STRUCTURAL STRESS ANALYSIS OF PREMOLARS AND BIOIMPLANTS USING VARYING OCCLUSAL FORCES

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ABSTRACT

The biomechanical performance of natural premolars and dental bioimplants under different occlusal loading conditions plays a crucial role in clinical success, especially in restorative dentistry and implantology. This study presents a comparative structural analysis of stress distribution in natural premolars and dental bioimplants using finite element modeling (FEM) under varying occlusal forces. The objective is to evaluate how load direction, magnitude, and material composition influence stress concentration patterns in tooth and implant structures. The model simulates axial, oblique, and lateral forces representative of chewing activity. Results reveal that natural premolars, owing to their anisotropic and viscoelastic structure, exhibit better stress dispersion compared to bioimplants, which tend to concentrate stress around the implant-abutment interface. The findings offer insight into the mechanical behavior of dental systems under functional loads, supporting improved implant design and treatment planning.

1. INTRODUCTION

Dental biomechanics is an essential field in understanding how the human dentition responds to routine mechanical loads, particularly those generated during mastication. Premolars play a transitional role in chewing, bearing a substantial portion of occlusal stress. With the increasing use of bioimplants to replace lost premolars, it becomes critical to investigate whether artificial substitutes can replicate the stress-bearing and dispersive functions of natural teeth.

While bioimplants offer high durability and compatibility, their stress-handling capacity is significantly influenced by material composition, structural geometry, and the surrounding bone interface. In contrast, natural premolars consist of dentin, enamel, and periodontal ligaments, which provide a shock-absorbing, flexible biomechanical advantage.

This study aims to conduct a finite element analysis (FEA) to compare stress distribution in premolars and bioimplants when subjected to different occlusal forces—specifically axial, oblique, and lateral forces that simulate real-world chewing actions. By doing so, the research seeks to highlight how structural and material differences impact stress propagation, offering valuable data for both clinical applications and implant development.

On the other hand, metallic materials sometimes show toxicity and are fractured because of their corrosion and mechanical damages [1]. Therefore, development of new alloys is continuously trialed. Purposes of the development are:

- To remove toxic element.
- To decrease the elastic modulus to avoid stress shield effect in bone fixation.
- To miniaturize medical devices.
- To improve tissue and blood compatibility.

Figure 1. Different types of biomedical implants

Human Teeth Anatomy: There are 32 permanent teeth. There are 16 teeth on both the top and bottom jaw. Each jaw consists of specific teeth, which are incisors (cutting teeth), canines (tearing teeth) and molars (grinding teeth). From the midline of one side of each jaw consists of 2 incisors, 1 canine, 2 premolars and 3 molars (fig.2).

Figure 2. Human Teeth Anatomy

2. CAD

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD- based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments. CATIA is an acronym for Computer Aided Three-dimensional Interactive Application. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products. CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative.

3D model Assemble product

Figure 3. Solid model of implant (left). Model of premolars (right).

3. ANALYSIS

STATIC ANALYSIS OF PRE-MOLARS

Material properties

Material properties	Ni-Cr	Au-Ag	Zirconium
Density (Kg/m³)	8400	8000	4560
Possion's ratio	0.325	0.33	0.26
Young's modulus(Gpa)	245	91	97
Yield strength(Mpa)	2100	800	810
Ultimate tensile strength (Mpa)	2300	855	939

Imported model

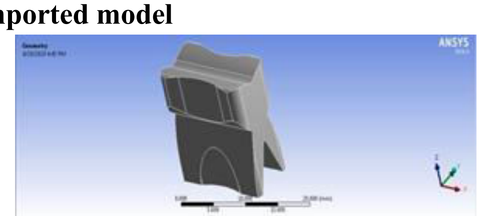

Figure 4. Imported model form modelling software

Meshed model

Figure 5. Meshing model

According above figure shows divided by elements through fine meshing. below figure shows number elements and number nodes as:

