Original Article

Stress Distribution Produced by Correction of the Maxillary Second Molar in Buccal Crossbite

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Abstract: The purpose of this study was to evaluate the stress distribution produced in the dentoalveolar system by a maxillary posterior crossbite appliance used for the correction of maxillary second molars in buccal crossbite. A photoelastic model was fabricated using a photoelastic material (PL-3) to simulate alveolar bone and ivory-colored resin teeth. The model was anteriorly and posteriorly observed with a circular polariscope and photographically recorded before and after activation of the maxillary posterior crossbite appliance. An uncontrolled palatal tipping and a rotating force were generated when the traction force was applied on the palatal surface of the maxillary second molar. A controlled tipping and an intrusive force were generated when the traction force was applied on the buccal surface of the maxillary second molar. (*Angle Orthod* 2002;72:397–401.)

Key Words: Stress distribution; Photoelastic analysis; Buccal crossbite: Ectopic eruption

INTRODUCTION

Ectopic eruption is a broad term referring to any abnormal or aberrant eruptive position taken by a tooth.[1] The normal eruptive pattern of the maxillary second molar tilts the long axis of the tooth in a mesial-palatal direction.[2] In many cases, however, the maxillary second molar erupts with excessive disto-buccal inclination after the distalization of a maxillary first molar. A posterior arch length discrepancy may also result from insufficient growth of the maxillary tuberosity. As a result, inadequate arch length is available to enable the maxillary second molar to reach an upright position. The palatal cusp of the maxillary second molar may become too prominent occlusally and, in more extreme cases, may cause buccal crossbite. Furthermore, heavy contacts on the balancing side may lead to a detrimental disharmony of the masticatory system.[3]

Cureton[4] studied the incidence of malaligned second molars in untreated individuals. He noted that maxillary second molars erupted more buccally than did mandibular second molars. Most of the malposed maxillary second molars were inclined with their roots to the mesial and their crowns to the distal. La Kind[5] suggested a treatment method using a cemented bite plate to open the bite and allow the palatal movement of the maxillary second molar out of buccal crossbite.

In spite of its limited portion of the dental arch, a posterior crossbite is clinically difficult to correct. Buccally erupted maxillary second molars must be intruded and moved palatally. A buccal crossbite can be corrected using a modified transpalatal arch with a soldered spur and an elastomeric chain running to a button bonded to the palatal or buccal surface of the maxillary second molar.[6–8]

Various techniques have been applied for the correction of a maxillary second molar in buccal crossbite. The literature, however, lacks biomechanical studies evaluating their mode of action. The purpose of this study was to evaluate the stress distribution produced at the dentoalveolar system by the maxillary posterior crossbite appliance when used for the correction of maxillary second molar buccal crossbites.

MATERIALS AND METHODS

For the biomechanical testing, a photoelastic model was fabricated using a birefringent alveolar bone simulant (PL-3; Photoelastic Inc., Malvern, PA). PL-3 is a two-component room temperature curing resin/hardener system for making contourable photoelastic plastic models.

A photoelastic model of the upper arch was constructed to

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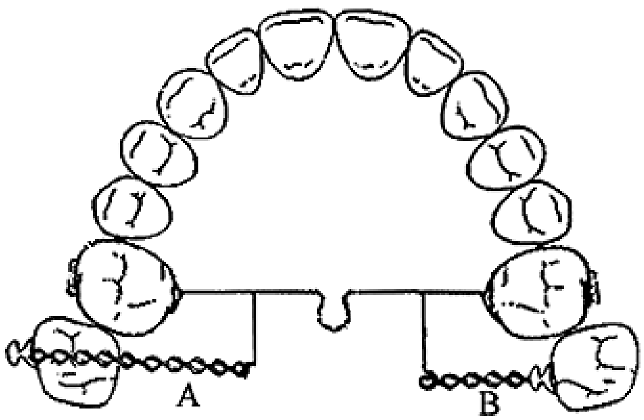

FIGURE 1. Maxillary posterior crossbite appliance. (A) Buccal traction. (B) Palatal traction.

simulate a second molar in buccal crossbite relative to the corresponding mandibular arch. Ivory-colored resin teeth were used. A wax mold was used to set up the malocclusion. A silicone impression of the simulated buccal crossbite was made, and the teeth were inserted separately into the dento-alveolar segment, which was poured in wax to make the wax model. The model was polished and used for silicone impressions, which were cast in a photoelastic material (PL-3).

