

# Omurga Biyomekaniği ve In Vitro Modelleme

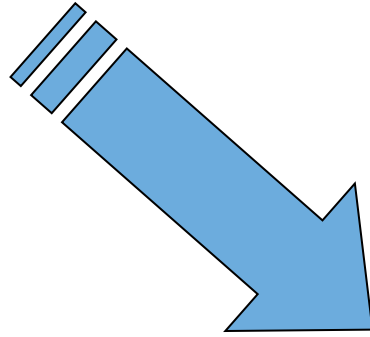
Dr.Hakan BOZKUŞ

# Omurga Sorunları Çözümü ?

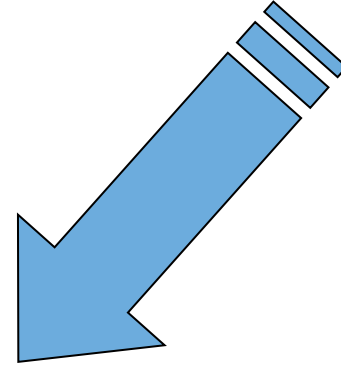
1. Deneysel uygulama sonuçları
2. Klinik uygulama sonuçları

# Deneysel Çözüm

MÜHENDİSLİK



TIP



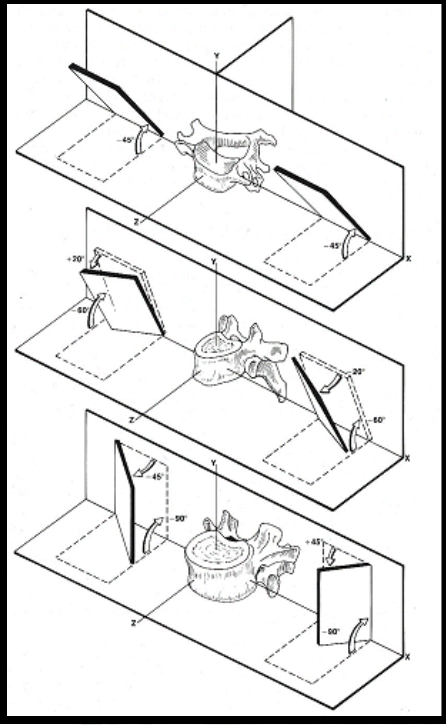
BİYOMEKANİK



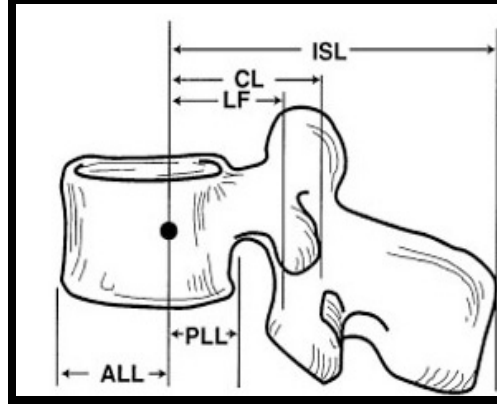
# Omurga Biyomekanik Davranışı

- Hareket aralığı (ROM)
- Rotasyonun anlık eksenini (IAR)
- Yük/Deformasyon Eğrisi
- Stabilite
  - Cerrahi
  - Fiksasyon

