Final Event, NWE6
Tuesday, 23rd November 2021

Planning and Assessment Techniques for Spine Surgeries

ESR4: Jennifer Fayad

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 766012

spinner
next generation spine experts

SPINNER Training Network:

- Started in November 2018
  - 4 months at UNIBO
  - 19 months at NCSD
  - Return to UNIBO to complete PhD

- Training events
- Yearly meetings
- Bi-monthly ESR meetings

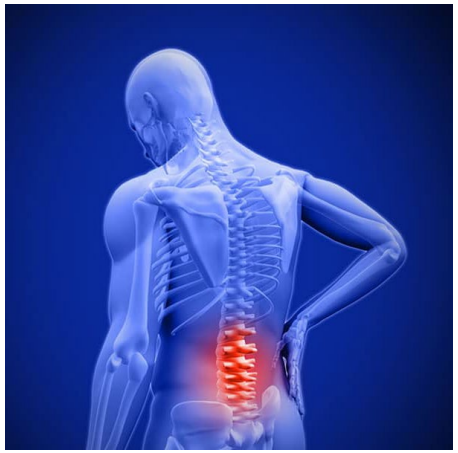
NATIONAL CENTER FOR SPINAL DISORDERS

ISBL

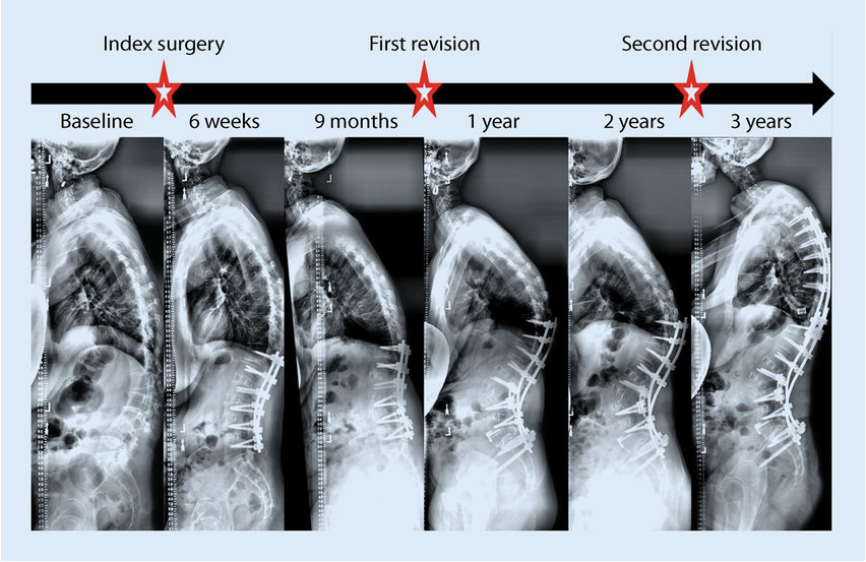
ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
A.D. 1088

Background:

- **Low back pain** and **Adult Spine deformity** are increasing with age
- Surgical interventions needed in some cases
- **Posterior Spine Fusion** (PSF)
  - Fusion of 2+ vertebrae to
    - Manage pain
    - Correct Deformities
    - Restore Spine Balance



- **Proximal junctional kyphosis** (PJK) is an abnormal kyphotic deformity
- Prevalence rates between **5%-40%** in adult spine deformity patients
- Develops within **3 months** of surgery in 80% of affected patients

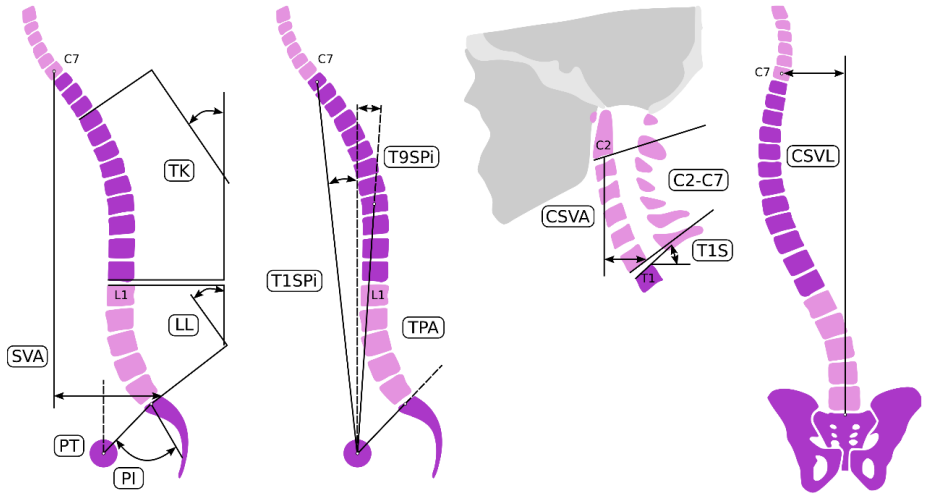


J. Lee and Y.-S. Park, "Proximal Junctional Kyphosis: Diagnosis, Pathogenesis, and Treatment," *Asian Spine J.*, vol. 10, no. 3, pp. 593–600, 2016
R. Lafage et al., "Validation of a New Computer-Assisted Tool to Measure Spino-Pelvic Parameters" , The Spine Journal 15 (2015) 2493–2502

Background:

Current Preoperative Planning:

- Vital to minimize surgical complications
- Imaging techniques are the methods of choice



X-rays to measure Spino-pelvic parameters

- Measure degrees of correction needed

CT Scans

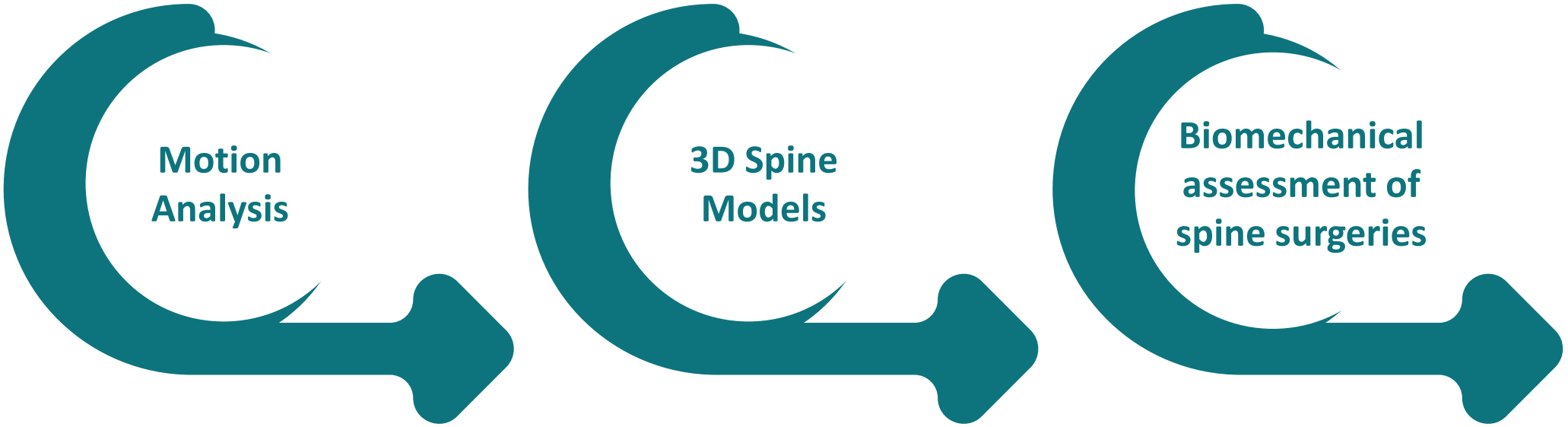
- Evaluate bone density
- Screw placement location

