Retentive force analysis of new dental implant solution

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Introduction

A dental prosthesis, by mimetizing the natural teeth, plays an important role in the maintenance of oral functions (eating, speaking and equilibrium). As the population gets older, the use of implants and implant-supported prosthesis is rising for the replacement of missing teeth. With the development of new bio compatible polymeric materials, it opens a new windows to innovative dental prosthetic for rehabilitation.

The SIMPLIFIED Project aims to offer patients and healthcare professionals a new product that is significantly faster, cheaper and more beneficial to the success of dental treatment. The new dental implant solution is based on a universal abutment, compatible with any conventional implant, in a single, simplified retention system, applicable to fixed or removable prostheses, whether total or partial, without the need of screws or cements.

AIM

The aim of this work was to design, simulate, produce and test a new implant solution that is cheaper, more practical and beneficial for dental prosthesis. The result is a set of parts, abutment and retainers, made the first in a Titanium alloy and the seconds of PEEK, that are able to make the connection between the dental prosthesis, an abutment and a conventional implant.

The individual parts, as well as the assemblage were development, simulated and validated using finite element analysis (FEA) in a Computer-Aided-Engineering (CAE) software ABAQUS®.

CAD Models and materials

The new retention system is composed by two polymeric components (injection moulding retainers) and a machined titanium abutment. The system assembly 3D model is shown in Figure 1.

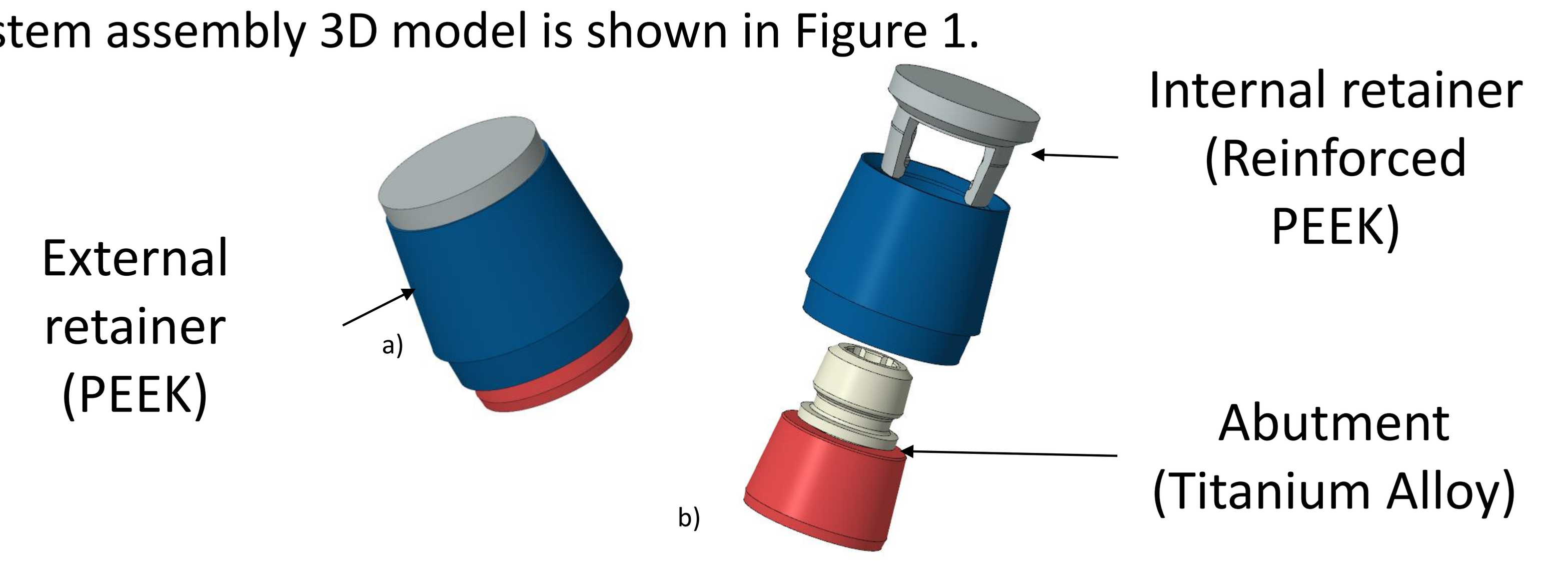

Figure 1. Developed retention system; a) Assembled model view; b) Exploded model view

Computer simulation

A finite element analysis (FEA) was applied to the assembly model to validate the mechanical performance of the new design.

The interaction between the components was simulated with the help of ABAQUS®/CAE 6.14-3 software, assuming a brief transient dynamic event (quasi-static simulation with ABAQUS®/Explicit), due to the severely nonlinear behaviour introduced in contact simulation. A friction coefficient of 0.1 was assumed, also, with the expectation of high retainer deformations, the Non-linear geometry formulation present in ABAQUS® was used .

To mimic the accurate mounting of the system, the simulation was performed in a series of steps described in Figure 2. Since, one of the system requirements is reutilization, steps II (Insertion) and W (Withdraw) were performed until 2 more full using cycles were simulated.

