

Preoperative Segmental Disc Geometry as a Possible Predictor for the Clinical Outcome of Lumbosacral Total Disc Replacement

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Abstract

Total disc replacement has been developed as an alternative to fusion. However, several factors are associated with an inferior clinical mid-term outcome. There is a need for simple but well-defined preoperative factors, which have a predictive value and facilitate patient selection for lumbosacral total disc replacement (TDR). Therefore, in the present study we investigated preoperative radiological parameters to serve as predictors for the clinical outcome after TDR at the lumbosacral junction.

A total of 34 patients (16 females, 18 males) with the primary diagnosis of lumbosacral degenerative disc diseases who underwent TDR between 08/2005 and 12/2010 were evaluated in a clinical examination (Oswestry Disability Questionnaire (ODI) and visual analog scale (VAS) for overall, back, and leg pain) after a mean follow-up of 59.5 (24–87) months. A correlation analysis was performed between preoperative radiological parameters (segmental lordosis (SL), mean disc height (meanDH), anterior (aDH), middle (mDH), and posterior disc height (pDH) as well as geometrical relationships of these parameters: nA Index=aDH/meanDH, nP-Index=pDH/meanDH, AP-Index=aDH/pDH, and nAP Index=aDH/pDH/meanDH) and clinical pain scales (ODI, VAS) at follow-up.

Particularly the relationships nA-Index, AP-Index, and nAP-Index were found to be strongly negatively correlated to the clinical outcome. Weaker correlation was found between: ODI and aDH, nA-Index, AP-Index (negative), and nP-Index (positive); VAS overall and SL, nP Index, mDH, and pDH (positive); and VAS back and nP-Index, and pDH (positive).

The preoperative normalized anterior-disc-height-index (nA Index) and the normalized anterior-posterior-disc-height-index (nAP-Index) can serve as prognostic radiographic parameters before patients undergo lumbosacral TDR.

Keywords: Total disc replacement; Lumbar spine; Degenerative disc disease; Clinical outcome prediction; Lumbar disc arthroplasty; Facet arthritis; Arthroplasty contraindications

Introduction

Lumbar total disc replacement (TDR) has been introduced as an alternative procedure in the surgical treatment of low back pain resulting from degenerative disc disease (DDD) to avoid the negative side effects associated with spinal fusion [1-10]. Nevertheless, several factors that negatively affect the clinical outcome after TDR have been reported [11-14]. Strube et al. [15] demonstrated that the sagittal profile types 1 and 4 after the classification of Roussouly et al. [16] represent a contraindication for lumbar TDR at both L4–L5 and L5–S1. Siepe et al. [17,18] further showed that TDR in L4–L5 is clinically superior to L5–S1 and that lumbar facet joint pain is the most common cause for insufficient results following TDR.

Previous studies, however, focused only on possible iatrogenic changes related to the surgical procedure and did not have a predictive value for lumbosacral TDR. Therefore, there is a basic need for well-defined preoperative factors, which have a predictive value and facilitate patient selection for lumbosacral TDR. For this purpose, the present working group previously investigated in a finite element model study the effect of pre-operated disc parameters on the segmental range of motion and facet joint loads after TDR [19]. We demonstrated that larger disc heights caused larger facet capsule forces after TDR and concluded that the patient satisfaction rate after TDR is significantly lower in patients with a greater preoperative disc height. However, this predicted relationship between preoperative disc height and postoperative patient satisfaction rate was not confirmed in clinical trials. Therefore, the aim of the present retrospective analysis was to correlate preoperative sagittal disc parameters with clinical pain scores 5 years after lumbosacral TDR to confirm the outcome of our previous model simulations.

Methods

Study design and patient selection

The clinical output of 34 patients (16 females, 18 males) with the primary diagnosis of lumbosacral DDD who underwent TDR between 08/2005 and 12/2010 at Charité – Universitätsmedizin Berlin were evaluated after a mean follow-up of 59.5 (24–87) months. Patients received surgery if they had painful (as confirmed by provocative discography), single-level DDD (grade \geq III° [20], grade \leq II° [21]) of segment L5–S1 after an unsuccessful period of conservative treatment for a minimum of 6 months. Patients were not considered for surgery when they had adjacent disc degeneration (verified by magnetic resonance imaging) and/or facet joint degeneration (grade \geq III° [22]) at any segment of the lumbar spine. Further exclusion criteria were additional degenerative findings, spinal deformities, spondylolisthesis (grade \geq I° [23]) or destructive processes, previous operations on the lumbar spine with the exception of sequestrectomy, patients on long-term medication with corticoids or non-steroidal anti-inflammatory drugs, those with psychological distress syndrome or a somatization

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disorder (grade \geq II° [24], patients with osteoporosis, kidney or liver diseases, malignant tumors, BMI >30 kg/m², aged >65 years, pregnancy, and chronic nicotine, alcohol, or drug abuse.