MRI Scans

- Visualize intervertebral disc
- Nerve impingements

Project Objectives and Aims:

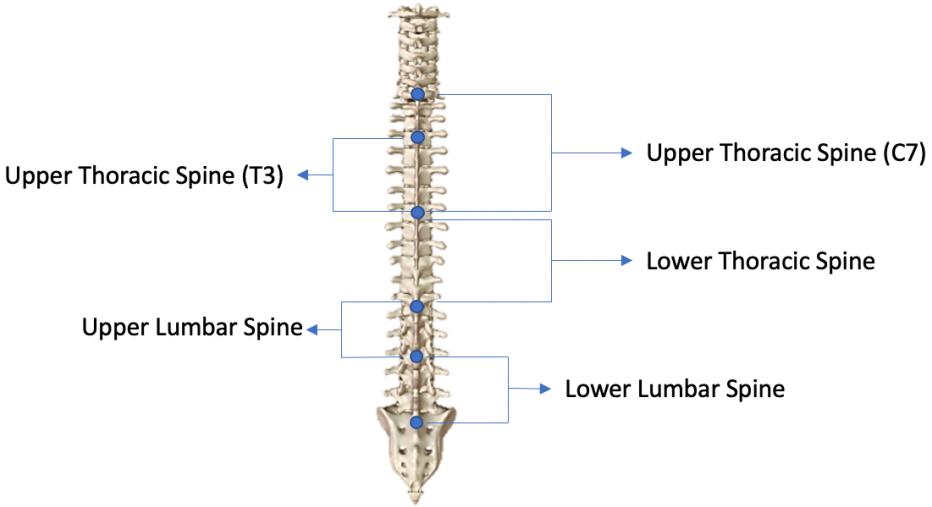
Introduce and investigate future techniques for surgical planning of PSF surgeries

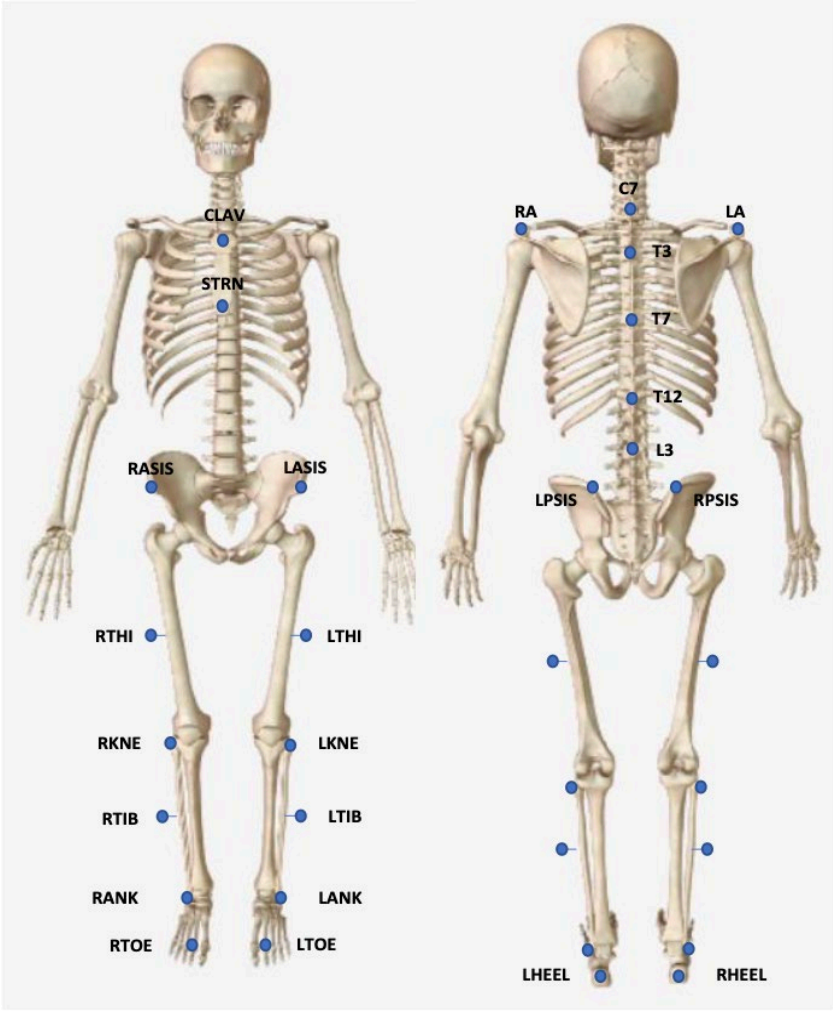


Marker Setup:

- Motion analysis protocol and marker setup developed:
  - Marker setup includes 25 markers
  - Markers attached on C7, T3, T7, T12 and L3
  - Lower Limbs markers followed the Davies protocol

- Spine Divided into 4 Segments
- Two marker placement techniques and 3 capture systems





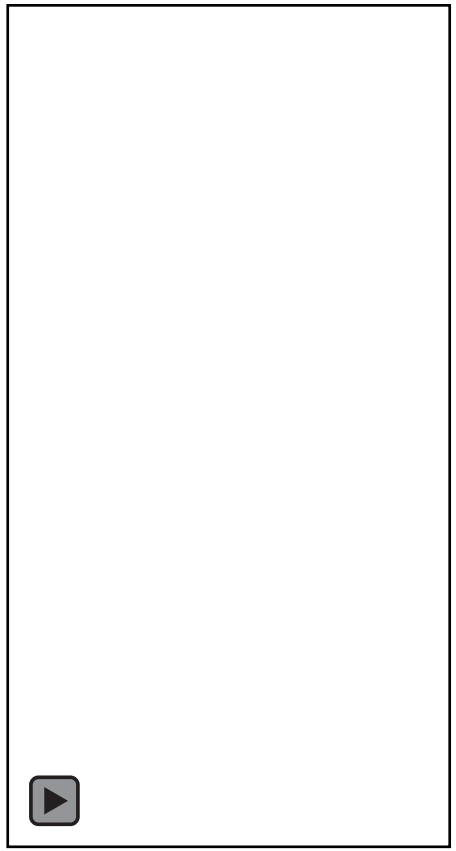
E. Papi *et al.,* "Spinal Segments do not move together predictably during daily activities," Gait & Posture, vol 67, pp. 277-283, 2019
Christe *et al.,* "Multi-Segment analysis of spinal kinematics during sit-to-stand in patients with chronic low back pain," JBiomech, vol 49, pp. 2060-2067, 2016
Gombatto *et al.,* "Lumbar spine kinematics during walking in people with and people without low back pain," Gait & Posture, vol. 42, pp. 539-544, 2015

