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A COMPARISON OF DENTOFACIAL AND TEMPOROMANDIBULAR JOINT MORPHOLOGY IN CHILDREN AND ADOLESCENTS

by

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Submitted in partial fulfillment of the requirements for the Degree of Master of Science in Dentistry.

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TEMPOROMANDIBULAR JOINT MORPHOLOGY IN

CHILDREN AND ADOLESCENTS

Abstract

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Previous studies have reported that the morphology of the articular eminence of the temporal bone is related to various dental and skeletal parameters as well as chronological age in populations with normal occlusions. The main objective of this study was to determine if a structural or morphologic relationship exists in a sample of children and adolescents with developing malocclusions. A secondary objective was to evaluate the relationship among joint function as determined axiographically, eminence morphology, and various clinical exam parameters.

Fifty patients, 10 to 16 years of age, from Case Western Reserve University's Orthodontic clinic were randomly selected for study. Dental study models, a lateral cephalogram, and a thorough clinical exam were obtained for each subject as part of routine orthodontic records. In addition, axiographic tracings of condylar movements were recorded and a measurement of the height and angle of the posterior slope of the articular eminence derived. These parameters were statistically compared

to population characteristics and 36 cephalometric and dental cast measurements. Condylar subluxation was also determined from the axiographic tracings, and was compared to clinical exam parameters and eminence morphology.

The findings of this study indicate that the angle of the posterior slope of the articular eminence is not related to age or gender. The height of the eminence is not related to gender, but is positively correlated with the subject's age. Of the comparisons between eminence morphology and the cephalometric and dental cast parameters studied, the sole statistically significant finding was an inverse correlation between mandibular plane angle and the angle of the posterior slope of the eminence (r=-.229). Therefore, it is concluded that the eminence and dentofacial complex are independent of each other developmentally. In addition, the incidence of condylar subluxation as determined from the axiographic tracings was found to be independent of the presence or absence of pain upon palpation in the muscles of mastication, pain upon palpation of the TMJ, and TMJ clicking. The incidence of condylar subluxation may be related to the height and angle of the articular eminence. Further study with a larger sample is indicated.

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INTRODUCTION

The relationship between dental occlusion and the morphology and function of the articular eminence has been extensively discussed in the dental literature. For years the prevailing opinion has been that the morphology of the articular eminence and temporomandibular joint are related to the morphology of the face and teeth. Entire texts have been written on this topic. Gnathologists suggest that there is an ideal relationship that exists when the inclination of the eminence and the teeth are in functional harmony (McHorris, 1979; Roth, 1981; Lucia, 1983), and that violation of this ideal relationship may cause excessive wear on posterior teeth, tooth mobility, and TMJ disturbances (Kaplan, 1963; Stallard and Stuart, 1963).

More, recently, numerous studies have attempted to delineate this "ideal" relationship (Bell and Harris, 1983; McHorris, 1979; Maglione, 1989; Kohno and Nakano, 1987), implying that a developmental relationship exists between the eminence/TMJ complex and the teeth and face. The underlying problem with these studies is that the subjects were pre-selected as meeting certain "ideal" criteria and then the morphology of the eminence and dentofacial structures were compared. This teleological type of experimental design necessarily produces positive correlations.

This study was undertaken to evaluate this question on a sample consisting of randomly selected children and adolescents with developing malocclusions. If a biologically dependent relationship exists between the

articular eminence and facial or dental structures, then one would expect the correlation to be independent of sample selection criteria.

The main objectives of this study are to compare the morphology of the articular eminence to that of the dentofacial structures as well as to several population characteristics. A second, less central objective is to quantitatively compare functional characteristics of the temporomandibular joint to eminence morphology and clinical examination data.

LITERATURE REVIEW

Anatomy and Function of the Temporomandibular Joint

The area of articulation between the mandible and the base of the cranium is the temporomandibular joint (TMJ). The osseous components of the TMJ consist of the mandibular condyle situated in the mandibular fossa of the squamous portion of the temporal bone (Okeson, 1989). From an anterior view, the condyle has medial and lateral projections called poles. The medial pole is normally more prominent than the lateral pole. The mediolateral length of the condyle averages 15-20 millimeters, while the anteroposterior width is between 8-10 millimeters. The articular surface of the condyle is slightly convex when viewed from the lateral and strongly convex anteroposteriorally (Sicher, 1975). Directly anterior to the mandibular fossa of the temporal bone (also referred to as the glenoid or articular fossa) is the articular eminence or tubercle. A convex bony projection, the eminence is an important structure, as its morphology directly influences the pathway of the condyle in conjunction with the muscles of mastication, the ligamentous structures of the joint, and the disc. The inclination of the posterior surface of the eminence has been shown to be highly variable (Lindblom, 1960). The bony architecture of the fossa is thick and dense along the eminence, indicating that it is designed to sustain heavy forces, whereas the posterior roof of the fossa is thin and not intended to endure heavy loading (Okeson, 1989). The articular surfaces of the temporomandibular joints are avascular and composed of dense fibrous connective tissue (Bell, 1983).

