CHAPTER 13
UNIVERSITY OF ALABAMA AT BIRMINGHAM

School of Engineering
Department of Biomedical Engineering
Hoehn 368, 1075 13th St. S.
Birmingham, Alabama 35294

Principal Investigator:

Alan W. Eberhardt, PhD (205) 934-8464

aeberhar@uab.edu

TEST FIXTURES FOR BIOMECHANICAL ASSESSMENT OF MURINE TIBIAE AT EARLY STAGES OF DISTRACTION OSTEOGENESIS

Designers: Meredith Reid, Andrea Rossillon, and Sarah Shadix
Client Coordinators: Shawn Gilbert, MD, Division of Orthopedic Surgery; Alan Eberhardt, PhD, Department of Biomedical Engineering
Supervising Professor: Alan Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION

Distraction osteogenesis (DO) is the process of fracturing a bone (osteotomy), allowing the fracture to begin to heal (latency phase), and distracting the bone with an external fixator at a set rate over a period of days or weeks (distraction). Finally, the newly-formed callus is allowed to mineralize (consolidation). DO is used to correct deformities or malformations that result from injury or disease.

Current research suggests that the development of hypoxia, specifically the elevation of hypoxia inducible factor-1α (HIF-1α) in cells, is a key feature of the angiogenic response during fracture healing. A researcher aims to investigate the effects of pharmacological activation of the HIF-1α pathway on bone healing when the Von Hippel-Lindau (VHL) complex is deleted in mice.

In order to assess the mechanical and structural properties of healing DO bones, a protocol for biomechanical assessment of murine tibiae was needed. The goal was to design appropriate fixtures for tensile and four-point bend testing of DO murine tibiae. The design constraints included the size of murine bones (15-20 mm length, two to three mm diameter, three mm callus) and the loading

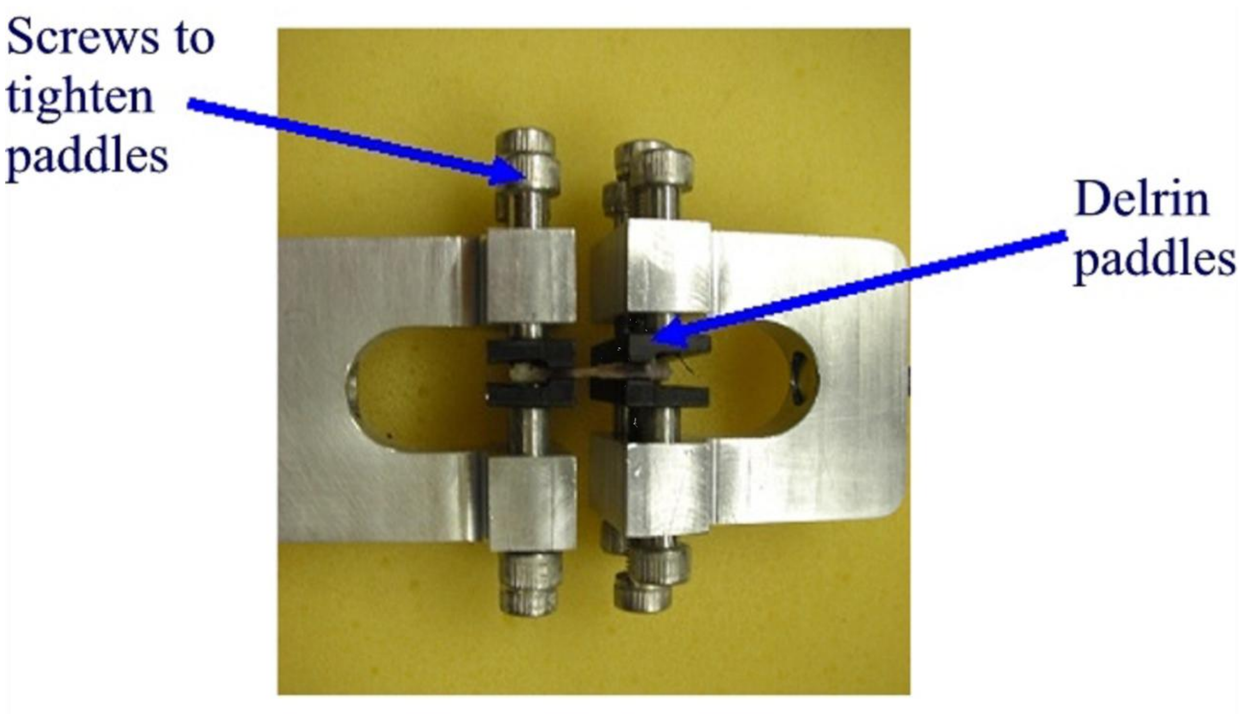

Fig. 13.1. Tensile Test Fixtures Holding a Murine Tibia.

capabilities of a Bose Testbench system (20 N maximum load, 80-100 g. maximum fixture weight). Also, a graphical user interface (GUI) and the appropriate data analysis techniques were needed to provide a convenient means for outputting structural and mechanical properties of the healing callus.