The transpalatal arch was used as a maxillary anchorage unit. It was made with 0.036-inch stainless steel wire and soldered to the palatal surface of the maxillary first molar band on each side. A lingual button was bonded to the buccal and palatal surfaces of the maxillary second molar. Two hooks made from 0.032-inch stainless steel were soldered close to the ends of the transpalatal bar (Figure 1).

Before photoelastic testing, the model was examined in polarized light to ensure the absence of residual stresses. Loads were applied to the maxillary second molars, and the model was viewed in the field of a circular transmission polariscope. Elastomeric chain (Energy Chain: Rocky Mountain Orthodontics, Denver, Colo.) with a force of 8∼10 ounces was attached to the hook from a button bonded to either the buccal or palatal surface of the maxillary second molars. Three types of forces were applied to the maxillary second molars: (1) the elastomeric chain was attached to a button bonded to the palatal surface, so that the traction force could be applied to the palatal surface; (2) the elastomeric chain was attached to a button bonded to the buccal surface, so that it ran through the fossa of the molar and over the crown; and (3) the elastomeric chain was simultaneously attached to a button bonded to the buccal surfaces of the maxillary right and left second molars.

The stressed model was then examined in a diffuse light polariscope, which employs a mercury and white light source. The polariscope consists of an illumination system, a pair of polarizers, and a means of locating the specimen in a position between the polarizers (Figure 2).[9]

The illuminating source employed in the present study

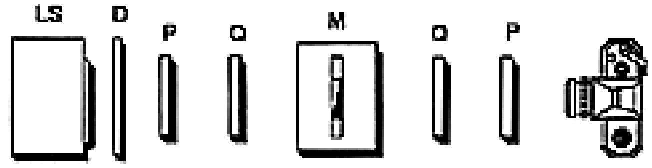

FIGURE 2. Schematic representation of circular polariscope arrangement. LS indicates light source; D, diffuser; P, polarizer; M, model; and Q, quarter-wave plate.

was a white-light and mercury-light incandescent projection lamp. The resultant stress patterns, therefore, show the colors of the spectrum rather than a single color, as in the case of a monochromatic light source. White light produces stress patterns of colored fringes in such a way that, with relative retardation of the same value, the same colors are transmitted in the same proportions. Fractional fringe orders,[10] color patterns caused by stress distribution, were measured and analyzed. An unloaded photostress-coated part, observed with a reflection polariscope, will usually be obvious by its black color. The black zero-order fringes, regarded as a neutral rotational axis, are usually isolated spots, lines, or areas surrounded by or adjacent to higher-order fringes. As a load is gradually applied to the part, the most highly stressed region begins to take on color. First a gray appears, then a white, and when the violet is extinguished, a yellow. With further load, the blue is extinguished, producing orange, and then green is extinguished, producing red. The next color to vanish with increasing load is yellow, leaving a purple color. Orange is then extinguished, producing a deep blue fringe.

RESULTS

Passive fit of the appliance was photoelastically confirmed before the application of any forces. As the force was applied, stress patterns developed throughout various regions of the photoelastic model, and stresses were observed at the apices of the roots of the posterior teeth. Primary stresses were seen radiating from the apices of maxillary first and second molars to the alveolar structure. The initial effects of force application were observed in the alveolus between the maxillary first and second molars.

Force application on the palatal surface of the maxillary second molar (Figure 3A)

The stresses produced by force application on the palatal surface of the maxillary second molar were concentrated on the palatal and buccal roots. The largest group of stress fringes was shown at the palatal and buccal root apices and emanated along the root surface. The intensity of the distributed stress on the palatal root surface in the alveolus was heavier than that on the buccal root surface. The color pattern around the apices of buccal and palatal roots was yellow, which is equivalent to a 0.6 fringe order. The color pattern around the middle one-third of the palatal root was

