Cairo University

BIOMECHANICAL SYSTEM FOR ORTHODONTIC TEETH MOVEMENTS USING FINITE ELEMENTS

By
Kadry Ali Ezzat Kadry Awad

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
In
Biomedical Engineering and Systems

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Title of Thesis:

BIOMECHANICAL SYSTEM FOR ORTHODONTIC TEETH MOVEMENTS USING FINITE ELEMENTS

Key Words:
(Finite elements- Displacement- Expert system- Orthodontic- Arch wires)

Summary:

One of the main principles in orthodontics is to impose irreversible bone progressive deformity gradually using specific tools as force systems applied on the teeth. The bone deformity will lead the teeth into new positions. By optimizing positions of applied forces and their intensities, orthodontic treatment could be reduced in cost and time. Routine orthodontic treatments are mainly base on empirical knowledge, experience, rather than simulation. It is interesting to list here the contributions of this thesis.

These are four different objectives: 1-Construct an expert system to give the time line of forces required and to make a decision about reaching the final destination from treatment. 2-This expert system is built using C# and fuzzy logic technique depending on displacement, young's modulus of the material and degree of pain 3-Assisting the orthodontist in selecting the suitable materials of braces and arch wires during the treatment process 4-Assist the arch wires and braces companies to validate the quality and the efficiency of new materials of their new products.

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DEDICATION

Thanking Allah for all the blessings that are given to me in life

I would like to thank my parents for their efforts, love and care for me since my childhood until now. I like to thank them for helping me to achieve my dreams and wishes.

.

I would like to thank my Brother, Who helped me a lot in facing many obstacles. I wish him happiness and success.

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Finally, I would like to thank my daughter and my little son who are the secret of my happiness.

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Nomenclature

AAO	American Association Orthodontics
CAD	Computer Aided Design
CAM	Computer Aided Manufacturer
CT	Computer Tomography
CBCT	Cone Beam Computer Tomography
DICOM	Digital Imaging and Communications in Medicine
FEM	Finite Elements Method
BC	Boundary condition
2D	Two Dimension
3D	Three Dimension
GUI	Graphical User Interface
COR	Center Of Resistance
STL	Sterolithography
GPU	Graphics Processor Unit
CPU	Central Processing Unit
SAT	Application Programming Interface
IGES	Threaded Building Blocks
ROI	Region of Interest
Ni-Ti	Nickel-Titanium
LANL	Los Alamos National Lab
DOF	Degree Of Freedom
VTK	Visualization Tool Kit
SldPrt	Solid Part
MFC	Microsoft Foundation Class
COA	Center Of Area
MF	Membership Function
COG	Center Of Gravity
PDL	Periodontal Ligament
MRI	Magnetic Resonance Imaging
FL	Fuzzy Logic
VTK	Visualization Tool Kit

ABSTRACT

In orthodontic tooth movement, arch wire, braces and mandible bone have major influence on treatment plan; their mechanical and physiological responses to orthodontic forces are firmly connected. This mechanical/physiological coupling can be dealt with in biomechanical model, concentrating on the mechanics and considering just the phenomenological parts of the science and biology. Specifically, such model ought to represent the planned bone resorption and formation (bone rebuilding) in the mandible bone that causes orthodontic tooth movement.

The finite element method (FEM) is an engineering resource applied to calculate the stress and deformation of complex structures, and has been widely used in orthodontic research. With the advantage of being a non-invasive and it is considered an approximated method that provides quantitative and detailed data on the physiological reactions possible to occur in bone and teeth. Applying the FEM can anticipate the visualization of these bone and teeth responses through the observation of the stress distribution created from applied orthodontic mechanics.

Decision making in dentistry is a complicated task and hence it attracts attention of researchers from mathematics, operation research, statistics and computer science. Fuzzy Logic is a form of multi-valued logic derived from fuzzy set theory to deal with approximate reasoning. A Fuzzy Expert System (FES) is a form of Artificial Intelligence that uses a collection of membership functions and fuzzy rules. The motivation behind FL is to imitate human reasoning capability that deals with interacted terms

The objectives of our work are to assist the orthodontist to predict the full orthodontic treatment plan for patients. It starts by detecting the most misaligned teeth and moving them to reach the required positions, then computation of the magnitude of needed forces and then time of application is performed for each tooth. Suggest alternative plans in case the current plan fail, assist the arch wires and braces companies to validate the quality and the efficiency of new materials of their new products, develop a model to simulate tooth movement based on real teeth geometry. Compute the forces acting on arch wire depending on given displacement, compute the displacement of tooth depending on the value of force acted on arch wire, calculate stresses and strains of teeth and bone depending on the given force or displacement.