VIVO™

VIVO™

Bringing New Life to Joint Motion Simulation

AMTI
FORCE AND MOTION
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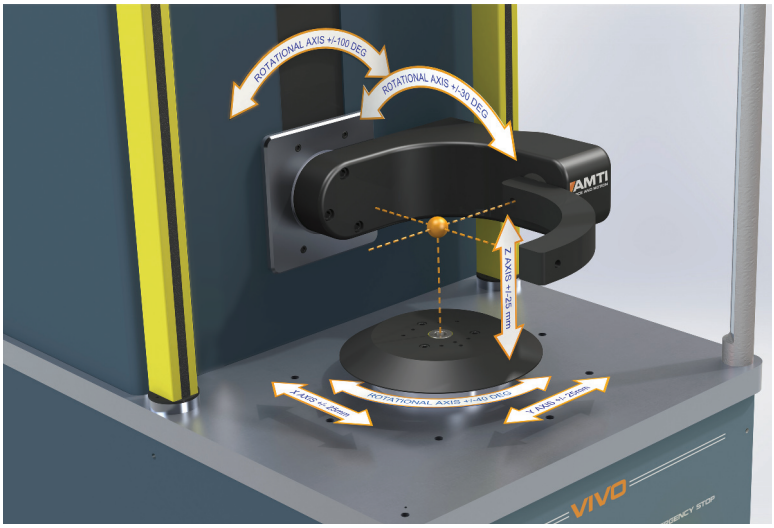
The VIVO™ Joint Motion Simulator

Versatile Design Tests All Joints of the Body

AMTI'S VIVO brings new life to joint motion simulation, dramatically increasing simulation realism. It provides realistic simulation of knee, hip, shoulder, temporomandibular, elbow, ankle and spinal joint motions. Its advanced control capabilities and extended range of motion enable simulating activities of daily living.

VIVO's patent pending design provides a fully servo controlled six degree-of-freedom environment in which to test total joint replacements as well as biological joint specimens. In addition to implant wear and lifetime durability testing, VIVO enables testing of real world implant failure modes that occur due to in-vivo multi-axis loading conditions. VIVO's virtual soft tissue constraint system and other control features further increase simulation realism and research flexibility.

Six-Axis Orthopaedic Testing System



DEGREE OF FREEDOM	RANGE
1. Axial load	±4500 N
2. Flexion	±100°
3. IE rotation	±40°
4. Y-Axis (AP) Translation	±25 mm
5. X-Axis (ML) Translation	±25 mm
6. Abduction/Adduction or Valgus/Varus	±30°

SIX DEGREES OF FREEDOM

Each test station is equipped with six precision displacement sensors to monitor translations and rotations of the joint components, and a six-axis force sensor to monitor the contact forces and moments.

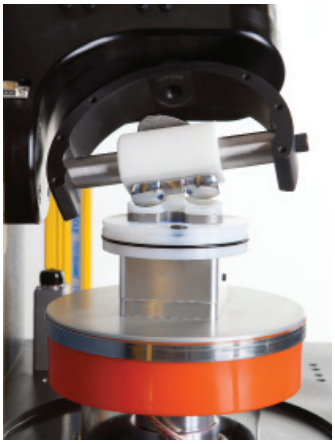
Each of VIVO's six degrees of freedom may be controlled independently in force control or displacement control. For example, a knee test can have the flexion axis in displacement control; joint compression, anterior-posterior, and medial-lateral motions in force control; and varus-valgus along with internal-external rotation in torque control.

MODULAR DESIGN & LARGE SAMPLE AREA

Capable of performing short-term kinematic and long-term durability evaluations, the configurable VIVO can have from one to three test stations. Each station is equipped with six servo-hydraulic actuators. The stations can be programmed to act independently or synchronized to provide the same kinematic activity.

VIVO's substantial sample area accommodates large test specimens such as shoulders and total joint replacement systems.

