# CHAPTER 1

## Introduction

### 1.1 Principles, Theories, and Rationale

Maxillary molar distalization has become a widely used procedure for non-extraction treatment of Class II malocclusion. The traditional approach to distalizing maxillary molars is the application of extra-oral headgear.[1, 2] However, social and esthetic concerns cause patients to refuse to wear it. Various intraoral appliances have been developed. Kinzinger et al.[3] categorized noncompliance appliances for molar distalization according to the location of the active components. The first category includes appliances with vestibular force application, such as the Jones Jig appliance,[4] repelling magnets,[5] and nickel-titanium (NiTi) coil springs.[6, 7] The second category includes appliances with palatal force application, such as the pendulum,[8] and the distal jet.[9] Although these devices are under the orthodontist's control and are not reliant on patient cooperation, they have side effects, including distal tipping of the maxillary first molars, and intrusion/extrusion of the maxillary first molars.[4-6, 8, 10, 11] To reinforce the anchorage unit, many researchers have developed appliances for maxillary molar distalization combined with skeletal anchorage. The anchorage can be placed at both non-dento-alveolar bone sites, such as the palatal bone, and zygomatic bone, and dento-alvelor bone sites, such as buccal and palatal alveolar bone. This anchorage can be categorized in two types; plate type and screw type. Nowadays, miniscrew implants are commonly used for orthodontic anchorage because of several benefits: the possibility of immediate loading, ease of placement and removal, lower cost, short treatment duration, independence of patient compliance and more anatomic sites for implant placement.[12, 13]

Bondemark et al.[6] and Bondemark and Kurol [7] combined the Nance button with open nickel titanium (NiTi) springs to distalize maxillary molars. The maxillary first molar was distalized 3.20 ±1.09 mm with distal tipping of 1.00 ±1.38 degree and extrusion of 0.80 ±0.66 mm in the study of Bondemark et al.,[6] and 2.60±1.17 mm with extrusion of 1.10±0.61 mm in the study of Bondemark and Kurol.[7] The distalizing force was applied by pushing distally with an open coil; therefore the forces could be transmitted along their line of action. When a single force is applied to a bracket, the crown and apex move in opposite directions. This movement, caused by the moment of force, is called uncontrolled tipping.[14]

The force recommended for molar distalization is approximately 180 to 250 cN per side.[3] The direction of the applied force can be either to the buccal side, palatal side, or both sides of the tooth. Applying the force on the buccal side allows the orthodontist to more easily apply and adjust the force directly to the tooth than by applying the force on the palatal side. In addition, it produces a simple force system.[15, 16]

Simultaneous distal movement of both first and second molars has been discussed.[4-6, 8, 11] Several authors reported that the eruption of the second molar had an impact on the distalization of the first molar. On the other hand, Ghosh and Nanda[4] concluded that the position of the second molar during distal movement of the first molar is of little significance.

The finite element method (FEM) is a method which can simulate applied force systems and analyze physiologic response within the dento-alveolar complex.[17] It can be used to gain an understanding of stress-related bone remodeling,[18, 19] and enables researchers to analyze the stress distribution on miniscrew implants used for orthodontic anchorage in terms of several miniscrew parameters.[20-22] Nowadays, the FEM has been used for assessing the effects of appliance systems by evaluating the stress distribution on the teeth.[23-27] *In vitro* study of the biomechanics in force systems and the side effects of appliances can be observed before further *in vivo* study.

**1.2 Purposes of this study**

1.2.1 To develop a three-dimensional computer-generated model simulating tooth movement.

1.2.2 To investigate and compare the stress and displacement effects of distalizing forces of 80 g, 150 g, and 200 g for maxillary molar distalization when either only the first molar is present, or both the first and second molars are present, using finite element analysis.

## 1.3 Anticipated benefits

1.3.1 To gain knowledge for further study

1.3.2 Clinical application

## 1.4 Definition

1.4.1 Von Mises Stress

Equivalent stress of material under multiaxial loading conditions which is calculated from combining the three principal stresses (x, y, and z).

1.4.2 Linear elasticity

A linear relation between the stress and strain. This relationship is known as Hooke's law. It can also be stated as a relationship between stress $\sigma$ and strain ε: $\sigma = E\varepsilon$ where $E$ is known as the elastic modulus or Young's modulus.

1.4.3 Isotropy

Uniformity in all orientations. An isotropic material is a material having the same elastic properties in all directions at any one point of the body.

1.4.4 Homogeneity

The quality or state of being homogeneous. In engineering a material is said to be homogenous if the material's elastic properties (E, μ) are the same at all points in the body.

1.4.5 Element

Basic building block of finite element analysis. There are several basic types of elements, such as, 1-D or line (spring, truss, pipe), 2-D or plane (plate, membrane), or 3-D or solid (bricks, tetrahedral, hexahedral) element.

1.4.6 Node

Interconnection of elements at points or coordinate location of elements

1.4.7 Discretization

Model body by dividing it into an equivalent system of many smaller bodies or finite elements interconnected at points