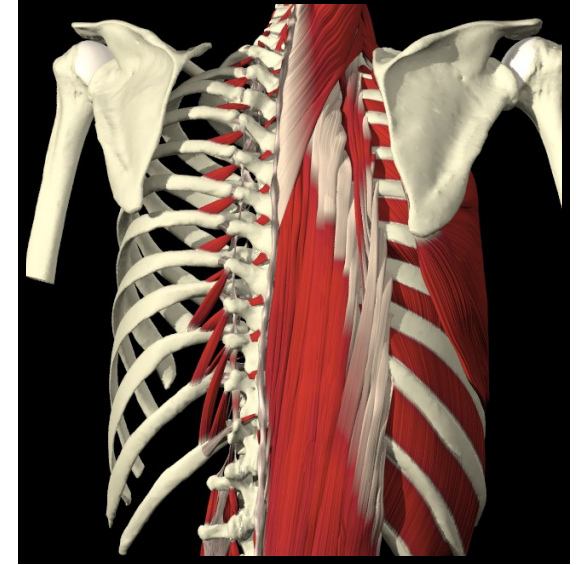
# Hareketi Sağlayan Yapılar



Fasetler



Ligamanlar

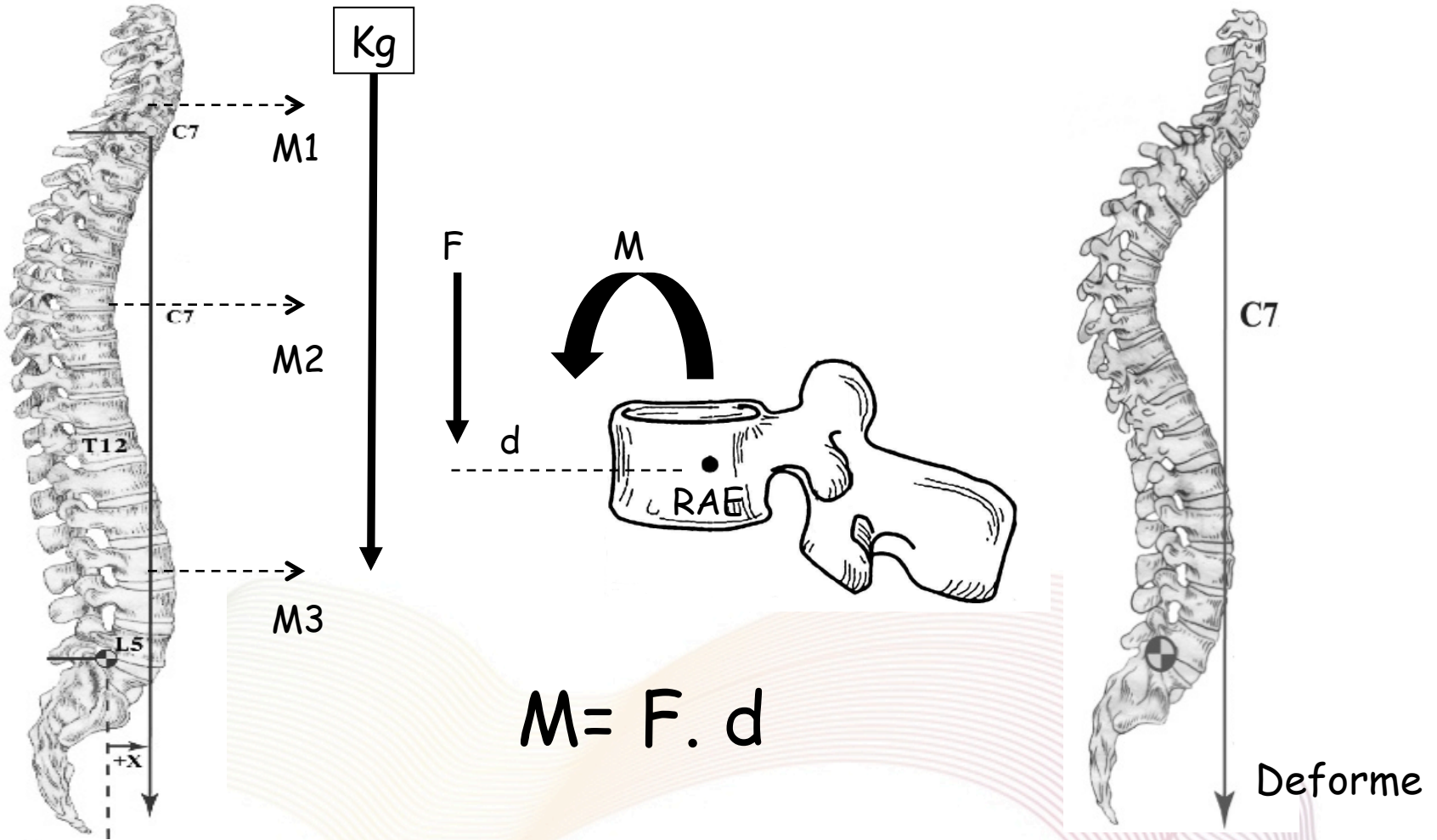


Adaleler

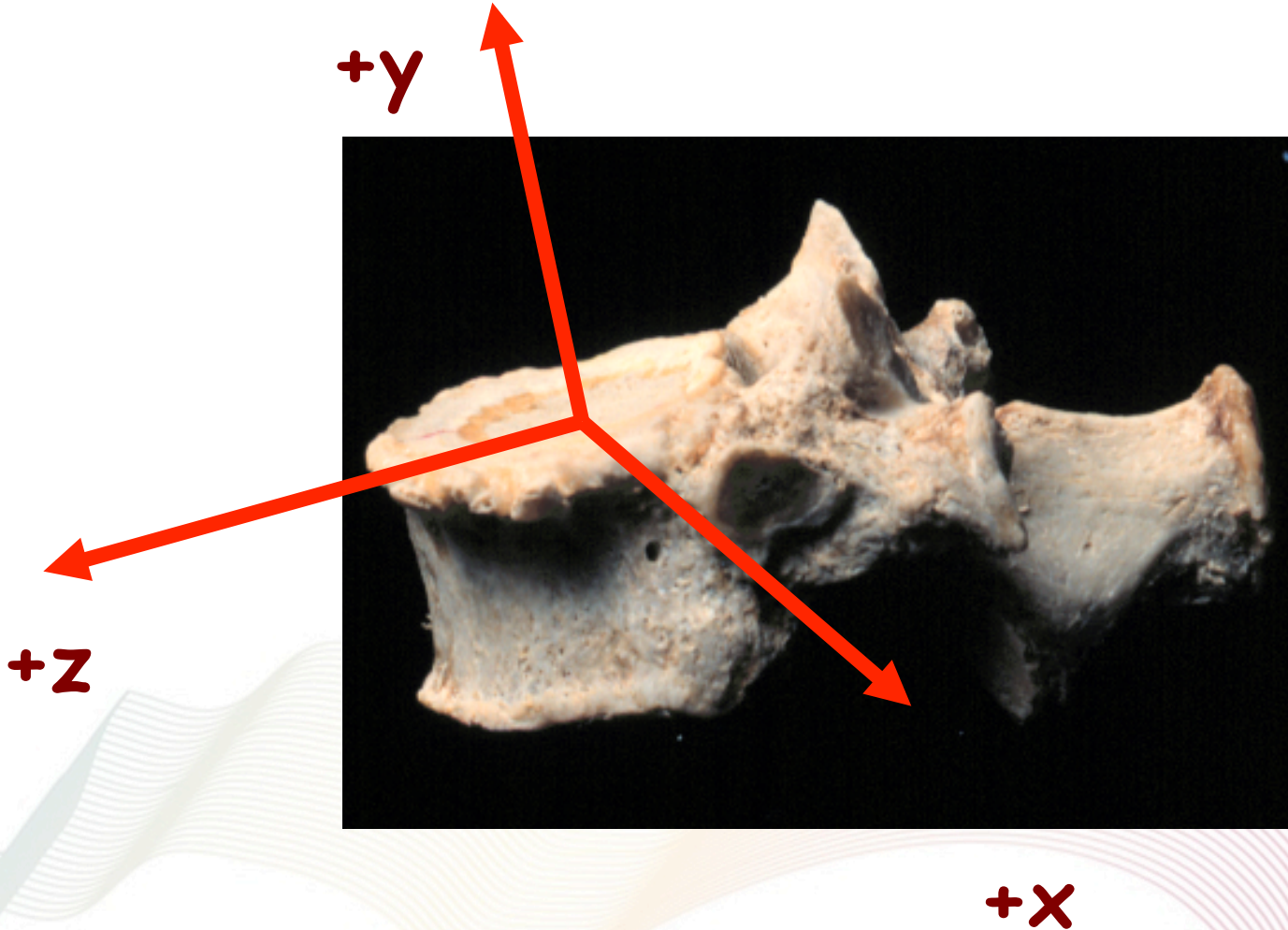


İntervertebral disk

# Moment

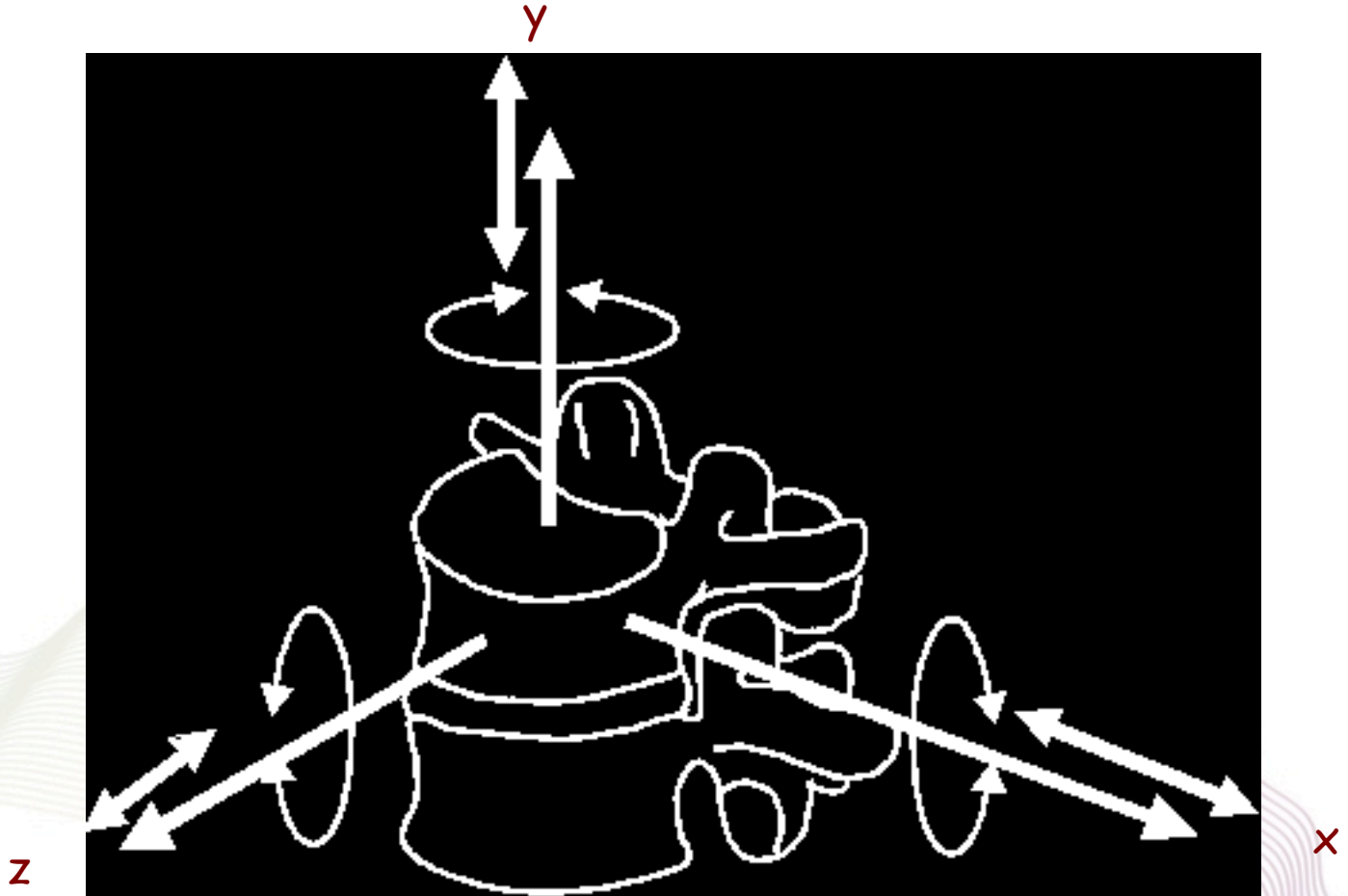


# Pozitif Eksen Takımı



# Hareket Serbestliđi

## 6 yönde hareket serbestliđi

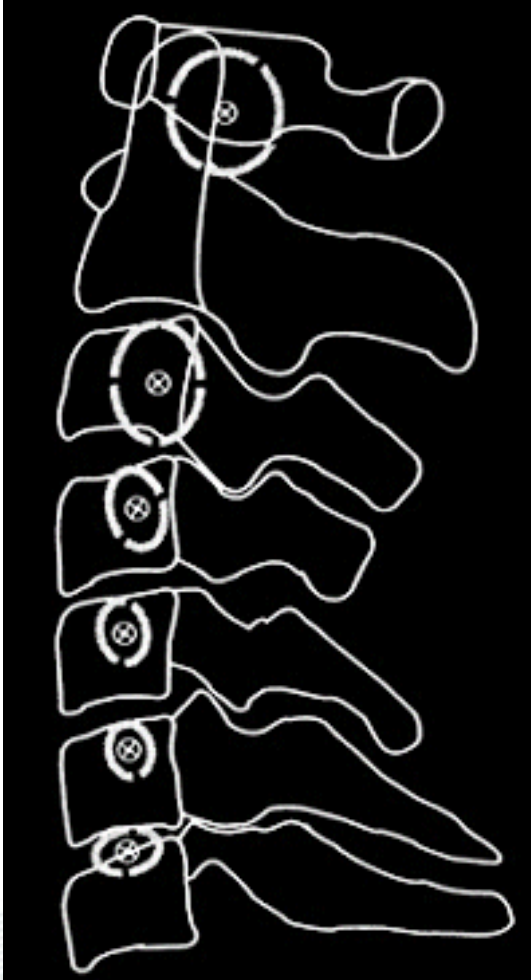




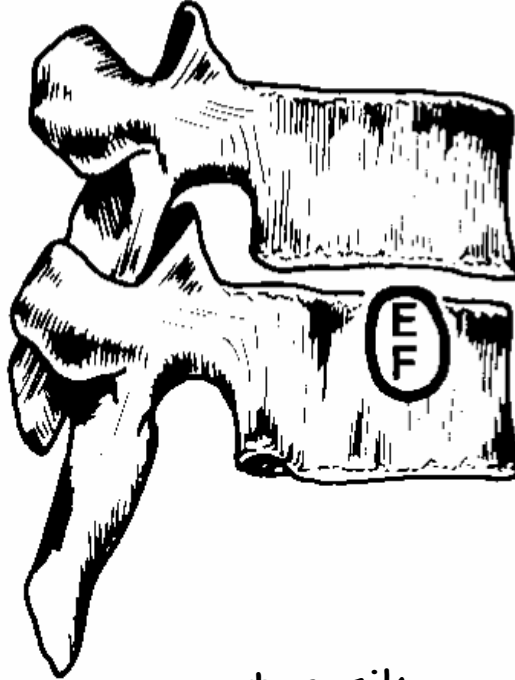


# Rotasyonun Anlık Ekseni (RAE)

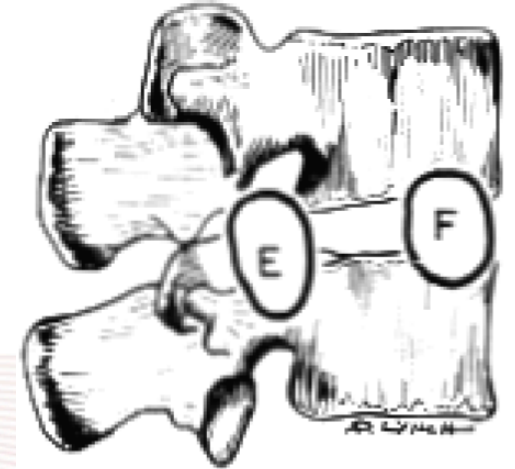
Sagittal plan



servikal

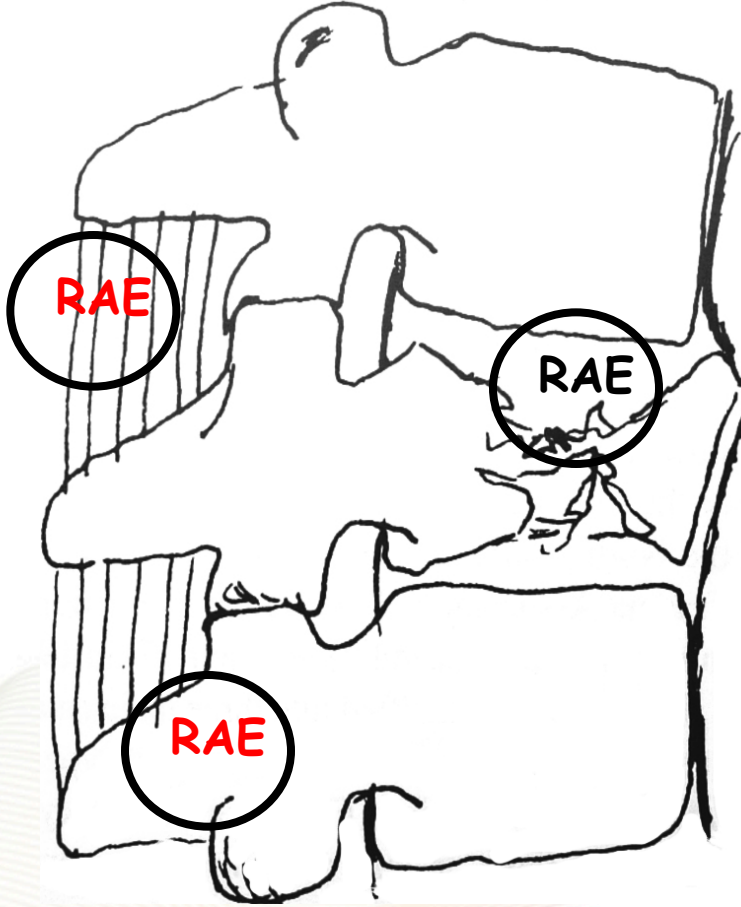


torasik



lomber

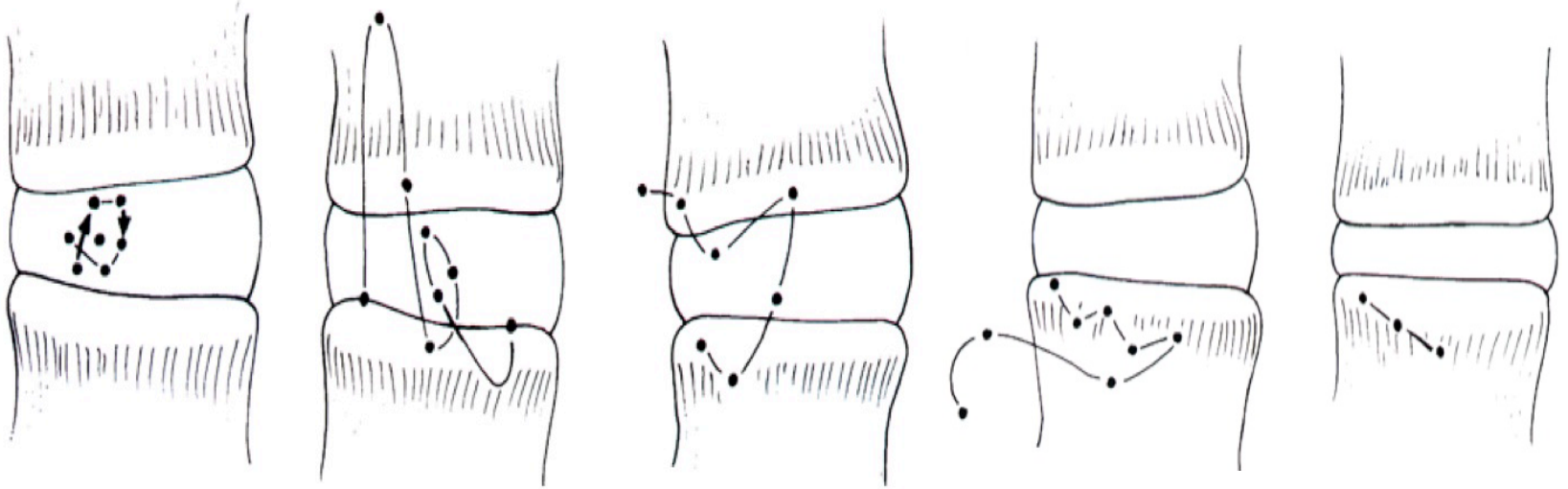
# RAE yer deęiřtirir mi ?



Stabilizasyon bozulması

# RAE yer deęiřtirir mi ?

## Lomber sagittal plan



# Tek Planda RAE Doğruluğu ?

GERÇEK KATI CİSİM HAREKETİNİ GÖSTERMİYOR !

A1A2 ve B1B2 noktalarının translasyonu tek bir doğrultuda olmayabilir.

İstatistiksel olarak aynı translasyon vektörlerinin kullanılması gerçekçi değil.

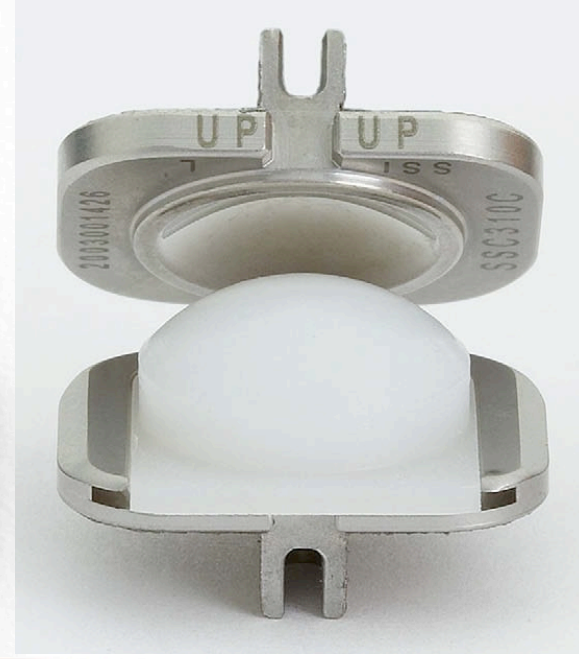
YAKINSAMA OLABİLİR !

# Gerçekçi RAE Çözümü ?

- En az 3 noktanın,
- Translasyon vektörü ve rotasyon matriksinin bilinmesi (röntgen sterofotogrametri)

ÜÇ BOYUTLU RAE !

# Helikal Rotasyon Ekseni

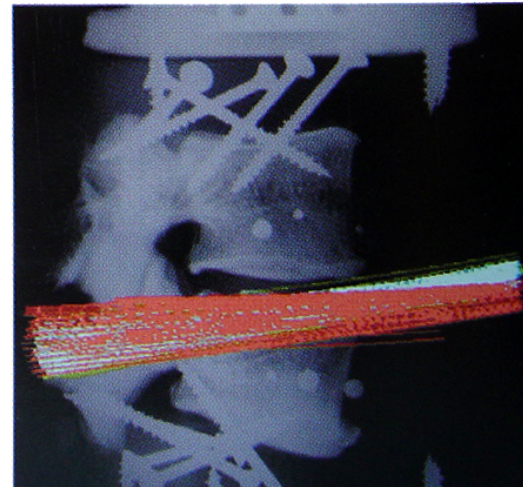
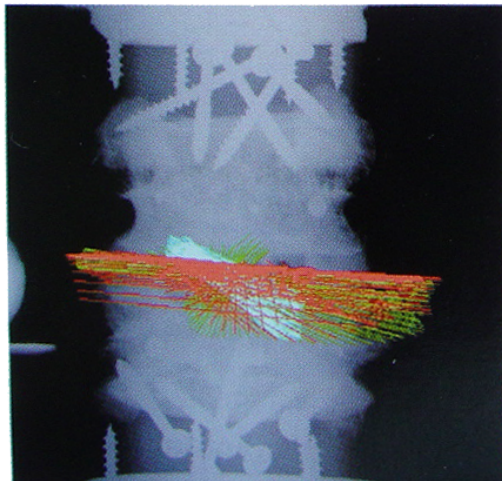
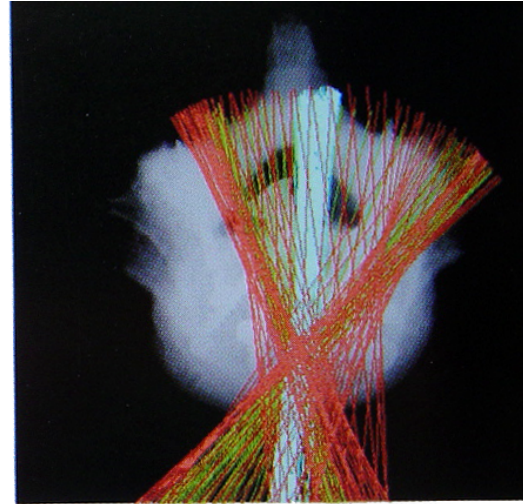
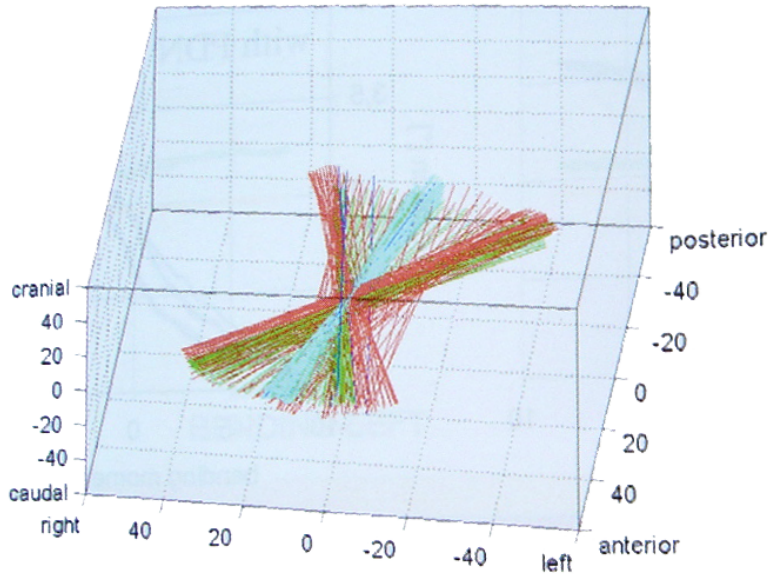