Advanced Features for Unsurpassed Simulation Accuracy and Versatility



ADVANCED CONTROL ENABLES REAL-WORLD APPLICATIONS

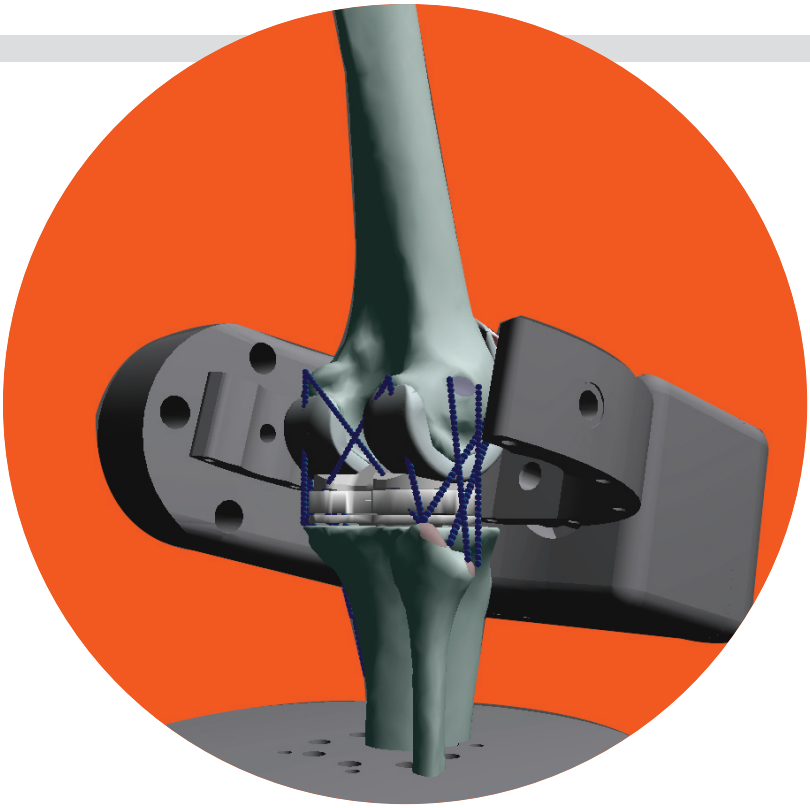
- Knee condylar liftoff
- Digital Fixturing™
  - » Knee: malalignment and malposition
  - » Hip: simulate anatomical alignment and in-vivo loading
- Knee post / cam engagement
- Hip microseparation under force control and ligament constraint
- Hip impingement
- ADL waveform sequencing
- Floating instant center of rotation
  - » Accurately simulates in-vivo joint alignment
  - » Eliminates joint alignment issues at test startup

TEMPERATURE-CONTROLLED ENVIRONMENTAL FLUID SYSTEM

Simulation of an implant's in-vivo environment is accomplished using VIVO's temperature-controlled recirculating fluid system. The fluid provides continuous lubrication of the specimen's contact surfaces and maintains body temperature, 37°C. Fluid level and temperature are continuously monitored during testing and appropriate actions may be taken in the event of a fault.

PROGRAMMABLE TEST SPECIMEN PROTECTION

VIVO sets a new standard of protection for your valuable test investment. Every physical quantity is continuously monitored and corrective or emergency actions may be enabled in the event of a fault. This rapid response prevents inadvertent specimen damage during setup as well as during operation of the machine. Safety is also enhanced with system control interlock circuits and a light curtain interlock which encloses the working volume of the machine.



SOFT TISSUE SIMULATION

The implanted joint is a composite of biological structure and artificially engineered components. Understanding kinematics, kinetics and durability of the implanted joint structure requires simulation in a realistic environment. To facilitate such studies, VIVO's Virtual Soft Tissue control system provides two simulation scenarios:

• Heuristic soft tissue constraint model (Patent 7823460) - permits testing to today's ISO and ASTM standards as well as to proposed ASTM standards of the future.

• Multi-fiber ligament constraint model - enables more life-like testing, providing the complex inter-axis coupling exhibited by the natural knee. For example, testing sensitivity to ligament balance and post-surgical ligament conditions is possible with this more advanced model.

AMTI's heuristic soft tissue model simulates the constraint characteristics of the natural joint using a two-dimensional model

"VIVO's multi-fiber ligament model uses a database of ligament fiber elements..."

for each of the controlled axes. The selected model input variables may be chosen from any of the stations' measured variables (either motions or forces). For example, in the case of knee simulation, constraint characteristics for anterior-posterior translation may be programmed to be dependent on anterior-posterior displacement and internal-external rotation or, alternatively, flexion-extension. This two-input constraint model permits characterization based on the most significant interaxis coupling of the joint.

