsal joint (3,0), and transfer lesions (1,0). In the crescentic group, 60% experienced complications whereas only 37.5% in the Mau group had complications (p=0.276). Significant differences between the crescentic and Mau groups were with respect to elevation (70% vs. 8.3%, p=0.001), transarticular hardware in the tarso-metatarsal joint (30% vs. 0%, p=0.02), and non-union (50% vs. 4.2%, p=0.006). **Conclusions:** The use of the Mau osteotomy resulted in good correction of the first intermetatarsal angle in patients with moderate to severe hallux valgus. The amount of correction obtained is lower than reported in literature and could be a result of undercorrection or recurrence in each group. Although, the Mau osteotomy avoided complications associated with the crescentic osteotomy.



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ACCELERATION OF FRACTURE HEALLING WITH ADENOVIRALLY TRANSDUCED HUMAN BMP-2 AND-6 GENES IN HORSE METATARSAL OSTEOTOMY AND OSTECTOMY MODELS

Authors: Akikazu Ishihara, DVM, Alicia Bertone, DVM, Alan Litsky, MD, ScD, J.S. Matoon, DVM, Steven Weisbrode, DVM

Presenter: Akikazu Ishihara, DVM

Introduction

Treatment of delayed or nonunion fractures can be challenging. Bone morphogenetic protein-2 (BMP-2) is one of the most studied growth factors associated with bone healing, and successful induction of bone formation by BMP-2 has been demonstrated both in vitro and in vivo. The less investigated member of BMP family, BMP-6, currently received attention because it may contribute bone formation¹ by an alternative mechanism compared to other BMPs.² The delivery of BMP gene may induce more sustained and higher local concentration of therapeutic agent and provide growth factors in a more biological active form compared to administration of recombinant protein and has promoted bone formation in a rat model.³ Adenoviral vector (Ad) was chosen as the gene delivery vehicle due to its remarkable transduction efficiency, easy preparation of high titer virus, capability of infecting both dividing and non-dividing cells, and short duration of transgene expression which may be appropriate for gene augmentation at fracture sites. This study was to compare the efficacy of BMP-2 and -6 genes in an acceleration of bone healing using two different sizes of unstable fracture models. This is also the first study using a large animal (horse) as the model for fracture gene therapy application.

Materials and methods

Transverse osteotomy at fourth metatarsal bones (Mt4) and gap ostectomy at second metatarsal bones (Mt2) were surgically created in 12 horses (Fig1). Two weeks after surgery, bone defects in one hindlimb had direct injection of Ad-BMP-2 or Ad-BMP-6, and the defects in the contralateral limb had no treatment or marker vector (Ad-LacZ). Six weeks following the injection, the horses were euthanized and Mt4 and Mt2 specimens were harvested. Fracture healing was assessed by weekly radiographs, quantitative computed tomography, mechanical testing, and histology. Biosafety was assessed by physical examination, blood chemistry, and adenovirus serum neutralization titer.