s

x

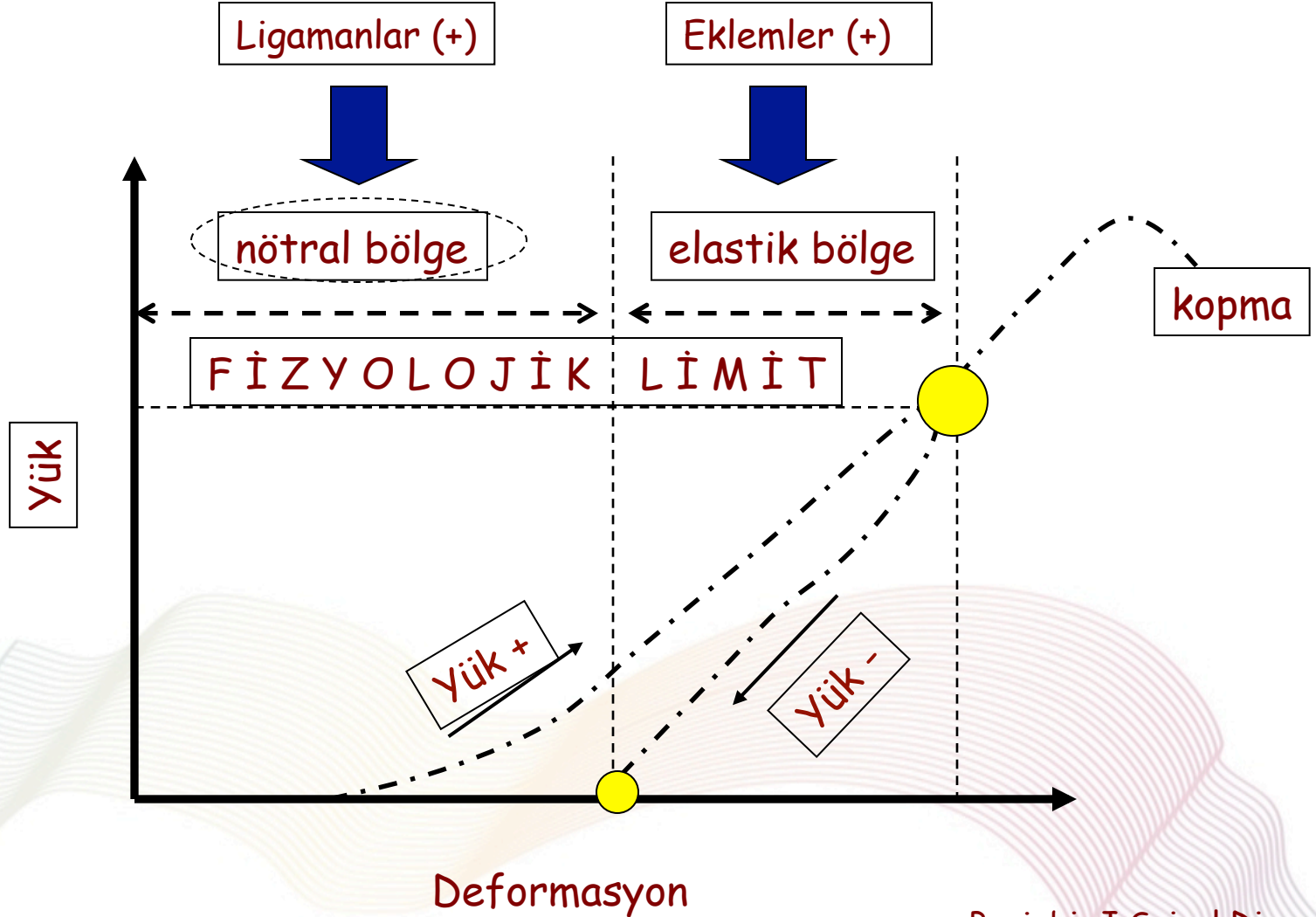
Helikal eksen

# Helikal eksen hareketi (HAM)

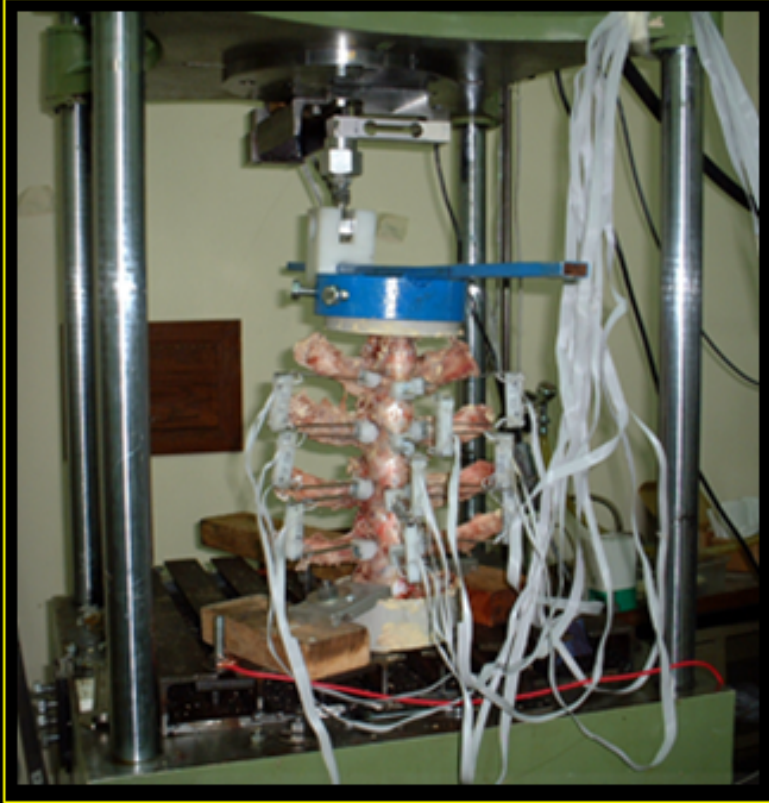




# Hareket Aralığı (ROM)



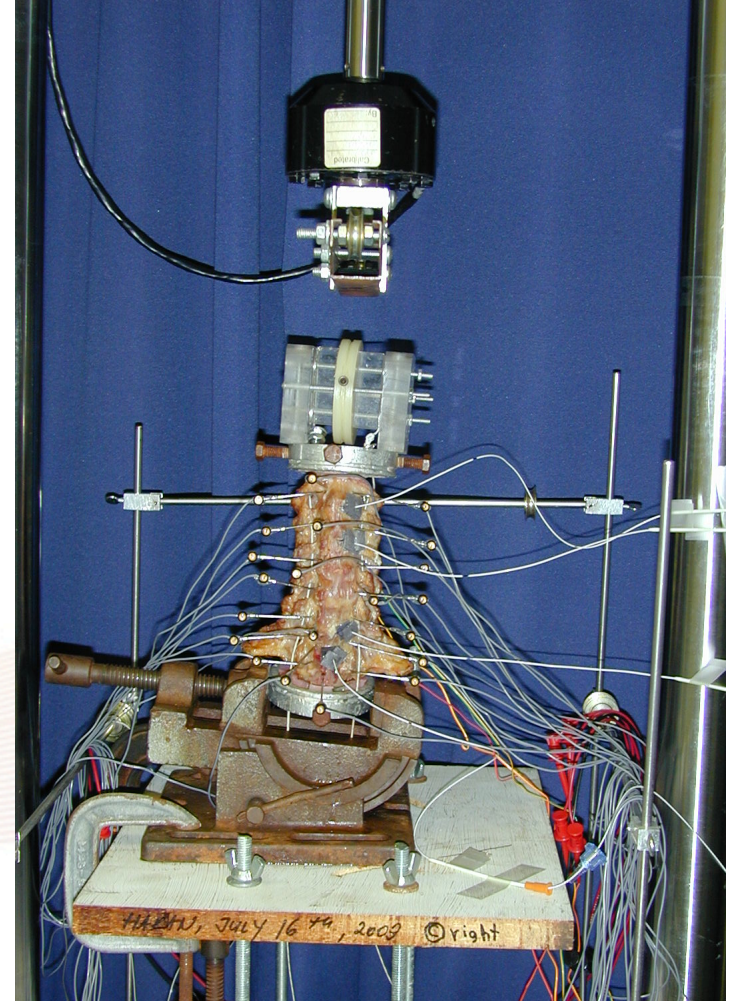
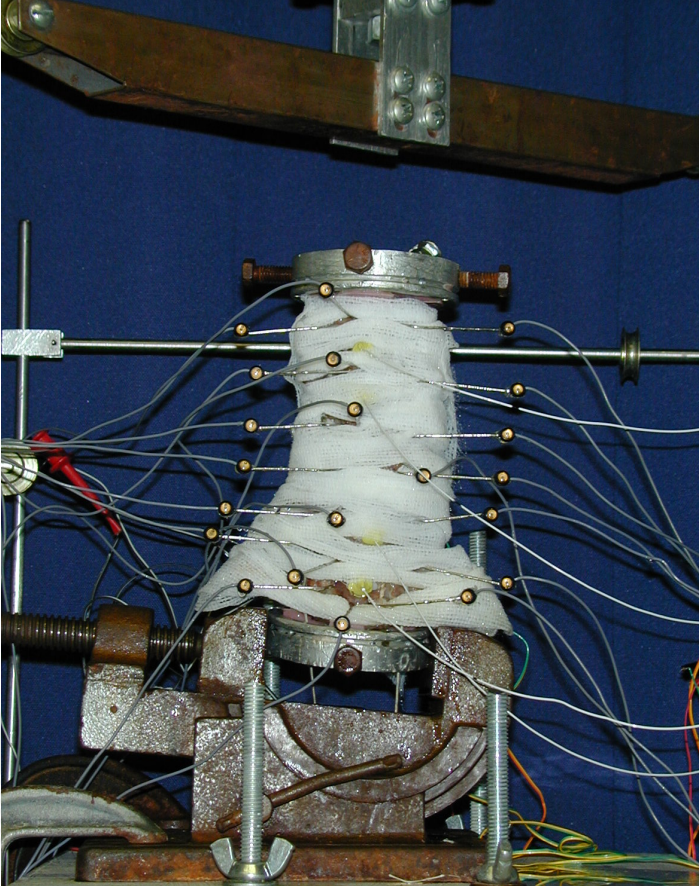
# Hareket Aralığı Ölçümü



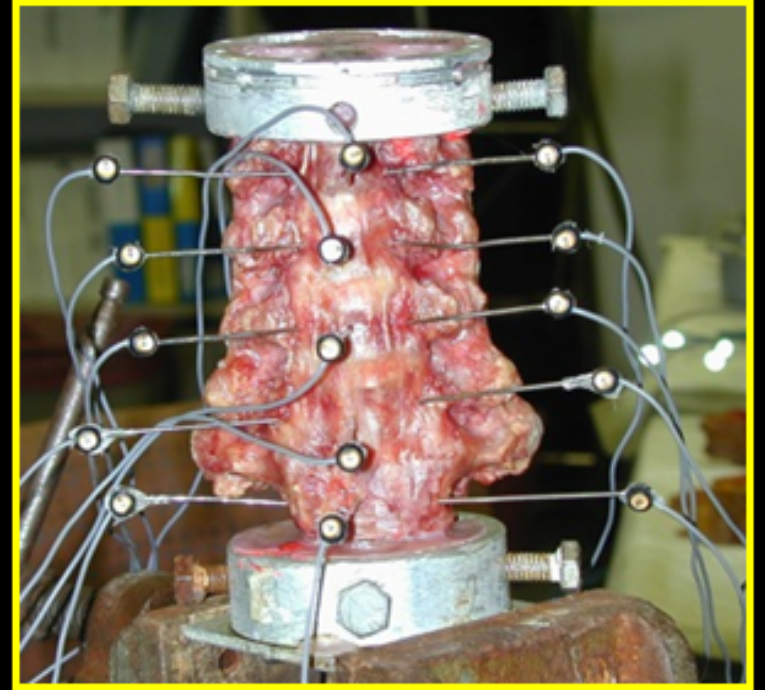
Ekstansometre

# Deney düzeneği

## İnfrared işaretlerin yerleştirilmesi

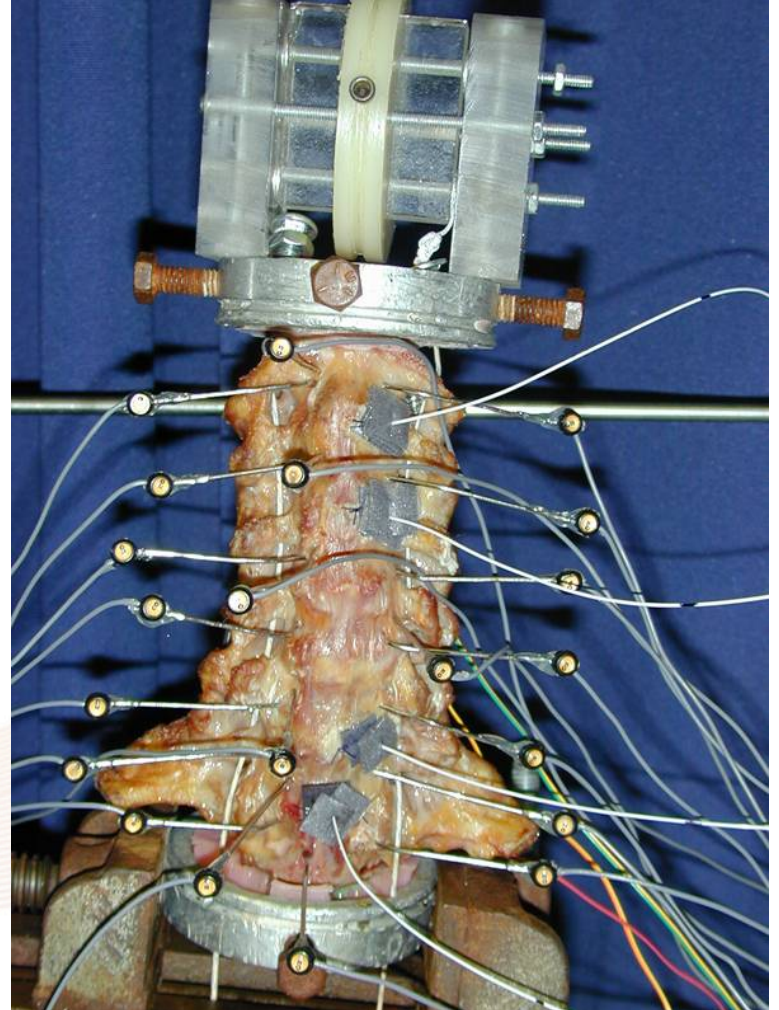
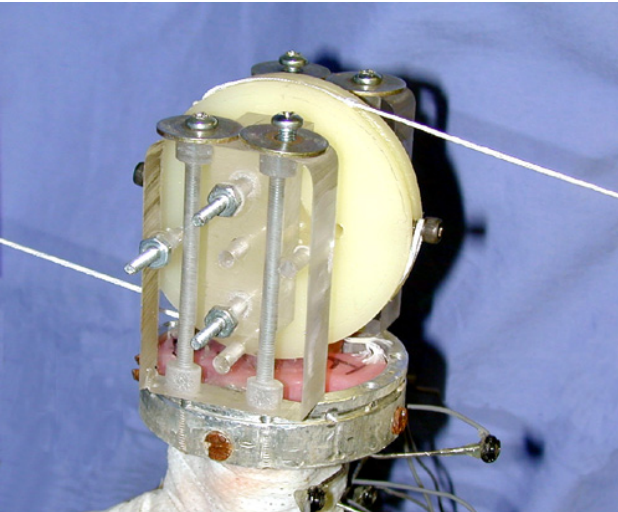
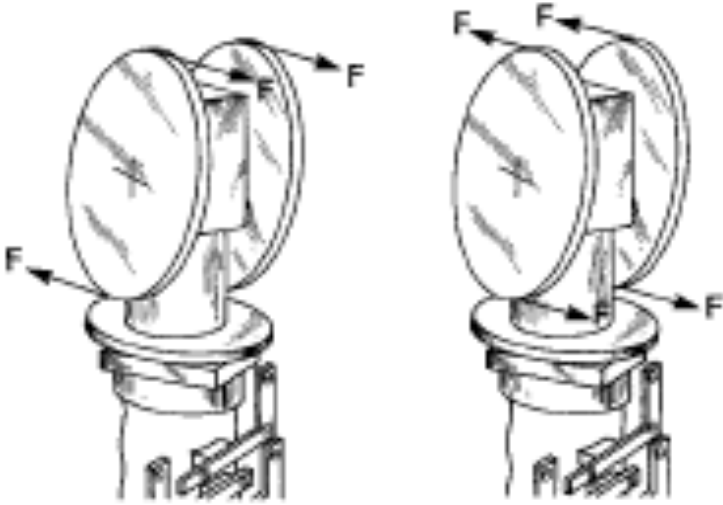


# Hareket Aralığı Ölçümü

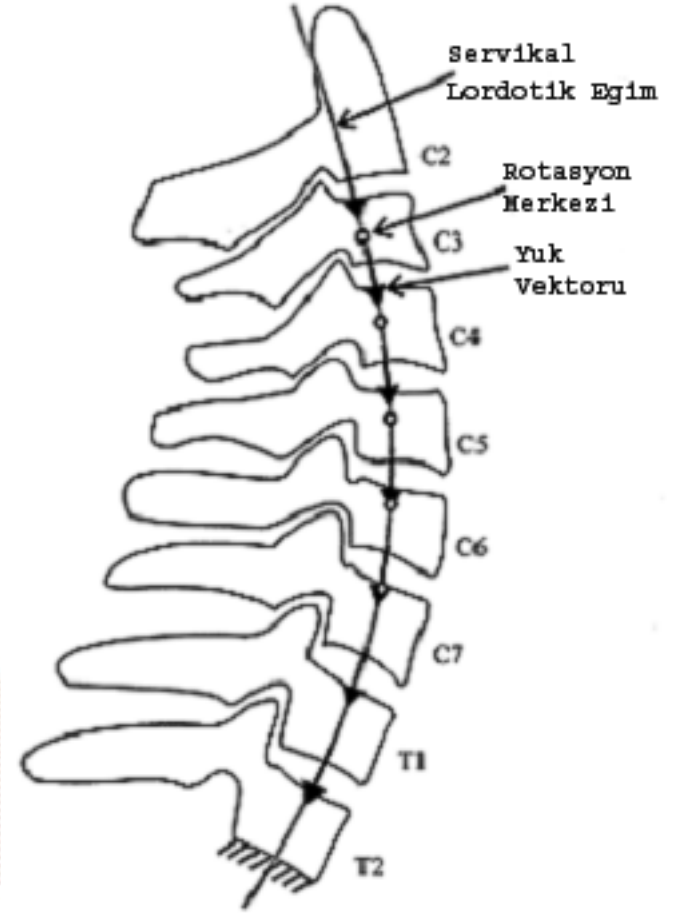
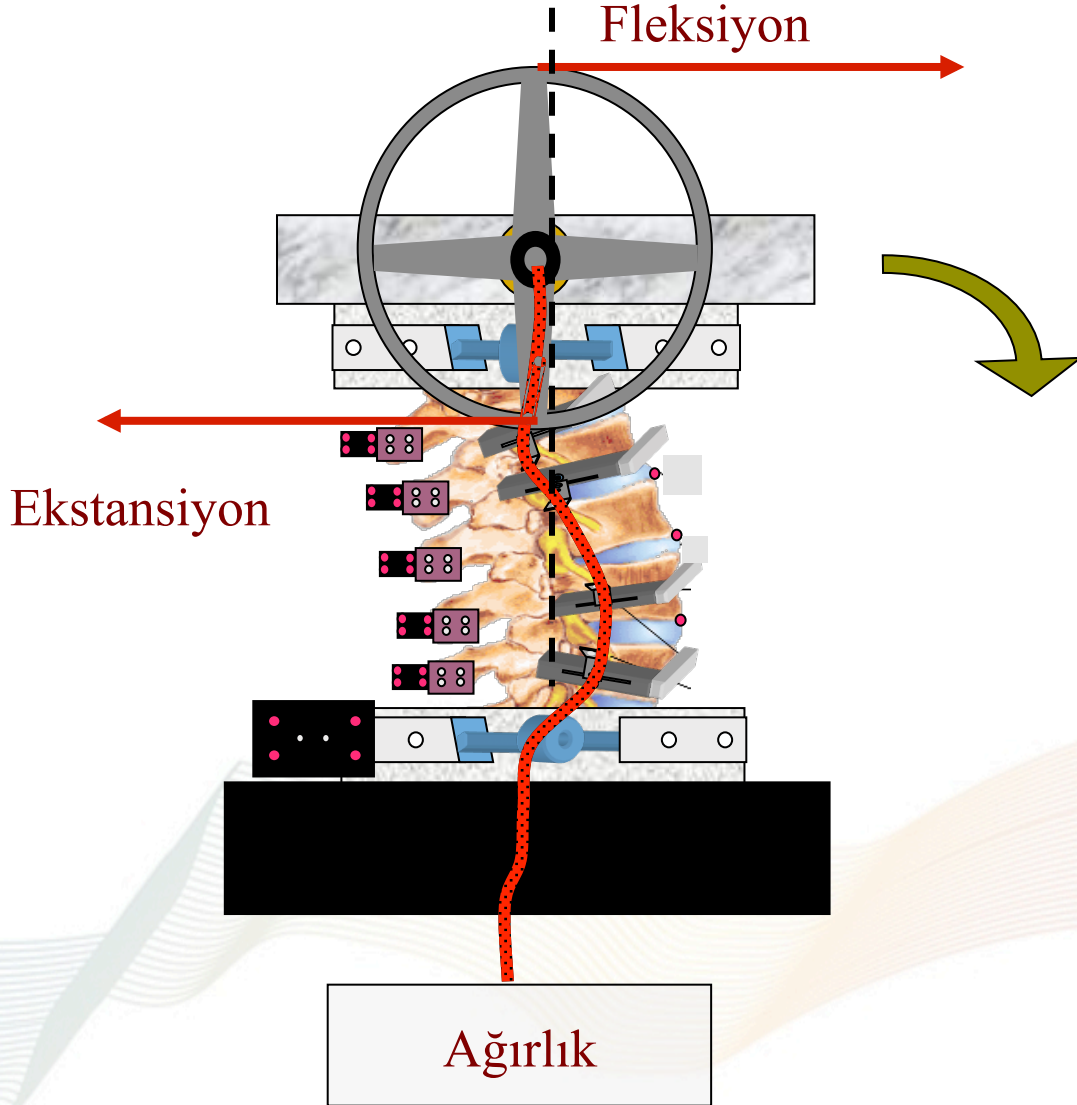