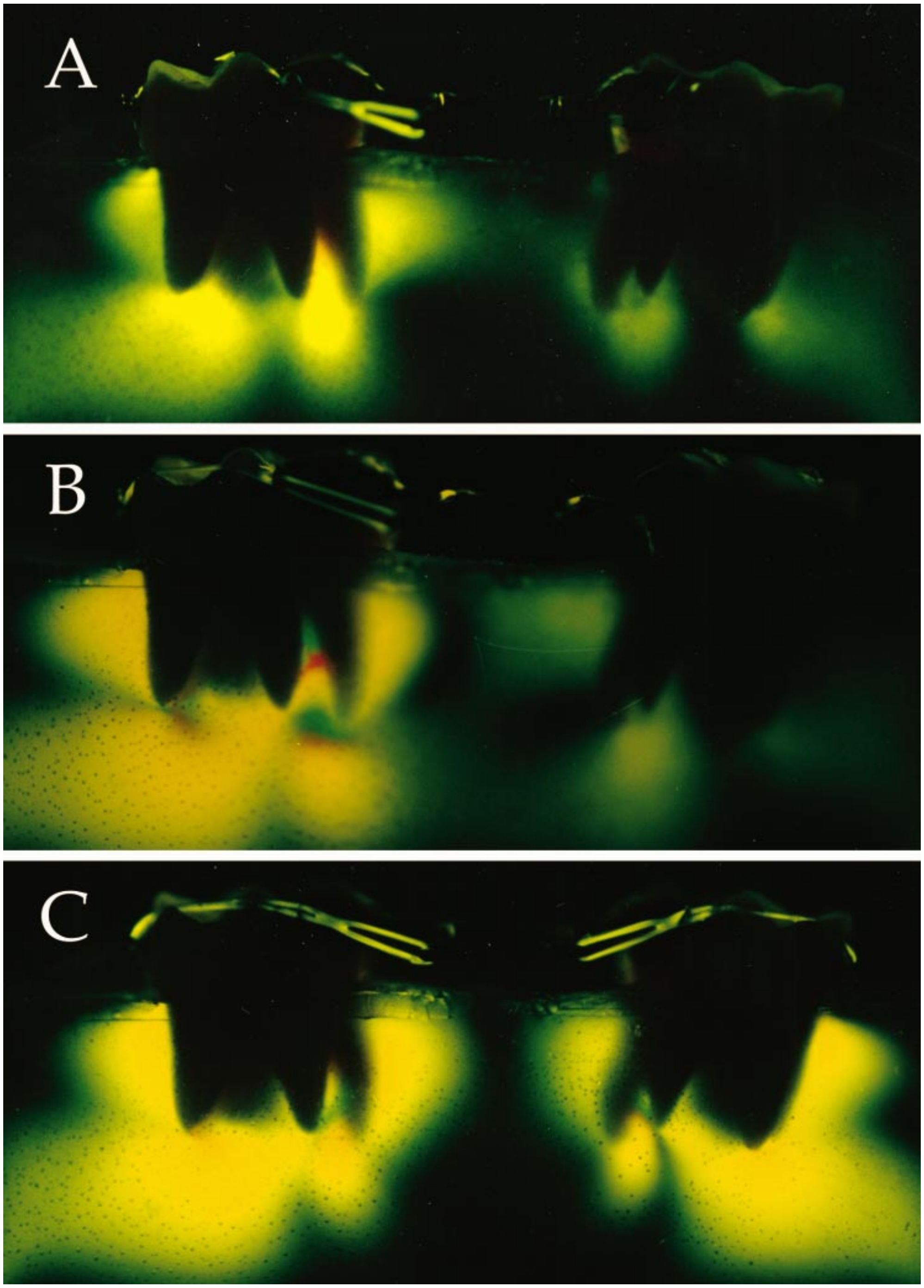

FIGURE 3. Distal view of stresses produced by force application. (A) Palatal traction of maxillary right second molar. (B) Buccal traction of maxillary right second molar. (C) Buccal traction of maxillary right and left second molars.

red, which is equivalent to a 0.9 fringe order. The rotational axis of the palatal root was at the root apex, and that of the buccal root was at the apical one-fourth area.

Force application on the buccal surface of the maxillary second molar (Figure 3B)

The stresses produced by force application on the buccal surface were concentrated in the palatal and buccal root apices as well as in the middle one-third of the palatal root of the maxillary second molar. The stresses were generally emanating from the buccal and palatal roots of the maxillary second molar. The stress intensity of buccal traction was heavier than that of the palatal traction. Stress of the palatal root apex was greater than that of the buccal root apex. The fringe order was increased along the palatal root surface from 0.9 to 2.2. The color pattern below the palatal root apex was red, blue-green, and gradually repeated yellow, red, red-green, and green. The amount of stress was also increased in the fringe order. The fringe order below the palatal root apex was 0.9; the apex of the palatal root, 1.2; the apical one-fourth of the palatal root, 1.75; the middle one-third, 2.0; and the apical three-fourths, 2.2. However, the stress of the buccal root area was increased to 1.2 in fringe order. Compared with the palatal traction, the rotational axis of the palatal root disappeared, whereas that of the buccal root was moved from the apical one-fourth area to the root apex.

