Predicting the Performance of Implant-Retained Prosthetic Screw Finite Element Analysis

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by Grant Wolfe and Sarah Schwartzman

Discussion

Patients with restored residual ridges may not have adequate bone mass for standard implants. If alle augmentation isn't an acceptable option for the patient, their restorative dentist can instead be used to retain a prosthesis when there is sufficient bone volume and density for primary stability.

Mini implants can provide exchange points for orthodontic treatment and retention for removable prosthesis, such as dentures. They are indicated for several situations where conventional implants are not suitable:[1]

- For patients with inadequate bone width
- For older or medically compromised patients (Hopina Insertion of a mini implant requires less surgery)
- For financially challenged patients who cannot afford conventional implant treatment
- For patients who are unwilling to undergo bone augmentation procedures
- For patients who are unwilling to wait the several months of healing frequently associated with conventional implant treatment

When mini implants are used to retain a denture, the prosthesis is immediately functional and is subsequently adjusted to avoid generating dentation. Using multiple mini implants to retain removable prosthesis reduces the forces experienced by individual implants. It has been reported that a single unscrewed implant can hinder the entire prosthesis and cause injury to the implant.[2]

Finite method analysis can evaluate surface transfer from the prosthesis to the implants and the supporting bone, and finite element analysis (FEA). The history of FEA dates back to 1941 when Richard Courant used triangular shaped elements to study torsion of a cylinder.[3] These elements are now considered the most versatile. They are used extensively for automotive and aerospace industries to simulate visualize and optimize structures for strength and stiffness.

Human tissue and bone are challenging to model with FEA because of their complicated geometries and its quality and quantity can vary considerably between individuals. When modeling FEA to evaluate the efficacy of these simplifications and assumptions are necessary in order to build a model that can be solved. These assumptions can have a significant effect on the accuracy of the results. They include:[4]

- The detailed geometry of the bone and the implant to be modeled
- Material properties
- Boundary conditions
- The interface between the bone and the implant

FEA gives engineers and product designers a powerful tool to evaluate the efficacy of their designs under simulated use conditions. It allows them to apply loads and forces and see how it is their designs and evaluate their expected performance. In addition, engineers can use this technology to assess product designs before and in conjunction with clinical analyses.[5]

Simulation Techniques

For our simulation, we used a dentoalveolar (DTL) model of an edentulous mandible from an optical scan. The STL model was imported into a CAD program where the bone was separated and placed anterior to the mental foramen. Implants were placed in the left and right distal cantilevering to the surgical site preparation were subtracted from the implant sites.

The model was printed using a rapid prototyping machine. The printed model had holes where the locations of the implants. Mini implants were placed in these locations, and the bone was then sealed over the implant sites (Fig. 1).

Figure 1: Four mini implants placed in the STL model.

Figure 2: The STL model with implants and soft tissue.

Figure 3: The model and the denture.

Figure 4: CAD assembly of jaw with implants, O-rings and implant housings.

A denture was then fabricated to fit the model (Fig. 3). O-ring housings and metal cores to retain dentures were incorporated into the denture and seated on the implants.

Next, an STL model of the denture was created and imported into a CAD program. In the CAD program, all the parts (jaw, implants, O-rings, implant housings and denture) were assembled (Fig. 4).

Boundary Conditions and Meshing

The mandible was restrained at the temporomandibular joint. A force of 200 N was applied to the denture in the direction between the sinuses (Fig. 5). The assembly was meshed and refined. A default element size of 2.5 mm was used.

Figure 5: Forces and constraints applied to the assembly.

Figure 6: Simulation results.

Analysis and Results

After establishing the boundary conditions and meshing on the assembly, FEA was conducted on the assembly. The analysis took approximately 12 hours to complete due to the complex shape of the model and the small size of the elements. The results of the FEA indicated that bite forces are distributed relatively evenly across the implants, even when force is applied at the middle of the denture, and that stresses are higher in the anterior segment compared to the molds implants (Fig. 6).

Conclusion

The results of the simulation indicate a safety factor of 3x relative to the strength of the implants when 200 N force is applied to the mandibular anterior segment, retained by four mini implants. Although the FEA results indicate that implants, bone, and soft tissue provide sufficient strength, the most important aspect of the implants are significant factors in how effectively occlusal loads are distributed. It must also be considered that occlusal loads that are significantly stronger than the sum of the implants tolerance stress gradients at the implant sites that are apparent in the simulation.

The bonus that are on simulation implant-retained prosthesis have complex spatial and temporal distributions, and they are very difficult to predict to define and simulate. The prosthesis incorporates complex geometry and has implants that undergo semi-restrained axial loading. Defining the same biomechanical forces also presents significant challenges. The simulation results are only as good as the inputs. In addition, bone is not a homogenous material and its structural characteristics can vary greatly between patients. To simplify the model enough to perform an analysis, assumptions have to be made that affect the accuracy of the results.

More research on the composition and simulation of the interaction of implant-retained dentures on implant-retained osteoblastomas is necessary to better approximate the simulation results. Finite element analysis is an approximate method of predicting how implant and prosthetic designs will perform. Testing is ultimately necessary to confirm that the results of the analysis are predictively valid.

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4141 MacArthur Blvd.
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