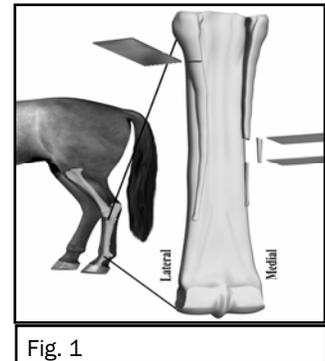


Fig. 1

Results

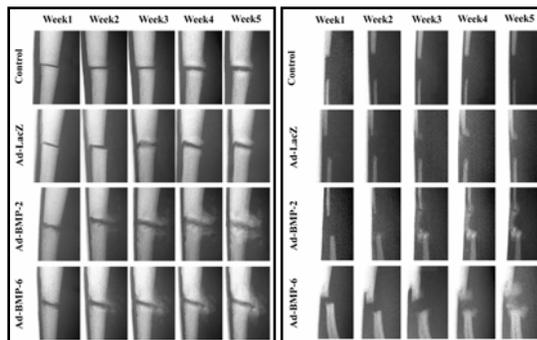


Fig2 - Mt4 (left) and Mt2 (right) bone defects at 1-wk to 5-wk

For both Mt4 osteotomy and Mt2 ostectomy models, rapid bone formation and a larger area of mineralization was observed radiographically within 2 weeks after injection (4 weeks after surgery) (Fig2) in the Ad-BMP-2 and Ad-BMP-6 treated osteotomies/ostectomies compared to the control or Ad-LacZ treated osteotomies/ostectomies. For Mt4 osteotomy model, the Ad-BMP-2 treated osteotomies had a significantly larger mineralization area than Ad-BMP-6 treated osteotomies at two weeks after injection. For both Mt4 osteotomy and Mt2 ostectomy

ACCELERATION OF FRACTURE HEALING WITH ADENOVIRALLY TRANSDUCED HUMAN BMP-2 AND-6 GENES IN HORSE METATARSAL OSTEOTOMY AND OSTEOTOMY MODELS, CONTD.

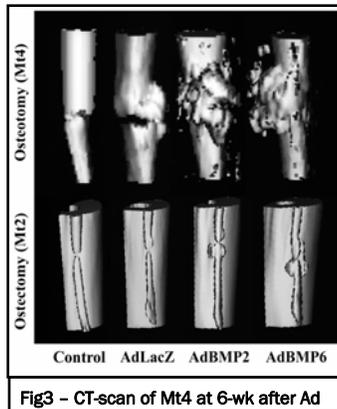


Fig3 - CT-scan of Mt4 at 6-wk after Ad

models, the cubic volume and ash density of formed bones were significantly greater in the Ad-BMP-2 and Ad-BMP-6 treated osteotomies/osteotomies compared to the control or Ad-LacZ treated osteotomies/osteotomies (Fig3). For Mt4 osteotomy model, all parameters of mechanical strength (failure torque, torsional stiffness, and energy absorbed to failure) were significantly greater in the Ad-BMP-2 and Ad-BMP-6 treated osteotomies compared to the control or Ad-LacZ treated osteotomies, which were 2- to 4-fold greater than control and not significantly different than the intact bones (Fig4). For both Mt4 osteotomy and Mt2 osteotomy models, histologic evaluation of bone defects showed that Ad-BMP-2 and -6 treated osteotomies had a larger and mature bony bridging and external callus formation. No signs of systemic infection were detected based on physical examination and blood chemistries. Serum neutralization antibody titer at six weeks after injection was significantly increased from the baseline (1 week before surgery) in both unilaterally and bilaterally injected horses.

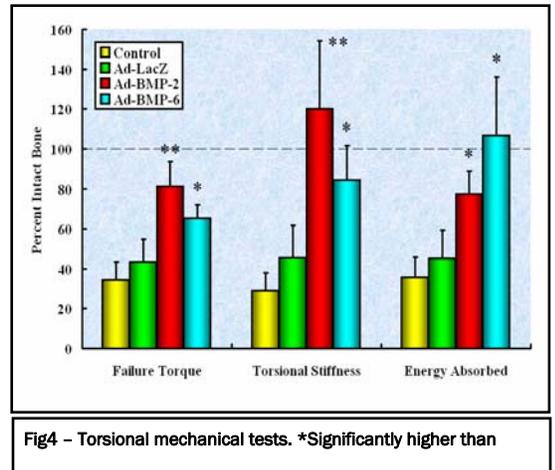


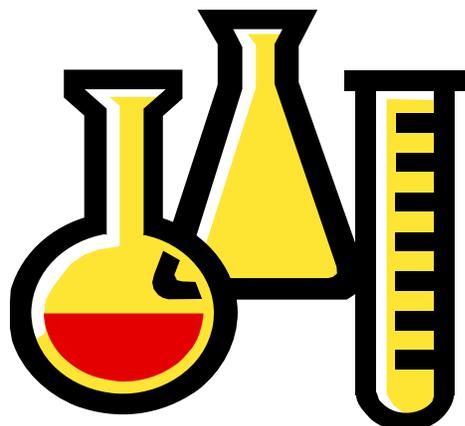
Fig4 - Torsional mechanical tests. *Significantly higher than

