A Review on Stress Analysis of Human Tooth Using Finite Element Method

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Abstract: *- Dental science, like much of the evolution of human civilization, progresses in the steps that are often the result of the complex relationship between science, empirical knowledge, and advances in technology. Computing has modified our perception, sense, use and interpretation of time and enabled scientists to perform existing procedures far faster and more accurately than ever. It has allowed them to make a reality of things they had only dreamed of before and perhaps of greater consequence and more excitingly. It has often stimulated them to perceive and focus on their subject with new eyes to see it on a different scale from a completely different perspective. Human tooth is a critical and most important part of human to survive.*

1. INTRODUCTION

Dental science, like much of the evolution of human civilization, progresses in the steps that are often the result of the complex relationship between science, empirical knowledge, and advances in technology. Computing has modified our perception, sense, use and interpretation of time and enabled scientists to perform existing procedures far faster and more accurately than ever. It has allowed them to make a reality of things they had only dreamed of before and perhaps of greater consequence and more excitingly. It has often stimulated them to perceive and focus on their subject with new eyes to see it on a different scale from a completely different perspective. Human tooth is a critical and most important part of human to survive.

1.1 Relevance

Biomechanics is fundamental to any dental practice. To analyze and study the functional loads created within the biological systems , "Biomechanics" is closely related to Mechanical engineering which uses traditional engineering techniques such as Applied mechanics, most notably mechanical engineering disciplines such as continuum mechanics, mechanism analysis, structural analysis, kinematics and dynamics . These methods play prominent roles in the study of stress and strains induced in human body.Tooth is an important part of human body which plays important role of tool for surviving. During eating process, while eating various kinds of foods various functional loads create stresses and strains inside human tooth. Stress at any point in the construction is critical and governs failure of the tooth. For many years researchers have been trying to describe the stress state in the human tooth using analytical, experimental and computational methods.

2. CAD MODELING IN DENTISTRY

Takashi MIYAZAKIA [17] presented the overview of the current dental CAD/CAM systems used for the fabrication of crowns and fixed partial dentures .He reviewed that after the abutment teeth are prepared the mainstream work-flow for conventional metal a restoration is first obtained by taking an impression followed by model production, wax up, and then casting. When this work is performed with the help of computer-assisted technology, abutment teeth are directly digitized within the mouth rather than taking typical impressions. Restorations are designed on a pc monitor using CAD code supported the digitized knowledge as a virtual wax-up. Finally, restorations are processed by a computer assisted processing machine. However, direct digitizing of abutment teeth in a mouth with a camera for crowns and FPDs was technically difficult because of the restricted measuring conditions in the mouth, including the presence of adjacent teeth, gingiva, and saliva, which made accurate recognition of the margin of an abutment difficult. This has been a essential limitation of the system to fabricate final preciseness restorations. This has been a essential limitation of the system to fabricate final preciseness restorations.The guidance [27] provides FDA's recommendations to manufacturers for evaluating and labelling optical impression systems for CAD/CAM of dental restorations. An optical impression system for CAD/CAM of dental restorations may be a device accustomed record the geography characteristics of teeth, dental impressions, or stone models by analogue or digital ways to be used within the pc assisted style and producing of dental restorative prosthetic devices. Such systems could comprises a camera, scanner or equivalent kind of detector and a pc with package.The progress happened over the period enhances the contribution and importance of CAD modeling in stress analysis.

3. ANALYTICAL AND EXPERIMENTAL APPROACHES IN DENTISTRY

Morethan anything else, an analytical approach is the use of an appropriate process to break a problem down into the smaller pieces necessary to solve it. Each piece becomes a smaller and easier problem to solve.

Analytical denotes using closed-form mathematical equations to describe the stress state of a structure. In general, biological systems are too complicated for analytical treatment. Human teeth are a good example of the complexity of such systems, the geometry is extremely intricate, teeth are composed of sophisticated materials (enamel, dentin, pulp, and the periodontium), and the force distribution due to chewing or dental work varies considerably from tooth to tooth and person to person. In short, there aren't any analytical stress descriptions of human teeth.

Ochiai[30]in his study visually monitored photoelastic stress fringes developed in the supporting mandible and recorded the same photographically. The stress intensity (number of fringes), stress concentrations (closeness of fringes), and their locations were subjectively compared in his study.His study revelsthat ,nonvertical stress transfer with slightly higher intensity was observed for the nonsegmented abutment.

