A new in vitro test system to evaluate adjacent level effects of the lumbar spine

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Introduction

In vitro testing of new surgical reconstruction methods provides essential findings for clinical use on biomechanics and physiology of the spine. Various concepts are established [de Visser, 2007; Gillespie, 2004; Lysack, 2000; Ingalhalikar, 2009].

They can be divided into:

- Constrained/Unconstrained
- Load or motion controlled
- Mono-/bi-segmental testing

Many experimental setup are restricted to one of these protocol types.

As surgical interventions affect the mechanics beyond one or two spinal segments, a biomechanical evaluation of more than two segments is required.

A multifunctional testing setup with different protocol options could meet this requirement.

Objectives

A new multifunctional system for biomechanical analysis under load-guided motion control was developed in order to:

- Investigate multisegmental intervertebral relative motion and biomechanical behavior.
- Evaluate the setup with calf specimen by means of mono-segmental literature data.
- Prepare the investigation of adjacent level effects in multisegmental specimen.
- Create the option of different testing protocols.

Materials & Methods

System components:

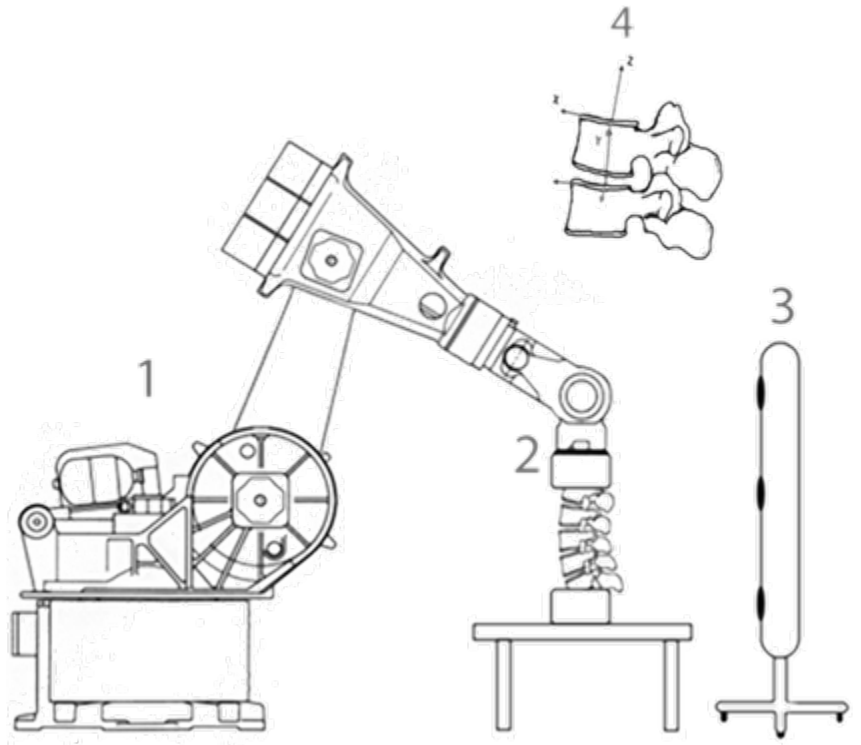
1. A robot - Kuka, KR125
2. A six component load cell - Mini45, Schunk
3. An optical tracking system - NDI, Optotrak

Test protocol:

- 4-segmental calf specimen from L2-L6 (n=6)
- 3 cycles of pure, unconstrained moments of 7.5 Nm in flexion/extension

Data analysis:

- Range of motion (ROM)
- Neutral zone (NZ)
- Finite helical axes (FHA)



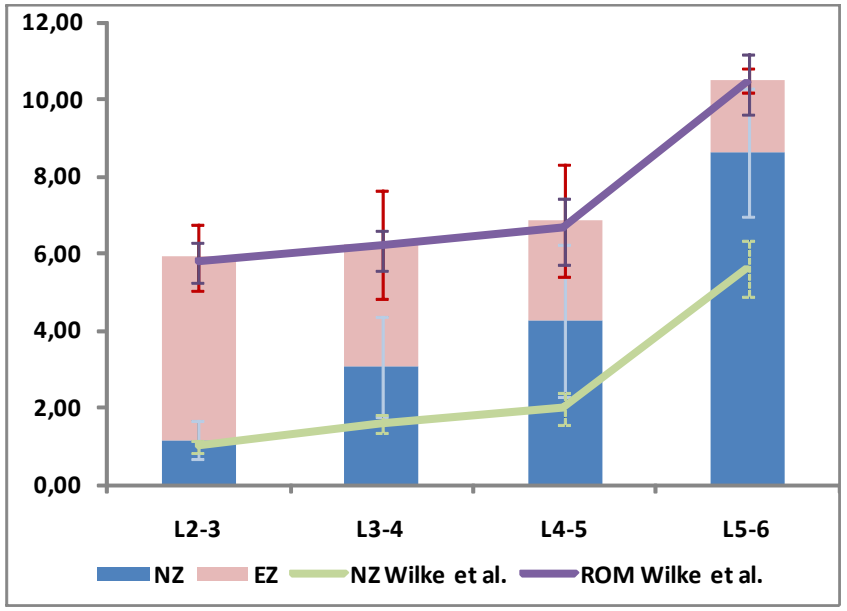
Scheme of the experimental setup.

