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Two-dimensional Photoelastic Stress Analysis of Traumatized Incisor

Bulent TOPBASI[1]
Mahir GUNDAY[2]
Mustafa BAS[1]
Cafer TURKMEN[1]

[1]Department of Restorative Dentistry and [2]Department of Endodontics
Marmara University, Faculty of Dentistry, Istanbul, Turkey

In this study, stress of traumatized incisor and the effect of stress on tooth and alveolar bone was studied with two-dimensional photoelasticity. Two homogeneous two-dimensional maxillary central incisor models were prepared. Loads were applied to the labial side of incisal edge and middle third of the crown at angles of 45° and 90°. It was observed that stress was increased on teeth and alveoler bone when load was applied 90° on labial side of incisal edge.

Key Words: trauma, incisor teeth, photoelastic stress analysis.

INTRODUCTION

Although traumatic injuries of teeth are not frequent, fractures that affect the pulp can cause complex healing and treatment planning. The most vulnerable tooth is the maxillary central incisor, which sustains approximately 80% of dental injuries, followed by the maxillary lateral and the mandibular central and lateral incisors. Root fractures occur rarely on the middle third of the root, and crown fractures are more frequent (1,2). Dental injuries affect predominantly enamel only or enamel and dentin fractures of the maxillary incisors (1). The crown and the root of teeth are fractured according to the direction of the force. Frequently the contour of the fractures are very close to incisal on the labial surface. But on the palatal surface they are vertical to the cemento-enamel junction. Two types of methods can be used for studying the mechanical behavior of teeth: the experimental methods of which the photoelastic method (3-6) and strain gauges (7,8) are well known and often applied for analysis of internal stresses; the numerical methods of which the finite element method is frequently applied (9-14).

Noonan (3) was the first to apply photoelasticity to restorative dentistry. Photoelastic stress analysis is based on the property of some transparent materials to exhibit colorful patterns when viewed with polarized light. The patterns that develop are consequently related to the distribution of the internal stresses. This study examined the effect of traumatic forces on the tooth and the surrounding alveoler bone by using two-dimensional photoelastic stress analysis.

MATERIAL AND METHODS

Two homogeneous two-dimensional central incisor models were prepared from Araldite B (Ciba-Geigy S.A., Bale, Switzerland), a birefringent plastic material with a modulus of elasticity within the range of human dentin. The geometry of the mid-labiolingual section of the human maxillary central incisor was adapted from Wheeler (15). The models were identical enlargements (X5) of an actual maxillary central incisor whose dimensions compared with average sizes. Each specimen was 5 mm thick. Alveolar bone was also prepared from Araldite B. The models were loaded with a constant

Correspondence: Dr. Bulent Topbasi, Department of Restorative Dentistry, Marmara University, Faculty of Dentistry, Buyuk Ciftlik Sok. No: 6 80200 Nisantasi, Istanbul, Turkey. Tel: +90-212-2319120-205, Fax: +90-212-2465247. E-mail: btopbasi@hotmail.com

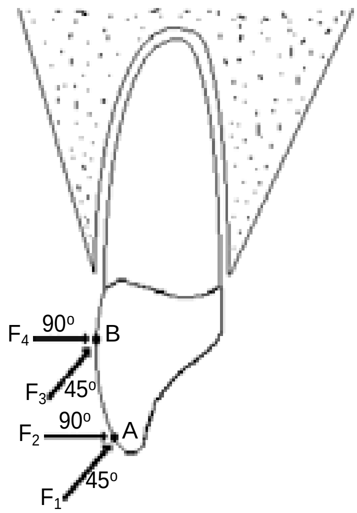


Figure 1. Direction and location of forces applied to the labial side of the model.

Table 1. Stresses occurring on the alveolar bone and tooth under traumatic loadings expressed as fringe order.

	Alveolar bone		Root	
Force	Palatal	Labial	Apex	Palatal-Labial
F_1	2.5	0.5	2	1
F_2	6	1	3	2.5
F_3	1.5	0	1	0.5
F_4	3.5	1	2.5	1.5

F_1 and F_3 = 45°, F_2 and F_4 = 90°

force of 1 kg. Loads were applied to the labial side of incisal edge (point A) and middle third of the crown (point B) at 45° (F_1 and F_3 forces) and 90° (F_2 and F_4 forces) (Figure 1). Before loading procedures were initiated, the models were placed in the polariscope to determine if any stress was produced during model preparation. When photoelastic material is subjected to force, optical properties change in direct proportion to the stresses developed. The material becomes "birefringent" and a colorful interference pattern is observed when polarized light passing through the stressed material splits into two beams. A fringe is defined as a line separating the red and green color bands. A fringe order will consist of a sequence of color bands, including fringe line. The zero fringe order is black and indicates no stress. Stress can be quantified and localized by counting the number of fringes and density. The closer the fringes, the steeper the stress gradient, indicating an area of stress concentration (16).