Discussion and Conclusion

Single percutaneous injection of adenovirus encoding BMP-2 or BMP-6 gene accelerated the healing of unstable fractures in a large animal model. Ad-BMP-2 treated bone defects had a greater structural integrity compared to Ad-BMP-6 treated defects. No adverse reactions were observed, but systemic antibody to Ad developed. Percutaneous AdBMP2 injection may accelerate fracture repair in horses and other species.

References

1. Bertone et al. J Orthop Res, 24:1261,2004.
2. Jane et al. Mol Ther 6:464,2002.
3. Betz et al. J Bone Joint Surg, 88:355,2006





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PERSISTENCE OF BACTERIA ON MATERIALS USED IN ARTICULATING SPACERS FOR TREATMENT OF INFECTED TOTAL KNEE ARTHROPLASTY

Authors: Bryan Chambers, MD, Richard Fankhauser, MD
Presenter: Bryan Chambers, MD

Background: The use of articulating temporary spacers for the staged treatment of infected total knee arthroplasty has become more frequent over the last decade. In addition to the use of antibiotic loaded acrylic cement, many surgeons are using metal femoral components and polyethylene tibial inserts. Our purpose was to investigate the in-vitro survival of typical knee infection pathogens on materials commonly used in articulating spacers.

Materials and Methods: We fashioned spacers using antibiotic loaded Palacos® with polyethylene and titanium imbedded into the surface of the cement discs. The spacers were then inoculated with methicillin sensitive staphylococcus aureus (MSSA), methicillin resistant staphylococcus aureus (MRSA), or staphylococcus epidermidis (SE) and placed in nutrient broth. Vancomycin was loaded into the cement for the MRSA group and tobramycin for the MSSA and SE groups. Control groups with only antibiotic cement were inoculated as well for comparison.

Results: In both the MSSA and MRSA groups, no organisms survived beyond 24 hours in the antibiotic bath; however, 83% of the samples inoculated with SE had viable bacteria at 96 hours. The group with only antibiotic cement had 13/15 specimens with viable SE at 96 hours, while the group with polyethylene and titanium had 12/15 specimens with viable SE.

Conclusion: Our in vitro model indicates that the addition of polyethylene and titanium to antibiotic loaded cement does not increase bacterial survival. Unexpectedly, 83% of SE isolates survived for 96 hours in the broth despite tobramycin levels far exceeding the minimum inhibitory concentration



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EVIDENCE OF GENETIC CONTROL OF INTRINSIC BONE TISSUE QUALITY IN THE MOUSE MANDIBLE

