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Finite Element Method and Applications in Dentistry-A Review

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FINITEELEMENTMETHODANDAPPLICATIONSINDENTISTRYAREVIEW

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Finite Element Method and Applications in Dentistry– A Review

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I. Introduction

The stress and strain that are induced by the various orthodontic forces need to be studied precisely for studying craniofacial orthodontics. To have a better understanding of these forces, various techniques were being applied. The engineers and mathematicians argued for several decades to come up with a solution that was mathematically precise as well as physically possible. The closest approach that met the arguments of both the worlds was Finite Element Method in 1943 which was introduced by R. Courant who utilised Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems.[1] The method was first used in 1956 for aircraft structural problems analysis. Later on, within a decade, the potentialities of the method for the solution of various types of engineering and applied science problems were recognized (Rao, 1982)2.Meanwhile in 1956, Turner MJ et al. published a paper thereby establishing a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures"3 It was introduced in implant dentistry in 1976 by Weinstein. Application of this technique in micro computers, pre and post processors and for analysis of large structural system was in 1980's and 1990's [4].

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The periodontium tissue is made up of periodontal ligament fibres, the root surface of the teeth and the alveolar bone. The various forces that exert stress on the periodontal ligament fibres cause the teeth to move. [5]. There are numerous reactions that take place at cellular level to make the teeth move. For getting the desired results using the orthodontic forces, there is a need to consider various other mechanical phenomena such as the stress strain relation and the force vectors. To get precise understanding of this, Finite Element Methods are being popularly used, since the models produced from this method closely resemble the actual structures.

II. Applications

a) FEM and Biomechanics

The field of biomechanics finds the usage of finite element modeling in analysing the following three: (i) Skeleton Analysis, (ii) Orthopaedic and Orthodontic Appliance Design (iii) Tissue Growth, Remodelling and Degeneration.

b) FEM and orthodontics

Another application of FEM can be in solving the problem of stress strain levels that are induced in the internal structures. Since, various complex structures can be simulated using the models produced by FEM, it becomes the best method for precisely modelling the tooth and periodontium in a 3-dimensional coordinate system.[6]

c) FEM and implants

This analysis is used to study the stress patterns in various implant components and also in the peri-implant bone. Demenko et al[7] suggested to select the implant size, giving importance to its load bearing capacity in one of the finite element analysis study. The long term results of mandibular implant supported overdentures suggest that loss of osseointegration without signs of infection was more common than peri-implantitis.[8]

d) FEM and Post and Core restorations

FEM simulations have been pivotal in significantly improving the mechanical stability. They have also led to an increase in the long term success of post and core-restorations. Liu et al [9] suggested that for teeth with limited coronal dentin at the loading location, as maxillary premolars with large-scale tissue loss it was crucial to lower the oblique forces by reducing the lateral occlusal contact area and by preventing contact on the top of the facial cusp, thus protecting the remaining dentin from fracture.

III. Discussion

FEM technique is used to obtain a solution to a complex mechanical problem by dividing the problem domain into a collection of much smaller and simpler domains (elements) in which the field variables can be interpolated with the use of shape function. The use of finite element method allows studying a single tooth, a set of teeth, or even the relationship between maxillary and mandibular dental arches on a more solid and precise biomechanical basis than other methods such as photoelastic models and strain gauges. So with this methodology it is possible to have quantitative and qualitative representations of dental and Mandibular biomechanics to evaluate displacements, strains and stresses, which may occur in biomechanical structures.[12]

Bujtar et al[10] estimated the stress distribution in the human mandible at three different life stages by FEA. It was observed that highest stress levels in the mandibular neck in an edentulous mandible of a 67 year old patient was attributed to bone stiffness. Tuna et al [11] simulated PDL as a contact model between the tooth and alveolar bone instead of a solid meshed FE model with poor geometric morphology or very dense mesh. It was proposed that this model saves time and pre/post processing workforce, increases the accuracy and adds to the smoothness of interface stress distributions as well. So its success depends on the accuracy in simulating the geometry and surface structure of the implant, the material characteristics of the implant and jawbone, the loading and support conditions as well as the biomechanical implant jaw bone interface.

IV. Conclusion

FEM is analytical tool for calculating stresses and strains within mechanically loaded structures. It is a non-invasive technique and a contemporary research tool for orthodontist. The finite element analysis (FEA) is significant research tool for biomechanical analyses in biological research and has many futuristic advantages. This ultimate method for modeling complex structures and analyzing their mechanical properties is promising and opens the new research perspectives in near future.

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