Data were photographically recorded in the field of a circular polariscope (Photoelastic Inc., Malvern, PA). Photographs were made with a Pentax SL 1000 (Asahi Optical Co. Ltd., Tokyo, Japan) camera on a tripod using 100 ASA Fujichrome Slide Film with an exposure of 1/2 second and a setting of f_4. In this study, the stresses were expressed as a fringe order.

RESULTS

Stresses that occur on alveolar bone and tooth under traumatic loadings for each case are summarized in Table 1. Under F_1 loading (45° to the labial side of incisal edge) higher stresses were found on the palatal side of the alveoler bone and also apex of the tooth. Under F_2 loading (90° to the labial side of incisal edge) higher stresses were similar to F_1 loading, but the magnitude was higher than F_1 loading. Tooth stresses occurring at the apex were on the labial side. The distribution of stress on alveoler bone was similar to F_1 loading except magnitude (Figures 2 and 3). Under F_3 loading (45° to the middle third of the crown) and F_4 loading (90° to the middle third of the crown) stress locations were similar to F_1 and F_2 loadings, but stress concentrations were reduced (Figures 4 and 5).

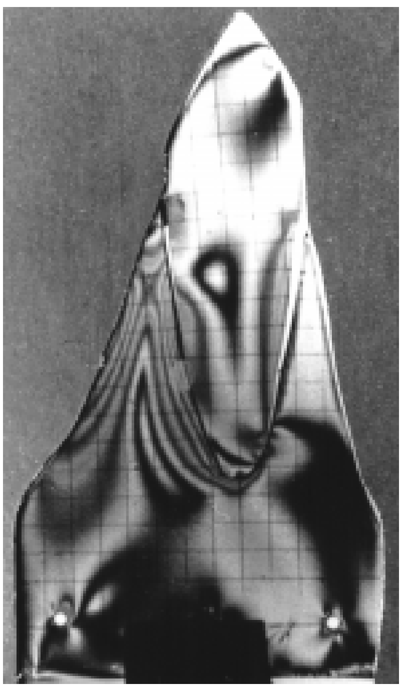
DISCUSSION

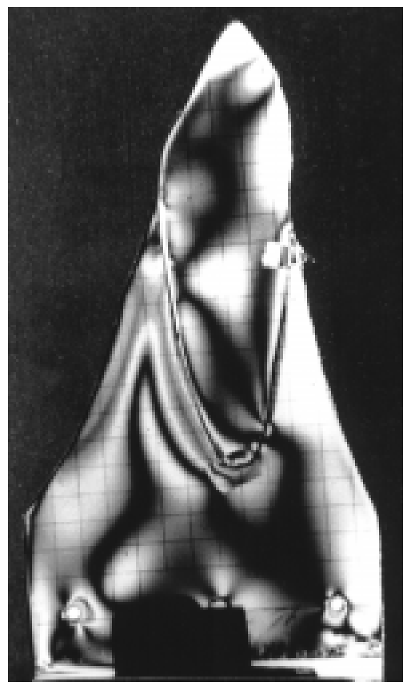
Stress is the internal response of a body to externally applied forces and is defined as the force divided by the area over which it acts. Only 3 types of stress are possible. Tension, compression and shear. Accompanying these stresses are corresponding changes in shape (1,13,17,18).

In this study, higher stress values were obtained on both the tooth and the alveolar bone by F_2 and F_4 forces exerted vertically on the tooth. Moment is the main factor causing stress on all substances. Since the moment influence increases when the force is applied vertically to the tooth, stress increases as well. Since F_1 and F_3 forces affect the tooth, the vertical component of the force decreases, and stress decreases as well.

