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Attachments in Implant-Assisted Removable Partial Dentures: A Design Dilemma

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Introduction

The placement of two distal implants has been recommended to transform Kennedy class I to a Kennedy class III situation. Different types of attachment were used in implant-assisted removable partial denture (IARPD). However, there is currently no available evidence to suggest the most effective attachment system[1]; The aim of this study was to assess the stress and strain behaviour of ball attachment systems with two different matrix designs (titanium vs. elliptical) incorporated into an existing removable partial denture using a three dimensional finite element analysis (FEA).

Material and Methods

A Faro Arm (Faro Technologies Inc, USA) was used to extract the geometrical data of a replicated partially edentulous human mandible. Standard plus regular neck (4.8 x 12 mm) Straumann® implant and attachment with two different matrix designs, tooth roots and periodontal ligaments were modeled using a combination of reverse engineering processes in Rapidform XOR2 and solid modeling processes in a FEA program Solidworks 2008 (Solidworks Corporation, Concord, MA, USA) (Figure 1, a & b).

Two models were generated:
1. Model A, An IARPD with ball attachment system with titanium matrix (Figure 1, c).
2. Model B, An IARPD with ball attachment system with elliptical matrix (Figure 1, d).

The Models were loaded with a vertical force of 120 N. ANSYS Workbench 11.0 (Swanson Analysis, Huston, PA, USA) was used to analyze the stress and strain patterns.

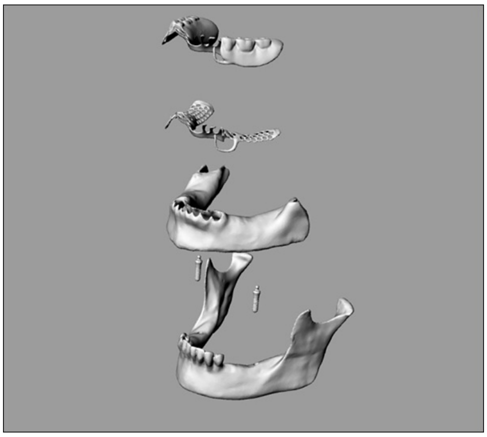


Figure 1(a): All components in the same orientation

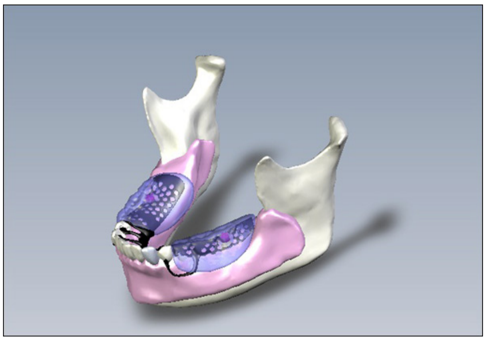
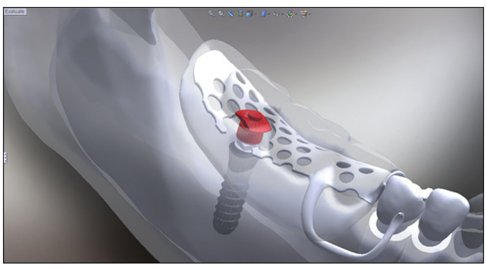


