FINITE ELEMENT ANALYSIS OF DENTAL IMPLANT SYSTEMS

DET TEKNISKE BUREAU

1 Introduction

This white paper will give an introduction to using the Finite Element Method (FEM) in the development of dental implant systems. We will look at the typical flow from product design and product optimization to testing and certification, and how to improve it using FEM.

2 Engineering challenges

When designing dental implants, the mechanical analysis often proves to be difficult. Geometries are complex, and the internal mechanics of the implant-abutment connections are also too complicated to analyze by simple engineering estimates or reasoning. Therefore, new designs often closely replicate existing solutions, only changing minor things. However, in case of dental implant design, *the devil is in the detail*. Even small changes in design parameters can make or break a design feature. A conical connection between abutment and implant is a good example of this. If the design is done right, the sealing pressure will increase with increased external loading. But often this design goal fails, and in consequence bacteria may enter into the implant. Figure 1 show an example of how FEM can be used to precisely analyze and optimize both gap and sealing pressure.

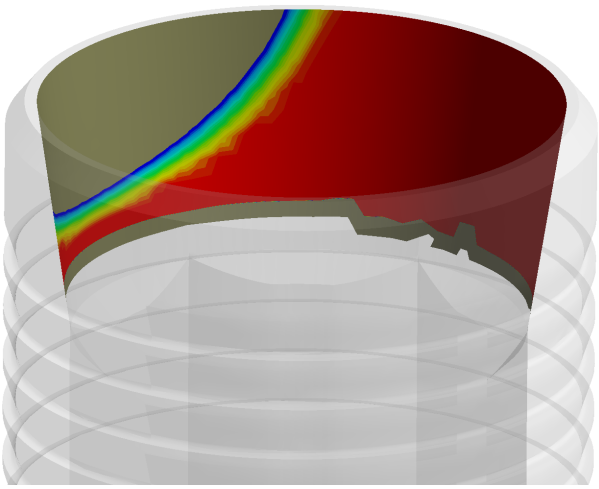

Figure 1: Gap and sealing pressure in the conical seal during different loading conditions can be studied and optimized using FEM.

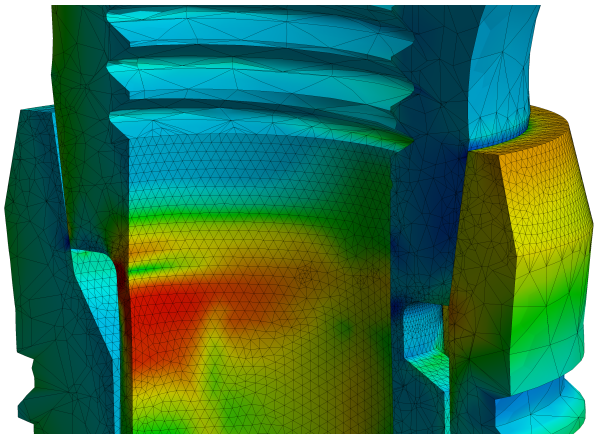

Figure 2: Example of internal stress distribution in implant and abutment, when subjected to ISO14801 loading-conditions.

A key element to the overall strength of an implant system, is how mechanical stresses arising from applied loads are distributed. A good design will typically seek to absorb the loading over a larger area, rather than focusing it in a small region. This is to avoid localized stress concentrations, in which the material is prone to deform or even exceed its structural strength. It is also preferable that stresses are absorbed in regions with large material-thickness and high tensile strength. These factors typically vary over the implant system, due to both geometry and the use of mixed titanium alloys.

FEM analysis can supply valuable insight, that would be practically impossible to derive from experiments, see Fig. 2. It is possible to precisely predict stress levels, strains and plastic deformation arising from various loading scenarios. The mechanisms with which external loads are absorbed by the implant system and the surrounding bone can also be simulated and studied. All this can be done in the product development phase, making it possible to experiment with designs, material choices, surface coatings and optimize geometry prior to prototyping.

Fatigue analysis is another challenge in implant system development. Experimental fatigue tests usually takes months to complete. FEM can help to identify and confirm the *worst case* component-configurations that need to be tested for medical approval. The fatigue analysis can also be simulated directly (see Fig. 3), minimizing the risk of a failed design setting back the product launch months.

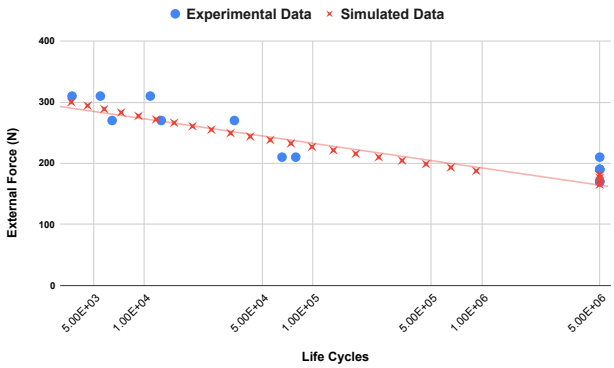

Figure 3: Results from a simulated vs experimental ISO14801 fatigue analysis.

3 Applying FEM correctly

The *garbage in, garbage out* saying is particularly relevant for Finite Element analysis. It is very easy to create a wrong FEM model, as well as get misleading results from an accurate model. Usually without any warning. Specialist knowledge is therefore paramount in FEM analysis.

A typical mistake is to discard important mechanical behavior or components. Simply because they are difficult to model correctly and require a lot of computational power. Frictional interfaces in conical connections and abutment screws are good examples of important elements, that are often disregarded. A half-correct model usually gives plain simple wrong answers.

Several commercially available softwares, such as *Creo Simulate*, *Solidworks* and *Inventor* have simplified FEM capability. Unfortunately, they do not model friction, plastic deformation and other important non-linear mechanisms with sufficient precision for implant system analysis.

4 Det Tekniske Bureau

is an experienced consultant engineering company, specializing in mechanical analysis of dental implant systems. We have developed our FEM simulation-models and modeling principals throughout years of research, testing and comparison with experiments. Our models are developed *not* on basis of what was possible, but on basis of what was necessary to get correct results.

Our clients include several of the largest implant-companies on the market, as well university research departments. Simulations are always done using the state-of-the-art industry standard software, able to handle the complex types of analysis. Calculations are made on high-performance clusters, so even large projects can be delivered quickly. Results are always critically evaluated and advice is based on well-established practical and theoretical knowledge.

5 Types of analysis

The following list contain examples of different types of analysis and services, that we can provide.

- ◇ *Simulation of ISO14801 loading tests.*
- ◇ *Performance-comparison of implant systems.*
- ◇ *Insight and evaluation for R&D, including parameter and geometry optimization. Help to realize your design-goals.*
- ◇ *Conical sealing connection analysis (gap and sealing pressure). Reduce the risk of bacteria entering into the implant due to leakage.*
- ◇ *Analysis of bone-inserted implants.*
- ◇ *Production tolerances min/max effect on performance.*
- ◇ *Complete or partial mechanical designs / redesigns.*
- ◇ *Identification and documentation of worst case component configurations (prior to fatigue testing).*
- ◇ *Simulated fatigue analysis.*
- ◇ *Handling of 3D scanned geometry and modification of CAD-models.*

Results can be delivered in many forms. Technical reports, presentations, table overviews, high quality pictures and video for marketing purposes etc.

6 Contact

Please visit www.tekniskebureau.dk for more information. If you have any questions or inquires, please send us a mail on: mail@tekniskebureau.dk or call on +45 2843 5906.