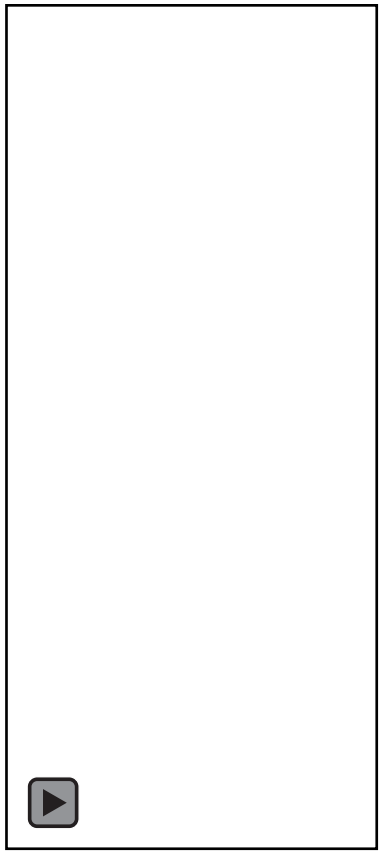
Participants:

- 22 healthy participants recruited (10F, 12M; age: 26.2±4; height: 1.74±0.08m; weight: 72.1±15kg)
- 30 patients recruited, 10 in the long fusion cohort, 20 in the short fusion cohort

	Long Fusion Mean (SD)	Short Fusion Mean (SD)
Gender	7F, 3M	8F, 12M
Age (years)	54.9 (10.7)	46.4 (11.9)
Height (m)	1.68 (0.10)	1.72 (0.08)
Weight (kg)	85.9 (23.9)	84.9 (16.5)
BMI (kg/m²)	30 (6.48)	28.4 (3.9)

- Tasks conducted:
  - Full Flexion
  - Thoracic Flexion
  - Lateral Bending
  - Sit to stand transitions
  - Object pickup
  - Walking trials



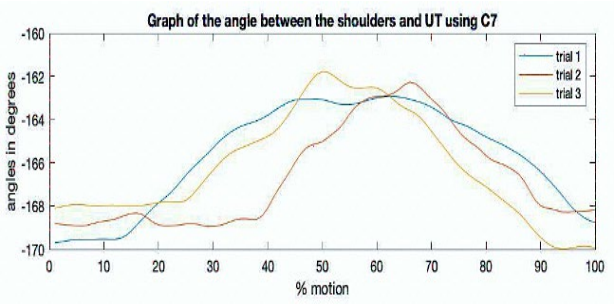


Data Processing:

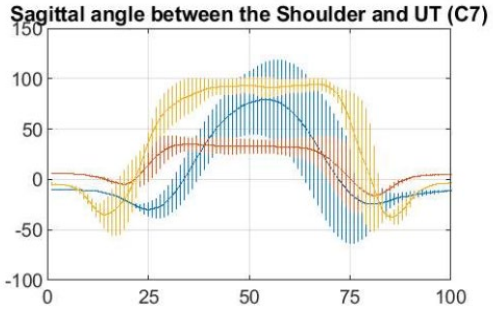
- The kinematic data collected was processed using VICON NEXUS and MATLAB
- The intersegmental and segment-pelvis angles were calculated
- Motion of the C7 marker was used to identify the start and end of the motion

Synchronisation of Motion:

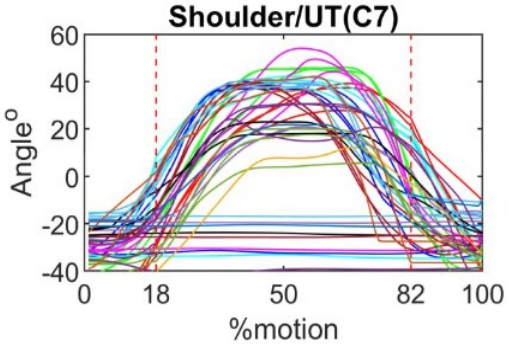
- Identification of key events depending on the slope of the joint angle
- Synchronisation is not operator dependent



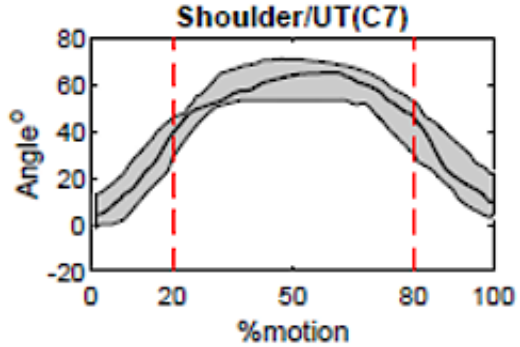
Intersegmental angle for 3 trials



Intersegmental angle of 3 participants



Synchronised angles all participants



Synchronised motion band all participants

Spine Parameters:

Following Synchronisation of all the tasks:

1. Differences between marker application methods and motion capture system
   - ROM of each segment
   - Percent Contribution of segments
     - Shoulder/Pelvis chosen as responsible for 100% motion
   - Timing of motion peak
   - Timing of key events

2. Characterize the motion of the spine
   - Motion Bands of intersegmental angle and segment-pelvis angle
     - Median, 25-75th and 10-90th percentiles reported as bands of motion

Findings:

