Effects of Orthodontic Intermaxillary Class III Mechanics on Craniofacial Structures Part I - Photoelastic Analysis

J. ALFREDO DE ALBA Y LEVY, D.D.S., M.S.
ANGELO A. CAPUTO, M.S., Ph.D.
SPIRO J. CHACONAS, D.D.S., M.S.

Bone tissue changes are an expected reaction to orthodontic or orthopedic treatment. These changes can be controlled or undesirably unforeseen.

In orthopedics, for instance, there are clinicians who treat scoliosis with the nonmodified Milwaukee brace. This apparatus permits the chin to rest on a hard surface, while traction is exerted on the affected vertebrae. This chin rest can cause severe skeletal deformation to the mandible, even though the original problem is somewhat relieved.

This represents a good example of what controlled and unforeseen orthopedic forces can do for the clinician or against him in common everyday practice. In orthodontics, utilization of an extra- or intraoral apparatus can produce orthopedic effects on the structures where the forces are applied, confirming that permanent changes can be created by the operator.

The purpose of this two-part article is to give the researcher and clinician a biological and objective view of the considerations of treatment of Class III malocclusions with intermaxillary elastics.

Part I deals with the effect of Class III intermaxillary traction on a simulated human skull utilizing current photoelastic materials and techniques.

Part II will explain by means of computerized cephalometrics the effects of Class III intermaxillary vector force in ten treated cases. The last section of Part II will discuss the relation between active growth and induced anatomic changes when utilizing photoelastic stress techniques and computerized cephalometric analysis.

From the Departments of Orthodontics and Biomaterials, Univ. of California at Los Angeles, California.

REVIEW OF LITERATURE

Utilization of extra- and intraoral force in the correction of a malocclusion is not a new or recent idea. Gellier and Fox[1] in the early 1800's reported the utilization of mandibular chincup and maxillary traction. Kingsley made use of extraoral anchorage with the aid of intermaxillary rubber bands in 1875.[2] Graber[3] also reports that Farrar, Kingsley and Angle were utilizing orthopedic extraoral force in the correction of Class III malocclusions with a chincup in the late 1800's. Although Angle felt extraoral appliances were going to play a role in orthodontics, he did not think their use would become very popular.[4]

It seems that past investigators concentrated on the changes of the lower face. Few authors gave much attention to the upper structures and, ironically, it may be action in sutural areas that will provide the key for the successful correction of prognathic cases of malocclusion. In this field the literature is even more limited concerning action of mechanical forces on sutural areas of the upper face by intraoral means.

Stewart, Chaconas, and Caputo[5] in a thorough photoelastic study concluded that Class III elastics can increase the opening of the malocclusion as well as create occlusal plane rotation. Bales, Chaconas and Caputo[6] discussed the resilient properties of elastics comparing different latex materials and forces.

Graber has described anchorage control and space preservation utilizing Class III elastics in the correction of prognathic type of malocclusions.[3] Mechanical orthodontic considerations are to a high degree the extent of his dissertation in the uses of this type of appliance. Irie and Nakamura[7] in their article on orthopedic approach to severe skeletal Class III malocclusion discussed the use of elastics to advance the maxilla and retract the mandible stating that "dramatic success" is possible. As can be seen, claims are made that intermaxillary, as well as extraoral traction, produces very favorable results. However, the reports do not present the exact location, direction, and intensity of the forces produced by the intermaxillary traction utilized.

Photoelasticity is the property exhibited by some isotropic solids which become doubly refracting when subjected to stress. The principle is based on the fact that polarized light, passing through a transparent plastic under stress, will split into two polarized beams, which travel in the planes of the principal stress. These beams have different velocities, and the resulting phase difference shift is observed by viewing the light through a polarizing filter. These resultant stresses are viewed as colored fringes within the photoelastic resin. Photoelastic resins can be cast, shaped, or cut into models and are of varying sensitivity. The resins can also be calibrated as to the value to each fringe and, with proper instrumentation, accurate stress measurements can be made at any point within a model.[8]

Introducing the techniques of photoelastic stress to dentistry, Zak reviewed some of the effects of orthodontic mechanics within the alveolus.[9] Some of the more recent investigations were conducted by Caputo and Standlee who used photoelastic techniques in studying the effects of pin replacement on tooth structures.[10,11]