SUMMARY OF IMPACT

The completed fixtures will provide the means for testing mouse bones subject to distraction osteogenesis. The results of the effort will help researchers understand the pharmacological manipulation of the HIF-1α pathway, which is central to hypoxic response and neovascularization. The aim of the work is to improve bone healing in mice that have undergone distraction osteogenesis-a first step towards improving bone healing in children undergoing DO to correct deformations and malformations of the lower extremities.

TECHNICAL DESCRIPTION

The test fixtures were machined from 6061-T6 Aluminum. The tensile test fixtures contain adjustable paddles (see Fig. 13.1) that allow gripping of the tibia away from the healing callus along the diaphyseal region of the bone. The weight of each tensile grip is approximately 68 g. The four point bend test fixtures contain loading noses that are adjustable, both top and bottom, with an engraved scale (in mm) for span measurement (see Fig. 13.2). The entire four-point bend apparatus weighs 80 g. The GUI, programmed in MATLAB, allows the user to select a test method and structural properties are calculated directly from the imported load vs. displacement data. The material's properties (E, σ_{yield}, σ_{ult}) are calculated once the user enters additional information related to specimen geometry. The user also has the option of plotting load vs. displacement or stress vs. strain. All properties and the plots are displayed in the main GUI window.

The cost of materials and machining was $1500.

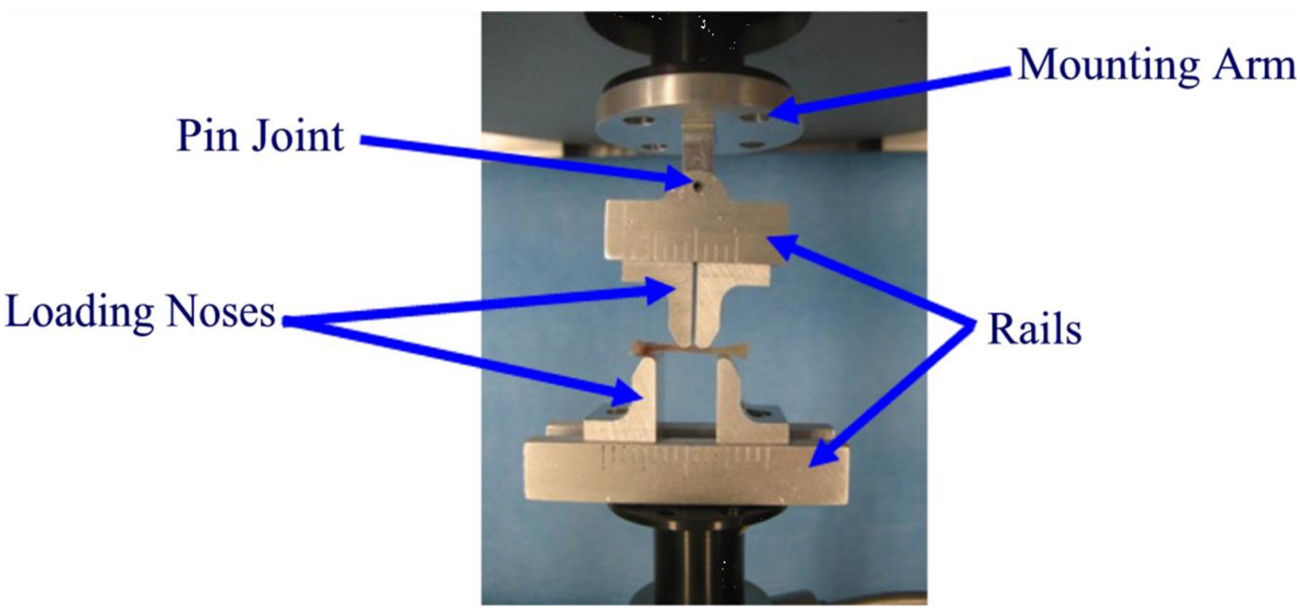

Fig. 13.2. Four-Point Bend Test Fixtures Supporting a Murine Tibia.