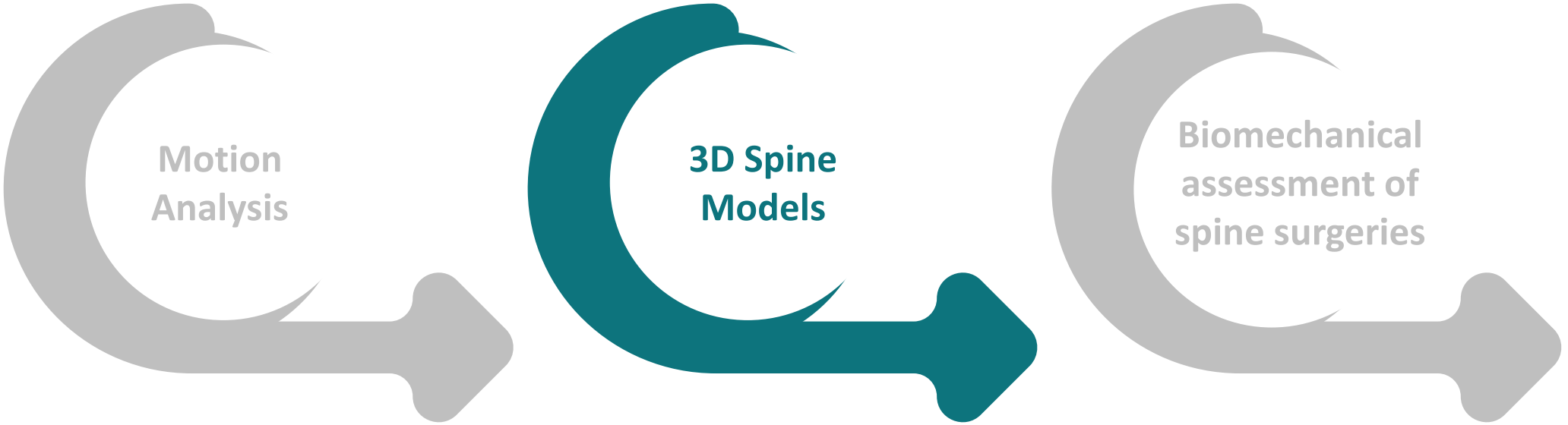
- The current protocol provided data on
  - Segmental Range of Motion
  - Coordination between segments
  - Key event timings
- Marker misplacement only affected certain tasks and segment-pelvis angles
- Motion Capture system had no effect on ROM and key event timings

Patient Motion Analysis:

- ROM lower in patients when compared to healthy participants
- Key events were achieved slower
- Patient data would needs to be compared individually to the reference to find fundamental differences in the motion before and after the surgery

Project Objectives and Aims:

Introduce and investigate future techniques for surgical planning of PSF surgeries



3D Anatomical Models for Preoperative Planning

Case Presentation

- 71 year old female patient
  - Severe low back pain (VAS=9)
  - Fatigue in lower limbs
  - Disability (ODI=80%)
  - Very poor quality of life

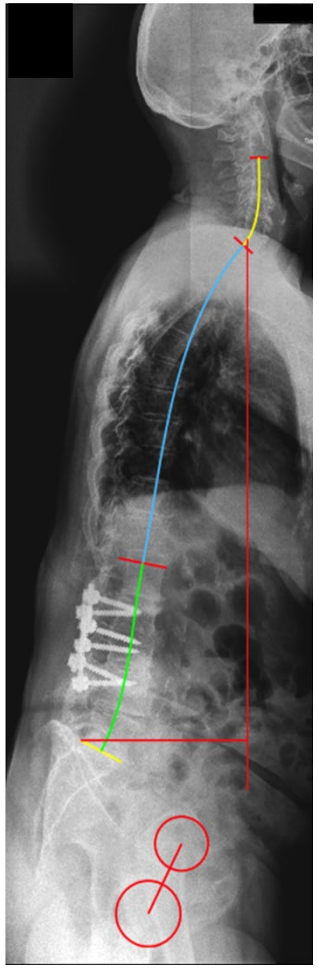
- Seven spine surgeries over 39 year period

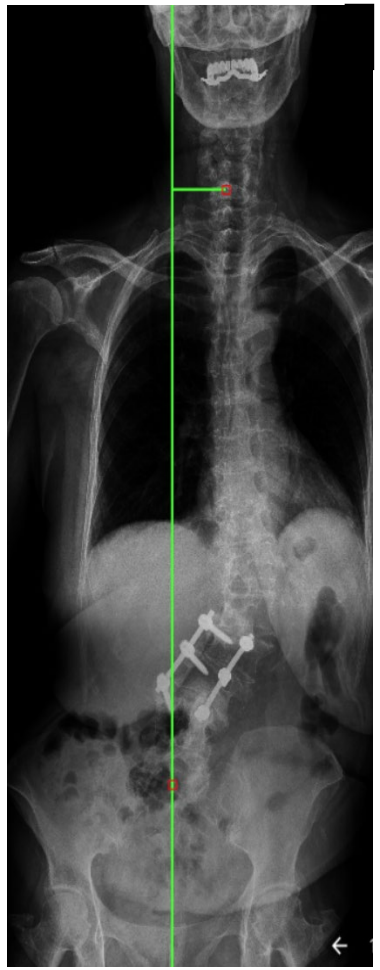
POSTOP FLAT BACK DEFORMITY

↓

SURGICAL SOLUTION: alignment correction with spinal osteotomy and fusion

Spinopelvic Alignment and Global Balance





Ideal LL (**ILL**) using Le Huec's Formula:

LL= 0.54*PI + 27.6°

↓

ILL= 57°

↓

Adjust to patient Age **65-74**
Avoid Significant Disability **(ODI< 40%)**
Aim for Minimal Disability **(ODI<20%)**