Sterofotogrametri

# Moment yüklemesi

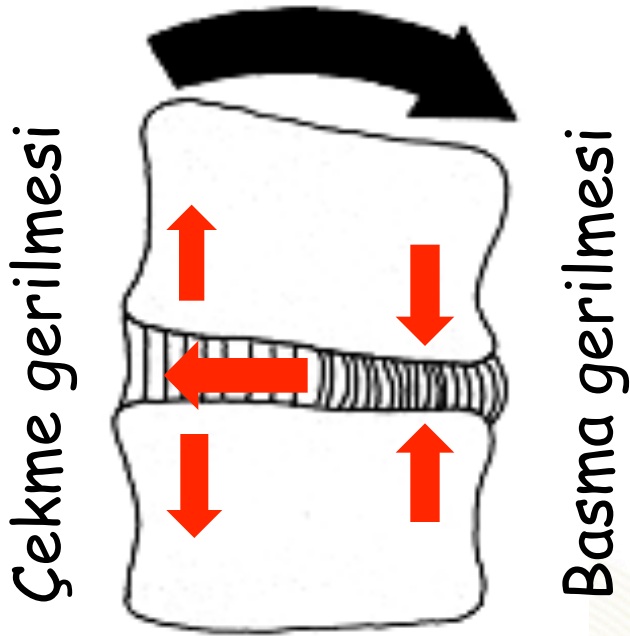


# Tanjansiyel aksiyal yüklenme



# Disk Dokusu Davranışı

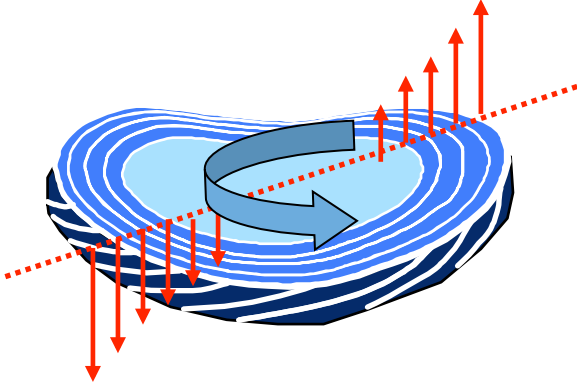
## Flexion/ Extention/ Lateral Bending



- Annulus lifleri basma olan tarafta basma gerilmesi altında
- Annulus lifleri çekme olan tarafta çekme gerilmesi altında
- Nukleus çekme gerilmesi olan tarafa yer değiştirir

# Disk Dokusu Davranışı

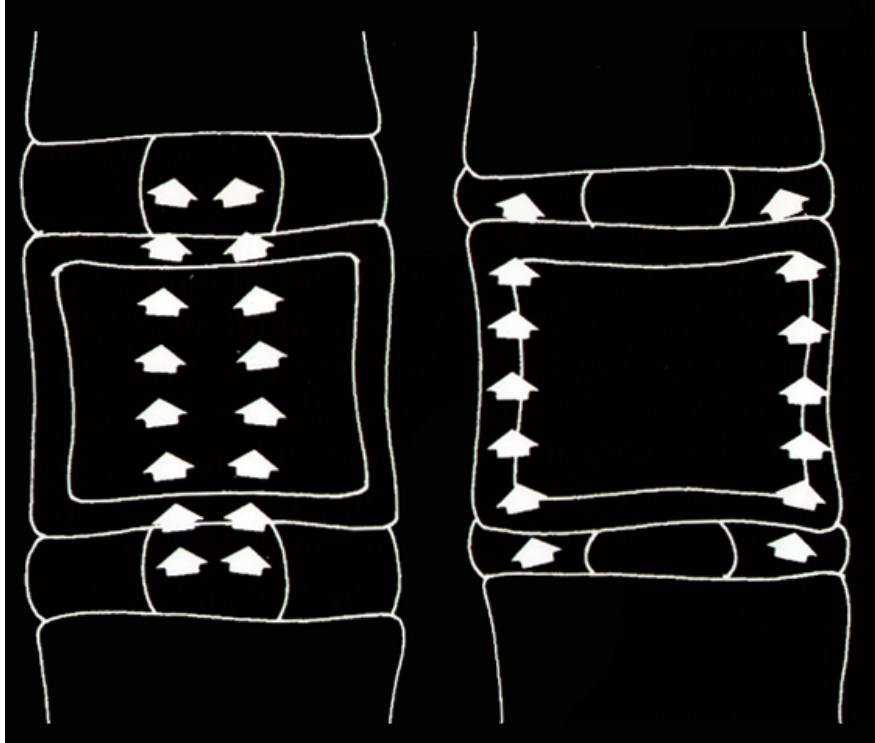
## Axial Rotasyon



- Kayma gerilmesi en fazla posterolateral annulus liflerinde olur
- Bu bölge yırtılmaya ve disk herniasyonuna duyarlı



# Disk Dejenerasyonu

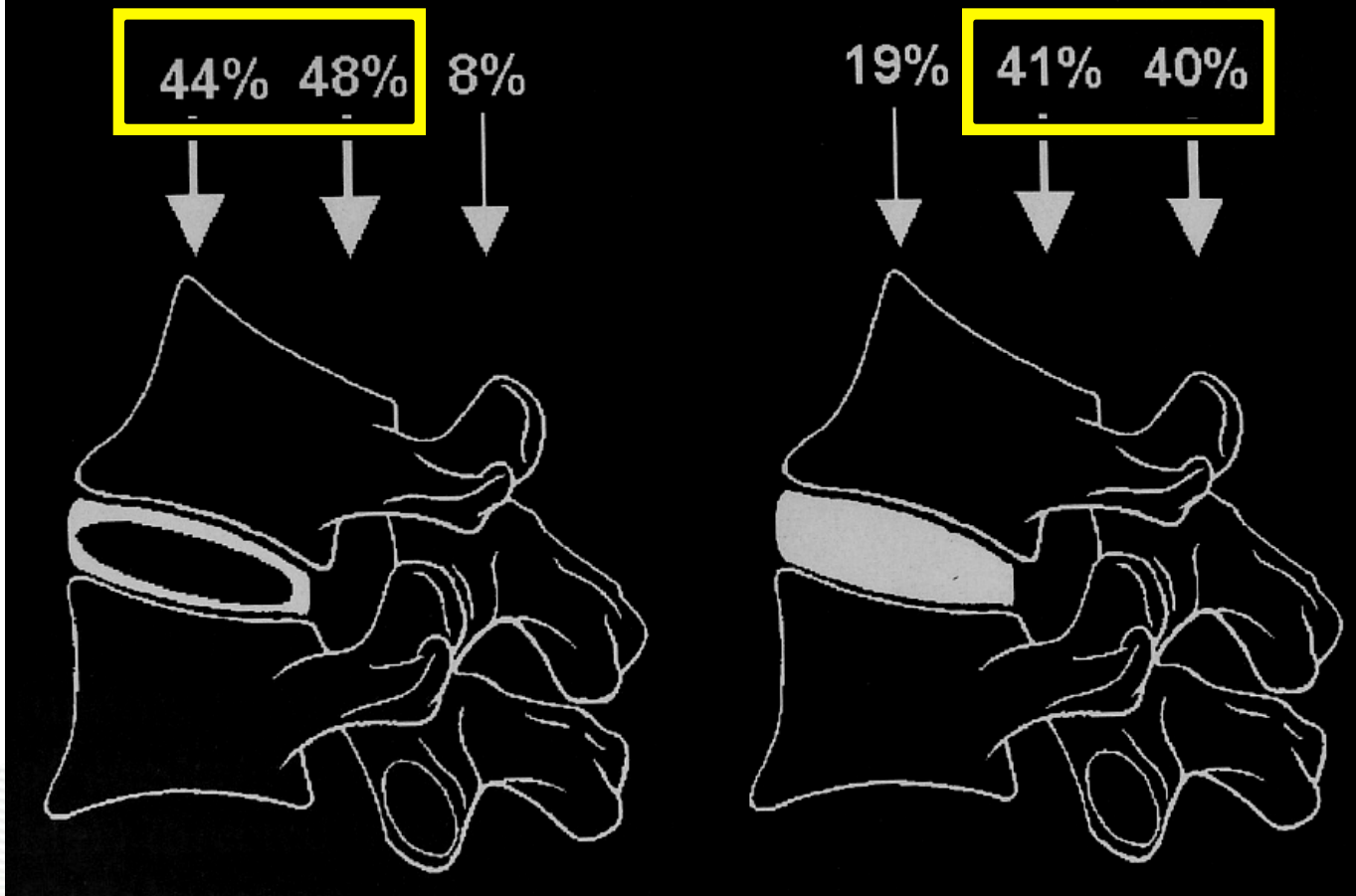


Normal

Dejenere

- Annulus nukleusdan daha fazla yük taşır

# Yük Dağılımı



Normal

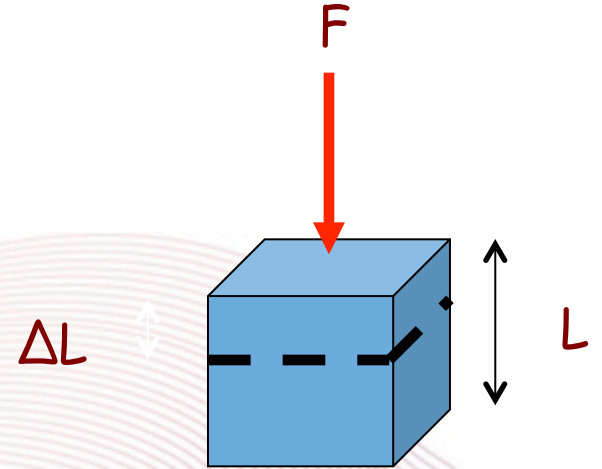
Dejenere

# Birim Şekil Değişirme (strain, $\epsilon$ )

- Geometride oluşan şekil değiştirmenin (uzama, kısalma, kayma) ilk duruma oranı (BİRİMSİZDİR!)

Birim şekil değişirme =  $(\Delta L / L)$

- Basma (compressive)
- Çekme (tensile)
- Kayma (shear)

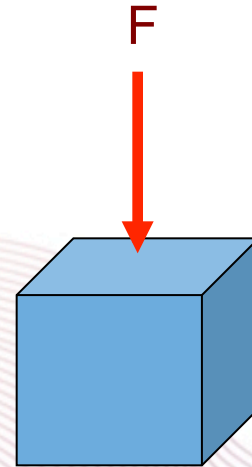


# Gerilme (Stress, $\sigma$ )

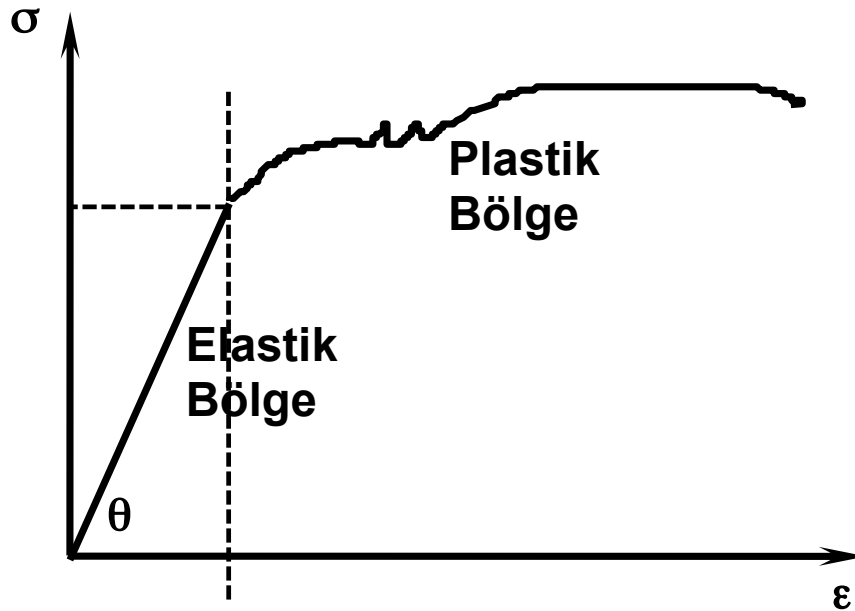
- Birim alana gelen kuvvet ( $\text{Pa} = \text{N}/\text{m}^2$ )

Gerilme = Kuvvet / Alan

- Basma (compressive)
- Çekme (tensile)
- Kayma (shear)



# Elastik bölge, Hooke kanunu



$$\epsilon = \frac{\Delta l}{l}$$

$$\sigma = E \cdot \epsilon$$

Elastisite modülü (Young Modülü) =  $(\sigma / \epsilon)$

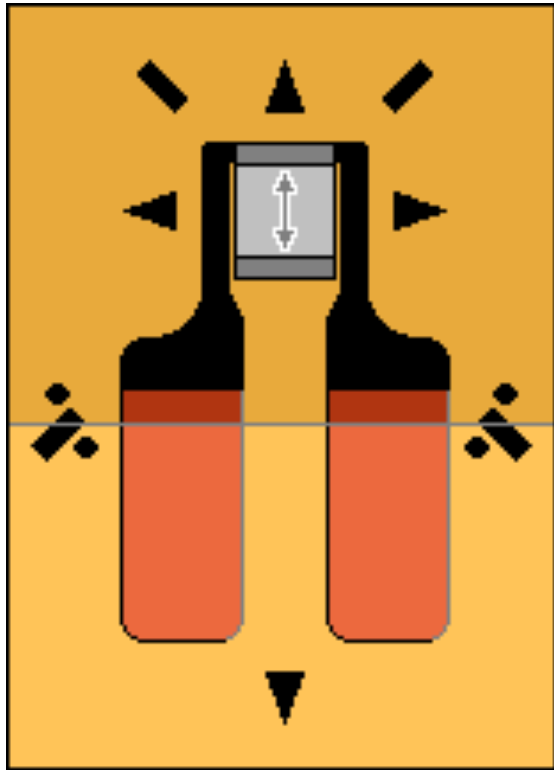
# Mühendislik Teknolojilerinin Kullanımı