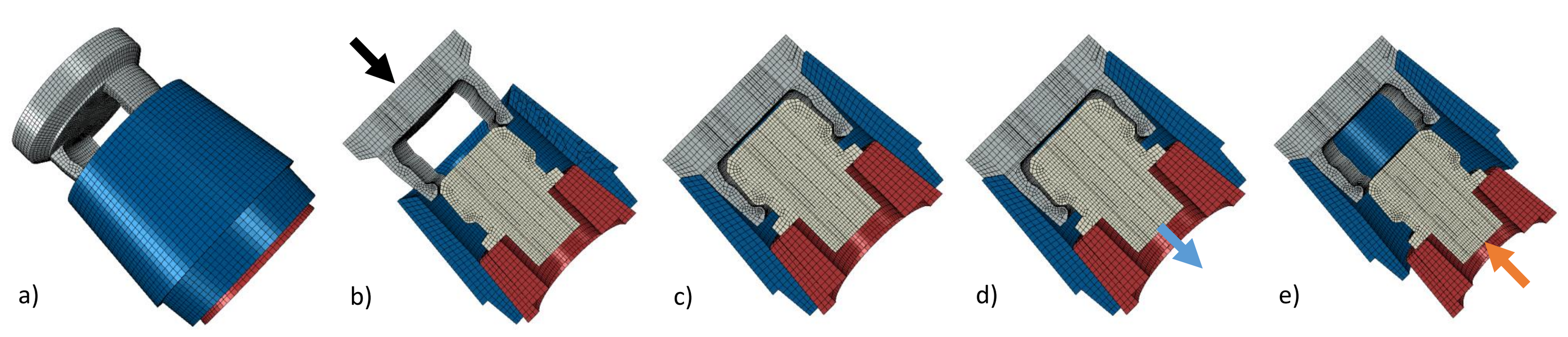

Figure 2. Simulation steps; a) Full meshed model consisting of 67544 three-dimensional hexahedral elements with reduced integration (C3D8R); b) First insert step [I], insertion of the internal retainer (IR); c) Accommodation of the IR; d) Withdraw step [W], separation of the abutment from the IR; e) Insertion step [II], insertion of the abutment in the IR;

Simulation results

The obtained Von Mises stress field for the IR and the system retaining force results are presented in Figure 3 and Figure 4 respectively. Table 1 shows the peak values obtained in the simulation for the force required during assembly and disassembly of the system.

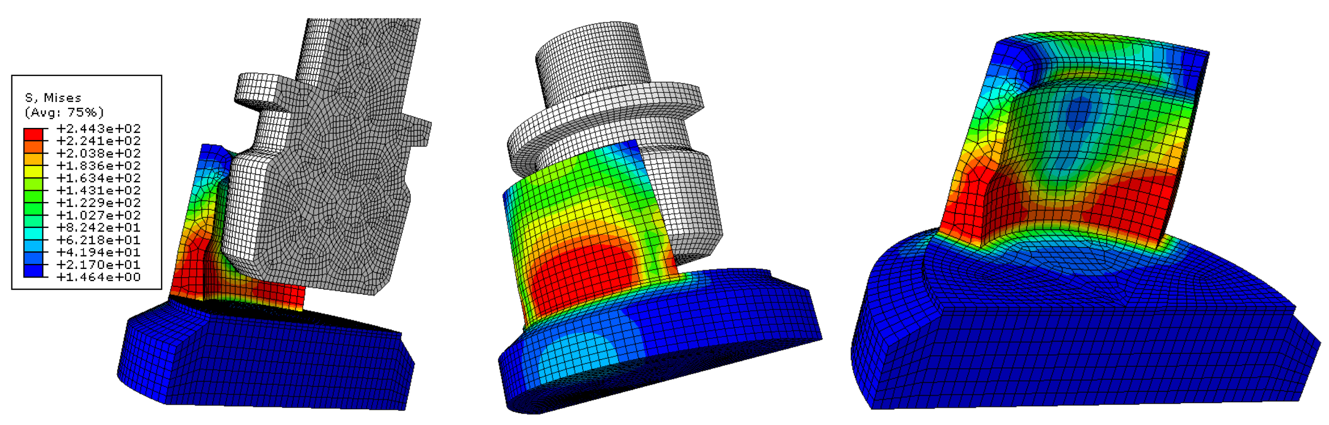

Figure 3. Internal retainer stress results during maximum deflection, half model view for better visualization.

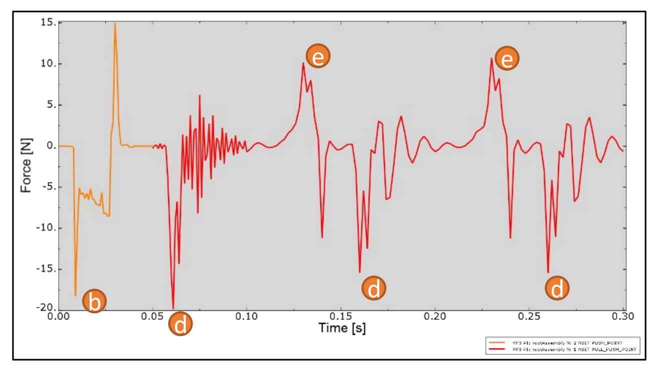

Figure 4. Retaining force results.