Authors: Isaac F. Meta, DDS, Sarandeep S. Huja, DDS
Presenter: Isaac Meta, DDS

The substantially high bone mineral density (BMD) of C3H/HeJ (C3H) compare to C57BL/6J (B6) mice makes these inbred strains extremely suitable to study genetic influences on skeletal phenotypes. Twin studies support that heritability accounts for 50 - 70% of BMD. We hypothesize that genetic factors determine the intrinsic bone tissue quality of the mandible. Mandibles were dissected from 17-week-old female C3H ($n=15$) and B6 ($n=15$) inbred mice. Immediately after dissection, a ~ 2-3 mm thin block located at the distal surface of the 3rd molar was obtained from each specimen. These blocks were stored in saline solution at -20 °C. One hour before mechanical testing, mandibular blocks were glued to a polycarbonate specimen holder. Each block was polished and sonicated. The polycarbonate holder containing the mandibular block was inserted into the receiving table of the indentation system (Nano-XP, MTS, Oakridge, TN). A set of indents were made on the mandibular bone at a rate of 10 nm/s and to a target depth of 500 nm as previously described. These indents were made on the cross sectional bone situated at the distal surface of the 3rd molar. Indentation modulus (E_i) and hardness (H) for each specimen were calculated as the average of total indents on each mandibular block. E_i and H were analyzed using Mann-Whitney test. E_i was significantly higher for C3H ($E_i = 22.90 \pm 2.214$ GPa, Mean \pm SD) compare to B6 ($E_i = 20.69 \pm 2.22$ GPa). The H was also higher in C3H mandibles ($H_{C3H} = 0.83 \pm 0.071$ GPa, $H_{B6} = 0.74 \pm 0.070$ GPa). Differences of ~ 10% in the E_i and ~ 12% in the H between groups suggest that the intrinsic tissue quality of the mandible is genetically determined. Genetic differences of the intrinsic tissue quality would lead to morphological skeletal distinctions among populations.



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MANAGEMENT OF STABLE TYPE I OPEN FRACTURES IN CHILDREN WITHOUT OPERATIVE TREATMENT

Authors: Maureen J. Maciel MD, Martin Torch, MD, Thomas Durbin, Nicholas Pirnia, Walter Truong, MD
Presenter: Maureen Maciel, MD

Type I fractures rarely require debridement of more than a 1-2mm border of skin from the wound edges coupled with hand powered irrigation with 1000 to 2000 cc of irrigating solution, this, along with fracture stabilization, is performed as a formal operative procedure in most centers. The purpose of this study is to determine the outcome of nonoperative treatment of stable Type I open fractures with respect to incidence of infection (e.g., cellulites and osteomyelitis), delayed and non-union, malunion, wound healing, length of hospital stay, and hospital cost.

We retrospectively examined the results of emergency room based treatment of Type I open fractures at our institution from of 1994 to 2004. All patients included in the study population underwent irrigation and debridement of their wounds as well as closed reduction and cast stabilization in the emergency room under conscious sedation. They were then admitted to the hospital for 48-72 hours of intravenous antibiotics, and then followed in the outpatient setting to evaluate wound healing and to confirm fracture union. Any patient taken to the operating room during the course of their initial admission was excluded from the study. We identified 110 patients who meet these study criteria from emergency room records. Efforts continue to obtain and review their outpatient records in order to determine the results of the nonoperative management of their fractures.

Fracture types excluded from the study population regardless of Gustillo grade include femur fractures, fractures of the hand and foot, segmental fractures, and fractures associated with gunshot wounds. Femur fractures are by definition high energy injuries in children. A true Gustillo type I femur fracture is therefore highly unlikely. Open fractures of the hand or foot are often complicated by unique infections and the wounds are typically dirtier than those of type I open fractures in other regions of the body. Thus, open fractures of the hand and foot behave differently than open fractures in other areas of the body and are not comparable for this study. The standard of care for gunshot wounds and their associated fractures is different than that for open fractures caused by trauma, secondary to the heat created by a high velocity bullet. Thus, these fractures also were excluded. Segmental fractures result from moderate to high energy mechanisms, and usually require surgical stabilization at some point. Additionally, polytrauma patients who were described as having "grade I" open fractures, were also excluded from the study. Polytraumatic injuries result from a high energy mechanisms, and thus the individual fracture can not be compared to grade I fractures that occur as isolated injuries. Also, these patients are hospitalized for longer periods of time, receive multi-team care, and often receive multiple antibiotics for greater than 72h.

We predict that our practice of nonoperative management of stable type I open fractures in children results in a rate of infection, and time to wound and fracture healing that are at least comparable to those reported for pediatric type I open fractures treated operatively. Additionally, the nonoperative approach may reduce the length of hospital stays, as well as the cost to both patients and healthcare institutions.