1. Kolonlar arasındaki yük dağılımı analizi  
Arka kolon ----- strain gage  
Ön ve orta kolon ----- load cell
2. Komşu disk mesafesindeki basınç değişimi  
Basınç transduserler
3. Omur segmentleri arasındaki hareket  
Sterofotogrametri

# Strain (birim şekil deęiřtirme) ölçüm teknikleri

- Gevrek kaplama
- Fotoelastisite
- Termografi
- Elektrik rezistans strain gage teknięi
- Sonlu eleman yöntemi

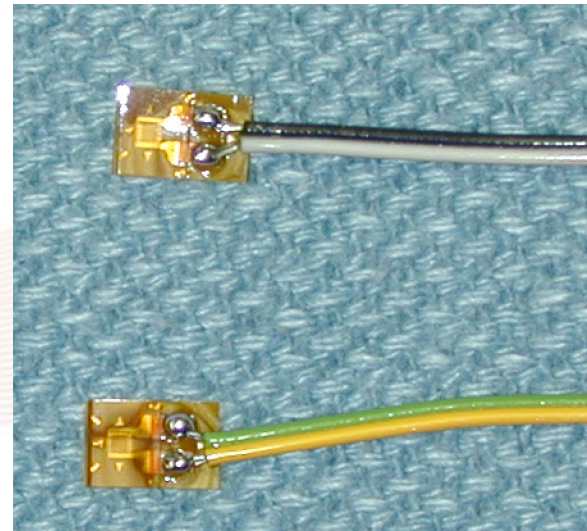
# Strain gage



6.9 mm

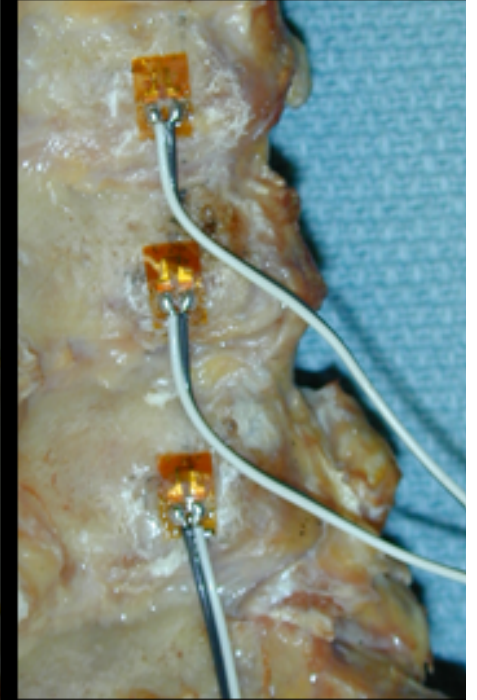
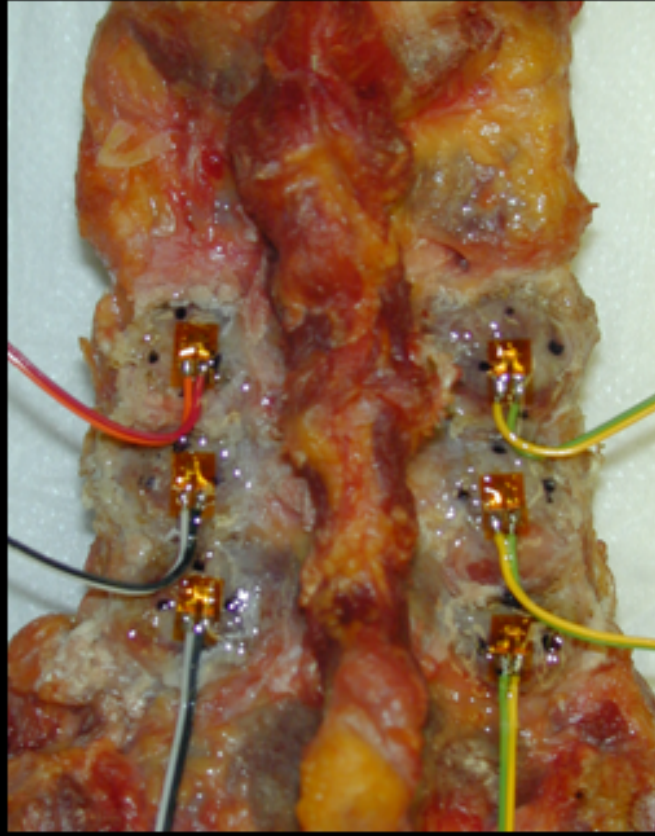
4.8 mm

- Tek eksenli strain gage
- Statik ve dinamik gerilme analizi.





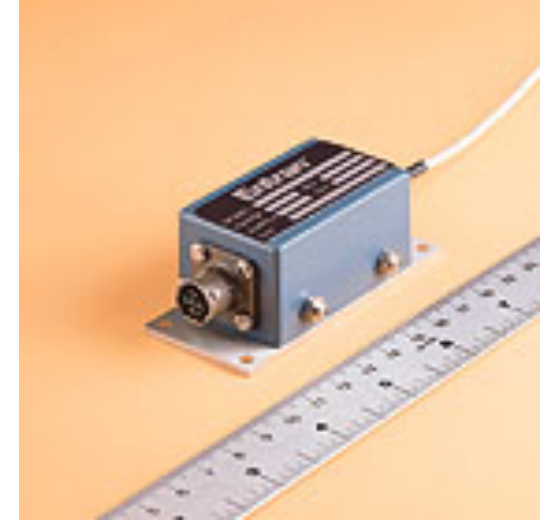
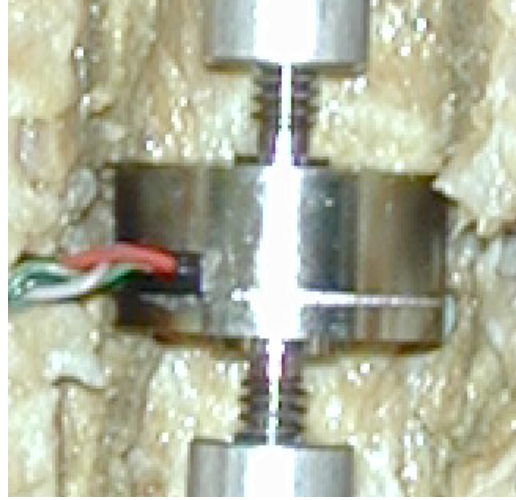
# Lateral mass' lara strain gage yapıştırılması



# Load cell



17.35 mm

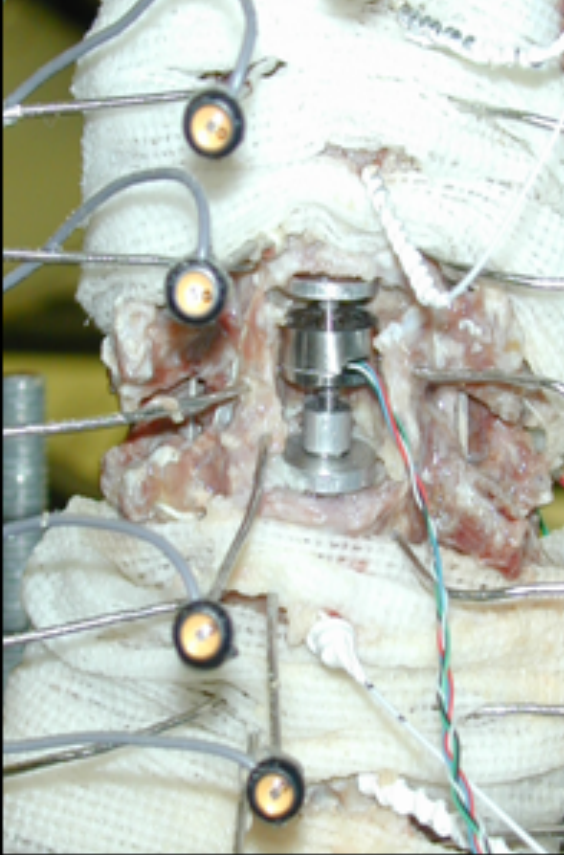


12.7 mm

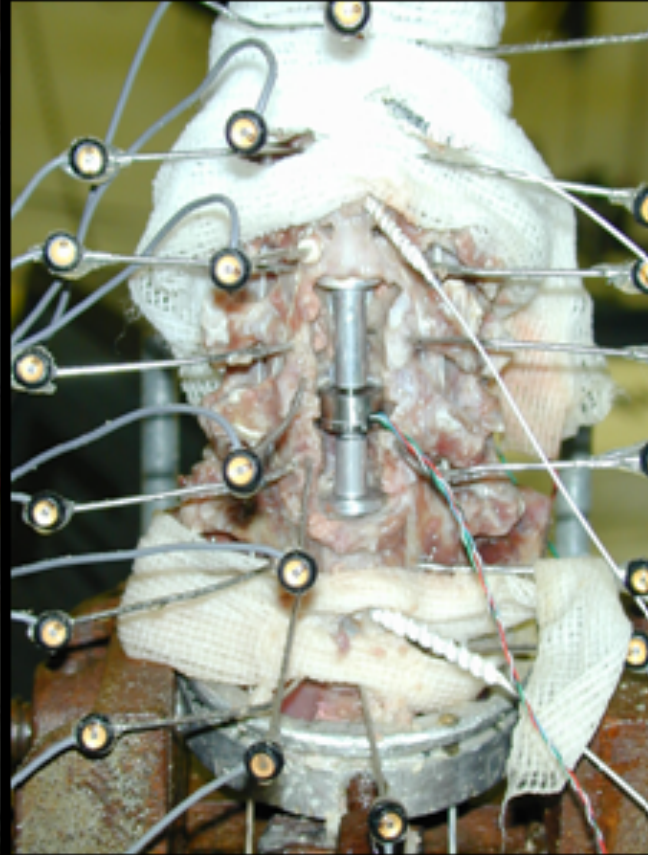
Yükseltici

- Load cell boyutu; 17.35 x 12.7 mm,
- Tek mesafe korpektomi için yeterli.

