



# Finite Element Analysis and its Role in Orthodontics

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## Abstract

Finite element analysis has found increasing use in the field of orthodontics due to its ability to deliver detailed yet precise information regarding stress on load application. It divides the object of study into a finite number of elements connected by a meshwork thereby making each element an individual object of study. Over the years, several studies have been done using the finite element method and there is a lot of scope for this experimental method to be used in future as well.

**Keywords:** Finite element analysis; Orthodontics; Periodontal; Stress and strain; Solid mechanics

## Introduction

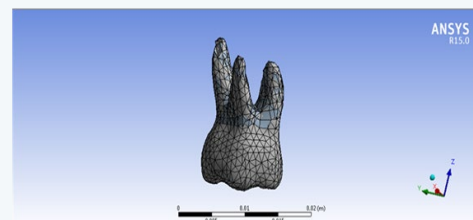
The study of craniofacial orthodontics requires the precise understanding of the stress and strain induced by orthodontic forces in the periodontium [1]. The periodontium comprises of the alveolar bone, the periodontal ligament fibers as well as the root surface of the teeth. The tooth movement is initiated by stress on the periodontal ligament fibers which transmit these to the surrounding areas. The applied force brings about resorption in the alveolar bone on the tension areas and deposition of new bone on the pressure areas. There are a variety of reactions that take place at a cellular level for tooth movement to come about. There are processes such as cellular signalling, coupling reactions as well as an effector response that bring about the resorption and deposition of bone. This is how the teeth are moved to their ideal positions in the dental arch by means of orthodontic forces. But there are also mechanical considerations that need to be made since there is a stress-strain relation as well as force vectors involved. This is the reason why there needs to be a better understanding of the forces involved and the effects they bring about for which finite element analysis is becoming a very popular method. Tooth movements, as well as a variety of methods such as distalization, protraction, implant-based tooth movement and a variety of expansion methods have been studied over the years using finite elements.

## Discussion

Finite element analysis was initially developed in the 1940's to study structural defects in aircrafts and continued to be used for that purpose for a long time. It was only in the year

1972 when Yettram started using this tool for orthodontic purposes.

Over the years this method has undergone refinement and the results obtained have become more precise. Using finite element analysis, the orthodontic force applied can be simulated and the results can be shown on a three dimensional model that can be fabricated using a CT scan. This method has become popular since it is completely non-invasive and very accurate because it is based on the mathematical properties of the structures. One can derive a precise and detailed description of the responses that the periodontal structures show in response to stress application [1]. Middleton et al. [2] stated that the data obtained from this analysis is more accurate than any of the other experimental methods currently in use. It also allows for complete control over the variables in use while studying a homologous sample [3] (Figure 1).



**Figure 1:** An image to show how a tooth can be broken down into a finite number of elements connected to each other by a meshwork pattern. This process of breaking down an element into several smaller units is known as discretization.

## Important Results Obtained using Finite Element Analysis

There are several studies that have already been conducted in the past using Finite element analysis [3-5]. One of the more important studies done using this method was by McGuinness

et al. [4] who studied the forces brought about by edgewise appliances. They concluded that there was more stress near the cervical area of the tooth than at the root apex. Another study was done by Kojima and Fukui [6] who studied whether the teeth used for anchorage moved when a passive Trans-palatine bar was used. They found out that there was almost minimal effect when a mesializing force was applied. A very relevant result was obtained by Tominaga et al. [7] when they studied en-mass retraction using finite element method. They concluded that for controlled retraction of the anterior, the ideal position to place the hook is distal to the lateral incisor and mesial to the canine.

### Conclusion

Finite element analysis has proved to be a very valuable aid in the field of orthodontics and craniofacial orthopaedics so far as it has helped determine the precise forces that need to be applied in order to get physiological tooth movement. One of the major advantages of this method is that it is completely non-invasive yet very accurate. It has shown to be very detailed in terms of results yet sound knowledge of the software giving these results is required which can be a deterrent when proper digital aids are not available. Another shortcoming is the unavailability of accurate mathematical properties for each tooth and bone in various areas, which though not affecting the results too much could make the result better if present. Like any method this also needs improvement to make it more helpful in the field of orthodontics, among others.

### Acknowledgment

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