Hayashi, Caputo, and Chaconas visualized forces induced within the supporting structure by various cuspid retraction springs.[12,13]

Davis, Caputo, and Chaconas, utilizing photoelastic material, reproduced all the bones of the craniofacial complex to visualize orthopedic forces utilizing extraoral appliances such as cervical and highpull headgear.[14] De Alba et al. studied the photoelastic effects of Class III extraoral forces upon the mandible.[15]

The use of photoelastic material for analysis of stress and strain in bones has been criticized by some. Evans was quick to point out that these are different from bone.[16] However, the predictive validity of the modeling technique has been amply demonstrated by Standlee,[11] Glickman,[17] and most recently by Brodsky.[18] Being aware that plastics are not identical to bone but only a model resembling the bone, conclusions can still be reached and something learned from their use.

Material and Methods

Photoelastic Stress Analysis

From a human skull a three dimensional model was reproduced utilizing various birefringent materials to simulate periodontal ligament, bone, and teeth. The methods and techniques were similar to those employed by Davis and associates. Individual silicone rubber molds for each portion of the model were fabricated.

Cranial base and midface bones were fabricated separately and then assembled as a complete integral unit.

Maxillary and mandibular teeth were carved in wax, and molds were then made for each individual unit. The teeth were then reproduced from ivory-epoxy material. Simulation of mem-

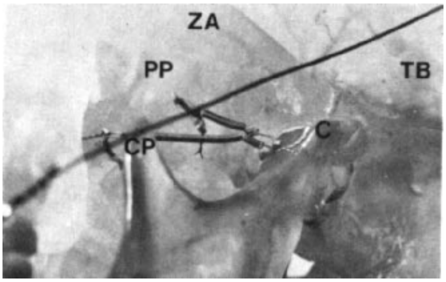

Fig. 1 Simulation of external pterygoid muscle by means of coil springs. CP = Coronoid process; C = Condyle; TB = Temporal bone; PP = Pterygoid plate; and ZA = Zygomatic arch.

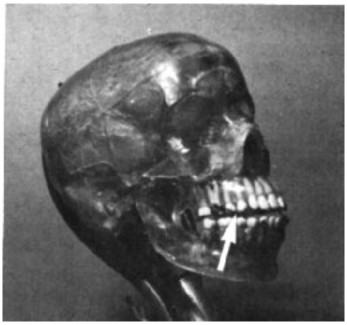

Fig. 2 Lateral view of the photoelastic human skull with the Class III intermaxillary traction in place (arrow).

branes was achieved by applying a thin layer of wax to the roots of the teeth. These teeth were then placed in the silicone molded mandibular and maxillary arches, where an epoxy-based birefringent plastic was utilized for the fabrication of these two arches. After complete polymerization the "teeth-P.D.L." units were removed from the fabricated maxilla and mandible. The wax was removed from the teeth; birefringent urethane plastic was added to the empty sockets and the teeth were then gently pushed into place. This resulted in a maxilla and mandible containing separate teeth.

Assembly of the model was achieved with the aid of an adhesive placing the model bones in their appropriate positions and maintaining the proper relationship until the adhesive completed setting. Repositioning of the mandible into a prognathic maxillomandibular relationship was achieved by remodeling the glenoid fossa.

For simulation purpose and following the work and conclusions of Petrovic and associates,[22] the external pterygoid muscle was simulated by means of a .009 x .036 inch closed coil spring (Fig. 1).

Attachment of the muscle was achieved by utilizing orthodontic molar cleats adhered with a dental bracket adhesive at the natural muscle insertion. The muscle force was distributed to the bone by a quantity of adhesive approximately ¼ inch in diameter. It is important to point out that no drills or burs were utilized to create the attachment of external pterygoid muscle in the photoelastic skull. A hinge stand was made to support the model being secured through the foramen magnum by one inch aluminum stock (Fig. 2).

Maxillary first molars and mandibular cuspids were banded utilizing orthodontic edgewise preformed bands. The Class III intermaxillary vector force was achieved by direct connection of the above-mentioned teeth with a .009″ x .036″ closed coil spring. A force of 8 ounces was produced bilaterally when the elastic simulators were in place.

The model with its appliance in place was heated to 180°F (stress freezing temperature) and slowly brought to room temperature. This procedure caused the resulting stresses to remain in place even after removal of the appliance.