↓

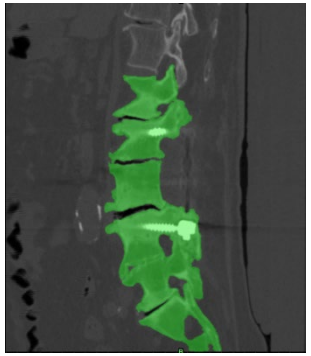
SVA = 50-90mm
PI-LL= 6°-18°
PT= 23°-25°

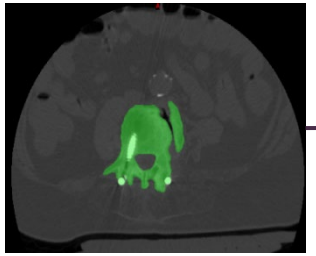
↓

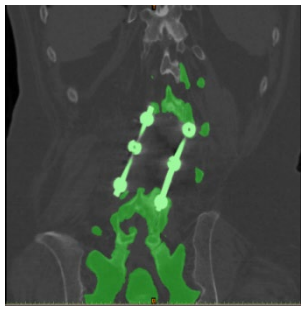
New ILL= 37°-49°

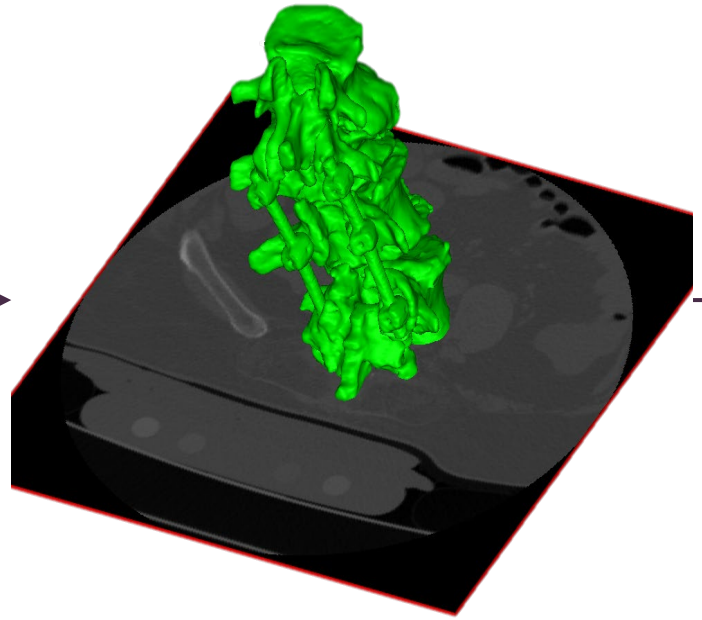
spinner
next generation spine experts

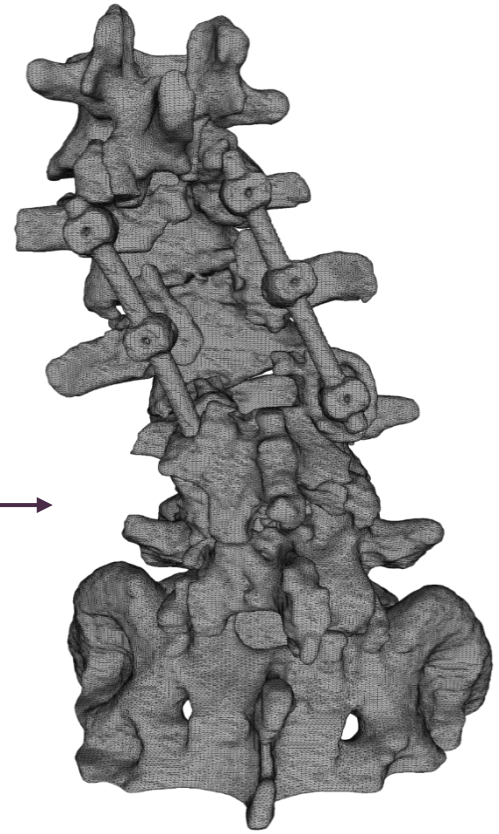
Virtual and 3D printed Model











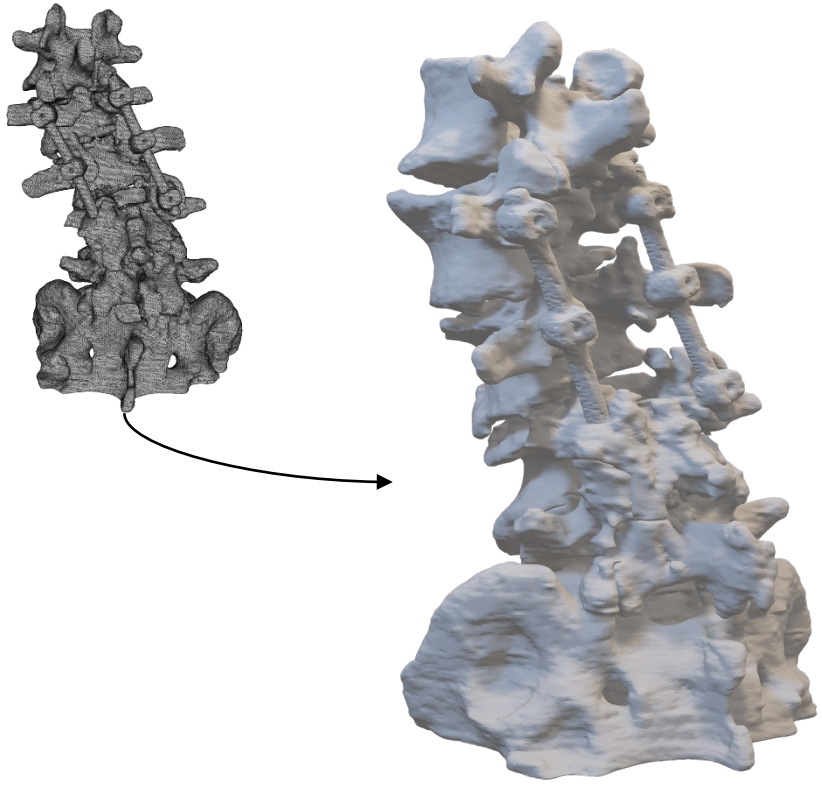
CT Scan

Segmented 3D Mask

Virtual 3D Model

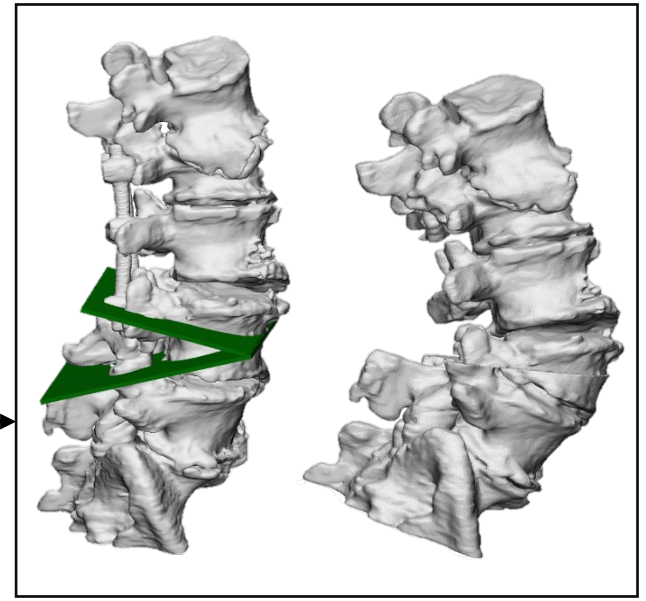
spinner
next generation spine experts

Virtual and 3D printed Model



Virtual 3D Model

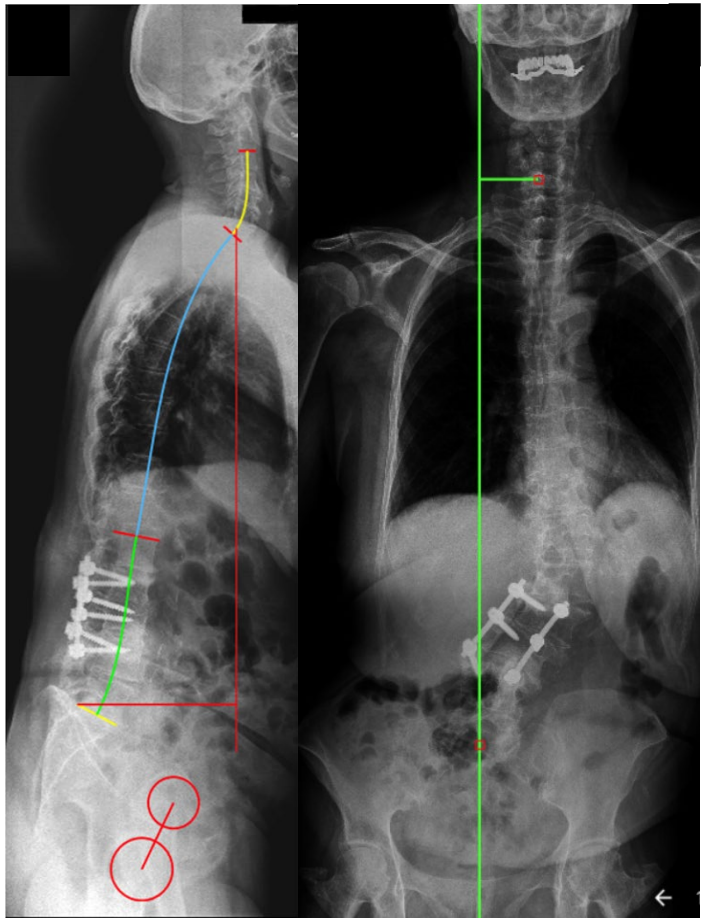
Printed 3D Model



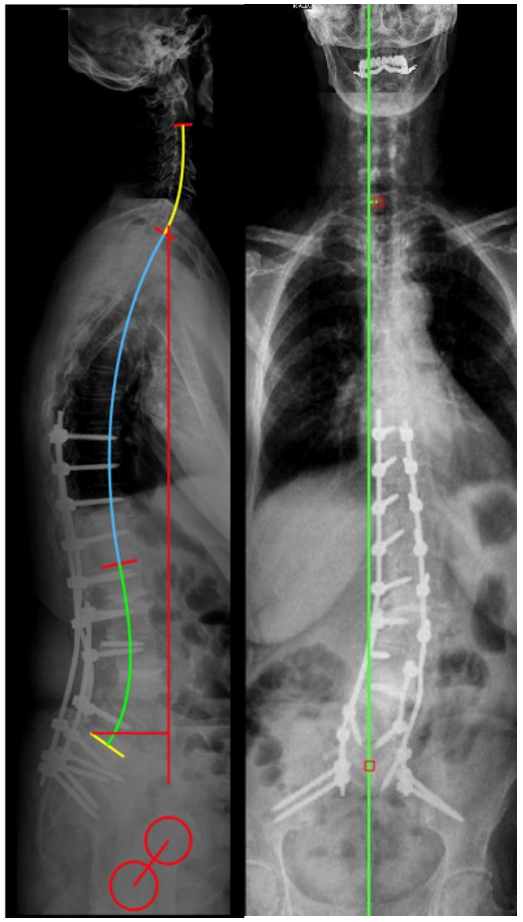
Virtual Osteotomy

spinner
next generation spine experts

Results:



Pre-Op



Post-Op

Parameter	Pre-Op	Post-Op
Pelvic Incidence (°)	55	55
Pelvic Tilt (°)	27	21
Sacral Slope (°)	28	34
Lumbar Lordosis (°)	17	47