To provide a more realistic soft tissue constraint model that accounts for the complex interactions in-vivo, VIVO's multi-fiber ligament model uses a database of ligament fiber elements that are user-defined or selected from a library. In the database each fiber is represented with the coordinates of a proximal and distal insertion site, an elastic tangent stiffness, a viscoelastic time constant, and a reference strain. During operation, VIVO measures the relative positions and orientations of the joint components and computes the positions of the fiber insertion sites. The strain in those elements is determined, and from the strain and strain rate the tension in each fiber element is then determined. The overall joint constraint forces are then resolved from the combination of individual ligament fibers' forces.

Sophisticated Robotic Control System

THE CONTROL SYSTEM

The VIVO™ Joint Simulator control system is the most sophisticated robotic control system available for joint motion simulation. AMTI's extensive biomechanical simulation experience, coupled with the most recent advances in control technology, has culminated in the new VIVO control system. The control system provides two modes of operation:

Joint Coordinate System mode - implements the Grood and Suntay Joint Coordinate System (JCS). In JCS mode, control inputs and data outputs are resolved to represent forces and displacements relative to the joint itself. The JCS has been adopted by the International Society for Biomechanics and ISO for describing joint motions.

Machine Coordinate System mode - for more general purpose work, this mode provides control of kinematics and kinetics relative to an orthogonal world coordinate system.

POWERFUL SIMULATION CONTROL SOFTWARE

VIVO's simulation control software, running on a PC, provides the user interface, supervisory functions and powerful motion programming tools. The control system accepts two types of inputs: six reference waveforms, or temporal signals representing either the kinematics or kinetics of a particular physiologic activity.

DESIGNED FOR LONG SERVICE LIFE

For compactness and maximum service life, VIVO utilizes an all-hydraulic actuator design. The main bearing of the system is hydrostatically supported to provide low friction, more accurate control, and long life. AMTI's unique seal-less actuators reduce maintenance downtime and provide maximum service life. A separate hydraulic power unit is required for operation.

Technical Data

HARDWARE REQUIREMENTS & DIMENSIONS VIVO requires an external 5.5 MPA (800 psi) hydraulic power supply. Overall VIVO system dimensions shown below do not include the computer or hydraulic power unit.

VIVO OVERALL DIMENSIONS	PER TEST STATION
Height	1900 mm
Width	635 mm
Depth	965 mm
SPECIMEN WORKING AREA	**WITH ABDUCTION / ADDUCTION GIMBAL**
Vertical	
Below gimbal centerline	Adjustable, 130 mm - 310 mm
Above gimbal centerline	Unlimited
Width	
Right of gimbal centerline	120 mm
Left of gimbal centerline	Unlimited
Depth	240 mm

ISO & ASTM TESTING STANDARDS

VIVO performs a wide range of testing standards—capable of performing tests to

ISO 14242-1
ISO 14243-1
ISO/CD 14243-3
ISO 14879-1
ISO 16402
ISO18192-1
ISO/TR 22676
ISO 7206-4
ASTM F1223-08
ASTM F2790-10
ASTM F2694-07
ASTM F2777-10
ASTM F2028-08
ASTM F1829-98

SPECIFICATIONS

TEST STATIONS	SPECIFICATION
Modular, 1 to 3 test stations	All stations' motions are independent.

DEGREE OF FREEDOM/AXIS	FORCE/TORQUE	DISPLACEMENT/ROTATION
Axial Load	±4500 N	±25 mm
Flexion	±80 N-m	±100°
IE Rotation	±40 N-m	±40°
Y-Axis (AP) Translation	±1000 N	±25 mm
X-Axis (ML) Translation	±1000 N	±25 mm
Abduction/Adduction or Valgus/Varus	±60 N-m	±30°

CONTROL AND DATA ACQUISITION ELECTRONICS

VIVO includes a complete data acquisition system, supervisory PC and internal real-time controller.