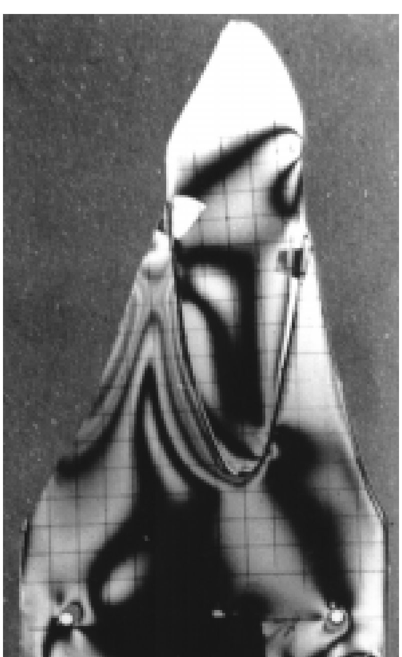
In this study as the application point of the force moved from the incisal edge to the crown the force caused by this movement was observed to decrease. In this case, as the moment increased on the incisive side, the resulting force and stress increased. The application point and the angle were found to be two important factors in the formation of stress in tooth and alveolar bone.

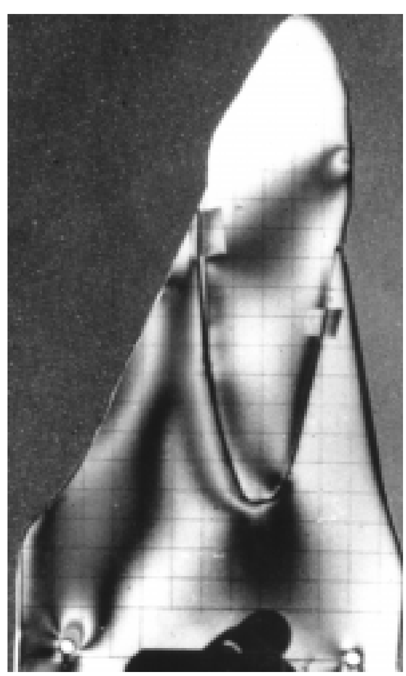
Location of stresses that occur on the root of the tooth is directly proportional to alveolar bone loss. Reinhardt et al. (9), studying dentin stresses from simulated functional loads to post reinforced tooth models with four levels of periodontal support, reported that as bone levels diminished, stresses increased dramatically and this would be a potential for root fracture. Ko et al. (12) showed that in pulpless teeth under traumatic loading maximal tensile and compressive stresses were concentrated on the facial and lingual sides, respectively.





Figures 2 and 3. Stresses occurring on the alveolar bone and tooth with loading applied at point A (loading 45º at right side, loading 90º at left side).





Figures 4 and 5. Stresses occurring on the alveolar bone and tooth with loading applied at point B (loading 45º at right side, loading 90º at left side).

In this study, stress was observed on both sides of the root but a little more on the forces exerted on point A (labial side of incisal edge). It has also been observed that the stresses on alveolar bone are more on the palatal surface, but denser on the labial surface of the apical area when F_2 and F_4 forces are applied vertically to the tooth. This case shows that the normal forces applied to teeth on the apical area cause more stress than those applied at an angle.

It has been observed that the highest stress value is obtained under F_2 loading. This fact clearly shows that pulp dies when the effected force is transferred to the apical third of the tooth that has not been fractured after trauma. When crown fracture occurs, the force affecting the tooth divides into its components and causes less damage to the pulp. A fracture occurs if the effecting force exceeds the resistance against the sliding force of hard tissue. Otherwise the resistance depending on the strength and direction of the force may cause pathological damages.

Finally, the forces exerted horizontally to the labial side of the tooth caused more stress on the tooth and alveolar bone than inclined forces.

RESUMO

Topbasi B, Gunday M, Bas M, Turkmen C. Analise de fotoelasticidade bi-dimensional de incisivos traumatizados por carga. Braz Dent J 2001;12(2):81-84.

Nesse trabalho estudou-se o efeito da aplicação de cargas em incisivos traumatizados e o efeito desse no osso alveolar através de fotoelasticidade bi-dimensional. Dois incisivos centrais superiores homogêneos dimensionalmente foram preparados e usados como modelo. Cargas foram aplicadas na linguo-incisal e no terço médio da coroa em um ângulo de 45º e 90º. Observou-se que o stress era maior nos dentes e osso alveolar quando a carga era aplicada na linguo-incisal dos incisivos.

Unitermos: trauma, incisivos, foto-elasticidade bi-dimensional.

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