Figure 1(b): All body parts and components are assembled



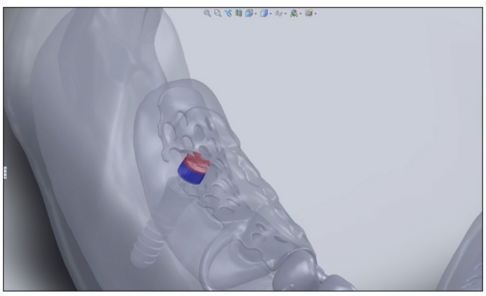
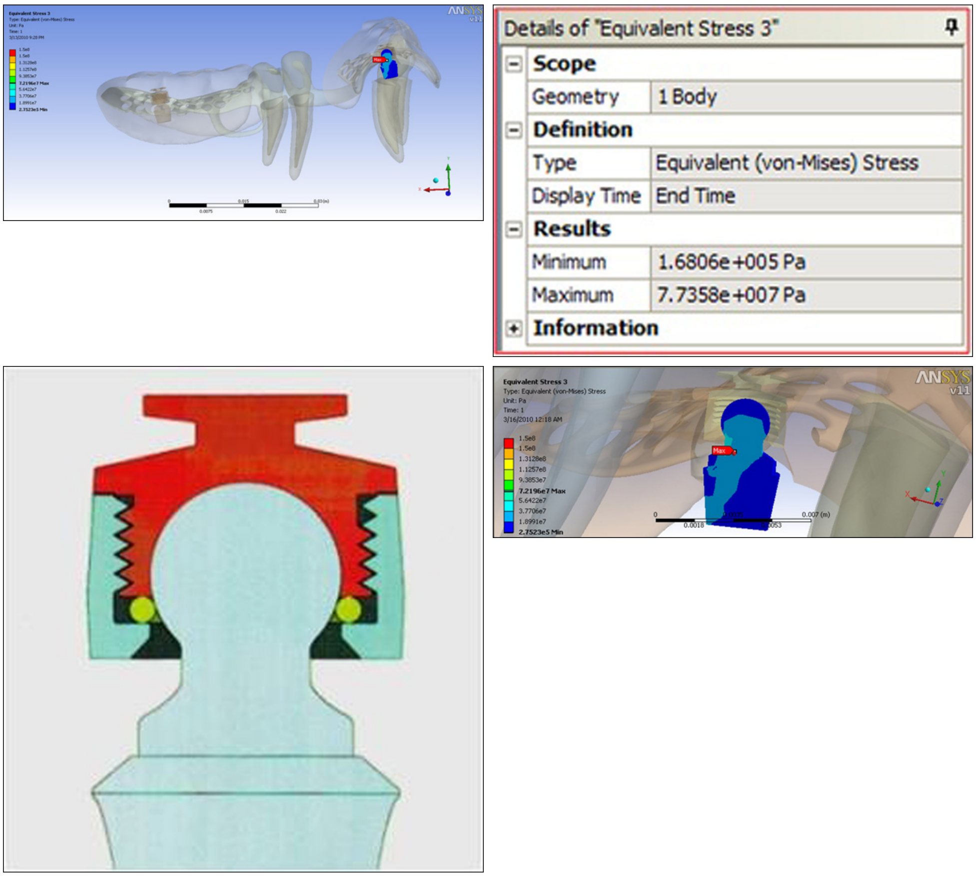


Figure 1(c): Model B with elliptical matrix   Figure 1(d): Model A with titanium matrix

Results

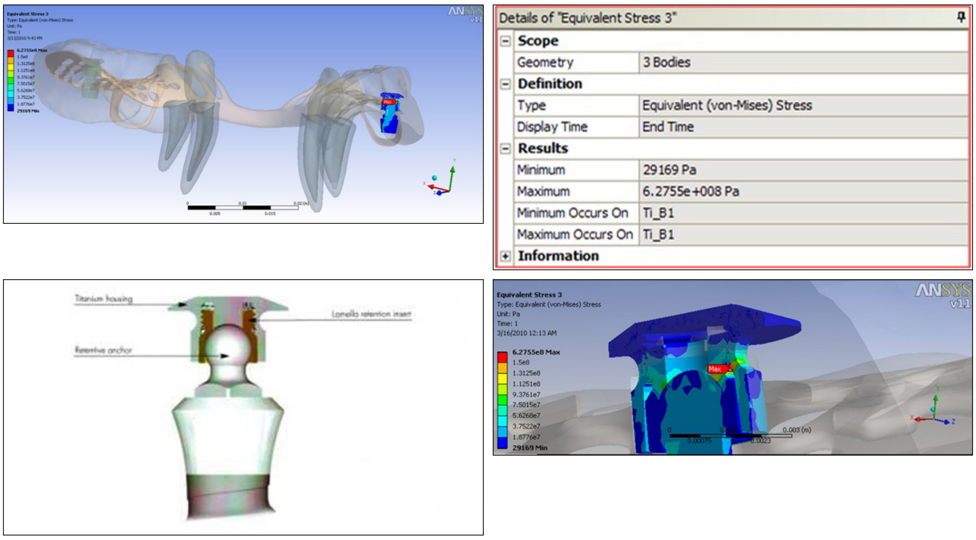
- Model A: maximum stress was concentrated around the neck of ball attachment (male part) (Figure 2),
- Model B: maximum stress was located on the lamella retention insert (female part) (Figure 3).
- In addition, more strain values were observed at the outer surface of titanium matrix (Figure 4).