CONTINUED

SPECIFICATIONS CONTINUED

ACTUATOR TYPE	SPECIFICATION
All Degrees of Freedom	Servo-hydraulic

D.O.F. / AXIS	SENSORS	AVAILABLE CONTROL MODES
Vertical Actuator	Fz force & position	Force or displacement control
Flexion	Mx torque & position	Torque or displacement control
IE Rotation	Mz torque & position	Torque or displacement control
Y (AP) Translation	Fy force & position	Force or displacement control
X (ML) Translation	Fx force & position	Force or displacement control
Abduction/Varus	My torque & position	Torque or displacement control

LOAD CELLS	SPECIFICATION	MEASURED FORCES & MOMENTS
Six-Axis	Removable	Fx, Fy, Fz, Mx, My, Mz

PHYSICAL SPECIFICATIONS	SPECIFICATION
Height	1900 mm
Width	635 mm
Depth	965 mm
Weight	272 kg (800 lbs)

HYDRAULIC SYSTEM [1]	SPECIFICATION	COMMENT
External hydraulic power supply		Required, quoted separately
Pressure	5.5 MPa (800 psi)	Required
Required Flow	30 LPM (8 GPM) Typical Gravity drain return	Required
Oil Temperature	38°C	Recommended at outlet
Water Cooling	3kW Typical 2 LPM @ 15°C	26°C Max cooling water temperature

POWER [2]	SPECIFICATION	COMMENT
Electric	115/230 VAC, 1500 watts	1 phase, 50/60 Hz
CE Compliant		

DYNAMIC PERFORMANCE

ITEM	MAXIMUM REPETITION RATE (REPETITIONS/SECOND)
Controller	30 Hz

D.O.F	TYPICAL REPETITION RATE (REPETITIONS/SECOND) [3]	MAXIMUM SPECTRAL CONTENT (HZ) [4]	RMS ERROR (% FS) [5]
Axial Load	2.0 Hz	10 Hz	< 1 %
Flexion Extension	2.0 Hz	10 Hz	< 1 %
IE Rotation	2.0 Hz	10 Hz	< 1 %
Y (AP) Translation	2.0 Hz	10 Hz	< 1 %
X (ML) Translation	2.0 Hz	10 Hz	< 1 %
Abduction/Varus	2.0 Hz	10 Hz	< 1 %

ENVIRONMENTAL CONDITIONING FOR SPECIMENS

SPECIMEN FLUID RECIRCULATION	SPECIFICATION	COMMENT
Pump	100 ml/min	60 RPM peristaltic with #25 silicone tubing
Reservoir	500 ml	Stainless steel tank
Fluid Level	High/Low	Magnetic sensor/float

SPECIMEN FLUID TEMPERATURE	SPECIFICATION	COMMENT
Temperature Controller	50 watts heating/cooling	Thermoelectric

SPECIMEN FLUID	SPECIFICATION
Suitable fluids	Bovine serum, saline solution, water

MEASUREMENT INSTRUMENTATION

DATA ACQUISITION	CHANNEL	RANGE	COMMENT
Data Rate	All channels	10-2000 samples/sec	User selectable
ADC Resolution	All channels	14 bit	
Digital Filters	All channels	10-500Hz	User selectable
Anti-Aliasing Filters	All channels	600 Hz	

MULTI-AXIS LOAD CELL	CHANNEL	RANGE
Axial Load	Fz	±4500 N
AP Force	Fy	±2200 N
ML Force	Fx	±2200 N
Flexion Moment	Mx	±200 N-m
Valgus Moment	My	±200 N-m
Axial Moment	Mz	±100 N-m

ANGLE AND POSITION	RANGE	NOMINAL RESOLUTION
Axial Position	±25 mm	0.1 mm
Flexion	±100°	0.1°
IE Rotation	±40°	0.1°
Y (AP) Translation	±25 mm	0.1 mm
X (ML) Translation	±25 mm	0.1 mm
Abduction/Varus	±30°	0.1°

OTHER SENSORS	COMMENT
Serum Temperature	Dual sensors
Oil Temperature	Table top temperature
Serum Fluid Level	High/low safety shutoff
Hydraulic Pressure	Dual gauges and supply sensor