Results

Under flexion / extension mean segmental RoM from L2-3 to L5-6 differed by 0.9-2.8% from reference literature [Wilke, 1997].

Absolute RoM/NZ (mean ± standard deviation) for all segments in °.

Level	RoM±SD	NZ±SD
L2-3	5.9±1.0°	1.2±0.5°
L3-4	6.3±1.8°	3.1±1.3°
L4-5	6.9±2.2°	4.3±2.0°
L5-6	10.5±1.6°	8.6±1.6°

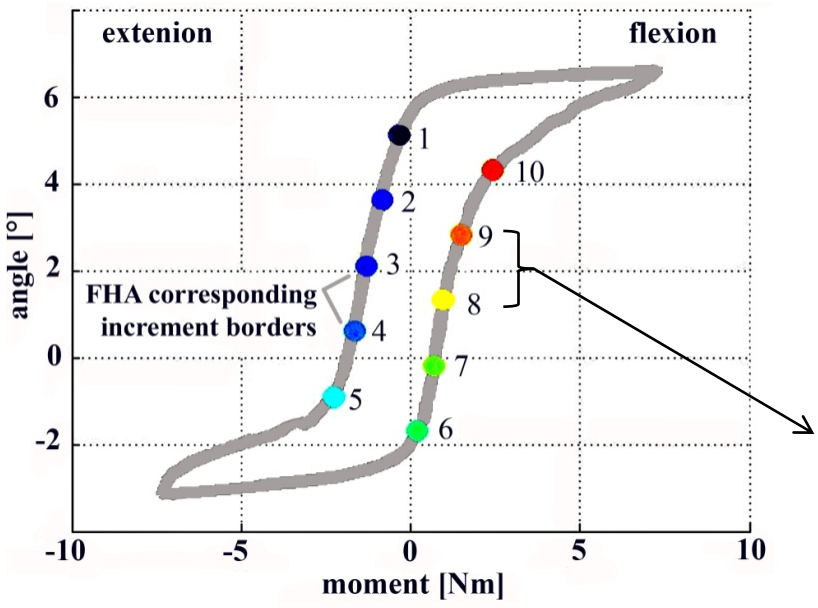


Graphic illustration of mean angles in °for 6 specimen compared to reference mono-segmental data.

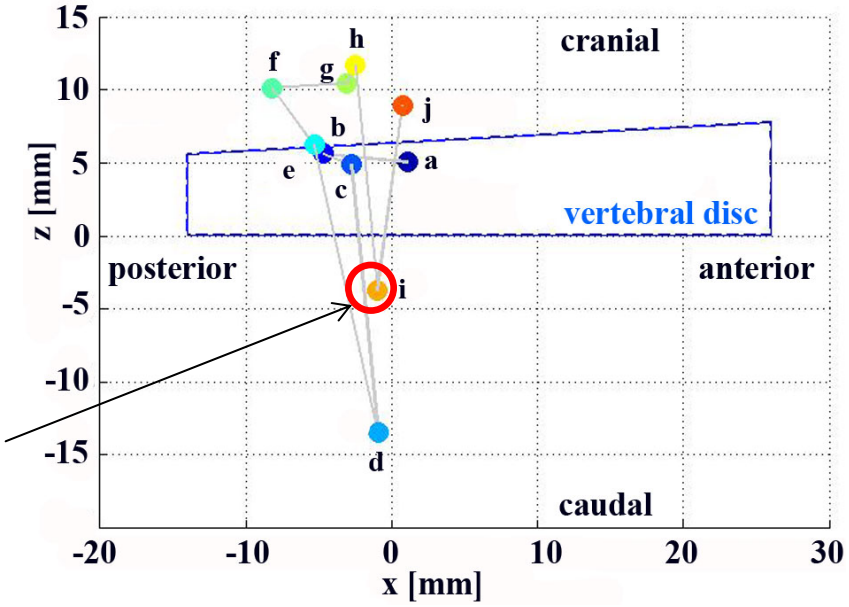
Results

Distance from origin of all helical axes (FHA) in the sagittal plane was between 2.6 and 15 mm for L4-5.

A dorsal trend of the FHA was observed for L3-4 to L5-6.



Load displacement curve for L4-5 with increment borders (1-10) for FHA calculation:
e.g. increment 8-9 includes FHA i)



Corresponding path (a-j) of the FHA penetration in sagittal plane relative to the origin

Discussion

- ✓ The test setup provides adequate precision, which is shown by
- ✓ Good correlation comparing RoM data from literature.
- ✓ Differences between NZ of compared data and collected data , which could be due to:
  - Varying specimen age
  - Differing testing velocities
  - Viscoelastic effects on structures
- ✓ A dorsal trend of FHA, though varies for each segment and between specimen
- ✓ We confirmed the load transmission of pure bending moment through a multisegmental spine is equal to the same load in a monosegmental specimen.

Conclusion

- The system is of adequate precision to investigate intervertebral motion in a multisegmental test setup
- Correlation of compared RoM data is generally good.
- We are ready to proceed with multisegmental studies of the human spine with an increased testing velocity (already realized).
- Hybrid testing protocols are subject to further studies.

We are confident that the presented setup has an influence on the increasing relevance of in vitro analysis of complex multisegmental spinal biomechanics for surgical treatment.

Literature

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