Details of "Equivalent Stress 3"

Scope	
Geometry	1 Body
Definition	
Type	Equivalent (von-Mises) Stress
Display Time	End Time
Results	
Minimum	1.6806e+005 Pa
Maximum	7.7358e+007 Pa
Information	

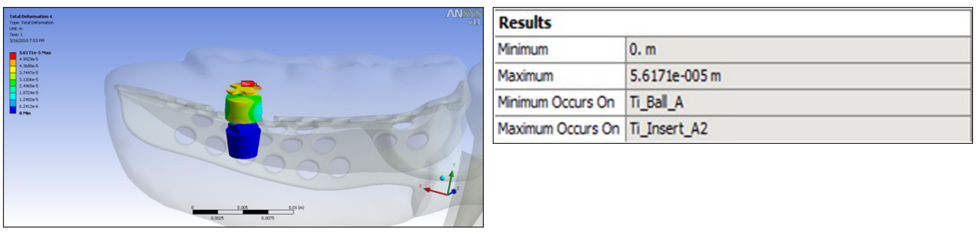
Figure 2: Model A: Stress concentration on the neck of ball attachment



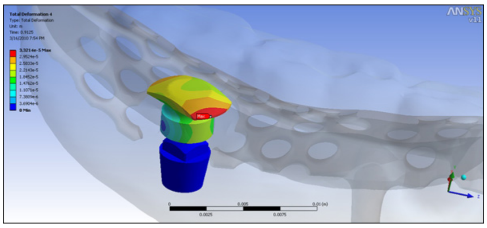
Details of "Equivalent Stress 3"

Scope	
Geometry	3 Bodies
Definition	
Type	Equivalent (von-Mises) Stress
Display Time	End Time
Results	
Minimum	29169 Pa
Maximum	6.2755e+008 Pa
Minimum Occurs On	Ti_B1
Maximum Occurs On	Ti_B1
Information	

Figure 3: Model B: Stress concentration on the lamella retention insert



Results	
Minimum	0. m
Maximum	5.6171e-005 m
Minimum Occurs On	Ti_Ball_A
Maximum Occurs On	Ti_Insert_A2



Results	
Minimum	0. m
Maximum	3.3214e-005 m
Minimum Occurs On	Ti_Ball_B
Maximum Occurs On	Ti_B1
Information	

Figure 4: Higher strain value were observed on Ti matrix (Model A)

Discussion

Ball attachments has been used to provide retention and support of IARPD[2] as well as reducing stress concentration around implants and abutment teeth. However, acrylic fracture of IARPD bases was one of the most commonly reported complications[3]. In this study, FEA was used to evaluate the stress-strain patterns of two matrix designs incorporated into the same acrylic base. Elliptical matrix showed a more favourable stress-strain behaviour compared to the titanium matrix. The maximum stress concentration of the elliptical matrix was located on the lamella retention insert, which acted as a stress breaker. Hence, the stress transfer to the ball attachment and underlying structure was reduced. Additionally, less strain values were observed at the outer surface of the attachment which was embedded into the acrylic base. Nevertheless, there is still currently no available clinical evidence to suggest one design over the other in terms of retention and support[1].

Conclusions

Within the limitation of this study, the embedded elliptical matrix in acrylic may achieve a more favourable stress/strain distribution during functional loading compared to the titanium matrix. Further long-term randomized controlled studies are needed.

References

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2. Kuzmanovic, D. V. ; Payne, A. G. T. ; Purton, D. G. Distal implants to modify the Kennedy classification of a removable partial denture: A clinical report. Journal of Prosthetic Dentistry 2004; 92:8-11.
3. Payne, A. ; Kuzmanovic, D. V. ; De Silva-kumara, V. ; Van Staden, I. P. Mandibular removable partial dentures supported by implants: one-year prosthodontic outcomes. Journal of Dental Research 2006; 85 (Spec Iss B):2570.

Abbreviations

IARPD = Implant Assisted Removable Partial Denture

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