Interposed between the condyle and fossa is the articular disc. Lacking innervation and vascularity, the disc is composed of dense fibrous connective tissue. In the sagittal plane, the disc can be separated into three clearly defined zones with varying thickness. The central portion of the disc is the thinnest and has been termed the intermediate zone. Anterior and posterior to the thin central area, the disc is thickened, with the posterior band usually thicker than the anterior band (Rees, 1954). In an undamaged joint, the condyle articulates in the intermediate zone. During function, the disc is flexible enough to adapt to the articular surfaces, helping to maintain joint stability.

The articular disc is held in place by a complex system of attachments. Posteriorally, the disc is attached to an area known as the bilaminar zone. The superior retrodiscal lamina attaches the disc to the tympanic plate of the temporal bone, while the inferior lamina connects the disc to the posterior aspect of the of the condylar articular surface. The area between these two lamina is known as the retrodiscal tissue and consists of highly vascularized loose connective tissue. In contrast to the disc, this area is also well-innervated. Anteriorally, the disc attaches to the capsular ligament which surrounds the joint. In addition, the disc also has a tendinous anterior connection to the superior head of the lateral pterygoid muscle. The articular disc is connected medially and laterally to the capsular ligament, and to the poles of the condyle via the collateral discal ligaments (Choukas and Sicher, 1960). Anatomically, the disc separates the joint into a superior and inferior cavity. These cavities are bathed in synovial fluid which serves as a lubricant during rotational and

translatory movements of the joints and as a medium for metabolic exchange (Bell, 1983).

There are several ligamentous components of the TMJ. They do not enter actively into joint function; rather, they function passively to limit and restrict joint movement (Bell, 1983). The collateral discal ligaments function to discourage separation of the disc and condyle as it moves anteriorally and posteriorally. However, these ligaments do permit rotation of the disc on the articular surface of the condyle. The TMJ is completely surrounded and encapsulated by the capsular ligament (Sicher, 1975). Superiorally, the fibers of this structure are attached to the temporal bone following the periphery of the articular surfaces of the glenoid fossa and articular eminence. Inferiorally, the capsular ligament attaches to the neck of the condyle. The function of the capsule is to resist forces that would tend to separate the condyle from the articular fossa (Okeson, 1989). The lateral portion of the capsule contains the strong reinforcing fibers of the temporomandibular ligament, which extends from the lateral and inferior surface of the zygomatic arch to the outer surface of the condylar neck. A deep horizontal section of this ligament extends from the crest of the articular tubercle to the lateral pole of the condyle (Solberg and Clark, 1980), serving to resist posterior displacement and subsequent damage to the retrodiscal tissues.

The joint recieves its vascular supply from the deep auricular branch of the internal maxillary artery. Nerve supply is via a plexus of fibers throughout the fibrous capsule and associated tissues. Afferent fibers enter regional branches of the auriculotemporal, masseteric, deep

tempopral, and lateral pterygoid nerves and continue into the sensory root and spinal tract of the trigeminal nerve (Solberg and Clark, 1980; Sicher, 1975).

Functionally, the temporomandibular joint is an extremely complex system. Both joints are connected to the mandible with a rigid endpoint of closure determined by the teeth and alveolar bone. The TMJ is a compound joint which can be separated into two structural and functional systems (Bell, 1983). The lower portion of the joint consists of the condyle and articular disc. Because the disc is tightly bound to the poles of the condyle, the only physiologic movement that can occur in the inferior joint compartment is rotation of the disc on the articular surface of the condyle. It is this interaction that is responsible for the hinge-like rotational movement in the TMJ (Okeson, 1989). The second functional component involves the articulation between the disc-condyle complex and the temporal fossa. Because the disc has no tight connection to the temporal bone, free-sliding, translatory movements of the joint occur in the upper joint compartment (Bell,1983). Stability of the joint and contact of the articular surfaces is maintained by constant activity in the elevator muscles. In addition, the contour and movements of the articular disc permit constant contact of the articular surfaces of the joint, even as the width of the joint space changes during function (Okeson, 1989).