The mandible was carefully sectioned with a saw using mineral oil as a coolant and lubricant. These sections and the upper anatomical structure were examined with a circular transmission polariscope arrangement. Stress patterns on upper and lower face were recorded

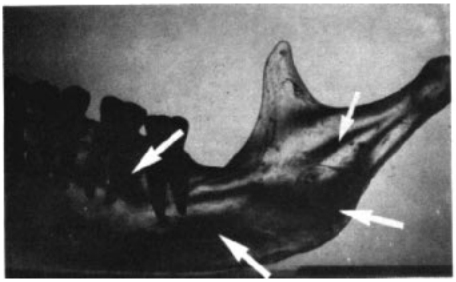

Fig. 3 Mandibular right hemisection; stress patterns are readily noted following the mandibular corpus (arrows).

Fig. 4 Buccolingual view of the stress activity observed mesially and distally at the apex and midroot level of the maxillary posterior teeth (arrow).

with a 35 mm single lens reflex camera.

Results

After assembly of the simulated human skull, reexamination was necessary to assure that it was initially free of stress. Following the "freezing cycle" with the activated intermaxillary coil springs in place, stresses were observed in different anatomical areas of the skull.

Lower Facial Structures

The intermaxillary Class III force produced a noticeable effect in the mandible. This can be observed in the analysis of the right hemimandible presented in Figure 3. Stress concentrations were observed in the following areas: 1) mesial and distal of the second molar, and at the apical and midroot areas of the first molar, and canine, 2) emanating posterior-superiorly to the second molar and following the mylohyoid groove, stresses concentrate along sigmoid notch, and at the anterior and posterior aspect of the head of the condyle at the external pterygoid muscle insertion level, 3) beginning directly inferior to the second molar and extending toward the bony ridge of the mandible, the stresses follow a posterosuperior direction along the body of the bone creating a dramatic effect at the gonial angle and lower portion of the mandibular ramus.

It is of interest to point out that no stress activity whatsoever was observed at the mandibular central incisors and coronoid process in the photoelastic analysis.

Upper Craniofacial Structures

Examination of the various sutural areas of the craniofacial complex revealed that the Class III intermaxillary elastic force delivery affected to a great extent the following upper structures and anatomical sutures:

1. In the molar and premolar areas, stress is noted extending from the mesial buccal root of the first molar, mesial and distal surface of the second premolar, to the mid- and apical root levels of these posterior teeth (Fig. 4).

2. In a palatal view the effect is readily observed on the lingual aspect of the second premolar along the midroot and apical areas (Fig. 5).

3. Proceeding to analyze osseous internal craniofacial structures, stress is noted in the outer surface of the pterygoid plate due to the action of the simulated external pterygoid muscle (Fig. 6).

4. Emanating from the molar, the stress trajectory concentrates on the zygomaticotemporal suture. Stresses are transmitted across the suture anteroposteriorly extending along the zygomatic arch (Fig. 7).

5. Stresses radiating from the maxillary first molar are shown in an antero-

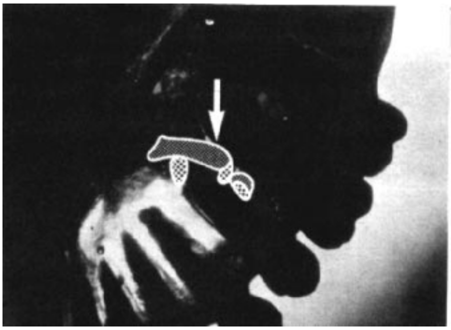

Fig. 5 Palatal view of posterior segments, note the stress distal and apical of the second premolar (arrow).

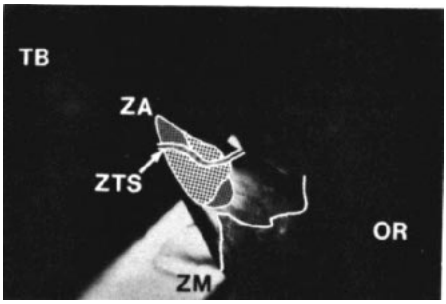

Fig. 7 Lateral view of the stress effect observed on the zygomaticotemporal suture. OR = Orbital ridge; ZA = Zygomatic arch; ZM = Zygomaticomaxillary suture; ZTS = Zygomaticotemporal suture; and TB = Temporal bone.