Simultaneous force application on maxillary right and left second molars (Figure 3C)

A purple color (fringe order: 1.0) pattern of stress distribution was observed at the buccal root apex of the maxillary right and left second molars, and a blue-green color (fringe order: 1.2) pattern was observed at the palatal root apex of the maxillary right and left second molars. The stress intensity around the root area of the maxillary first molar was increased.

DISCUSSION

Ectopic eruption of the maxillary second molar

The area of immediate concern in the eruption of the maxillary second molar is the maxillary tuberosity and the space available for eruption of maxillary second and third molars. During growth of the maxilla, space to accommodate the erupting first, second, and third molars must be created by growth at the posterior region of the maxillary tuberosity. The maxillary growth in this area normally is downward and forward to create room for the eruption of each succeeding molar. However, if growth is insufficient, abnormal eruption or lack of eruption will result. In the absence of the required room to move the maxillary dentition posteriorly for the restoration of normal dentoskeletal relationships, an impasse is often reached. This results in the buccal displacement of the maxillary second and third molars.

It is not unusual to observe maxillary second molars erupting in buccoversion because of a lack of development in the tuberosity area. They must either erupt in this manner or be impacted, and this condition is magnified with respect to the available room for the eruption of maxillary third molars.[11–12] Depending on the circumstances, it may be possible to substitute the discounted third molar for the second molar and, at the same time, solve the problems in the maxillary tuberosity area. However, this method has a limitation because the maxillary third molars must have fair size and shape with the possibility of good root development.

Selection of photoelastic stress analysis

The photoelastic model was designed to provide a reasonable estimate of the stresses produced by the maxillary posterior crossbite appliance. Of the various experimental techniques used for studying stress response,[13–16] photoelastic stress analysis is particularly useful as a predictor of biologic response. In contrast to strain gauges that measure surface strains only at discrete points, the photoelastic technique permits the visualization of the global state of stress within a structure. Color patterns developing under loading of the photoelastic model manifest the relative magnitude and distribution of the internal stresses. In addition, the redistribution of stresses following alterations in loading patterns or resistance is easily visualized and recorded. This photoelastic information has important clinical implications because stress concentration areas indicate the regions of potential weakness as well as areas requiring major biologic responses.

For quantification of the internal stresses, it is necessary to determine the fringe value and order of the material. However, the fringe value depends on the kind of material used, its thickness, the wavelength of the light employed, and the temperature of the model.[17] Therefore, we assessed the direction and distribution of the internal stresses rather than quantifying their intensity.

Stress direction and distribution

Application of the maxillary posterior crossbite appliance. Before photoelastic testing, the model was examined in polarized light to ensure the absence of residual stresses. Forces derived from the maxillary posterior crossbite appliance caused various stresses on the dentoalveolar structures. The maximum stress occurred at the root surfaces. Stresses were seen to radiate from the root surface and apices of maxillary second molars. The nature of stress patterns elicited by the maxillary posterior crossbite appliance indicated the direction of force application.

Force application on the palatal surface of the maxillary second molar. The stress was greater in the palatal root surface than in the buccal root surface. A very heavy concentration of stress was observed in the apex, middle surface of the palatal root, and cervical area of the palatal surface, suggesting that a rotating force was generated on the maxillary second molar. The rotational axis of the palatal root was at the root apex, and that of the buccal root was at the apical one-fourth area. Stress intensity of the palatal root surface was heavier than that of the buccal root surface. The fringe order of the middle one-third of the palatal root was 0.9 (red color) and that of the middle of the buccal and palatal root apices was less than 0.6 (yellow color). These forces may result from the palatal traction of the malpositioned maxillary second molar, producing an uncontrolled palatal tipping and a rotating force.

Force application on the buccal surface of the maxillary *second molar.* A great deal of stress was noted in the buccal and palatal roots. When compared with the force application on the palatal surface, more stresses were observed in the palatal and buccal roots, creating an intrusive force and a palatal traction of the maxillary second molar. The color of the buccal root area was changed to red and blue-green, and the color of the palatal root area was gradually changed to yellow, red, red-green, and green. The fringe order of this area was also increased. In addition, the rotational axis of the palatal root disappeared, whereas that of the buccal root moved to the root apex. These forces may result in the intrusion of the maxillary second molar, producing a controlled tipping and an intrusion. The closer to the edge of the crown the lingual button is bonded, the more effective the intrusive force will be, although it may become uncomfortable for the patient. Consequently, to eliminate possible rotation and uncontrolled tipping of the malpositioned maxillary second molar, we recommend buccal traction forces rather than palatal traction on the molar.

