Practical Course #18

Practical Spine Biomechanics for Clinical Practice

2012 CNS Annual Meeting
October 6-10 in Chicago, Illinois.
Biomechanics and Surgical Decision Making

Present and Future

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DePuy
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BIOMECHANICS OF SPINAL COLUMN FAILURE

\[ M = F \times D \]
BIOMECHANICS OF SPINE INSTRUMENTATION

SIX DEFORMATION RESISTANCE MECHANISMS
- Distraction
- Three-Point Bending
- Tension-Band Fixation
- Fixed Moment Arm Cantilever Beam Fixation
- Non-Fixed Moment Arm Cantilever Beam Fixation
- Applied Moment Arm Cantilever Beam Fixation

\[ M = F \times X \times D \]
PRINCIPLES

Use as Many Mechanisms as Possible to Resist Deformation

Implants Function Uniquely Under Different Loading Conditions

DEFORMATION RESISTANCE MECHANISMS

Distraction
Tension-Band Fixation
Three-Point Bending
Cantilevers
Understand Limitations of Strategy
Wolff’s Law

Every change in the form and function of a bone, or of function alone, is followed by specific definitive change in its internal architecture and equally definitive secondary changes in its external configuration, in accordance with mathematical laws.

“Structure is nothing else than the physical expression of function… under pathologic conditions the structure and form of the parts change according to the abnormal conditions of force transmission”
LOADING THE BONE GRAFT

Significant Loading and Unloading in Flexion and Extension

Buffered by Dynamic Implant

DiAngelo and Foley
CONSTRUCT FAILURE

MODES OF CONSTRAINED CONSTRUCT FAILURE

Construct Failure
Implant Failure
Stress Shielding
LOAD SHARING versus LOAD BEARING

THE BIOMECHANICS OF FAILURE
\[ Z \sim D^3 \]

\[ \theta = \frac{M}{Z} \]
Cervical Spondylosis

Myelopathy

Deformity

ENCROACHMENT

TETHERING

REPETETIVE TRAUMA

SURGICAL STRATEGIES
Focus on Deformity

Why?

- Neck Pain
- Myelopathy
- Improve Short-Term Success
- Decrease End Fusion Changes
- Improve Long-Term Success

Kyphosis
Trapezius Sign

Intra-Operative Deformity Correction

Ventral vs Dorsal
Its all about the leverage!!!

Dorsally, leverage is VEEEEERRRRYYYY difficult to achieve!!!

Polyaxial Screws

Exception
Capital Flexion and Extension
Gravity

Could Correct Ventrally
Because Facets not Ankylosed
It's all about leverage!!!
Fixation Follows!!!
CSM

Repetitive Trauma and Tethering / Distraction
Could Correct Dorsally

Because Relaxed/Released
Correct at Another Level
STAGING?
Dorsal
Releasing (eg Osteotomy)
Fixation

Ventral
Releasing
Fixation
Correction

Posture

Back Pain

Fundamentals
"The treatment of back pain falls primarily in the non-operative domain. Surgical management for such a malady, therefore, should be a relative exception."

Deep, Agonizing Pain
Worsened with Loading
Improved with Unloading
MOTION PRESERVATION

Interspinous Spacers
(Motion Preservation)

Diam (Medtronic)

Wallis (Spine Next, Bordeaux)

X-Stop (St. Francis Medical)

Dynamic Stabilization
(Motion Preservation or Fusion Enhancement)
Clinical Experience With the Dynesys Semirigid Fixation System for the Lumbar Spine
Surgical and Patient-Oriented Outcome in 50 Cases After an Average of 2 Years
Victor Grob, MD, Arnold Beravi, MD, Achim Junge, PhD, and Anne F. Marwan, PhD


Pain Generator

TDA
DISCOGENIC BACK PAIN

DYSFUNCTIONAL MOTION SEGMENT

Mechanical BACK PAIN
Deep, Agonizing Pain
Worsened with Loading
Improved with Unloading
**ATTRIBUTES**

- Replicates Anatomy
- Replicates Motion
- Replicates Mechanics
- Minimal Complications
- Acceptable Revision Strategies
- Longevity
- Retardation of Degenerative Changes
- Symptom Relief

**REPLICATES ANATOMY**

- Disc Interspace Height
- Disc Interspace Angle

**REPLICATES MOTION**

- Translation
- Angular
- Axial
- Coronal
- Sagittal

**In Which Plane?**

- Axial?
- Translational?
- Bending?

**Along Which Axis?**

- Axial
- Coronal
- Sagittal

**REPLICATES MECHANICS**

- Stiffness
- Shock Absorption
- Creep
Stiffness

Unconstrained
Semiconstrained
Constrained

In Which Plane?
Axial?
Translational?
Bending?

Motion Segment Stiffness
Unconstrained    Semiconstrained    Constrained
Disengagement    Engagement

Clinical Application
Structural Pathology
Anatomic
Mechanical

The Biomechanical Correlate of Mechanical Back Pain

Widened Neutral Zone

FLEXION AND EXTENSION
Unconstrained       Semiconstrained       Constrained
Disengagement                                        Engagement

Mechanical Back Pain
Begins as Biochemical / Nutrient – Related then
Becomes Structural
Mechanical Surgery
~
Mechanical Pathology

Mechanical BACK PAIN

Deep, Agonizing Pain
Worsened with Loading
Improved with Unloading
IAR

Appropriate Loading
Bone Supporting Soft Tissues
MINIMAL COMPLICATIONS

Short Term
- Vascular
- Neurological
- Expulsion

Long Term
- Expulsion
- Subsidence
- Failure of Ingrowth
- Osteophyte Formation

Osteointegration
Bony Ingrowth

PP-PMMA
Large vs Small Pore Size
Short - Long Term Fixation

- Short Term Fixation
- Intermediate Term Fixation
- Long Term Fixation

ACCEPTABLE REVISION STRATEGIES
Dorsal Fusion and Instrumentation Removal?

LONGEVITY

RETARDATION OF DEGENERATIVE CHANGES
SYMPTOM RELIEF

Anecdotal Information
Non-Inferiority ~ Inferior Device
Bias
Investigator Bias
Patient Selection Bias
Winner-Loser Bias

Case Against
Cervical
TDA

Adjacent Segment
Degeneration

Adjacent Segment
Disease

ASDeg vs ASDis
3 Studies – Ave Followup 4.5 Years
Prevalence of ASDis – 9-17%
Prevalence / years followed
Annual Incidence of ASDis Requiring Surgery
1.5 - 4% / year

846 Patients – PLF – f/u 2.8 yrs
Prevalance ASDis - 9%
Annual Incidence ASDis - 3%

253 Patients ACD w and w/o F
f/u 3 years
Prevalance ASDis – 7%
Annual Incidence ASDis – 2.5%
No Difference - w and w/o

253 Patients ACD w and w/o F
f/u 3 years
Prevalance ASDis – 7%
Annual Incidence ASDis – 2.5%
No Difference - w and w/o

409 ACDF
f/u 2-21 years
Prevalence ASDis – 14%
Annual Incidence ASDis – 3%

Risk Factors
Neural Element Compression at Adjacent Levels
Surgery Adjacent to C56 or C67

Multilevel ACDF Lower Incidence of ASDis
(12% vs 18%, p<0.001)
Back to the Basics
What Happens in 10, 15, 20 .... Years?

The art of medicine is amusing the patient until nature cures the disease.

Voltaire

THANKS!!!