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THE EFFECTS OF LOW-DYE STRAPPING ON THE RADIOGRAPHIC PARAMETERS OF THE FOOT

Authors: Shelly Bowers, DPM, John Dawson, DPM, Alan Block, DPM
Presenter: Shelly Bowers, DPM

The purpose of this study was to determine whether low-dye strapping has any effect on specific radiographic measurements of the foot. There have been past studies examining the effectiveness of the low-dye strap, but no studies examining its effect on radiographic parameters.

This study compares certain angles from 7 pairs of feet with and without low-dye strapping applied. The primary author measured all the angles, blinded to which were strapped and unstrapped. The angles taken include lateral calcaneal inclination, lateral talo-1st metatarsal and AP 1st-metatarsal. These are the most common radiographic angles associated with examining for a pronated or pes valgus foot type, presumably the type of foot that would indicate a low-dye strap as treatment for heel and arch pain.

The results show no significant difference between the taped and untaped feet for the angles measured. Although there was some difference noted in the measurements, they were not statistically significant. This demonstrates that although this taping method may be effective in reducing painful symptoms of pronation, it cannot structurally correct the intrinsic bony position of the foot.



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TIBIALIS TENDON ALLOGRAFTS IN ACL RECONSTRUCTION: AN ANALYSIS OF FAILURE RATES IN TISSUE BANKS AND PATIENT DEMOGRAPHICS

Authors: Bret Powers, DO, Christopher Kaeding, MD, Eric Pifel, MD, Angela Pedroza, BS, Ryan Siegel, BS, ATC
Presenter: Bret Powers, DO

Advances in medical science and cell biology have allowed for allograft tissues to be used in over 750,000 patients annually. It is estimated that more than 100,000 anterior cruciate ligament (ACL) reconstructions are performed in the United States each year. Allograft tissue options continue to gain popularity in ACL reconstruction surgery. There are few studies which have looked at complication rates of soft tissue allografts in ACL surgery. This is a series of 236 patients receiving tibialis anterior or posterior allografts from two different tissue banks (Tissue Bank A, and Tissue Bank B) in ACL reconstruction. Retrospectively patients were evaluated for graft failure via telephone interview or clinic appointment with a minimum of 18 months of follow-up. Time to failure between the tissue banks, as well as, primary versus revision surgery were compared and were not statistically different ($p=0.420$ and $p=0.990$). The Cox Proportional Hazards model was used to evaluate what variables are important to predicting the time to failure. The tissue banks, primary vs. revision, donor age, patient sex, and patient age were all considered. Interestingly, we found that rate of failure decreases as age increases, showing that younger patients are more likely to fail no matter what tissue bank was used. Tibialis allografts are a viable option for ACL reconstruction. However, patient selection may be more important than previously expected.



Terri Zachos, D.V.M., Ph.D is an Assistant Professor of Orthopaedic Surgery at Michigan State University

MESENCHYMAL STEM CELL-MEDIATED GENE DELIVERY OF BONE MORPHOGENETIC PROTEIN-2 IN AN ARTICULAR FRACTURE MODEL

Authors: Terri A. Zachos, DVM, Steven E. Weisbrode, DVM. PhD,
Alicia L. Bertone, DVM, PhD

Presenter: Terri Zachos, DVM, PhD

Introduction: Approximately six million fractures occur yearly in the United States. Ten to 15% of these will become delayed or nonunions, resulting in prolonged pain and frequently surgery, increasing the monetary burden on the health care system. Articular fractures are particularly problematic. Gene therapy may represent a viable treatment option. The purpose of our study was to create a clinically relevant animal model of articular fracture healing, and to evaluate use of genetically modified bone marrow-derived mesenchymal stem cells (BMDMSC), to heal bone and cartilage. Our hypothesis was that BMDMSC genetically modified to express bone morphogenetic protein (BMP)-2, delivered in a three-dimensional alginate (ALG) matrix, would augment healing of bone and cartilage to the greatest extent, when compared with other delivery methods.