Table 1. Point values from force results; (I – insert movement; W – withdraw movement)

Points	b	d	e	d	e	d
Step	I	W_1	II_1	W_2	II_2	W_3
Values [N]	-18.3	-19.8	10.2	-15.2	10.8	-15.4

Experimental results and discussion

The comparison and validation of the simulation results were evaluated through real prototype testing. The experimental setup is shown in Figure 4a/b and the acquired force values are presented in Figure 4c.

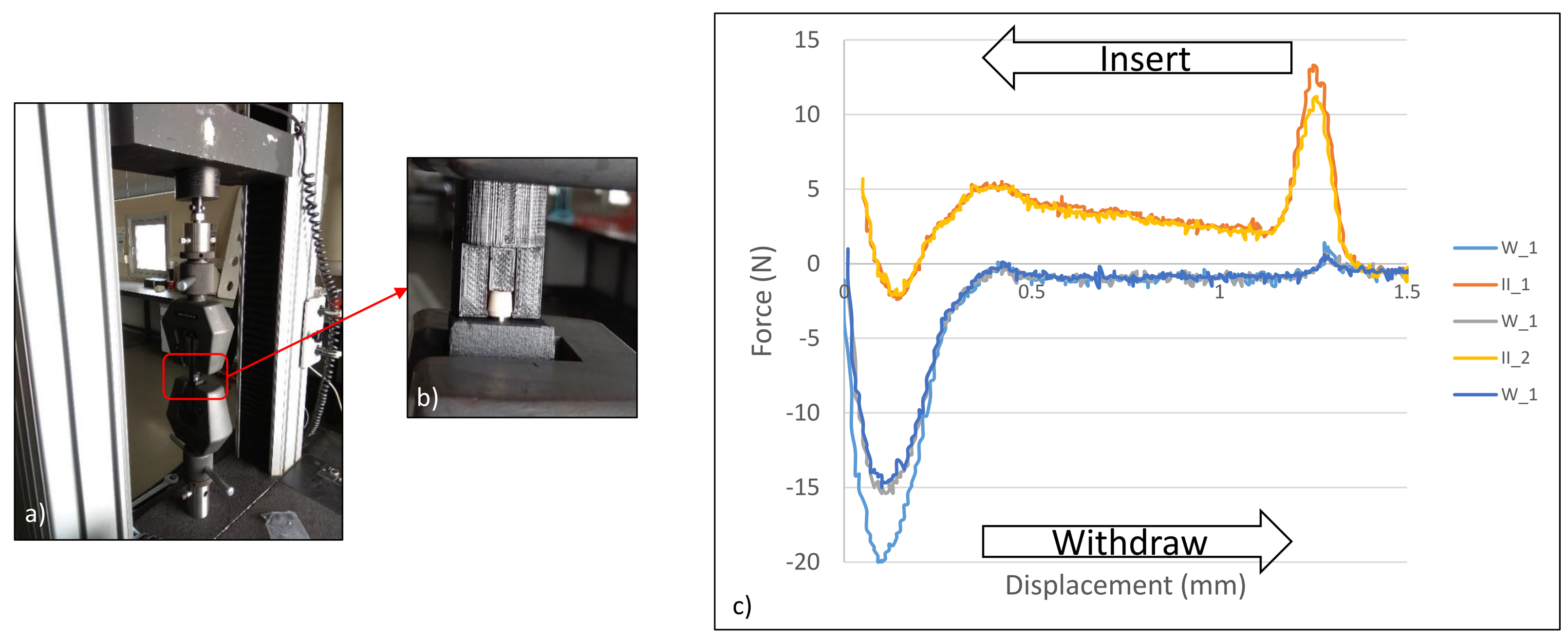

Figure 5. a) Tensile testing machine used for experimental validation; b) Blow up detail of the developed system in the testing machine; c) Experimental results obtained from the system assembly/disassembly, due to setup limitations the first insertion force could not be measured.

Concerning the IR model, during the insertion/withdraw stage when the maximum deflection of the snap occurs, stress concentrations near the PEEKs ultimate tensile strength (UTS) appear at the base (Figure 3). Since, the IR snap is subjected to this magnitude of stress, some plastic deformation will occur in that zone. However, the material maximum strain is not reached, due to plastic deformation the IR snap does not fully recovers the original position. Therefore, the retaining force will drop until the snaps deforms to a position from which it can recover elastically.

The experimental values obtained (Figure 4c) from the cycle test corroborate the FEA results, with similar values between the two.

Conclusions

All proposed objectives for the development and testing of a new attachment implant solution were achieved.

The polymeric materials in the retainers worked was expected, without suffering damage during the assembly or disassembly of the system and presenting a retaining force of 20 N during the first withdraw.

Correspondingly, the results obtained through the FEA were corroborated through the experimental results.

Acknowledgments

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