Chapter 7
Finite Element Modelling Studies

Computer aided mechanical analysis is a common application for engineering problems. Conducting such analysis to newly developed systems can reduce the number of design variations without testing. Finite element modeling (FEM) gives the advantage of disabling the over usage of cadavers, synthetic materials, test equipment and so on.

Following the FEM studies, results are also compared with biomechanical tests to validate the model. There are several studies that FEM were used as a design tool.

For instance, Wagnac et al. [5] investigated the pullout strength of pedicle screw through a detailed FEM to demonstrate pullout mechanism and analyze bone-screw mechanical interaction. New model's pullout strength was compared with experimental data and the predicted pullout strength found within the range of the experimental data. In other words, this research can lead the researchers for the further FEM studies on pullout strength of pedicle screw.

Furthermore, a finite element model was designed in Zhang et al.'s [7] study to determine the effects of bone materials on the screw's pullout. The FE model's pullout strength results in different foam materials were then compared with the experimental results. As a result, bone mineral density was significantly correlated with the stability of pedicle screw.

Chatzistergos et al. [3] also designed a finite element model to predict pullout strength of cylindrical pedicle screws. To obtain experimental results three types of pedicle screws were pulled out from polyurethane foams. Then both results were compared. It was obvious that the new model could be a good predictor of cylindrical pedicle screws' pullout behavior. Recorded parameters which were projected to change pullout strength of a pedicle screw were outer diameter, core radius, pitch, thickness and inclination of the thread. The most recognizable change in parameter was apparently outer diameter. 36 % increment on outer diameter provided 34 % increment on screw's pullout strength, as expected.

Moreover, experimental and finite element analyses were done by Hsu et al. [4] to compare mechanical performances of conical pedicle screws and cylindrical pedicle screws. Experimental studies were performed on polyurethane foams

T. Demir and C. Başgül, *The Pullout Performance of Pedicle Screws*,
SpringerBriefs in Computational Mechanics, DOI 10.1007/978-3-319-16601-8_7

with two different densities. Three different screws and three different sizes of each screw type were used for the test. The experimental results were as follows; for the foams with high density, pullout strength and insertion torque was higher than low density foams. Conical screws showed higher pullout and insertion torque than cylindrical screws. Pullout strength and insertion torque was correlated. FEM showed similar results with the experimental results. FEM showed that increasing the outer diameter caused increment on pullout strength approving the Chatzistergos et al.'s [3] study.

Another study was done to compare the conical and conventional cylindrical pedicle screw by Chao et al. [2]. Ten types of pedicle screw with different core tapering and core diameter were tested on polyurethane foams. In addition to those experimental results, finite element models were used and the results were compared with the tests. Conical screws showed higher pullout strength than cylindrical screws as expected. This study showed that there was a good correlation between finite element analysis and the actual test results.

On the other hand Bianco et al. [1] investigated effect of the screw placement on the pullout by FE analysis. Two types of trajectories (straight ahead and straight forward), two different screws (single leaded and dual leaded) and major diameter and length of the screw were parameters that researched in this previous study. The core diameter, length, type of the screw and insertion trajectory were founded to be the main factors that significantly affect the peak pullout force. Screw diameter played a major role on the pullout force and initial stiffness. On the other hand, entry point enlargement 46 % decreased the peak pullout strength of pedicle screw. This was FEM only study.

On another research made by Yan et al. [6], three different finite element models (2 screw-foam models and 1 screw-bone model) were designed to evaluate the proper cement amount injected through the pedicle screw. Region of effect (RoE) and proper amount of injection cement (AIC) were investigated by using these models. The outcomes were compared with the previous experimental data from the literature, and models showed promising results. This FE study could be a lodestar for the future studies and spinal instrumentation with cement augmentation.

References

1. Bianco RJ, Arnoux PJ, Mac-Thiong JM, Wagnac E, Aubin CE (2013) Biomechanical analysis of pedicle screw pullout strength. Comput Methods Biomech Biomed Eng 16(Suppl 1):246–248
2. Chao CK, Hsu CC, Wang JL, Lin J (2008) Increasing bending strength and pullout strength in conical pedicle screws: biomechanical tests and finite element analyses. J Spinal Disord Tech 21(2):130–138
3. Chatzistergos PE, Magnissalis EA, Kourkolis SK (2010) A parametric study of cylindrical pedicle screw design implications on the pullout performance using an experimentally validated finite element model. Med Eng Phys 32:145–154
4. Hsu CC, Chao CK, Wang JL, Hou SM, Tsai YT, Lin J (2005) Increase of pullout strength of spinal pedicle screws with conical core: biomechanical tests and finite element analyses. J Orthop Res 23:788–794

5. Wagnac E, Michardiere D, Garo A, Arnoux PJ, Mac-Thiong JM, Aubin CE (2010) Biomechanical analyses of pedicle screw placement: a feasibility study. Stud Health Technol Inform 158:167–171
6. Yan YB, Teo EC, Qiu TX, Wu ZX, Qi W, Liu D, Lei W (2013) Finite element study on the amount of injection cement during the pedicle screw augmentation. J Spinal Disord Tech 26(1):29–36
7. Zhang QH, Tan SH, Chou SM (2006) Effects of bone materials on the screw pull out strength in human spine. Medical Eng Phys 28:795–801