Methods: A recombinant human adenovirus was used as a vector to deliver the gene encoding BMP2 (AdBMP2) to BMDMSC from Lewis rats. Articular osteotomies of the distal femora were created in athymic nude rats. This study was approved by the Institutional Laboratory Animal Care and Use Committee (ILACUC) at The Ohio State University. Osteotomies were treated with BMDMSC, either wild-type (NoAd) or transduced with AdBMP2 or an adenoviral-luciferase reporter gene transgene construct (AdLuc). Cells were delivered in ALG or injected in saline. Controls were empty ALG, saline injections, and untreated osteotomies. Differentiation of BMDMSC *in vitro* was monitored in ALG constructs using real-time reverse transcriptase polymerase chain reaction (RT-PCR) to document changes in gene expression of aggrecan, type II collagen, type I collagen, and BMP2. Healing was compared using quantitative micro-computed tomography, fluorescent labeling, *in vivo* imaging of expression of luminescent reporter transgene products, and histology at day 14 following the treatments described above.

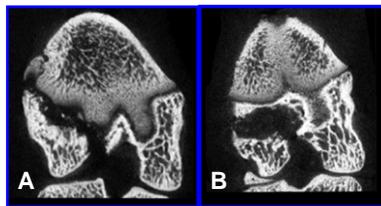


Figure 1. Coronal micro-CT images.

A. Untreated osteotomy.

B. AdBMP2x-BMDMSC/ALG

Results: Upregulation of aggrecan, type II collagen, type I collagen, and BMP2 gene expression were confirmed using real-time RT-PCR in BMDMSC transduced with AdBMP2 and suspended in ALG. Significant differences in osteotomy gap area ($p < 0.0001$) and gap volume ($p < 0.05$) were found. The AdBMP2x-BMDMSC/ALG group (**Fig. 1B**) had the greatest values for both parameters. In all ALG groups, bone healing was impeded by development of a cartilage mass. Untreated osteotomies (**Fig. 1A**), those treated with saline, and those treated with injections of wild-type BMDMSC in saline filled with fibrous tissue. Injection of AdBMP2-transduced BMDMSC in saline accelerated bone healing and induced a more biologic restoration of the joint surface than that seen with all other treatments and untreated controls.

Discussion: Injection of AdBMP2-transduced BMDMSC in saline accelerates bone healing in a rat model of articular fracture healing. A three-dimensional matrix is not necessary for delivery of genetically modified cells to an articular fracture, and prevented healing of bone and cartilage. Pending further study in immunocompetent animal models, injection of BMP2-expressing BMDMSC suspended in saline solution may be an effective, minimally invasive, treatment for complex articular fractures.



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Ohio State
University*

MECHANICAL EVALUATION OF CROSSPINS USED FOR FEMORAL FIXATION OF HAMSTRING GRAFTS IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTIONS

Authors: Greg Bellisari, MD, Christopher Kaeding, MD, Alan Litsky, MD, ScD

Presenter: Greg Bellisari, MD

INTRODUCTION Both bone-patellar tendon-bone and quadrupled hamstring tendon autografts are viable options for anterior cruciate ligament (ACL) reconstruction. With less harvest morbidity (1,2) and higher ultimate tensile load, the hamstring graft is becoming an increasingly popular choice (3,4). Secure graft fixation is vital to the success of the ACL reconstruction; the construct has to endure the stresses of daily activities and rehabilitation until the graft becomes biologically healed in bone tunnels (5). Graft fixation is usually the weakest link of ACL reconstructions (3). Crosspin femoral fixation has been shown to undergo less permanent elongation than other methods. The objectives of this study are a) to test the initial mechanical strength of four different crosspin products currently available for femoral fixation by loading each crosspin to failure, and b) to determine the effect of one million cycles of fatigue loading on the mechanical strength.