PERSONAL LIFTING PEDESTAL

Designers: Megan Chamlee, Rakesh Lala, and Saso Klesnik
Client Coordinators: Mr. Harlan Dutton; Alan Eberhardt, PhD, Department of Biomedical Engineering
Supervising Professor: Alan Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION

There are currently over one million people with amputations in the United States and approximately 133,000 hospital amputation discharges every year. Currently there are no devices specifically designed to assist people with lower-limb, above-the-knee amputations safely reach standing heights. The only similar devices currently on the market are wheelchairs that allow the user to stand. These designs, however, are not conducive to people with lower limb amputations because they require the presence of lower limbs for support.

The goal was to design a user-controlled Personal Lifting Pedestal (PLP) for the lower limb of an average-sized male (160-lb) with an above-the-knee amputation. The average male's sitting eye height is 48.5" and the average male's standing eye height is 67". Thus, the device would raise the user from a sitting position to a standing height of 5' 7" - a required rise of 15.9". Other design parameters for the PLP consisted of: 1) ease of entry/exit; 2) user friendly controls; 3) safety; and 4) stability.

SUMMARY OF IMPACT

Following amputation, many individuals seek ways by which they can regain independence in performing their daily tasks and activities. Research has shown that the ability to elevate to a standing height can have psychological, physiological, and social advantages for the amputee. The present design represents phase one of a two-phase project to develop a motorized PLP, which will permit the user to move throughout a room and raise and lower himself or herself to perform various tasks that require the user to reach standing heights, such as placing books on upper shelves, for use in a work environment.

TECHNICAL DESCRIPTION

The frame was designed out of carbon steel due to its impact resistance, strength-to-weight advantage, and weldability. The dimensions of the frame are 30"x26"x30". The frame consists of two 26" hollow bars and two 30" hollow bars along the top and bottom, each two inches by one inch in cross section. The side bars are four telescoping hollow rods (outer diameter of one inch). The frame is open in front which allows for easy entry into the PLP. The frame was painted to make it corrosion resistant. Two DL4 Desklift Actuators (Linak) are used as the lifting mechanism for the PLP. These actuators were selected because they had telescoping casings that resist bending and because they offered the appropriate stroke length and thrust. The actuators are controlled simultaneously using a remote with a memory function and height display. A DeltaTM II Bosun Chair Harness (Western Safety) was chosen for the hanging seat since it had a seat board that provides built-in suspension support and a harness for restraint.

The user climbs into the chair and fastens himself or herself in using the harness when the pedestal is in the lowest position (see Fig. 13.3, left). Using push button controls, the user actuates the system to rise to a standing height (see Fig. 13.3, right). Preliminary calculations were performed to ensure the stability of the PLP. The completed device was tested in various positions using a 160-lb male and the device was determined to be safe and functional.

The cost of materials and machining was about $1316.

Fig. 13.3. Personal Lift Pedestal for People with Lower Limb Amputations.

CYCLE ASSIST: JAVIER MODEL 1.0

Designers: Nick Cutchens, Ross Lumsden, and Soli Zadeh
Client Coordinators: Mr. Javier Flores; Brian Mueller, UAB HSF Ortho/Pros. Division
Supervising Professor: Alan Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION

The objective of this project was to redesign a hand-to-handlebar attachment device. A male client had a below-elbow amputation; he lost his left hand and forearm in a work-related accident. His right hand has a remaining index finger and thumb. He is an avid cyclist and was having problems with his prosthetic hand (Otto Bock®). The hand was constructed to be closed in its normal state, with a pull-cord that opens the hand. A strap system connected to the pull-cord goes around his back; when he flexes his shoulders, the hand opens. The back strap was found to be a problem for the client because it restricts his range of motion while on his bicycle. Also, the hand was found to disengage from the handlebars during strenuous activities, such as biking up a steep hill. The hand was tested using a spring scale and showed release with pull-off forces greater than 30 lb.

Design goals were to develop a lightweight device that enables the client to grip his handlebar with his prosthetic arm, allows for comfortable riding positions, and operates reliably with an automatic emergency release and without unintentional disengagement. It was also necessary to eliminate the back strap and to create a device that would withstand at least 50 lb of rider-applied tensile forces, which was the reported strength of the threaded forearm attachment.