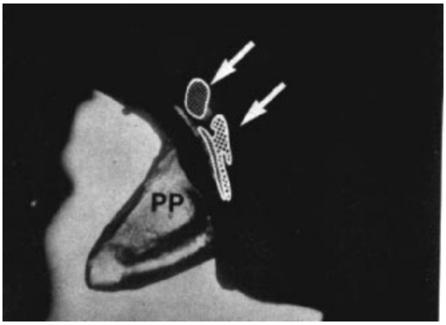

Fig. 6 Stresses concentrated at the outer surface of the pterygoid plate due to the action of the external pterygoid muscle (arrow). PP = Pterygoid plate.

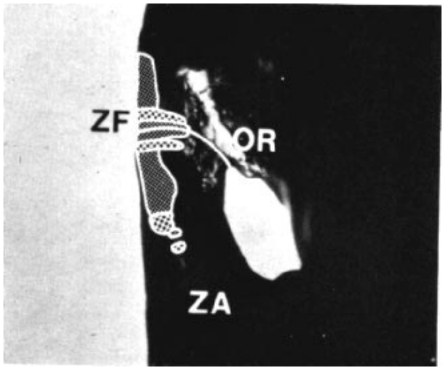

Fig. 8 Posteroanterior view of the zygomaticofrontal suture area. Note stress concentrations along the ridge and lateral walls of the orbit; action is also observed at the zygomaticofrontal suture. ZF =Zygomaticofrontal suture; ZA = Zygomatic arch; and OR = Orbit.

posterior view of the zygomaticofrontal suture at the bony ridge of the orbit. Lateral stresses were also noticed on the orbital wall in a superoinferior fashion (Fig. 8).

6. Stress was also noted at the nasal lacrimal area and superiorly at the frontomaxillary suture (Fig. 9).

7. In an inferior-superior view of the head of the condyle, stress is observed in its anterior portion in the area where the external pterygoid muscle retains its natural insertion (Fig. 10).

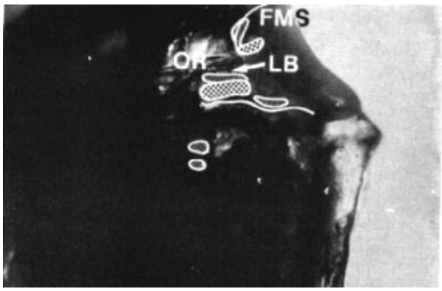

Fig. 9 A lateral view of the orbital area shows stress concentration at frontomaxillary suture and lacrimal bone level. FMS = Frontomaxillary suture; OR = Orbit; and LB = Lacrimal bone.

Discussion

Previously developed molding and casting photoelastic techniques were utilized to study the stress concentration

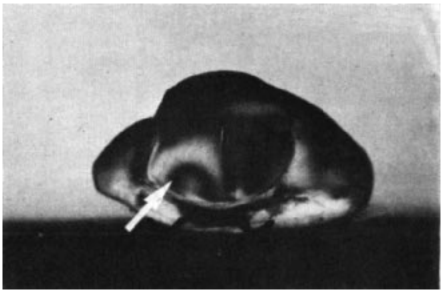

Fig. 10 An inferosuperior view of the condyle shows evidence of stress at external pterygoid muscle insertion (arrow).

of Class III elastic therapy in order to evaluate the direction and magnitude of the forces developed within the craniofacial complex.

Palatal Displacement

Normal maxillary growth is a process that follows an orderly sequence. Sites of growth for the maxillary complex are located mainly at three sutures: frontomaxillary, zygomaticomaxillary, and pterygomaxillary. Also affecting growth, and adjacent to these, are the zygomaticofrontal and zygomaticotemporal sutures. Combined growth of all these translates the maxillary complex in a downward and forward direction.

Analyzing photoelastic results in the above-mentioned structures, it was found that the majority of these were affected to varying degrees (Figs. 6, 7, 8, 9). The stresses upon the upper sutures have some effect on the growth pattern of the upper and midface. In Figure 7 the stress distribution follows the zygomaticotemporal suture borders dispersing anteroposteriorly. These effects are thought to be the end result of a series of stress trajectories emanating from the maxillary first molar.

