ANATOMY BASED TEST MODEL OF THE SACROILIAC JOINT FOR BIOMECHANICAL TESTING OF IMPLANTS

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Introduction

Spino-pelvic fusion is a surgical intervention, which is frequently performed for fracture stabilization of the sacral bone or for caudal anchoring in spinal deformity correction. However, this surgical procedure is associated with a high failure rate like screw loosening or implant failure [1]. On the one hand, this is attributed to the high loads of the trunk weight combined with long lever arms of multisegmental spinal fusions. On the other hand, this is also caused by the complex loading situation in the sacro-iliac joint (SIJ) from bipedal walk with intermittent one footed stance phases resulting in phasic loading with nutation and counternutation as well as inflare and outflare movement of the SIJ [2]. However, these physiological loading conditions are not yet part of the pre-clinical evaluation of SIJ implants. Therefore, we aimed to create a test model for generating SIJ kinematics based on an anatomical mechanism as a basis for biomechanical implant testing close to the physiological situation.

Methods

An experimental model based on a mean CT scan of 98 patients was built, including L4 and L5 vertebrae, sacrum, ilium with pubic symphysis and proximal femur. The landmarks and basic dimensions of the bones were integrated and the SIJ surfaces were modelled as spherical segments with low distal congruency. The top border of L4 was placed horizontally, a sacral slope of 40° and a pelvic tilt of 12° were realized. All bones were produced out of 3D printed polyamide and the pubic symphysis was made of silicone. The anatomy and the identified landmarks were used to set up attachment points for seven ligaments and muscles. The ligaments were modeled with pretensioned wires whereas the muscles are passively activated using tension springs. Hip joints were emulated with hip cups and heads. The model is loaded by proximo-distal displacement of the L4 vertebra, leading to movement at the SIJ. With both femurs standing on the ground, a symmetrical two leg loading situation can be simulated. By changing the configuration of the ground support with a horizontal actuator, the model transfers from two leg stance into a right or left sided one leg loading situation by only supporting one femur. All movements are tracked using an optical measurement system (ARAMIS 12M, Carl Zeiss GOM Metrology GmbH, Braunschweig, Germany).

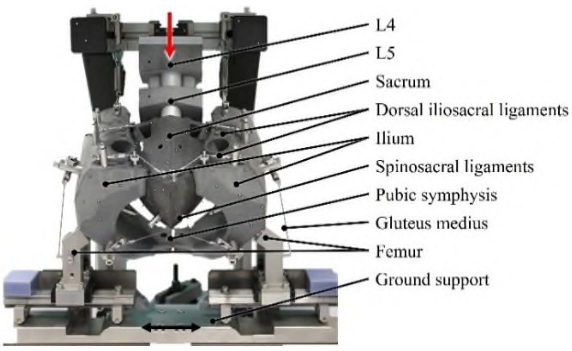

Figure 1: Anatomy based model of the SIJ.

Results

An inflare-outflare movement of the two ilia, leading to an opening of the pubic symphysis, in combination with a nutation-counternutation movement, was generated. Symmetrical inflare and nutation movements were measured for two leg stance. When changing to left/right one leg loading situation, an asymmetric movement was generated (Tab. 1).

	Inflare in °		Nutation in °	
	Left	Right	Left	Right
Two leg stance	0.3	0.3	1.0	1.1
One leg stance right	0.1	0.2	0.5	0.8
One leg stance left	0.4	0.1	0.8	0.5

Table 1: Range of motion of the SIJ model during two leg stance and right/left one leg stance loading situation.

Discussion

The test-model creates a complex movement of the SIJ which is based on an anatomical mechanism and is well in line with reported values of biomechanical in vitro and in vivo studies [3]. In a next step, implant constructs for spino-pelvic fusion will be attached to the model to study and optimize implant failure mechanisms.

References

1. Banno et al, Spine (Phila Pa 1976). 2017;42(17)
2. Kiapour et al, Int J Spine Surg. 2020 Feb 10;14(Suppl 1):3-13
3. Casaroli et al, Medical Eng and Phy, 76:1-12, 2020.