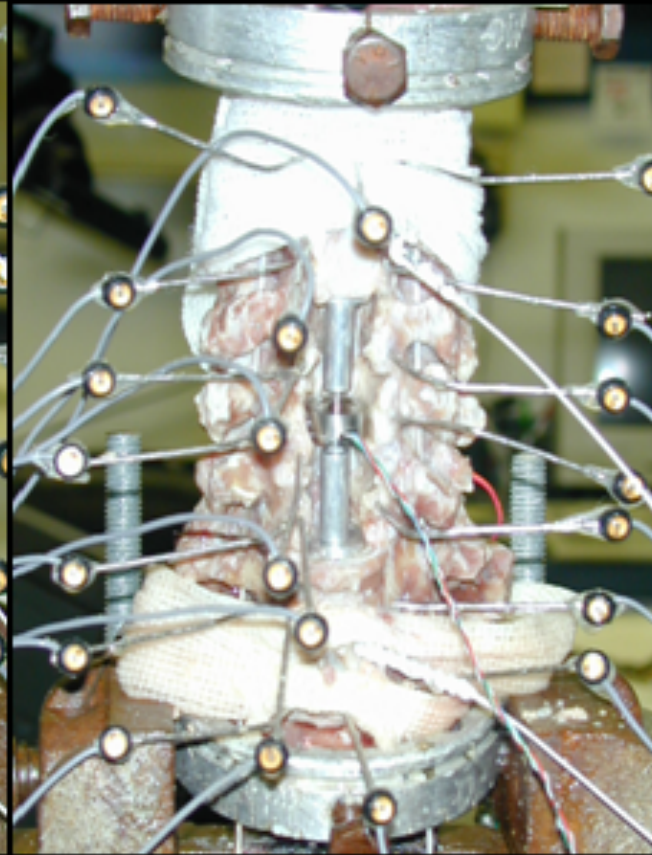
# Load cell' lerin yerleştirilmesi



C5 load cell

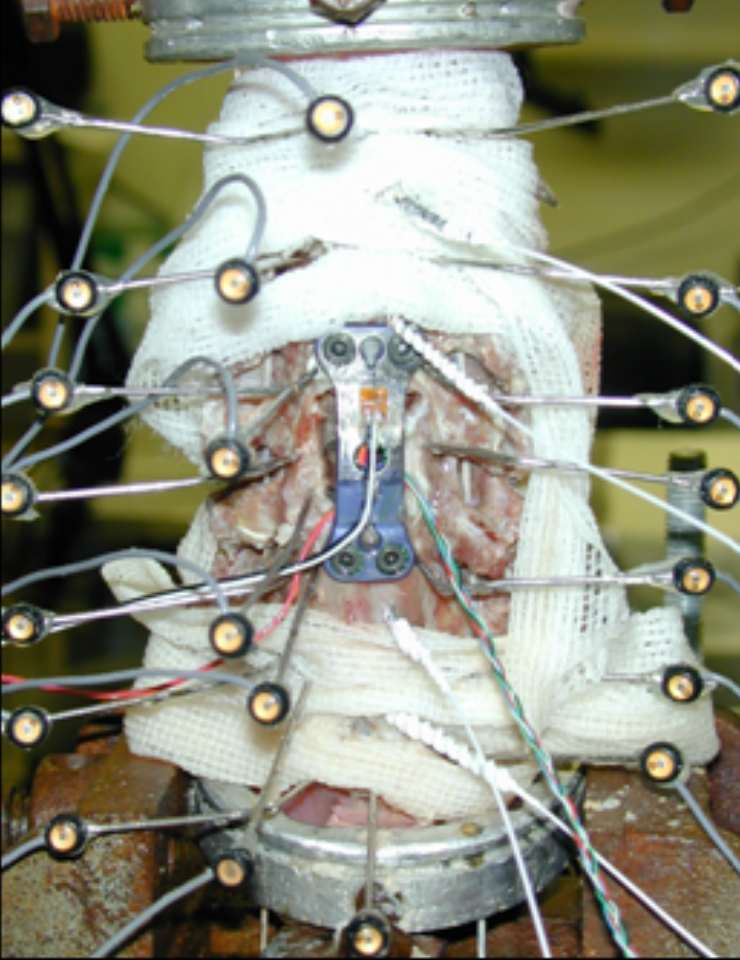


C5-6 load cell

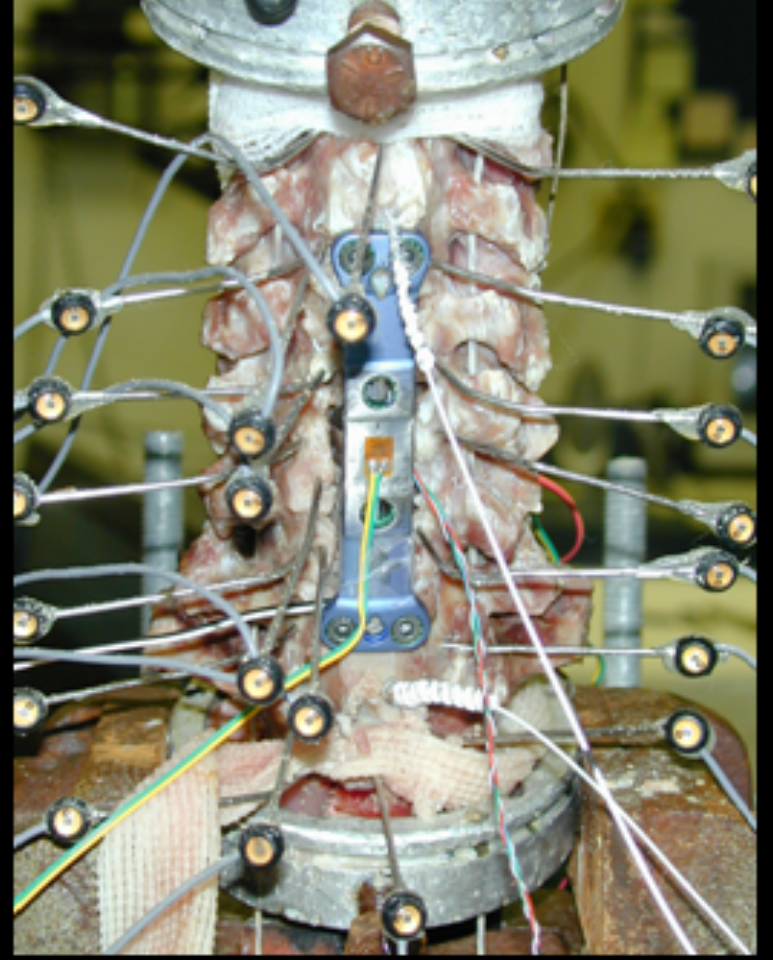


C4-5-6 load cell

# Load cell ve plak yerleřtirilmesi



C5 anterior plak



C4-5-6 anterior plak

# Ultra-minyatür tek alıcılı mikro basınç transduseri



SPR-524

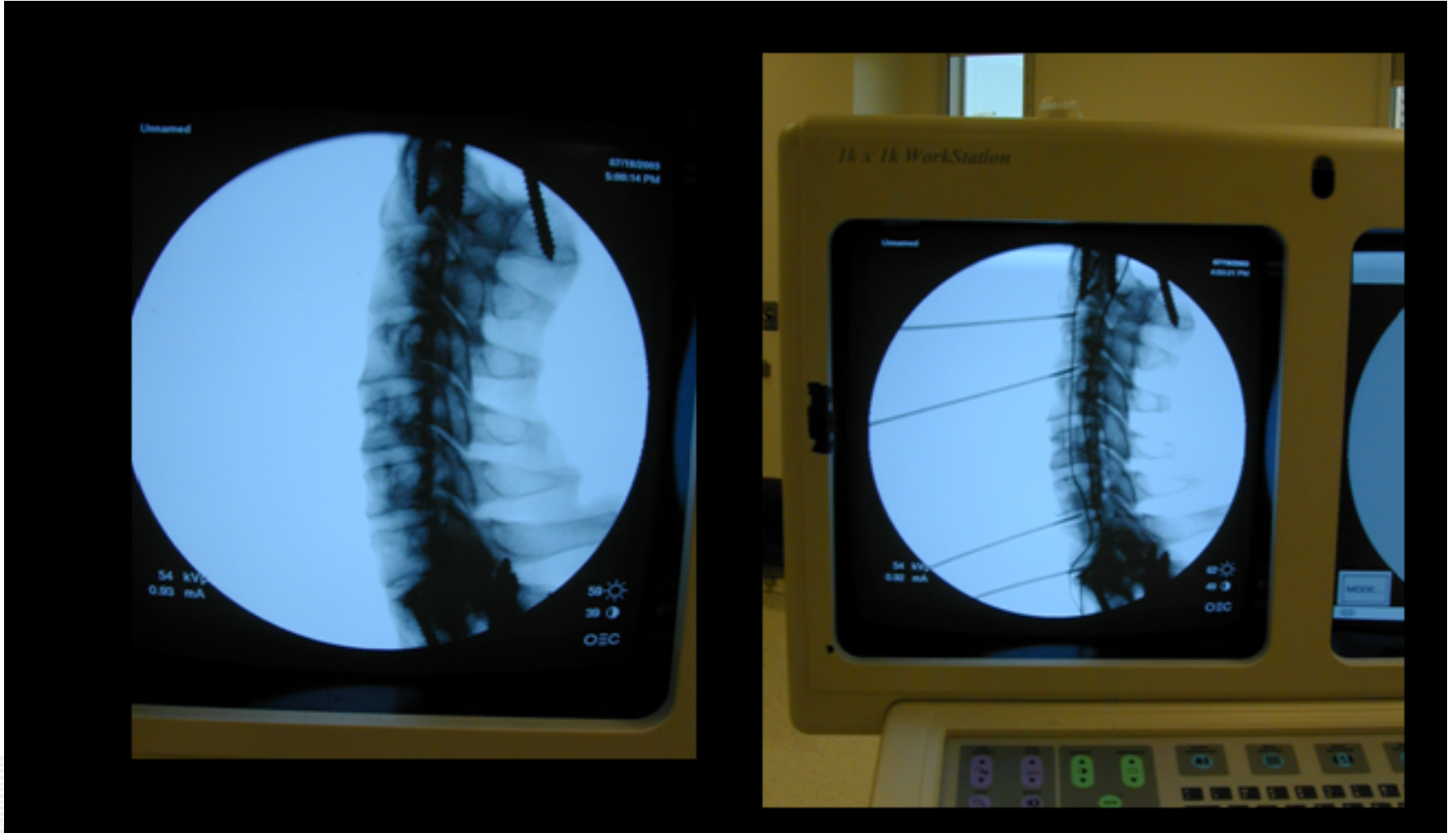
3.5 French (alıcı)

*(3 French ~1 mm)*

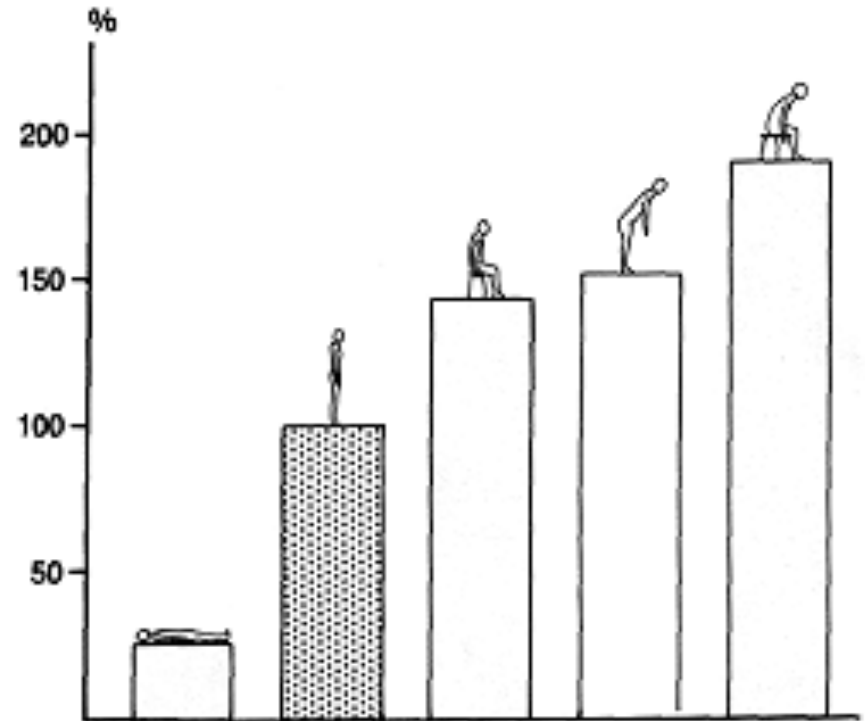


Basınç kontrol ünitesi

# Basınç transduserlerinin yerleştirilmesi

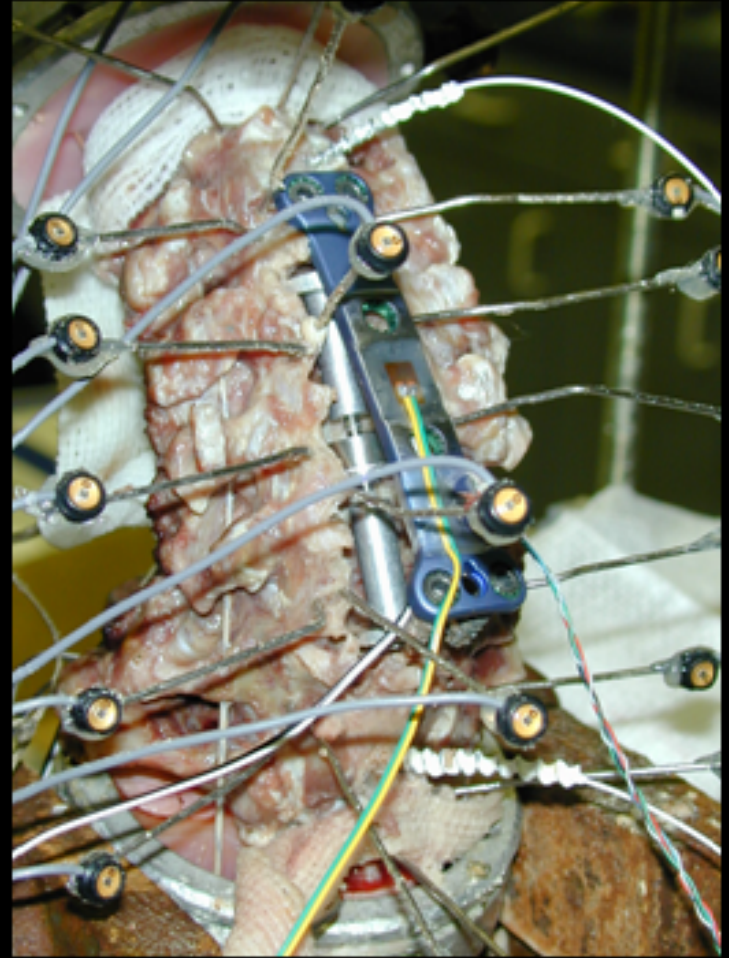
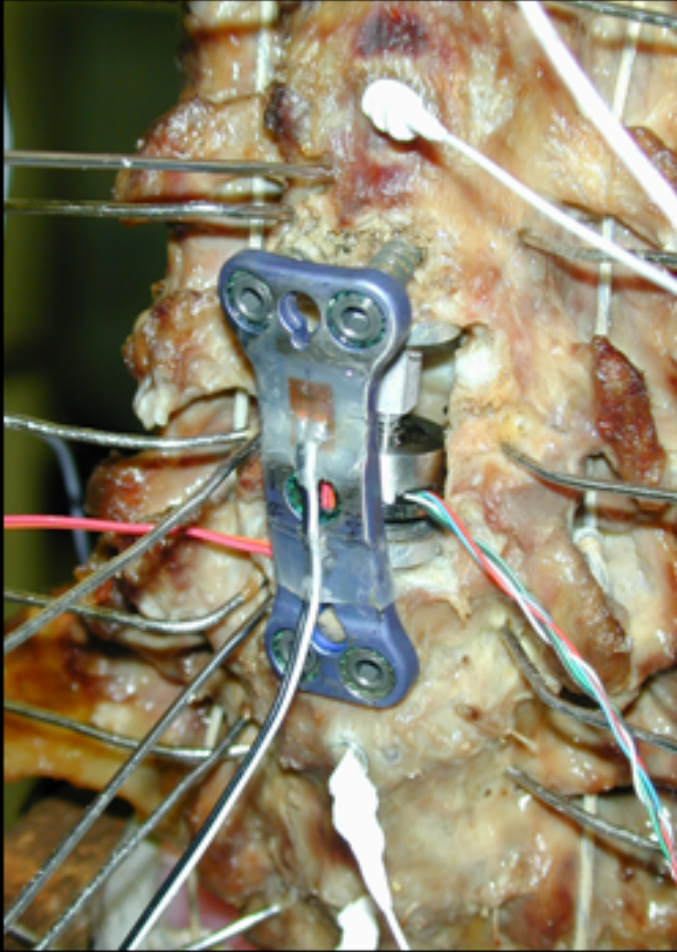


# Disk içi basınç



Nachemson., 1966

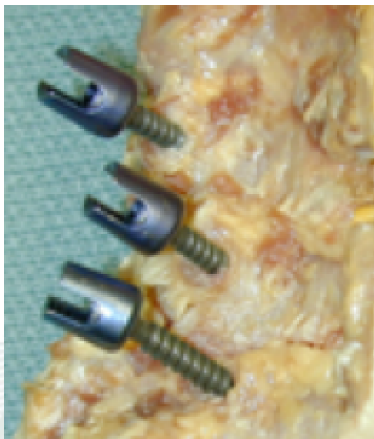
# Başarısız sonuçlar





## Biomechanical Analysis of Rigid Stabilization Techniques for Three-Column Injury in the Lower Cervical Spine

Hakan Bozkus, MD,\* Christopher P. Ames, MD,† Robert H. Chamberlain, MS,‡  
Eric W. Nottmeier, MD,§ Volker K. H. Sonntag, MD,‡ Stephen M. Papadopoulos, MD,‡ and  
Neil R. Crawford, PhD‡

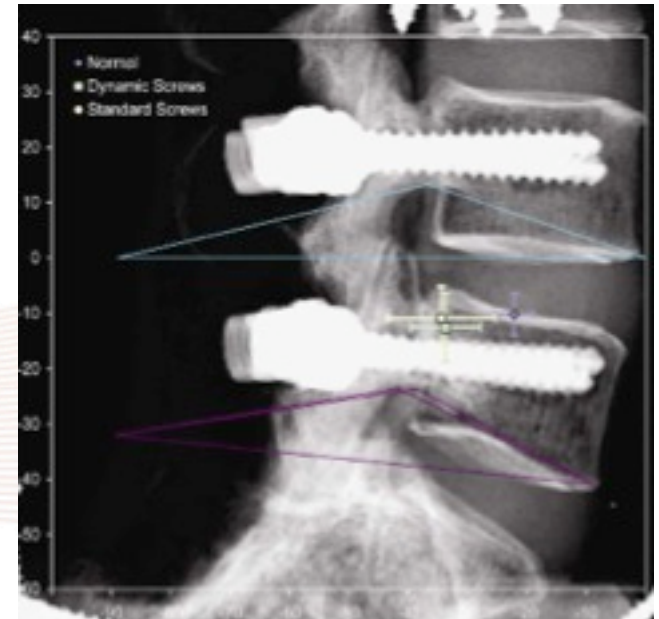
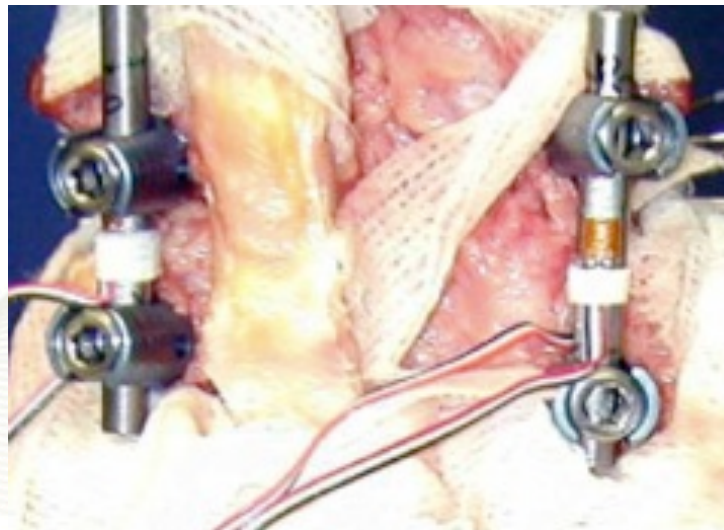
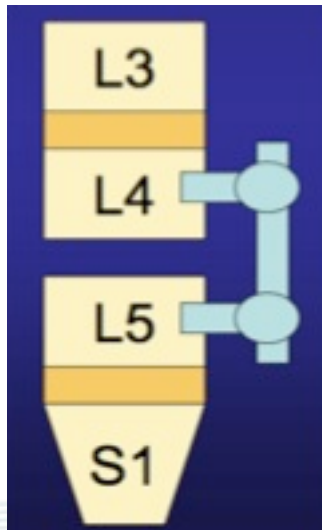


## Dynamic lumbar pedicle screw-rod stabilization: in vitro biomechanical comparison with standard rigid pedicle screw-rod stabilization

### Laboratory investigation

**HAKAN BOZKUŞ, M.D.,<sup>1</sup> MEHMET ŞENOĞLU, M.D.,<sup>2</sup> SEUNGWON BAEK, M.S.,<sup>2</sup>  
ANNA G. U. SAWA, M.S.,<sup>2</sup> ALI FAHIR ÖZER, M.D.,<sup>1</sup> VOLKER K. H. SONNTAG, M.D.,<sup>2</sup>  
AND NEIL R. CRAWFORD, PH.D.<sup>2</sup>**

*<sup>1</sup>Department of Neurosurgery, VKV Amerikan Hastanesi, Istanbul, Turkey; and <sup>2</sup>Barrow Neurological Institute, Spinal Biomechanics Research Laboratory, Phoenix, Arizona*



# Standartlar

## ASTM F1717 - 13

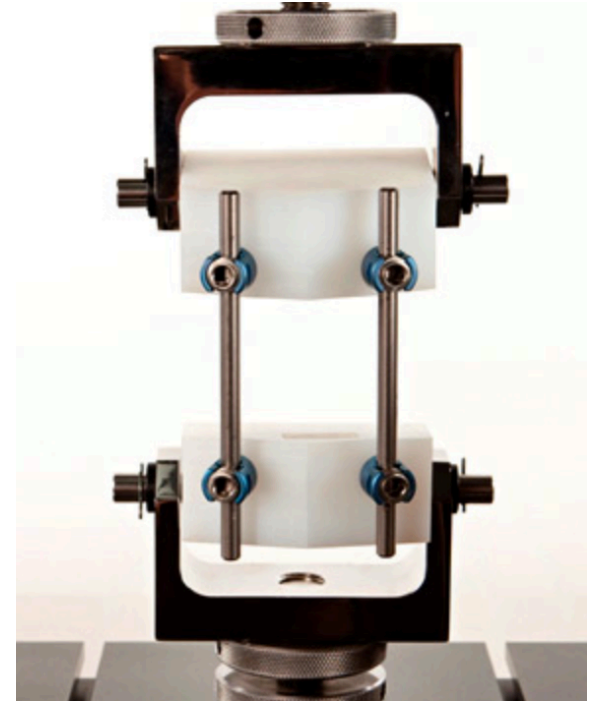
Standard Test Methods for Spinal Implant Constructs in a Vertebrectomy Model

