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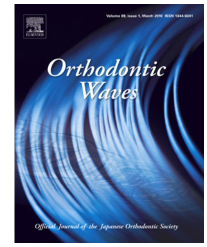

Research paper

Pattern of stress distribution in different bracket–adhesive–tooth systems due to debonding load application

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ABSTRACT

Purpose: Orthodontic bracket debonding during treatment period is an unbecoming occurrence for both orthodontists and patients. Various clinical and numerical studies have been done to specify different parameters which affect the bond strength of bracket–adhesive–tooth system. Pattern of stress distribution seems to be an appropriate factor to estimate bond strength of different systems. Since it is not possible to experimentally define stress distribution in bracket–adhesive–tooth systems, three dimensional finite element method is used. The purpose of this study is to obtain and compare stress distribution of five bracket–adhesive–tooth systems with various enamel surface morphologies as an indicator parameter of these systems' bond strength.

Materials and methods: In order to specify and compare stress in five different teeth, including maxillary central incisor, mandibular central incisor, maxillary canine, and maxillary and mandibular premolar, 3D STL files of teeth and brackets were reconstructed in MIMICS10 and were imported to HYPERMESH for each tooth, separately. Space between enamel and bracket was filled with orthodontic adhesive, mechanical property of each layer was assigned and appropriate boundary conditions were applied.

Results: It was observed that stress distribution in bracket, adhesive and tooth due to shear load application had irregular pattern. For all of systems stress concentration was observed either on the borders or incisal and gingival regions of enamel–adhesive bonding region and adhesive layer.

Conclusion: Despite the overall similarity in stress distribution pattern of different bracket–adhesive–tooth systems, some differences on pattern of stress distribution and magnitude of stress were also observed. This may bring about more susceptibility of curved enamel surface teeth to lower bond strength, damage and fracture than flat enamel surface teeth.

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1. Introduction

Orthodontic bracket debonding during treatment is an undesirable incident for both patient and orthodontist [1], since it would bring about an increase in both period of treatment and reliability of enamel damage [2]. Various studies have been done to define different factors which effect the shear bond strength of bracket–adhesive–tooth system since 1960 [3,4]. Knoll et al. revealed that bond strength of incisor teeth were higher than molar teeth through an experimental study [3]. Bishara and Sulieman came to the result that there were no significant difference between bond strength of incisor, premolar and third molar teeth [5]. Hobson et al. mentioned that brackets bonded on premolar teeth debond from these teeth earlier than brackets bonded on central teeth [1]. In contrast to experimental works, finite element method has the susceptibility to calculate stress distribution pattern and have widely been applied in dentistry recently. Hioki et al. showed that incisors have higher shear bond strength than maxilla premolar tooth; however, they used simplified geometries for teeth [7].

To our knowledge, any previous studies have not considered the real geometry of teeth and brackets to obtain shear bond strength of bracket–adhesive–tooth system. It was hypothesized that different teeth would show different bond strength due to their various enamel surface geometries. Therefore, the purpose of this study is to identify the pattern of stress distribution in enamel, adhesive and base of bracket thorough three dimensional finite element method using Micro CT images of teeth. The comparison of pattern of stress distribution in different systems would be helpful to compare bond strength in different teeth, and to recognize the regions with high stress concentration and prone to failure. Hence, the results of this study seem to be much more accurate than previous ones.

2. Materials and methods

A three dimensional finite element analysis was applied to identify and compare stress distribution in 5 different bracket–adhesive–tooth systems, while a shear load was applied along the long axis of enamel for each system five different teeth were selected to be studied in order to cover different enamel surface morphologies. Previous finite element method studies have not considered this much variety. Flat enamel surface tooth, mono-directional curved enamel surface tooth and bi-directional curved enamel surface tooth has been investigated in this study. They included maxillary central incisor, mandibular central incisor, maxillary canine, and maxillary and mandibular premolar teeth considered.

Micro CT scans of each tooth and bracket were prepared with Sky-Scan1172 High Resolution Micro CT device (Sky-Scan, Kontich, Belgium) and were imported to MIMICS10 (an image processing software package for three dimensional designs, Materialise software). Three dimensional layers of each tooth and bracket were reconstructed in this software. MIMICS also has the capability of thresholding and segmenting of tooth layers (enamel, dentin and pulp). Each 3D layer of tooth and bracket was exported as STL file. Fig. 1 shows

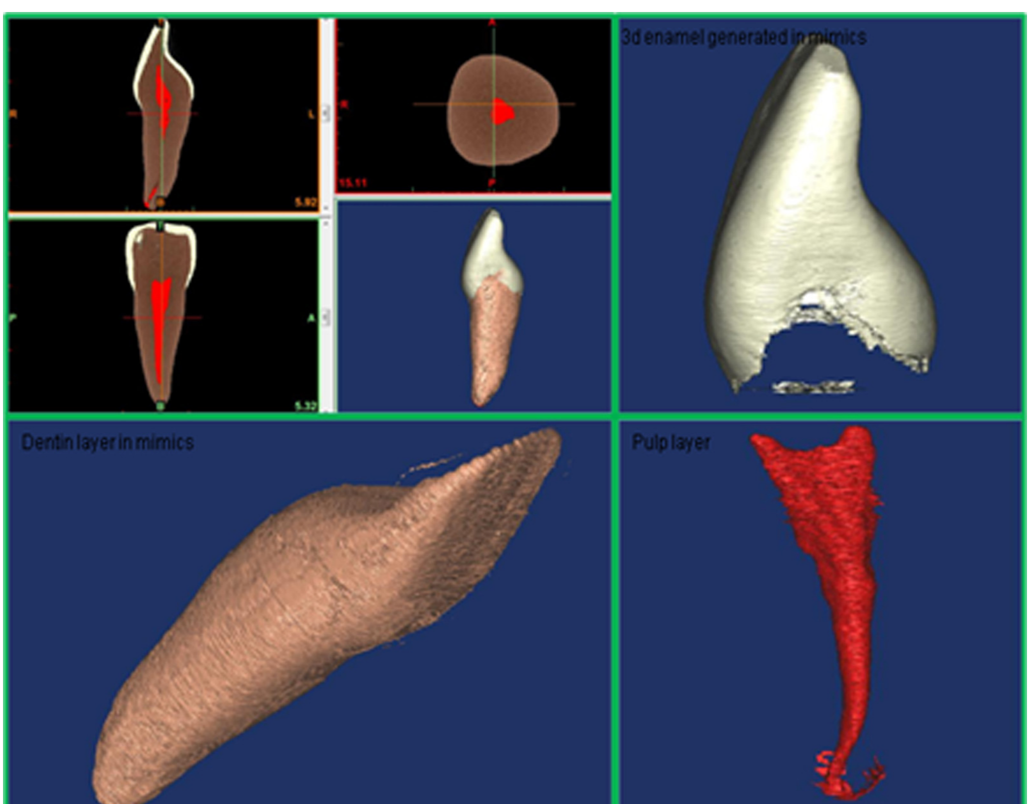

Fig. 1 – Three layers of maxillary central incisor obtained in MIMICS10.