PI-LL (°)	38	8
Thoracic Kyphosis(°)	16	30
SVA (mm)	156	82
C7 to CSVL (mm)	48	5
GAP Score	8	3
ODI (%)	80	20
VAS	9	3

Findings:

Patient specific 3D printed models:

- Increase understanding of the anatomy through haptic perception
- 3D printing for preoperative planning associated with
  - Increased instrumentation accuracy
  - Favourable surgical outcomes
  - Reduced surgical time

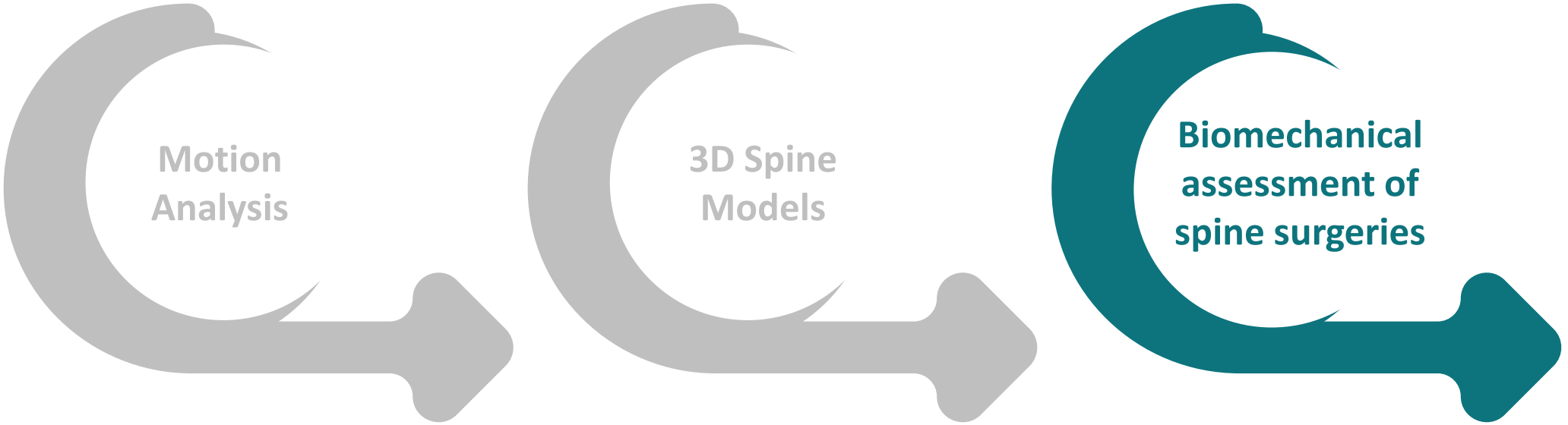
Complicated Postoperative Flat Back Deformity Correction With the Aid of Virtual and 3D Printed Anatomical Models: Case Report

Jennifer Fayad, Mate Turbucz, Benjamin Hajnal, Ferenc Bereczki, Marton Bartos, Andras Bank, Aron Lazary, and Peter Endre Eltes

Frontiers in Surgery, Volume 8, May 2021, Pages 1-7

Project Objectives and Aims:

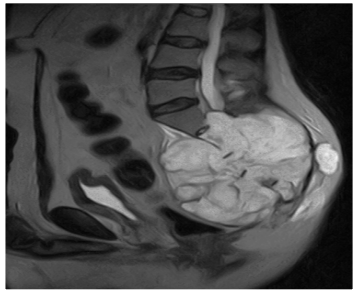
Introduce and investigate future techniques for surgical planning of PSF surgeries