Active Standard **ASTM F1717** | Developed by Subcommittee: [F04.25](#)

Book of Standards Volume: [13.01](#)

## ISO 12189:2008

**Implants for surgery -- Mechanical testing of implantable spinal devices -- Fatigue test method for spinal implant assemblies using an anterior support**


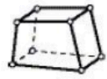
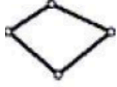




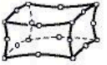

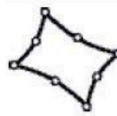



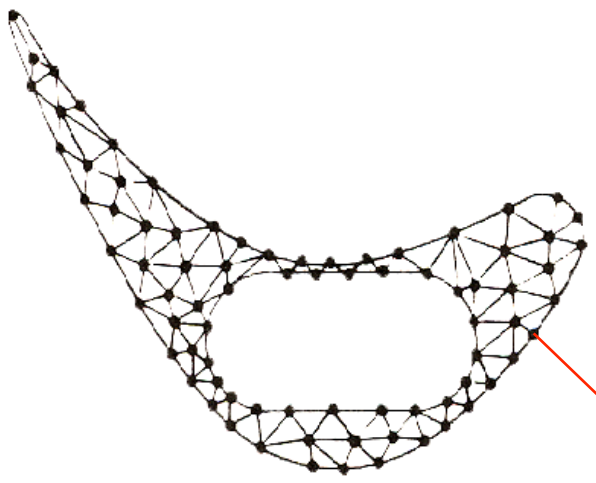
# Sonlu Eleman Yöntemi

- Bir bütünün parçalara ayrılarak incelenmesi
- Uygun geometri (model)
- Mesh yapılması
- Materyel özellikleri
- Sınır şartlarının belirlenmesi
- Yükleme
- Sonuçların deneysel modeller ile kanıtlanması

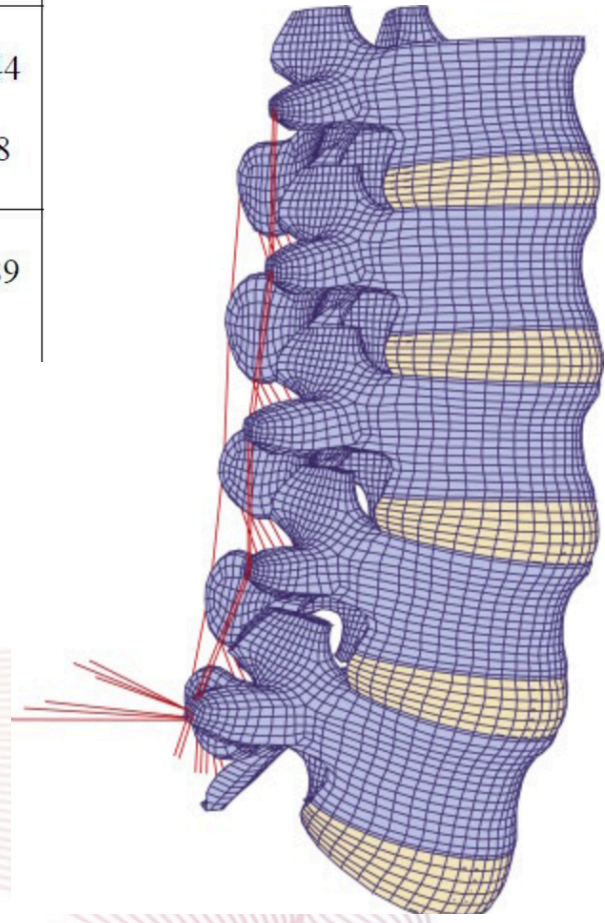


# Model ve Mesh

2D Solid		3D Solid		3D Shell		Line Elements	
 PLANE42 PLANE182	 SOLID45 SOLID185	 SHELL63 SHELL181	 BEAM3/44  BEAM188				
 PLANE82/183  PLANE2	 SOLID95/186  SOLID92/187	 SHELL93	 BEAM189				



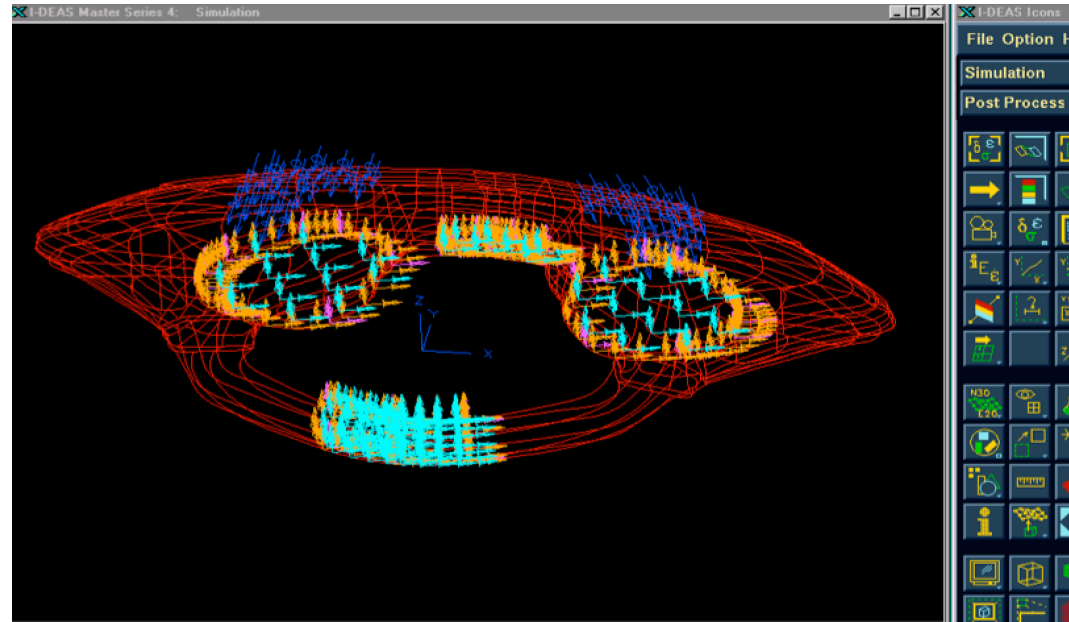
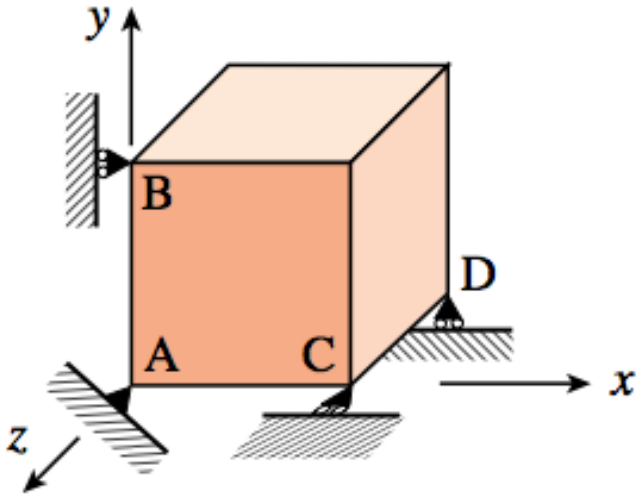
nod



# Materyel Özellikleri

<b>Anatomik bölge</b>	<b>Young's modülü (Mpa)</b>	<b>Poisson's oranı</b>
Kortikal kemik	10000	0.29
Trabeküler kemik	100	0.29
Endplate	500	0.40
Lamina, spinoz proses	3500	0.29
Disk annulusu	3.4	0.40
Disk nukleusu	3.4	0.49
Anterior longitudinal ligaman	11.9	0.39
Posterior longitudinal ligaman	12.5	0.39
İnterspinoz ligaman	3.4	0.39
Ligamentum flavum	2.4	0.39
Kapsular ligaman	7.7	0.39

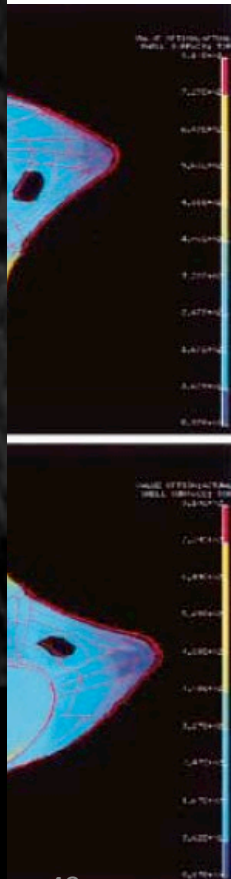
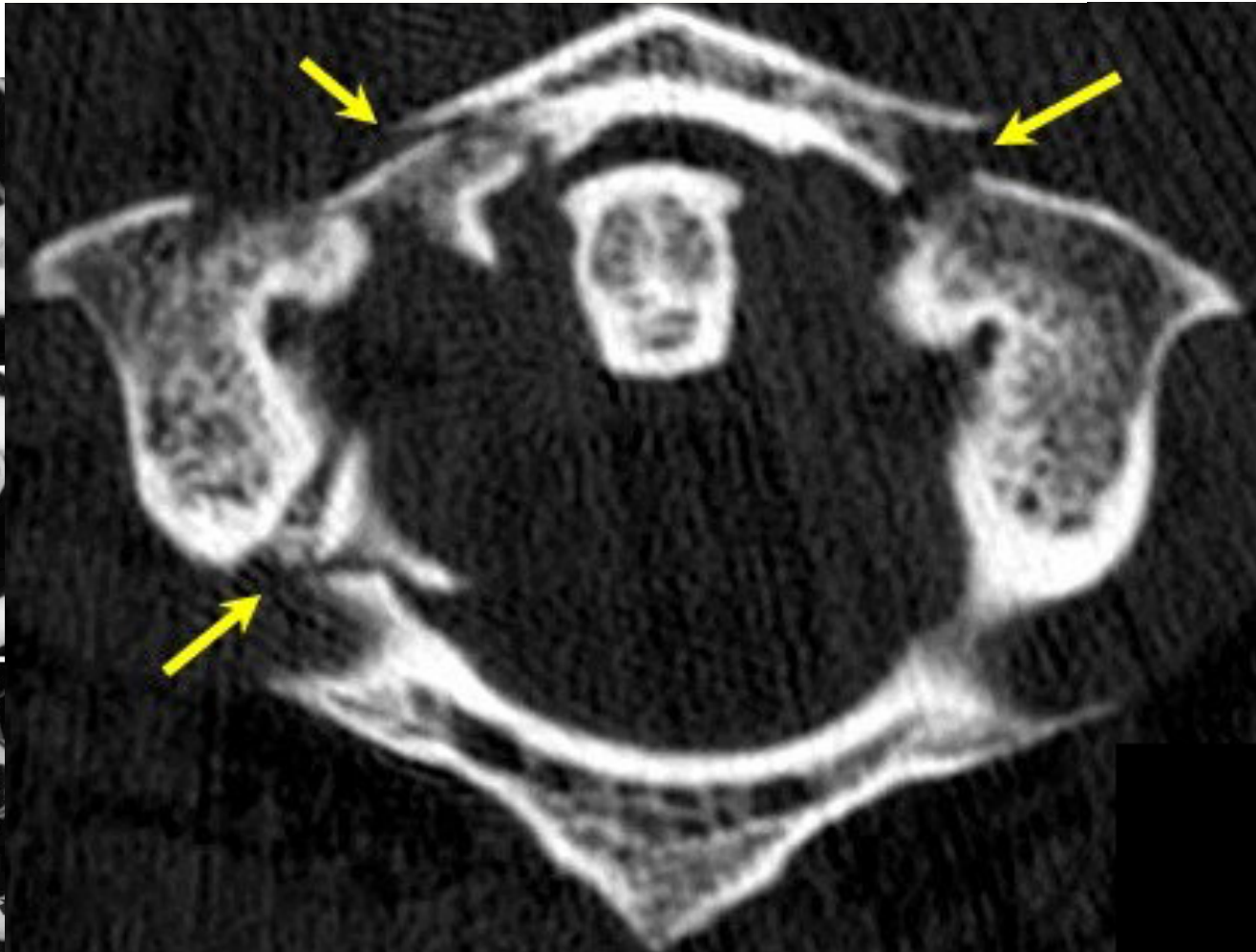
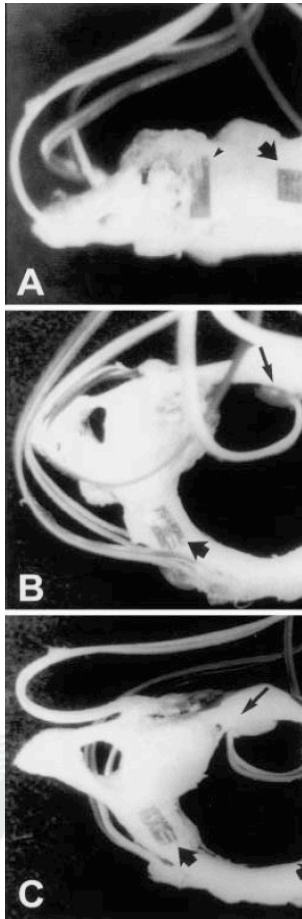
# Sınır Şartları ve Yükleme



Deneysel Model ile Geçerlilik ?

Hakan Bozkus  
Askin Karakas  
Murat Hanci  
Mustafa Uzan  
Ergun Bozdog  
Ali Cetin Sarioglu

## Finite element model of the Jefferson fracture: comparison with a cadaver model





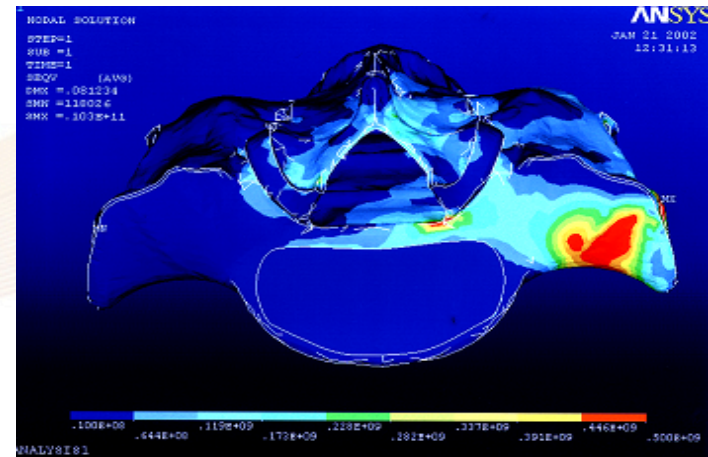
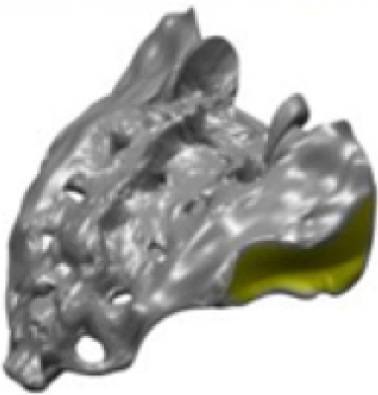
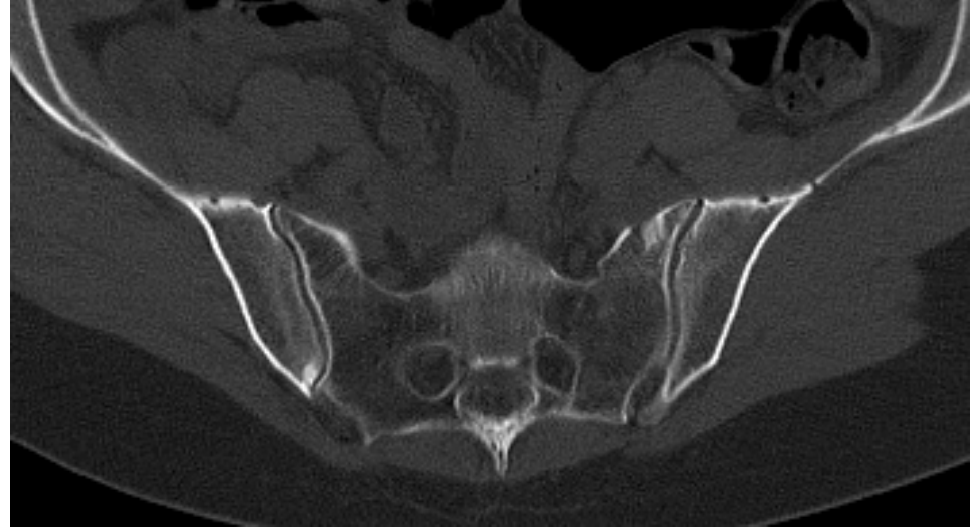
## Finite element method based stress analysis of zone I and zone II sacral fractures