During the initial phase of a typical opening movement, the suprahyoid musculature contracts and a true rotational movement occurs in the lower joint compartment. As opening continues, the neck of the condyle rotates posteriorally and the temporomandibular ligament

becomes taut. At this point, the second phase of opening begins. Translation occurs in the upper compartment of the joint, between the superior surface of the disc and the articular eminence. The disc is pushed anteriorally and medially by the condylar head as it moves forward. The superior retrodiscal lamina is stretched, creating a force to retract the disc during closure (Okeson, 1989). The inferior lateral pterygoid muscle, which extends from the lateral surface ot the lateral pterygoid plate to its insertion on the neck of the condyle, is also important during mandibular movements. When the right and left lateral pterygoids contract bilaterally, the condyles are translated downward and forward along the articular eminence and the mandible is protruded (Bell, 1983). Unilateral contraction results in mediotrusive movement of the ipsilateral condyle and lateral mandibular movement toward the contralateral side.

Gnathology and Condyle/Eminence Relationships

The temporomandibular joint in man and its relationship to mandibular movements have long been a topic of investigation by many workers. Posselt (1952) reported that studies of condylar movement had been done as early as 1748. Walker (1896) reported that condylar paths were reproducible and different among individuals. These studies and others led to the development of articulators to simulate mandibular movements during the construction of various dental prostheses. In the early part of this century, the pantograph was developed as a tool for recording mandibular border movements (Gysi, 1910). Chick (1953) emphasized the importance of recording pantographic tracings at the

emergence of the hinge axis of mandibular rotation in order to eliminate errors and artifacts inherent to the measurement procedures. In order to provide the most accurate reproduction of mandibular movements, some investigators have advocated the use of pantographic tracings of condylar movements to program fully adjustable articulators (Isaacson, 1958; Winstanley, 1977; Hobo and Takayama, 1988). In a study of patients with various symptoms of TMJ dysfunction, Shields et al., (1978) reported that the reproducibility of pantographic tracings were negatively correlated with TMJ and muscle dysfunction. The patients in the study with no signs of dysfunction provided the most reproducible tracings. In a study comparing anterior and posterior disclusive angles, Pelletier and Campbell (1990) also found that axiographic tracings provided reproducible measurements of posterior disclusive angles (the slope of the posterior surface of the articular eminence).

The body of information on studies of condylar paths and patients with a variety of stomatognathic dysfunctions has led several investigators to suggest that improper guidance of mandibular movements by the condyles and anterior teeth may cause excessive wear on posterior teeth, alveolar bone loss and tooth mobility due to traumatic occlusion, and temporomandibular joint disturbances (Kaplan, 1963; Stallard and Stuart, 1963). Gnathologists suggest that the existence of a mutually protected occlusion will decrease the incidence of these problems (McHorris, 1979; Roth, 1981; Lucia, 1983). That is, if the angulation of the path of the lower incisors down the lingual surfaces of the maxillary incisors approximates that of the mandibular condyles down the articular

eminence of the temporal bone, the posterior teeth will be discluded rapidly, thus decreasing the chance of posterior cuspal interferences. Furthermore, it is reasoned that if the lingual surface of the maxillary incisor (anterior disclusion) is much flatter than the path of the condyles down the eminence (condylar or posterior disclusion) posterior tooth interferences become more likely as well as any associated adverse effects (McHorris, 1979; Kaplan, 1963). Conversely, anterior disclusion much steeper than posterior disclusion could create unfavorable leverages on the anterior teeth or result in uncomfortable mastication. McHorris (1979) recommends:

> When there is conflict between the condylar components and the anterior teeth components, it is the condyles that we must seek to satisfy. The front teeth can be made subservient to the condyles by moving them orthodontically; changing their shapes by selective grinding; or by . . . restorations.

Several investigators have done extensive work examining the relationships between anterior and posterior discluding paths with widely varying results. In a two part study utilizing a combination of dry skulls and dental students, Bell and Harris (1983) concluded that there is a strong correlation between the angulation of the lingual surface of the maxillary central incisor and the angle of the articular eminence in individuals with normal occlusions, with the former being steeper than the latter by an average of 5.6 degrees when measured against the occlusal plane. They also suggest that the angulation of the articular eminence to the occlusal plane may be useful to orthodontists as a guide for establishing the inclination of the maxillary anterior teeth. The data presented by Bell and Harris is in agreement with McHorris (1979), who suggests that the ideal

relationship exists when anterior disclusion is greater than posterior disclusion by approximately 5 degrees. However, McHorris presents no experimental evidence to substantiate this assertion. Maglione (1989), in a study of patients with temporomandibular disorders, and Huffer et al., (1972), in a study of dental students with normal occlusions, also reached similar conclusions.