Stress trajectories to the zygomaticofrontal and frontomaxillary sutures (Figs. 8, 9) followed basically the same pattern as the zygomaticotemporal suture. From the zygomatic arch the stresses were directed in an anterosuperior direction along the anterior portion of this arch. In recent studies[15] it was found that when extraoral chincup forces were utilized to correct Class III malocclusions, no effect whatsoever was observed in the sutures affecting upper face growth. Therefore, it was assumed that the tension produced in the upper face by intraoral Class III forces causes appropriate biological responses, namely, the tension produced within the sutural structures caused an increase in the vascularity and a concomitant differentiation of the cellular tissue resulting in osteoblastic activity. Furthermore, the tension affecting the sutures produced a more pronounced bodily displacement of the maxillary complex than would have occurred with normal growth as described by Enlow et al.[19,20]

Mandibular Opening

The mandible is the only bone of the face with a combination of both endochondral and intramembranous type of osseous formation. Appositional growth occurs between the hyaline cartilage and the thick connective tissue layer of the condyle. The normal direction of growth is downward and forward with no opening of the mandibular plane. In fact, with normal growth there is a slight closure of the mandible.[21] As observed in the photoelastic studies, intermaxillary Class III traction produced an effect along the ramus and condylar neck of the mandible (Fig. 3). The pronounced effect at the mandibular angle could very well produce a bending at that site with consequential mandibular opening.

Photoelastically, the effect of intraoral Class III mechanics on the posterior maxillary denture was observed (Figs. 4 and 5). This tension theoretically could cause extrusion of these teeth with a concomitant bite opening and mandibular rotation.

Condylar Reposition

The growth center of the mandible is located in the condyle which increases in size by interstitial and appositional types of growth. The normal repositioning of the condyle during growth is in a downward and forward direction along the condylar axis.

As noted in the photoelastic observations, stresses occurred along the posterior border of the condylar neck (Fig. 3) and at the site of the external pterygoid muscle insertion (Fig. 10). The stresses at the prechondroblastic zone could alter the morphology of the condylar head and the glenoid fossa as described by Petrovic.[22,23] According to Petrovic, hypopropulsion of the mandible would increase the sarcomeres of the external pterygoid muscle and would decrease the proliferation of the condylar cartilage prechondroblasts causing a decrease in length between the posterior edge of the condyle and mental foramen.

Mandibular Incisor Retrusion

The normal position of the incisal edge of the mandibular central is one millimeter anterior to a line from Downs' point A on the maxilla to pogonion on the mandible. During normal growth the mandibular incisor is expected to erupt upward and forward but to remain in the same position relative to the APo line. The photoelastic observation in the study revealed an effect at the apices of the mandibular premolar teeth (Fig. 3), but no stress activity was observed in the incisal area. It is safe to assume that, if Class III mechanics were attached to the anterior segment of the mandibular archwire, this would affect the teeth connected to it. Due to the distal vector of force of the Class III intraoral traction, the mandibular incisors would be expected to retrude from their predicted position.

Mandibular Molar Change

During normal growth the mandibular molar is expected to erupt upward and slightly forward toward the new occlusal plane. Certain appliance techniques utilize the normal forward movement of the lower molar in the correction of Class II malocclusions.[3]

Physiologic mesial drift occurs when the deciduous molars are lost and the permanent first molars move forward to occupy the leeway space.

Figure 3 reveals the photoelastic effect of the Class III mechanics on the mandibular molars. Stresses seen at the mesial, distal, and apical positions of the mandibular first molars will tend to create a combination of both extrusion and distal tipping of these teeth. Clinically, this posterior vector of force would distalize or hold the molars from drifting mesially, or distally, depending on the magnitude of force.

Summary and Conclusions

The relation between active growth and induced anatomic changes was examined using photoelastic stress techniques. The following can be concluded from this investigation:

1. Utilization of Class III mechanics on the photoelastic skull affected the zygomaticotemporal, zygomaticofrontal, and frontomaxillary sutures.

2. The stress trajectories observed in the mandible lead to the conclusion that Class III traction affects mandibular growth and opening, as well as condylar repositioning.

3. Evidence of stress was observed in a section of the condyle due to the external pterygoid muscle.

4. The stress concentrated at the outer surface of the pterygoid plate was due to the action of the external pterygoid muscle.

5. The effect of the simulated Class III traction created concentrations of

stress mesial and distal of the second molars and at the apical and midroot areas of first molars.

Orthodontic Dept.
UCLA School of Dentistry
Los Angeles, California 90024

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