Wang [31]demonstrated a work for comparing stress transfer patterns with either 1 or 2 posterior implants connected to a single anteriorly located simulated natural tooth with either 1 or 2 segmented and nonsegmented implant abutments under relevant functional loads by use of the photoelastic stress analysis technique. Studyrevelsthat ,nonvertical stress transfer with slightly higher intensity was observed for the nonsegmented abutment. Nonvertical stress transfer with slightly higher intensity was observed for the nonsegmented abutment.

Above methods are useful for obtaining very general information about stress distribution, but it cannot take into account the different tooth materials, non-simplification of geometry nor the complete 3-dimensional nature of teeth.

What's more, the experimental process is expensive and time consuming, and any experimental procedure provides a solution for only one particular tooth shape for each experiment and not a general method for describing the stress in any tooth. So in present work CT scan of real human tooth gives input for CAD modeling and stress analysis on real live model which is very important and governing parameter from practical aspect.

4. FEA APPLICATIONS IN DENTISTRY

Finite element analysis (FEA) has been used extensively to predict the biomechanical performance of various dental implant designs as well as the effect of clinical factors on implant success. Stress analysis using computational methods would seem to be the most natural way to approach problem related with experimental approach.

FEA, a computer simulation technique, was introduced in the 1950 using the mathematical matrix analysis of structures to continuum bodies [1]. Over the past thirty years, FEA has become wide used to predict the biomechanical performance of varied medical devices and biological tissues attributable to the convenience of assessing irregular-shaped objects composed of many completely different materials with mixed boundary conditions.Unlike other methods (e.g., strain gauge) which are limited to points on the surface, the finite element method (FEM) can quantify stresses and displacement throughout the anatomy of a three dimensional structure.

5. RECENT ADVANCES

It was also recognized that inclusion of complete dentition is necessary to accurately predict stress-strain fields for functional treatment and jaw function [46]. Simplified models containing only a single tooth overlooked the effect of tooth-tooth contacts that is important in specified biomechanical problems such asorthodontic tooth movement and traumatic tooth injury. Many recent FE studies have demonstrated accurate 3D anatomic structures within dentistry [47-49] using medical imaging.

D Parle [47]in his study created three-dimensional CAD model from DICOM images and converted to STL format to use it further in FE analysis. Stress analysis using Hypermesh and Radioss on exact 3D model of premolar tooth created using medical imaging tools with the help of Computerized Tomography (CT) scanned images. Such FEA based studies help in improved understanding of biomechanics for dental structures and to produce artificial tooth with improved mechanical strength. He carried out 3D stress analysis of premolar tooth and concluded that stress during mastification is higher as compared to loading due to distalization.

Ausiello P et al[48] studied the cusp movements in a human upper premolar, restored with adhesive resin-based composites using a 3D finite element analysis and concluded that premature failure due to stress arising from polymerization shrinkage and occlusal loading can be prevented by proper selection and combination of materials. Thanks to the flexibleness and adaptableness to model even the foremost complicated of geometries it has been employed in the majority the fields of dental medicine and quiet expensively in prost hedonics and endodontia and implantology.

D Parle [49]study considers Abaqus based FEA approach on exact 3D model of human tooth created using medical imaging tools from Computerized Tomography (CT) scanned images. Four artificial dental materials are considered in this study. Stress distribution pattern is used to suggest suitability

of materials for the successful restoration treatment of teeth from strength perspective. Further, this study gives evidence of stress concentration locations which may fail during service along with stress distribution pattern using FEA.

6. SCOPE FOR THE WORK

It is a great challenge to carry out stress analysis of human tooth which has Irregular Geometry, Complex material properties and Complicated Loading conditions. The work scope widened the boundary to consider all above aspects by preparing actual 3 dimensional model form live tooth by the help of medical software's. Ithas emphasized to select appropriate material properties and loads by rigorous study of biomechanics and dentistry.

Present methods lacks in to accuracy & are more time consuming, so scope of work broadened the view to focus to bring accuracy in short time.

There is no or very few analytical calculation references available for stress analysis of human tooth , so it has given scope to prepare analytical stress calculation of complex dental structures on actual human molar tooth model in 3 dimensional and comparison of same with FEA result for validation.

7. CONCLUSIONS

This chapter presents a comprehensive literature review of experimental, analytical and numerical approaches in dentistry. Most of early studies used 2D FE analysis approach with or without axis-symmetric approach which do not reflect the actual scenario present in dental structures in terms of geometry, material and loading condition. Last decade saw growing use of three-dimensional models (with certain simplifications)which helps to understand the mechanical behavior of teeth structures in better fashion. Obtaining FEA solution for complex dental structures is not an extremely complex task given the availability of wide range of commercial FEA solvers but the creation of exact 3D CAD model compatible to subsequent discretization in suitable pre-processor poses a real challenge.

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