On the development of an artificial intervertebral disc

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Chapter 8 Summary

Degenerative disc disease is one of the causes of low back pain. There are two major surgical interventions: spinal fusion and implantation of an artificial intervertebral disc. Spinal fusion alters the biomechanics of the spine, which may lead to further degeneration of the surrounding tissues and the discs at adjacent levels. An artificial intervertebral disc could prevent this. Existing devices, however, do not comply, so it was decided to develop a new artificial intervertebral disc, consisting of a core with two endplates. This thesis describes the requirements for such an artificial intervertebral disc and presents the design of the endplates.

Chapter 1 gives an introduction of the vertebral column, its anatomy, degeneration and treatment methods.

In Chapter 2 the demands for the development of an artificial disc are presented. The artificial disc for total intervertebral disc replacement needs to have the same geometric properties as the disc it replaces. To prevent migration of the disc into the vertebrae, the size of the endplate of the artificial disc has to be as large as possible. However, if the disc protrudes outside the intervertebral disc space, there is a high chance that the aorta, vena cava or the spinal cord could be injured.

To have a proper long-term fixation, bony ingrowth into the coated endplates is favorable, thus requiring a limited gap between natural and artificial endplate. The height of the intervertebral disc space should be restored to the healthy situation, and the wedge angle of the disc has to be restored to the original situation, because a difference in height or wedge can alter the mechanics of the vertebral column.

So a proper matching between geometry of the natural and artificial intervertebral disc is required and thus a detailed overview of intervertebral disc space geometry. However, such a detailed overview cannot be found in the literature, so it was decided to start a research to find the relevant data. Results are described in Chapter 5 and 6.

The stiffness of the artificial intervertebral disc is less important for a good function of the artificial disc prosthesis, because the intervertebral disc does not play a major role in the total stiffness of the vertebral column. However, a good overview of stiffness data in all directions is required for a proper design of especially the core of the artificial intervertebral disc. Because data in the literature are conflicting, a study was performed to find the stiffness data. Results are presented in Chapter 4.

The range of motion of the artificial disc should be more than the range of motion of the natural disc. When the ligaments of the motions segment are unaffected during the implantation, they can still function as motion limiters of the motion segment. If the
range of motion is too small, the fixation of the intervertebral disc with the vertebrae can be overloaded, resulting in dislocation.

Since the anatomy of the spinal muscles is important for understanding the stability of the spinal column, in Chapter 3 a study is described in which not only the origins and insertions of the paraspinal muscles accurately were determined, but also the moment arms and the size and thickness of the spinal muscles. Each distinctive muscle fascicle of the erector spinae muscle and the spinotransverse muscles was determined in male cadavers. The position of the attachment points of the cadavers were first measured with the use of CT Tomography. In the same cadavers the origin and insertio of all fascicles of the iliocostal, longissimus, and spinal muscles of the erector spinae were measured and all fascicles of the spinotransverse muscles.

Chapter 4 describes the measurements to determine the compliance of the human vertebral column. Three equally build human cadavers were loaded with different weights. The resulting displacements were recorded with the use of the 3D Elite infrared measurement system. These measurements resulted in the compliance of the human torso at every lumbal level and every other thoracal level.

In Chapter 5 measurements on the geometry of the intervertebral disc are described, leading to requirements of the artificial intervertebral disc. The wedge angle for the artificial disc for levels L1-L2 to L3-L4 needs to be 6 degrees, the wedge angle for L4-L5 needs to be 9 degrees, and the wedge angle for L5-S1 must be 13 degrees. The average of the anterior and the posterior height of the artificial disc needs to be 8 to 14 mm. The endplate of the artificial disc must have a convex shape, resulting in a cavity with a maximum depth of 2 mm. This maximum depth not be located in the middle of the endplate, but at two-thirds of the anterior-posterior diameter.

In Chapter 6 the dimensions of the endplate of the endplates of the artificial disc are discussed. Five different endplates cover the size of the endplates of most patients. Two ribs that prevent lateral dislocation of the artificial disc and two ribs that prevent anterior posterior dislocation will provide initial fixation.

To conclude this thesis, a general discussion is presented in Chapter 7.