In each patient, the Maverick prosthesis (Maverick™ A-MAV™, Medtronic, Memphis, USA) was implanted. Dimensions, angulation, and height were defined by fitting a test specimen/template according to the individual size and angle of the intervertebral space. The surgical procedure and postoperative care have been described in more detail elsewhere [25].

Outcome measurements

The clinical outcome parameters were assessed using a visual analog scale (VAS) for overall, back, and leg pain as well as the Oswestry Disability Questionnaire Version 2 for assessing function (ODI). Radiographs of the lumbar spine were acquired preoperatively in the upright standing position.

Ethics

The study was approved by the local Research Ethics Committee of the Charité Universitaetsmedizin Berlin (EA1/297/11). Informed written consent was obtained from each patient.

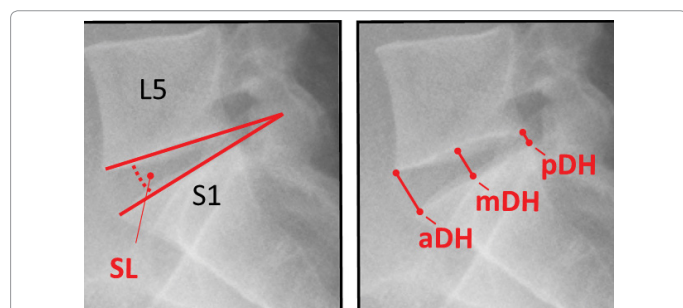


Figure 1: Pre-operative measurement of the segmental lordosis (SL) and the anterior (aDH), middle (mDH), and posterior disc height (pDH) of the surgically treated segment.

Clinical scores	Positive Correlations			Negative Correlations		
	Parameter	Pearson's co-efficient (r)	P-values	Parameter	Pearson's co-efficient (r)	P-values
VAS _{overall}	mDH	0.481	=0.004	nA-Index	-0.594	<0.001
	pDH	0.524	<0.001	AP-Index	-0.419	=0.014
	nP-Index	0.402	=0.019	nAP-Index	-0.644	<0.001
VAS _{back}	pDH	0.506	=0.002	nA-Index	-0.700	<0.001
	nP-Index	0.552	=0.001	AP-Index	-0.581	<0.001
				nAP-Index	-0.634	<0.001
VAS _{leg}	-	-	-	SL	-0.402	=0.018
				nA-Index	-0.382	=0.026
				AP-Index	-0.345	=0.046
ODI				nAP-Index	-0.393	=0.022
	nP-Index	0.416	<0.001	aDH	-0.346	=0.045
				nA-Index	-0.413	=0.015
			AP-Index	-0.561	=0.016	

Abbreviations:

SL: Segmental Lordosis.
aDH: Anterior Disc Height.
mDH: Middle Disc Height.
pDH: Posterior Disc Height.
nA-Index: Normalized anterior-disc-height-index (= aDH/mean DH).
nP-Index: Normalized posterior-disc-height-index (pDH/mean DH).
AP-Index: Anterior-posterior-disc-height-index (= aDH/pDH).
nAP-Index: Normalized anterior-posterior-disc-height-index (= aDH/pDH/mean DH).

Table 1: Correlation between ~5 year clinical scores and preoperative radiological disc parameters.

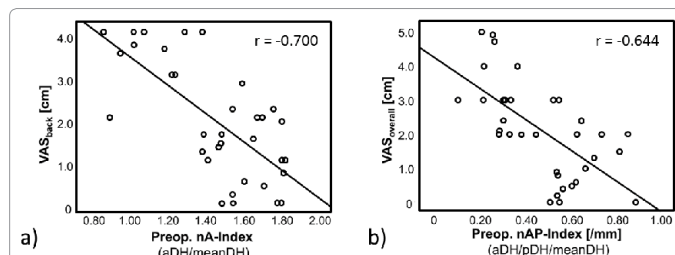


Figure 2: Scatter plot with VAS back vs. nA-Index (a) and VAS overall vs. nAP-Index (b) for 34 investigated patients.