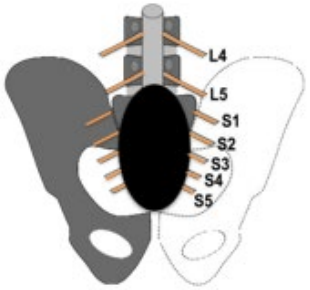


Biomechanical assessment of Closed Loop technique

Case Presentation

- 42-year-old male
- Sacral Chordoma Tumour
- All nerve roots below L5 lost

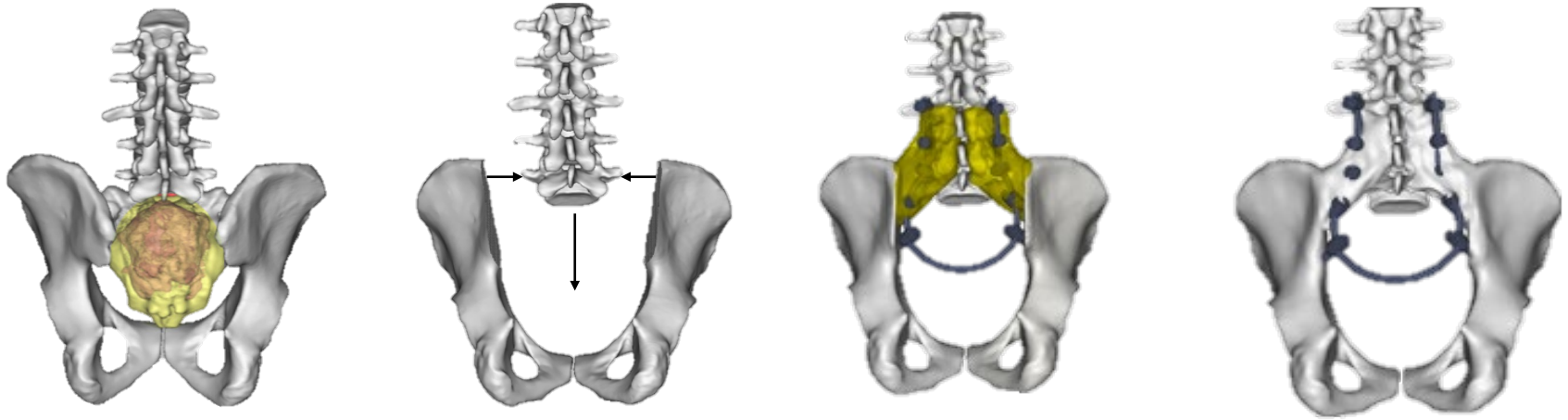




Biomechanical Assessment:

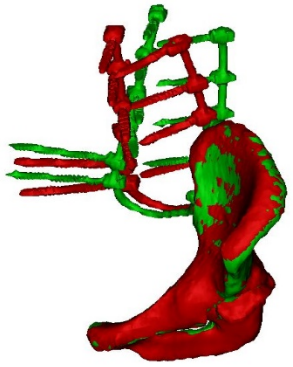
- 12 CT scans over 6-year follow up period
  - Tracking implant deformation
  - Assessing bony fusion at surgical site
- Gait Analysis 1 year Postop

Surgical Technique

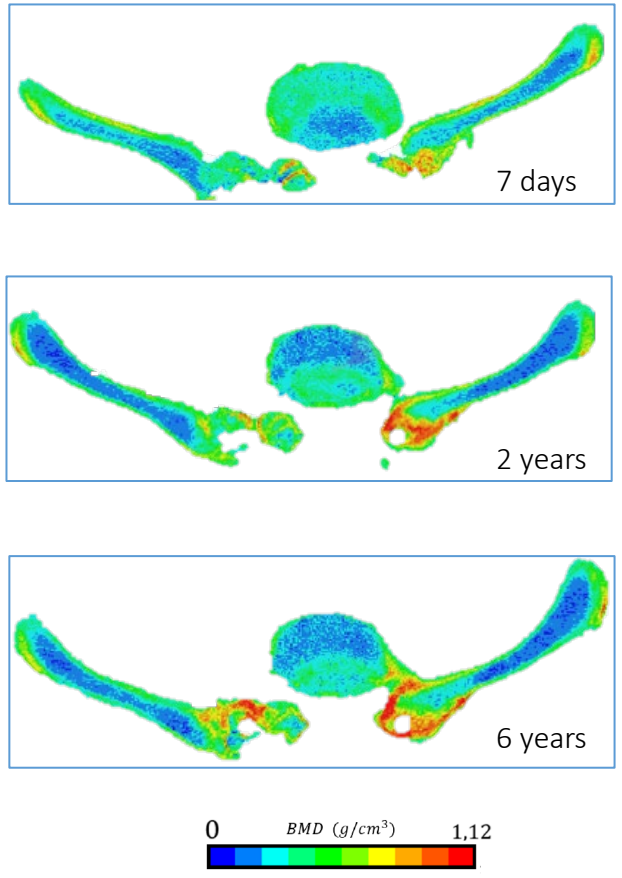


spinner
next generation spine experts

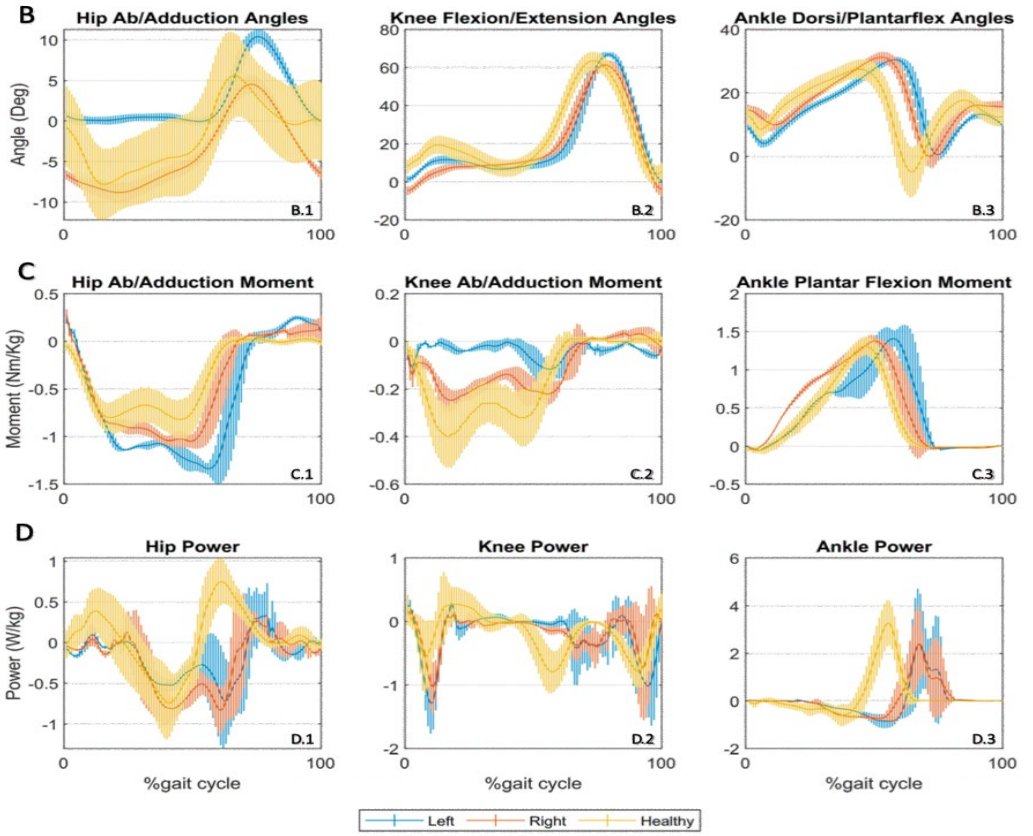
Results:



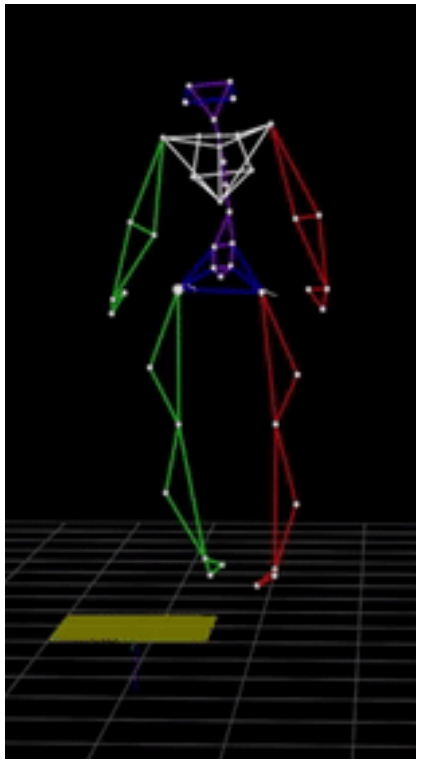
Implant Deformation



Bony Fusion



Gait Analysis



Findings:

- Bony fusion achieved within 2 years after the surgery
- Reconstruction technique provided excellent locomotor outcomes after the Sacrectomy
- Forward bending tendency of the construct detected from implant deformation and gait analysis
- The measurement method can be used for
  - Validation of complex patient specific FE models
  - Individualized preoperative surgical planning

frontiers in Surgery

A novel three-dimensional computational method to assess rod contour deformation and to map bony fusion in a lumbopelvic reconstruction after en-bloc sacrectomy

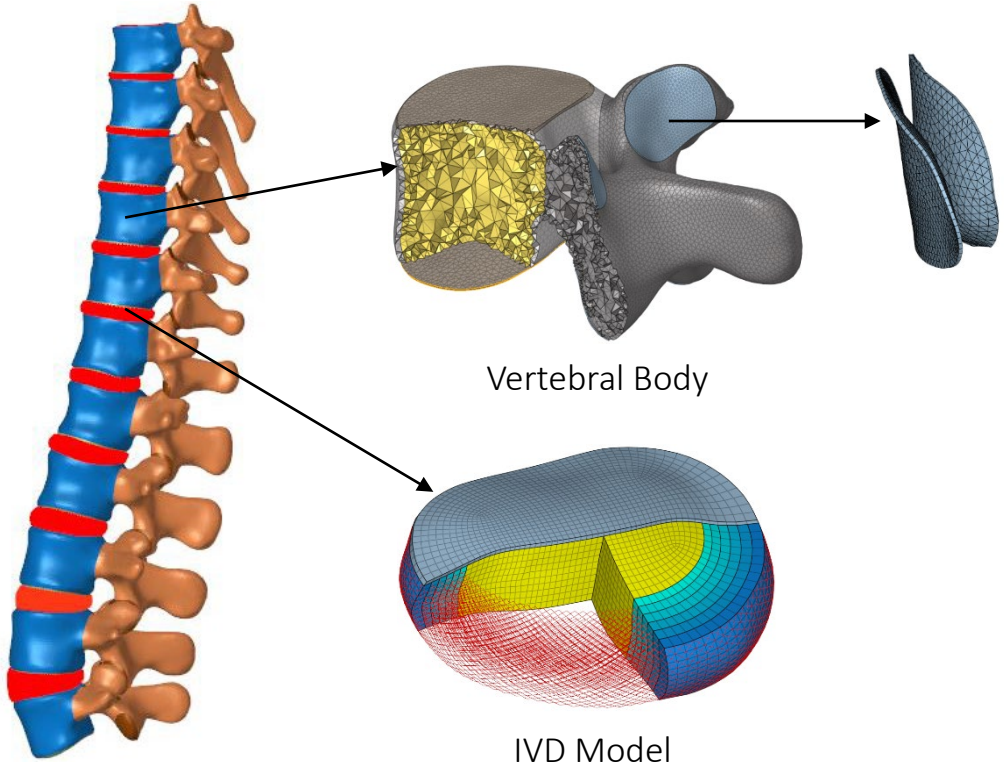
 Peter Endre Eltes,  Mate Turbucz,  Jennifer Fayad, Ferenc Bereczki, György Szőke, Tamás Terebessy, Damien Lacroix, Peter Pal Varga and Aron Lazary

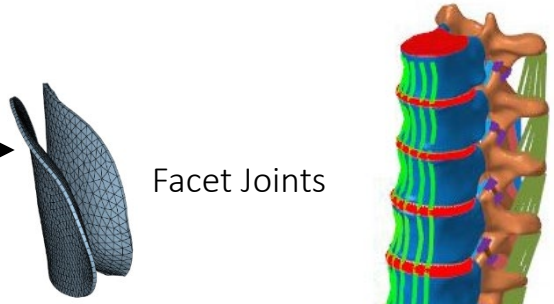
Effect of transitional rods on the onset of PJK:

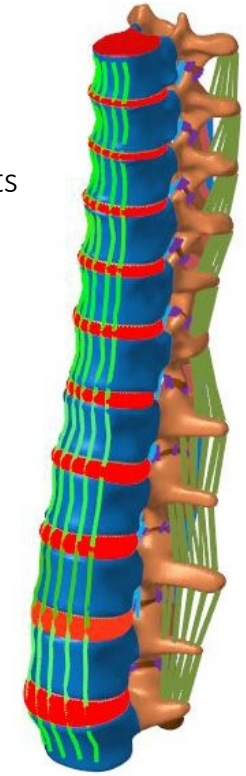
- PJK → Biomechanical failure due to the change in rigidity
  - Metal rods exhibit high stiffness

The aim of this study is to evaluate the effect of using multiple metal rods on an instrumented FE spine construct

T7-L5 Model







ALL: Anterior Longitudinal Ligament
PLL: Posterior Longitudinal Ligament
ITL: Intratransverse Ligament
ISL: Intraspinous Ligament
SSL: Supraspinous Ligament
FL: Ligamentum Flavium
CL: Capsular Ligament

Effect of transitional rods on the onset of PJK:

- Six models to be compared on:
  - Overall range of motion
  - Intervertebral ROM
  - Intradiscal Pressure
  - Pedicle Screw Forces
  - Ligament Forces
  - Stress at UIV+1

Dissemination:

Spinner Training events:

- Spine Surgery and workshop, Aesculap AG
- Biomaterials and Scientific Writing, University of Bologna
- Public Engagement and Media Training, University of Sheffield
- Numerical and Experimental repair strategies, Ansys and Adagos
- Cell Culture Training, University of Sheffield

Conferences and Workshops:

- Spine workshop 2019
- Modelathon 2020
- ESB 2021
- Global Spine 2021
- BioMedEng 2021
- SICOT 2021

Publications:

- 1 first author, 1 co-author paper
- 1 manuscript in preparation

spinner
next generation spine experts

Thank you

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

NATIONAL CENTER FOR SPINAL DISORDERS

ISBL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 766012