Simultaneous force application on maxillary right and left second molars. When the traction force was simultaneously applied on the buccal surface of maxillary right and left second molars, the stress intensity of the anchoring units (first molars) was increased. This indicates that higher stresses were generated in the anchoring first molars when the traction force was simultaneously applied on the buccal surface of maxillary right and left second molars. Therefore, simultaneous traction on both sides of maxillary second molars should be avoided to prevent harmful stress concentrations at the anchoring tooth.

CONCLUSIONS

In the present study, we demonstrated the following: (1) When the traction force was applied on the palatal surface of the maxillary second molar, stresses were concentrated at the buccal and palatal root apices and emanated along the root surface. The rotational axis of the palatal root was at the root apex and that of the buccal root was at the apical one-fourth area, producing an uncontrolled palatal tipping and a rotating force. (2) When the traction force was applied on the buccal surface of the maxillary second molar, heavier stresses creating a controlled tipping and an intrusive force were observed in the buccal and palatal root apices, as well as in the middle one-third of the palatal root, compared with the force application on the palatal surface. The rotational axis of the palatal root disappeared, whereas that of the buccal root moved from the apical one-fourth area to the root apex. (3) When the traction force was simultaneously applied on the buccal surface of maxillary right and left second molars, the stress intensity around the root area of the maxillary first molar was increased.

REFERENCES

1. Chattopadhyay A, Srinivas K. Transposition of teeth and genetic etiology. *Angle Orthod.* 1996;66:147–152.
2. Gatzalas P, Droschl H, Muchitsch AP, Fluch O, Bantleon HP. 3-dimensional location of the upper 2nd molars after the termination of orthodontic treatment. *Z Stomatol.* 1987;84:241–250.
3. Ramfjord SP. Dysfunctional temporomandibular joint and muscle pain. *J Prosthet Dent.* 1961;11:353–374.
4. Cureton SL. Second molar biomechanics. *J Clin Orthod.* 1995; 29:500–508.
5. La Kind SD. Ectopic maxillary second molars. *J Clin Orthod.* 1991;25:81–82.
6. Kucher G, Weiland FJ. Goal-oriented positioning of upper second molars using the palatal intrusion technique. *Am J Orthod Dentofacial Orthop.* 1996;110:466–468.
7. Nakamura S, Miyajima K, Nagahara K, Yokoi Y. Correction of single-tooth crossbite. *J Clin Orthod.* 1995;29:257–262.
8. Yoon YJ, Kim KW. Posterior crossbite appliance to correct the buccally ectopic eruption of maxillary second molar. *J Korean Dent Assoc.* 1997;35:140–141.
9. Chaconas SJ, Caputo AA, Brunetto AR. Force transmission characteristics of lingual appliances. *J Clin Orthod.* 1990;24:36–43.
10. Vishay Measurements Group. *Tech note (TN-702–1): introduction to stress analysis by the photostress method.* Malvern, PA: Vishay Intertechnology, Inc; 1989:1–12.
11. Chipman MR. Second and third molars: their role in orthodontic therapy. *Am J Orthod.* 1961;47:498–520.
12. Weinmann JP. *Bone and bones: fundamentals of bone biology.* St Louis, Mo: Mosby; 1947:98–100.
13. Tanne K, Hiraga J, Kakiuchi K, Yamagata Y, Sakuda M. Biomechanical effect of anteriorly directed extraoral forces on the craniofacial complex: a study using the finite element method. *Am J Orthod Dentofacial Orthop.* 1989;95:200–207.
14. Burstone CJ, Pryputniewicz RJ. Holographic determination of centers of rotation produced by orthodontic forces. *Am J Orthod.* 1980;77:396–409.
15. Gjessing P. Controlled retraction of maxillary incisors. *Am J Orthod Dentofacial Orthop.* 1992;101:120–131.
16. Brodsky JF, Caputo AA, Furstman LL. Root tipping: a photoelastic-histopathologic correlation. *Am J Orthod.* 1975;67:1–10.
17. Glickman I, Roeber FW, Brion M, Pameijer JHN. Photoelastic analysis of internal stresses in the periodontium created by occlusal forces. *J Periodontol.* 1970;41:30–35.