Fig. 13.4. Revised Otto Bock® Hand, Containing Extended Thumb.

SUMMARY OF IMPACT

Prior to his accident, the client was an extremely active person, competing in triathlons and working part-time as a personal trainer. He wanted to regain his ability to ride a bicycle without restrictions. The present design will provide the client with greater freedom to take longer bike rides without pain from the original back strap. The emergency release system will ensure that, in the event of an accident, he does not remain attached to his bike, causing serious injuries.

TECHNICAL DESCRIPTION

Three design solutions were initially formulated: 1) variations on ball-in-socket attachments; 2) a gear-driven clamping device; 3) modification of the client's existing prosthetic setup. Upon evaluation of the pros and cons associated with each design, it was decided to modify the existing Otto Bock® hand setup. To address the pull off issue, the thumb of the hand was lengthened and shifted laterally so the thumb would fit between the two fingers of the hand (see Fig. 13.4). Upon testing, the extended thumb resisted pull-off by applied forces over 50-lb.

An emergency release mechanism was designed and constructed of 6061-T6 aluminum. It employed a threaded connector, which contained a pin guide that ensured the pin would disengage the connector when the emergency release cord was pulled (see Fig. 13.5, left), at the base of the modified hand. The pull-cord extends from the pin release across the handlebars and loops over the rider's good thumb (see Fig. 13.5, right). In the event that the rider is thrown from the bike, the pull-cord would automatically disengage the threaded connector, releasing the rider's prosthetic forearm from the hand, which would remain attached to the bike.

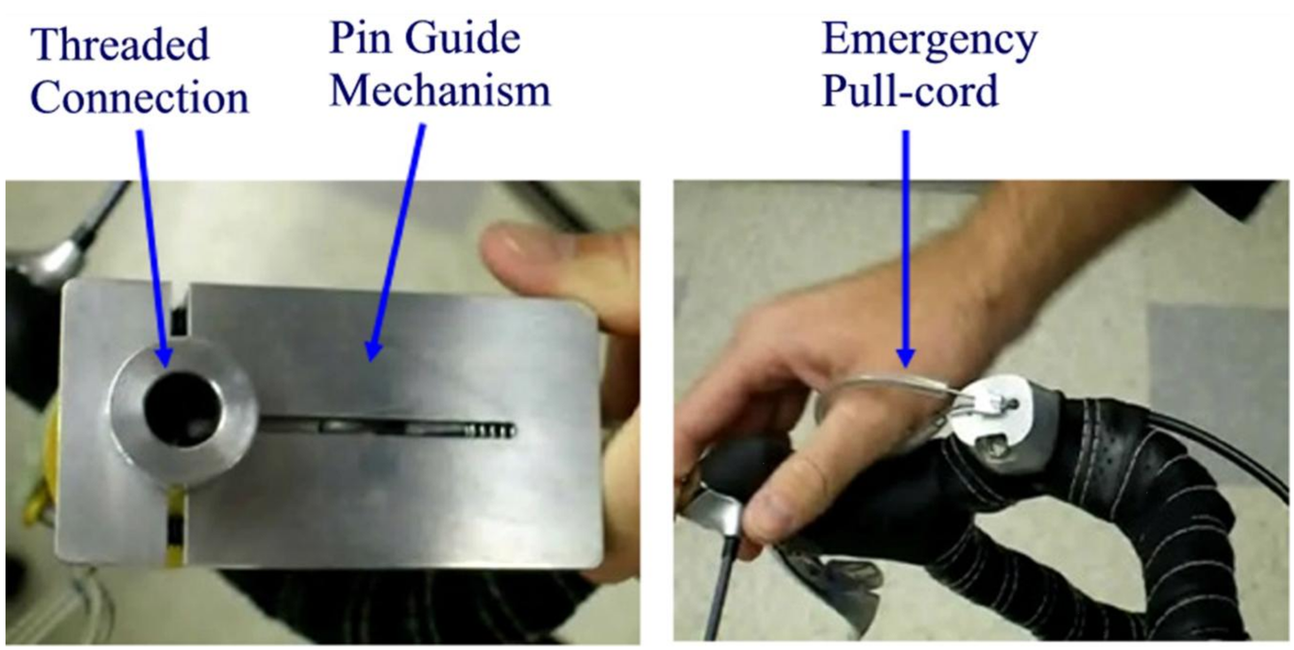

Fig. 13.5. Emergency Release Mechanism Including Pin Guide (left) and Emergency Pull-Cord (right).