MATERIALS AND METHODS The crosspins used in our study are: the Arthrotek **Lactosorb**[®] (50mm long x 4mm diameter polylactic/polyglycolic acid copolymer (PLLA/PGA)), the Mitek **Rigid-Fix**[™] (42mm x 3.3mm polylactic acid (PLLA)), the Arthrotek **Bone Mulch Screw** (25mm x 10.5mm Ti6Al4V alloy which measures 2mm width where the pin was tested),* **cortical** allograft (50mm x 4mm freeze dried ethylene oxide sterilized bone), and a **control** group consisting of 3.2 mm (1/8") diameter stainless steel rod.



Crosspins tested (from left): Lactosorb[®], RigidFix[™], Bone Mulch Screw, Cortical Allograft, Control

Six (6) implants of each design were randomly tested in 3-point bending using a servohydraulic materials testing system [Bionix 858, MTS Systems, Eden Prairie, MN] across a 12 mm span supported by 6.3 mm diameter cylindrical supports, and centrally loaded in a linear ramp at 1 mm/min until fracture or 1.5 mm central deformation. Load and deformation were continually recorded. Yield load, load at 1.5 mm deformation, and structural stiffness were compared across the different designs using an ANOVA and post-hoc analysis.

Three-point fatigue testing is underway; cyclic loads of 50 to 200 N are applied at 10 Hz for one million cycles followed by 3-point bending to failure as described above if the implant has not previously failed. Two hundred Newtons is representative of the literature values for ACL tension in normal walking. Five hundred Newtons is the highest reported value for ACL tension during normal walking, reported by Kuster and Wood (6). Grood and Noyes, however, reported values close to 500 N to occur only during strenuous athletic activities (7,8). One million cycles was selected to approximate one year of *in vivo* loading, sufficient time for the graft to be biologically secured in the femoral bone tunnel.

* [Each Bone Mulch Screw was prepared for 3-point bending by separating the central pin portion from the threaded portion in order for the pin to lay flat across the cylindrical supports]

MECHANICAL EVALUATION OF CROSSPINS USED FOR FEMORAL FIXATION OF HAMSTRING GRAFTS IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTIONS, CONTD.

RESULTS The results of the 3-point bending test without antecedent cyclic fatigue testing are summarized in Table 1. The mean yield load for the Bone Mulch Screw is significantly higher than the other implants ($p < 0.001$). The mean yield loads in the Lactosorb implant and the allografts were similar and significantly higher than the RigidFix implant ($p < 0.001$). The stiffness of the cortical allografts, however, is more than twice that of the Lactosorb implant. The greatest stiffness was observed in the Bone Mulch Screw.

The RigidFix implants and cortical allografts failed by fracture. The other three implants bent past 1.5 mm for failure without evidence of fracture. Load at 1.5 mm central deformation was 28 – 45% greater than the yield load; the allografts fractured at 0.3 ± 0.03 mm central deformation.

IM-PLANT	N	Yield Point (N)	Load at 1.5 mm deform ⁿ (N)	Stiffness (N/mm)
Lactosorb®	6	449 ± 23	642 ± 28	713 ± 28
RigidFix™	6	187 ± 4	244 ± 7	396 ± 29
Bone Mulch Screw	6	1146 ± 42	1470 ± 59	2787 ± 111
Cortical Allograft	5	397 ± 41	fractured	1576 ± 159
Control	6	2954 ± 164	4307 ± 185	6229 ± 788

Table 1: 3-point bending, single load to failure. (Mean ± sd)

Initial fatigue testing has revealed that the RigidFix implants ($n=6$) fail at $18,893 \pm 8365$ cycles (with a central deformation of 0.48 ± 0.11 mm prior to fracture); all other implants endure one million cycles of loading (50-200 N) without fracture or 1.5 mm central deformation. We are in the process of performing additional fatigue testing and 3-point bending, on those implants that don't fracture by one million cycles, in order to compare post-fatigue strength with the data listed here.