CONTROL SYSTEM

NETCONTROL INTERFACE	SPECIFICATION	COMMENTS
Included Computer Hardware		Windows based PC and accessories
Interface	Ethernet 1Gb	

REAL-TIME CONTROLLER	SPECIFICATIONS	COMMENTS
Intel Core 2 Controller	2.8 GHz	Double precision floating point math
Update Rate	2000 Hz	

CONTROL MODES	CHANNELS
State Space Control	6
Gain Scheduling	6
Adaptive Control	6
Virtual Soft Tissue	6

WAVEFORM GENERATOR	CHANNELS	RANGE	COMMENTS
Reference Waveforms	6		
Repetition Rate	All channels	0.01 to 30 Hz	
Programmable		1024 points	Interpolated

EVENT MONITOR	CHANNELS	SPECIFICATION	COMMENTS
Threshold Trigger	5 per station		Rising or falling edge
Response Time	All channels	0.0005 seconds	
Programmable Response	All channels		Soft stop, hold, shut down

DATA ACQUISITION	CHANNELS
Force/Torque	6
Displacement/Rotation	6
Temperature	4
Reference Waveforms	6
Servo Error	6
Soft Tissue Constraint	6
Sum Signals	6
Oil Pressure	1

[1] The external hydraulic system requires cooling water for operation, usually available from your laboratory's infrastructure. If not available, contact AMTI for information about chillers. [2] Contact AMTI for other power configurations. [3] The typical repetition rate corresponds to the maximum rate at which satisfactory performance will be achieved running the ISO standard gait cycle waveforms for knee testing. This is a somewhat subjective indication of dynamic performance. Overall tracking performance is reduced with higher frequency of operation. [4] The ISO waveforms contain spectral content in considerable excess of the fundamental driving frequency. Analysis of these waveforms indicates that tracking performance at a 1 Hz repetition rate is excellent up to the indicated frequency. [5] The RMS error provides a measure of the simulator's tracking performance (the extent that the machine's outputs differ from the target inputs). These values are typical for testing at a 1 Hz repetition rate while running the ISO waveforms and represent standard results while evaluating conventional prosthetics using AMTI's Adaptive Control Technology (iterative learning control algorithm). Different prosthetic devices or conditions may result in an increased or decreased tracking error.

Service & Support

BACKED BY GLOBAL SUPPORT

AMTI offers state-of-the-art technical support and field service through its ASAP service plan. The ASAP plan provides remote support from AMTI engineers and substantial discounts for on-site preventative maintenance and other post-warranty service needs.

The ASAP plan is highly customizable and can be constructed to meet the specific requirements of your lab. The AMTI sales team will be happy to assist you in determining the options that provide the greatest benefit to you.

ABOUT AMTI

As an ISO 13485- and ISO 9001-certified company, AMTI is committed to the constant evaluation and refinement of our products in order to best meet the needs of the clinical and research communities we serve. This collaborative relationship with our clients is the guiding force behind our company's evolution.

We currently design and manufacture the industry standards in force measurement devices, orthopaedic implant testing machines, and other specialty instruments. Our joint motion simulators, like our knee simulator and our hip simulator, are relied on by most major implant manufacturers. Our force measurement devices, such as our force plates and force sensors, are similarly well-used among clinical researchers in areas such as biomechanics, gait analysis and ergonomics.

AMTI also regularly partners with research institutions, such as NASA and the National Science Foundation, which have awarded AMTI numerous grants to conduct novel research in various areas of medical and industrial technology.

VIVO™

AMTI Worldwide Installations

AMTI simulators are the most advanced, reliable and accurate method for evaluating the design and materials of orthopaedic implants. Their unique combination of capabilities, performance and consistent operation has made them the most relied upon simulators of their kind in the world.

ISO 9001:2008 certified

ISO 13485:2003 certified

CE

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176 Waltham Street | Watertown, MA, 02472 | USA
+1-617-926-6700 | sales@amtimail.com | www.AMTI.biz

AMTI MULTI-AXIS FORCE MEASUREMENT AND TESTING

Biomechanics Force Platforms

Force Sensors

Instrumented Equipment

Multi-Axis Testing Machines

Amplifiers and Software