Birinci ve ikinci bölge sakrum kırıklarının sonlu eleman  
metoduna dayalı gerilme analizi

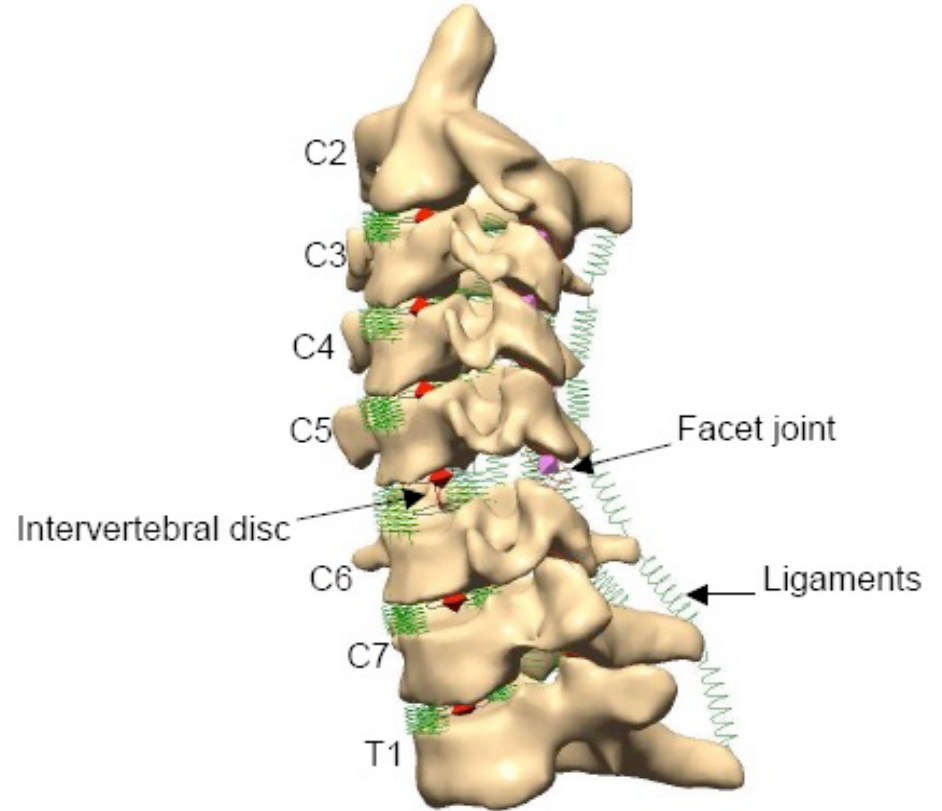
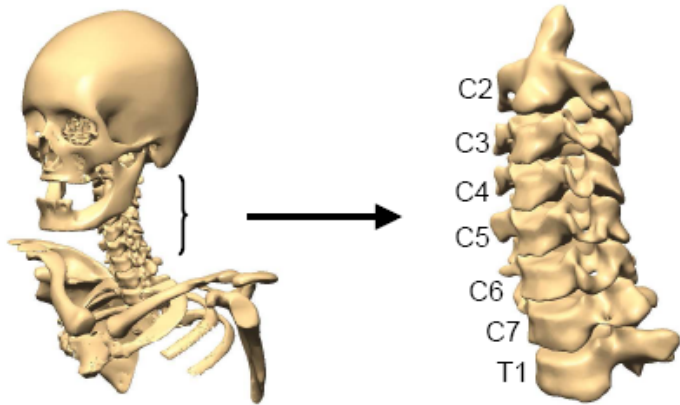
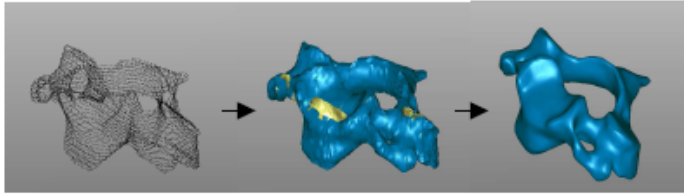
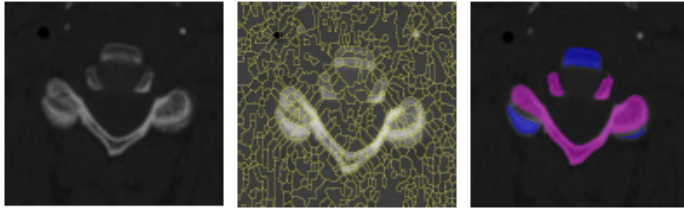
Hakan BOZKUŞ<sup>1,5</sup>, Murat HANCI<sup>2</sup>, M.Emin SÜNBUĞLU<sup>3</sup>, M.Ali TUNALI<sup>2</sup>,  
S.Ergun BOZDAĞ<sup>3</sup>, Önder AYDINGÖZ<sup>4</sup>, Alaattin ARPACI<sup>3</sup>

Turkish Journal of Trauma & Emergency Surgery

Ulus Travma Derg 2005

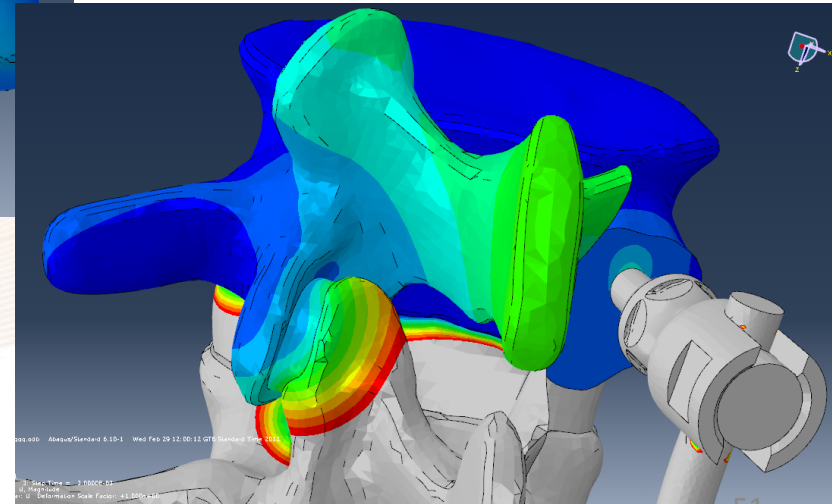
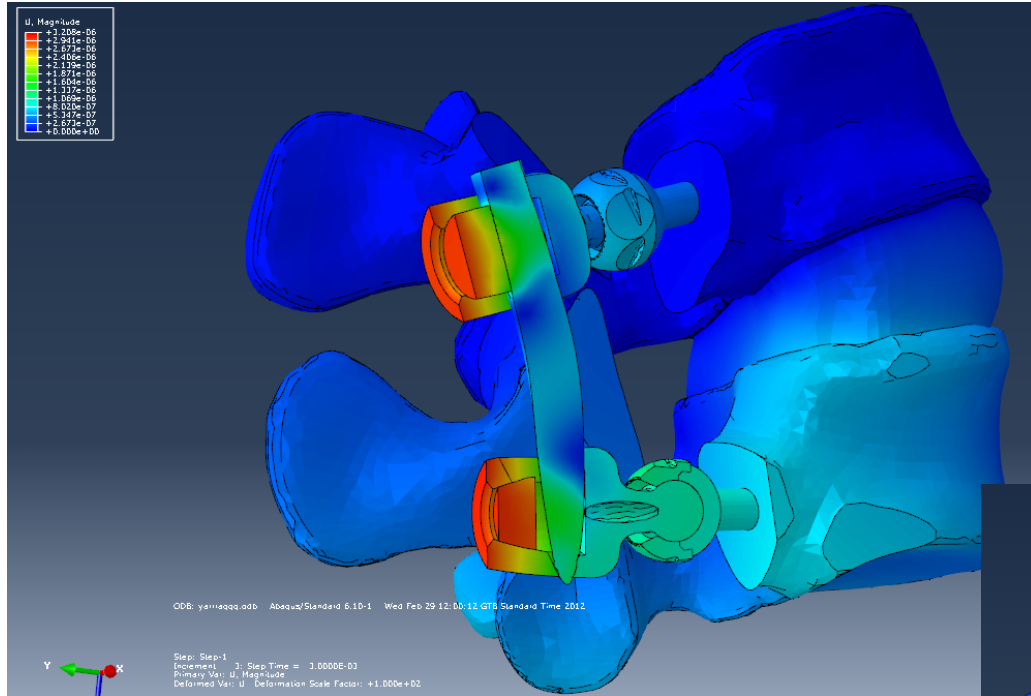


# Sonlu eleman yöntemi (FEM)



# FEM Kesitsel Von Misses Stress

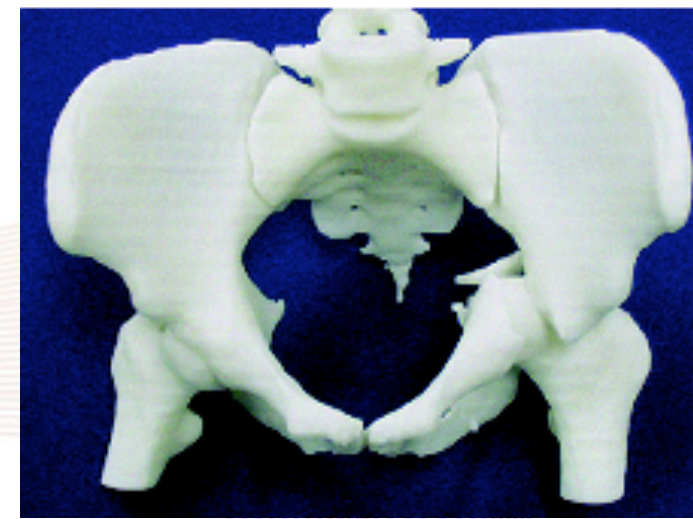
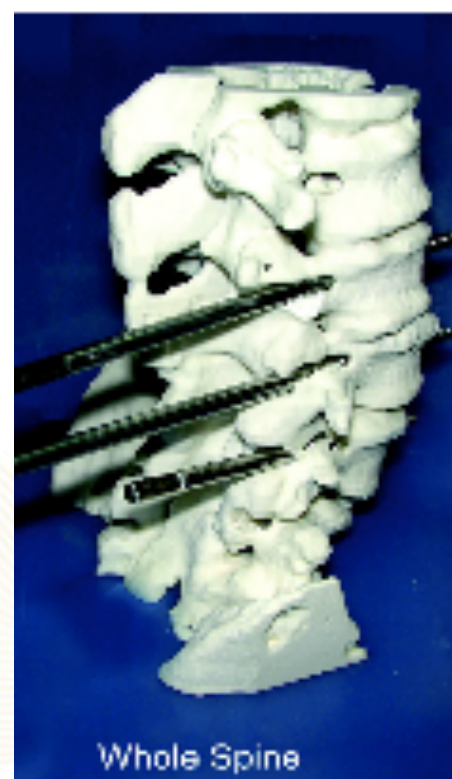
## Dinamik Pedikül Vida+ Rijit Rod



# Stereolithography Model

## RAPID PROTOTYPING: THE FUTURE OF TRAUMA SURGERY?

BY GEORGE A. BROWN, MS, MD, KEIKHOSROW FIROOZBAKHSH, PHD,  
THOMAS A. DECOSTER, MD, JOSÉ R. REYNA JR., MD, AND MOHEB MONEIM, MD



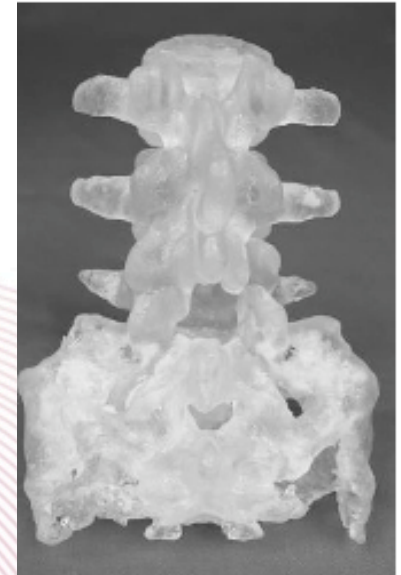
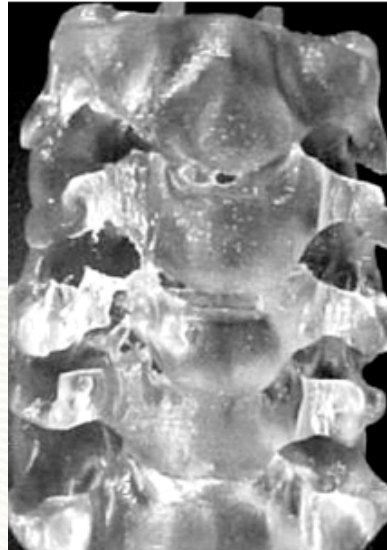
# Biyomodelleme (Stereolithography)

## APPLICATION OF THE STEREOGRAPHY TECHNIQUE IN COMPLEX SPINE SURGERY

*Wellington Silva Paiva<sup>1</sup>, Robson Amorim<sup>1</sup>,  
Douglas Alexandre França Bezerra<sup>1</sup>, Marcos Masini<sup>2</sup>*

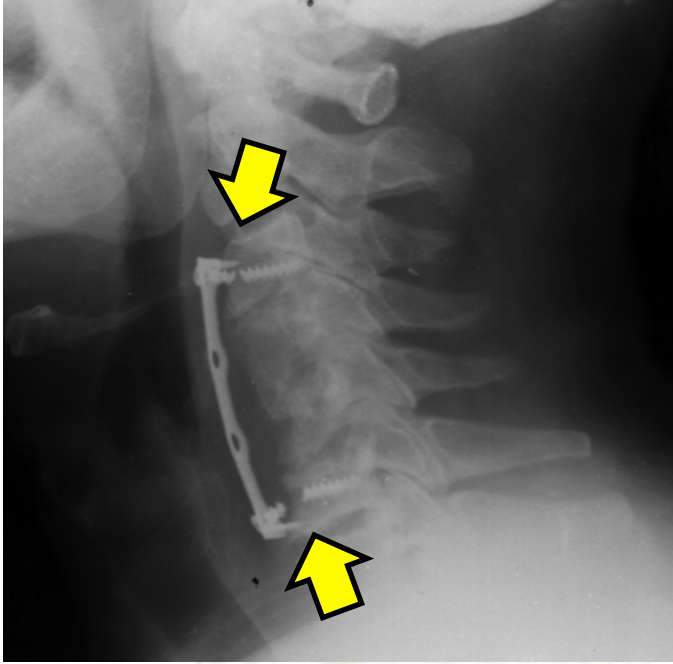
### Biomodeling as an Aid to Spinal Instrumentation

Paul S. D'Urso, MBBS, PhD, FRACS,\* Owen D. Williamson, MB, BS, FRACS,†  
and Robert G. Thompson, BInfoTech‡

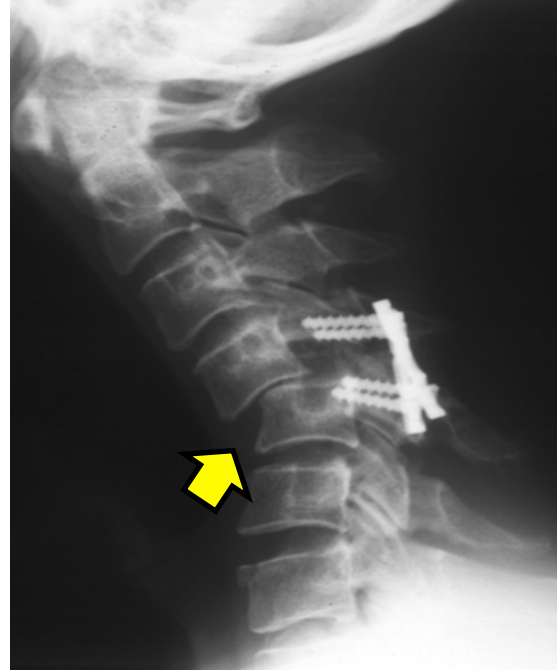




Ben cerrahım mühendis değilim !



Vida kırılması



Yetersiz stabilizasyon



Komşu segment hastalığı

# Konuřmanın Slaytları

[www.hakanbozkus.com.tr](http://www.hakanbozkus.com.tr)

Teřekkür Ederim