Statistics	
Nodes	12554
Elements	1728
Mesh Metric	None

Solution A6>insert>total deformation>right click on total deformation>select evaluate all result Insert>stress>equivalent (von misses)>right click on equivalent >select evaluate all results Insert>strain>equivalent (von misses)>right click on equivalent >select evaluate all results

Material: au-ag

Total deformation

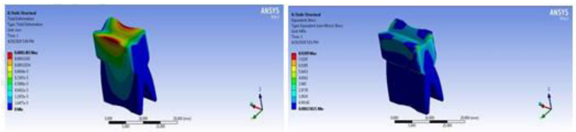

Figure 6. Deformation (left). Stress (right).

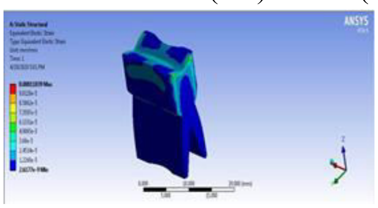

Figure 7. Equivalent strain

STATIC ANALYSIS OF BOI IMPLANT

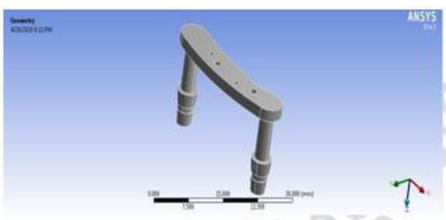

Figure 8. Imported model

Total deformation

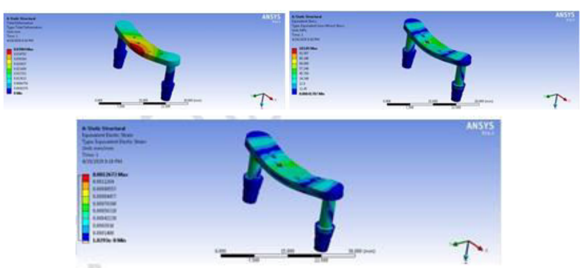

Figure 9. Deformation (top left). Stress (top right). Strain (bottom).

4. RESULTS AND DISCUSSION Static Results tables

Material	Load (Mpa)	Deformation (mm)	Stress (N/mm²)	Strain
Ni-Cr	1	6.1209e-5	9.943	4.5742e-5
	1.5	9.1813e-5	14.916	6.861e-5
	2	0.0012242	19.888	9.1484e-5
Au-ag	**1**	0.0001483	8.9209	0.00011039
	1.5	0.0002306	13.877	0.00017172
	2	**0.0002955**	17.842	0.00022079
	1	**0.00013886**	9.3236	0.00070927
	1.5	**0.0002162**	14.503	0.00016998
	2	**0.0002777**	18.647	0.00021854

Materials	Deformation (mm)	Stress (N/mm^2)	Strain
Ni-Cr	0.014508	103.33	0.00047215
Au-ag	0.03904	103.05	0.0012677
Zr	0.036853	107.04	0.0012411

5. CONCLUSION

The comparative stress analysis of premolars and dental bioimplants under varying occlusal forces underscores significant biomechanical differences between natural and artificial dental structures. The finite element simulations show that natural premolars distribute occlusal stress more evenly, benefiting from the elasticity of the periodontal ligament and the complex internal architecture of the tooth. In contrast, bioimplants concentrate stress at critical zones, particularly around the implant neck and cortical bone interface, which may predispose them to long-term mechanical complications if not optimally positioned or designed.

These findings emphasize the importance of customizing implant geometry and selecting biomaterials that mimic the mechanical properties of natural dental tissues. Additionally, occlusal load management and implant placement strategy must be carefully planned to reduce stress concentrations and enhance longevity.

In conclusion, understanding stress distribution in dental systems not only contributes to improved implant design and success rates but also reinforces the importance of biomimetic principles in modern prosthodontics.

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