DISCUSSION Femoral fixation of quadrupled hamstring grafts is a key element to a durable ACL reconstruction and there remain many implant designs to accomplish this. There is no consensus as to which method is superior. Our study focused on the mechanical characteristics of some of the more popular crosspin fixation devices. Fixation of the device in the femoral metaphysis was specifically not examined.

Kousa et al., in an *ex vivo* study (9), found no statistically significant difference between the Bone Mulch Screw and Rigid-Fix crosspins when tested under a 50 mm/min bending load to failure before or after 1500 cycles of fatigue loading (50-200 N). Their test was performed with cadaveric quadrupled hamstring grafts looped over the femoral fixation devices in porcine femora. They concluded that the afore-mentioned crosspins provided greater fixation strength than three types of interference screws included in their protocol and that “the rigidity of the device itself improves the fixation characteristics of the implant.”

Our results show a lower mean yield strength (187 N) compared to the findings of Kousa et al. (868 N) in the RigidFix crosspin. We tested one crosspin, but the RigidFix system uses 2 of these pins in the femoral tunnel to secure the graft. Our loading rate was also much slower. For the Bone Mulch Screw the mean yield strength (1146 N) found in this study was comparable to Kousa's data (1112 N). The stiffness values in our study were very different as a function of our decision to test the crosspin itself as opposed to testing the hamstring graft, crosspin, and its fixation in the femoral bone as Kousa, et al. did.



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TIBIALIS ANTERIOR ALLOGRAFT VS. HAMSTRING ALLOGRAFT OUTCOMES FOR ACL RECONSTRUCTION AT TWO YEARS FOLLOW-UP

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Presenter: David Galluch, MD

Study type: Prospective cohort

Methods: The Multicenter Orthopaedic Outcomes Network (M.O.O.N) database was queried for all patients who had undergone ACL reconstruction by the senior author and met minimum 2 year follow-up requirements. One hundred and ten primary ACL reconstructions were identified from January 1, 2002 to December 31st, 2002. Twenty-eight ACL reconstructions were performed with tibialis anterior tendon allograft, eighty-two reconstructions were performed with hamstring tendon autograft. All surgeries were performed by the senior author, utilizing the same bioabsorbable cross pin femoral fixation and bioabsorbable interference screw tibial fixation techniques. All patients were given a pre-operative questionnaire which included the Knee injury and Osteoarthritis Outcome Score (KOOS) and the Marx activity score. The same questionnaire was given at 2 years post-operatively. A phone interview was also performed at the 2 year interval to determine if graft failure had occurred. Statistical analysis involved the Wilcoxon signed-rank test to compare pre-operative KOOS/Marx to post-operative KOOS/Marx evaluations. Mann-Whitney test was performed to evaluate the tibialis anterior allograft group against the hamstring tendon group and the Chi squared test was used to evaluate failure rates between the two groups.

Results: Twenty-eight tibialis anterior tendon reconstructions were identified. All patients were contacted by phone at the 2 year interval (100%) and 22/28 (79%) completed their 2 year KOOS/Marx questionnaire. One graft failure (3.5%) occurred in the two year time period. Eighty-two hamstring tendon reconstructions were identified. Seventy-six patients (93%) were contacted by phone at the two year interval and Seventy-four patients (90%) completed their 2 year KOOS/Marx questionnaire. Six graft failures (7.8%) occurred in the two year time period. No statistical difference was found between the allograft and autograft groups regarding index KOOS/Marx evaluations and the two year follow up evaluations. There was also no statistical difference in failure rate between the two grafts groups.

Conclusion: In this evaluation of ACL reconstruction with tibialis anterior allograft vs. hamstring autograft, tibialis anterior allograft exhibited a lower failure rate and equal patient outcome scores with regard to knee assessment and activity as the hamstring autograft at the two year follow up period. Tibialis anterior allograft is a viable graft choice for ACL reconstruction

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