Data evaluation

Segmental lordosis (SL, measured between the inferior endplate of L5 and the endplate of S1) and the anterior (aDH), middle (mDH), and posterior disc height (pDH) of the surgically treated segment were evaluated using the FXA™ software (ACES GmbH, Esslingen, Germany). Subsequently, aDH, mDH, and pDH were used to calculate the mean disc height (meanDH) (Figure 1). Based on the aforementioned parameters, four additional parameters were calculated:

1. Normalized anterior-disc-height-index (nA-Index = aDH/meanDH).
2. Normalized posterior-disc height-index (nP-Index = pDH/meanDH).
3. Anterior-posterior-disc-height-index (AP-Index = aDH/pDH)
4. Normalized anterior-posterior-disc-height-index (nAP-Index = aDH/pDH/meanDH)

The preoperative radiological parameters of the groups were compared and a correlation analysis between the final clinical scores (VAS and ODI) and the preoperative radiological parameters were performed.

Statistical analyses

Data were analyzed using SPSS 22.0.0.1 (SPSS, Inc. Chicago, USA). The correlation analyses between the radiological parameters and the clinical scores were based on Pearson's correlation coefficient.

Results

mDH, pDH, nP-Index, and meanDH displayed statistically significant and positive correlations with the ODI and VAS scores (r between 0.402 and 0.552), whereas aDH, nA-Index, AP-Index, nAP-Index, and SL yielded significant negative correlations (r between -0.345 and -0.700) (Table 1). The three strongest correlations were observed between nA-Index and VASback (r = -0.700), nAP-Index and VASoverall (r = -0.644), and AP-Index and VASback (r = -0.634). Figure 2 shows the correlation between nA-Index and VASback (Figure 2a) and nAP-Index and VASoverall (Figure 2b).

Discussion

The influence of the preoperative disc height on the outcome after TDR is an ongoing subject of debate; some authors argue that a preoperative more rigid and collapsed disc might compensate for the rotational instability of an artificial disc as reported by Siepe et al. [26] and Tournier et al. [27]. In our previous finite element model study, we demonstrated that a greater preoperative disc height and thus lower disc stiffness is associated with a larger range of motion [19]. Due to the lower disc stiffness, the posterior spinal column experiences higher loads, which lead to larger facet capsular forces. Therefore, we expected

that these higher loads may explain why the patient satisfaction rate is significantly lower in patients with a greater preoperative disc height. Our current findings support this hypothesis; the patient satisfaction outcome is worse if the preoperative posterior and mean disc heights are large and the anterior disc height is small. This can be explained as follows: The surgical technique for TDR is usually performed with anterior release by resection of the intervertebral disc and the anterior longitudinal ligament while leaving posterior structures (facet joints, interspinous ligaments, etc.) intact. In a segment with a small anterior disc height, anterior distraction is more probable. However, a strong distraction might considerably increase facet capsule ligament forces and the forces in the interspinous ligaments [19] — possible new sources of back pain in the follow-up.

The mean disc-height is essential for the biomechanical behavior of a spinal segment and influences the disc-stiffness [28]. Spinal segments treated with TDR with a large mean preoperative disc-height, and thus a potentially small disc stiffness, might be at increased risk of postoperative segmental instability, a possible reason for low back pain. However, the elementary relationship between individual disc morphology, iatrogenic distraction, resultant postoperative biomechanics (e.g., segmental range of motion; loading of facet joints) and clinical results remains to be established.

Our study has some limitations. Because of the small number of patients, the results (especially the non-significant results) should be interpreted with caution. Even so, significant results were obtained despite the use of relatively rigid statistical methods. Another limitation of our study was that we only used one implant type: a (semi) constrained ball-socket model. Other implants may well lead to different results.

Conclusion

The preoperative normalized anterior-disc-height-index (nA Index) and the normalized anterior-posterior-disc-height-index (nAP-Index) can serve as prognostic radiographic parameters before patients undergo lumbar total disc replacement.

Highlights

- Clinical analysis 5 years after lumbar total disc replacement.
- Preoperative anterior-disc-height-index strongly correlated to clinical pain scores.
- Preoperative anterior-posterior-disc-height-index strongly correlated to clinical pain scores.
- Both can serve as radiographic predictors before patients undergo lumbar total disc replacement.

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