Several other investigators are in disagreement with these assertions. Kohno and Nakano (1987), in a kinesiologic study of the paths of the condyle and lower incisor tip in protrusion, reported that the ideal relationship exists when the inclination of the two paths is equal. In a review article, Kaplan (1963) attempted to establish that the angle of the anterior discluding pathway should be approximately equal to the angle of the condylar path. To the contrary, Ramfjord (1966) suggested that any relationship between the two slopes is negligible. Unfortunately, neither Kaplan nor Ramfjord provided any experimental evidence to support their conclusions. Ingervall (1972), in a cephalometric study of 91 children and 58 adults with normal occlusions also found no correlation between inclination of the condylar and incisal paths. At this point, it seems clear that the relationship between the anterior and posterior disclusive paths has not yet been fully delineated.

Several investigators have conducted studies examining the relationship between the sagittal path of the mandibular condyle and the morphology of the articular eminence of the temporal bone. Stallard and Stuart (1963) proposed that "the muscles . . . operating the mandible hold the condyles against the eminence throughout all condylar operations,"

concluding that the condyle should exactly follow the anatomical form of the articular eminence when the mandible is moved into protrusion. Jankelson (1962), however, feels that "the joint allows free movement anywhere within the limitations of the joint space and the surrounding capsule, ligaments, and musculature," suggesting that the condyle can follow a protrusive path that may be different from the form of the eminence. Ramfjord (1966) also suggests that there is little relationship between the condyle path and eminence form. More recently, Corbett et al. (1971), in a study of nine patients with ideal occlusions, utilized a cephalometric technique to delineate the relationship between the condylar head and the articular eminence at selected points during protrusion. A mathematically generated protrusive path was compared with axiographic recordings of condylar positions during mandibular protrusion for each patient. The authors concluded that "in protrusion the condylar head of the mandible follows closely the anatomical form of the articular eminence." These findings concur with those of another investigator (deFreitas, 1970) who conducted a similar study. DeFreitas found that there was no statistically significant difference between the path of the condyle in protrusion and the slope of the eminence determined radiographically. He also suggested that:

> An examination of TMJ anatomy shows that biologically normal TMJs posess a certain degree of functional tolerance. The posterior border of the articular tubercle can be considered as the basic guide for the condylar path, while the soft tissues are modifying factors.

Widman (1988) conducted a study comparing the recorded angle of the protrusive path of the condyle (as determined axiographically) with

the articular eminence angle determined from cephalometric radiographs in fifty post-orthodontic patients age 12-25. The primary finding of this study was a very high statistical correlation between these two measurements. This finding lends support to the conclusions of Corbett,et al., in 1971. In addition, Widman (1988) also uncovered an important morphological tendency: namely that the mandibular plane and the occlusal plane both had an inverse relationship to the angle of the posterior slope of the articular eminence. That is, the steeper (more vertical) the articular eminence angle, the more horizontal the occlusal and mandibular planes. He concludes that:

> These results suggest that brachycephalic facial types would tend to have more vertical eminence angles. Conversely, dolichocephalic facial types would tend to have a more flattened articular eminence angle.

In a multitude of studies, numerous investigators have attempted to quantify the posterior slope of the eminence in an angular measurement. In a mixed racial sample of over two hundred dry skulls, Angel (1948) measured the slope of the articular eminence relative to Frankfort horizontal plane. He found an average angle of 28 degrees at 6-7 years of age, 37 degrees at 15 years, and 40 degrees at 30-35 years. Ricketts (1950) employed laminagraphs of the temporomandibular joints in a study of one hundred patients. He found on overall mean eminence angulation of 54 degrees to Frankfort horizontal plane and 44 degrees to the occlusal plane. In addition, Ricketts noted that in regard to increasing steepness with age "a scatter diagram . . . failed to indicate any striking correlation". Ingervall (1972) determined cephalometrically that the

average inclination of the condylar path (utilizing the occlusal plane as a reference) in children with normal occlusions was 23 degrees at age 7 and 26.83 degrees at age 10. The average was found to be 36.33 degrees in adults. No statistically significant differences were found between sexes. Maglione (1989), in a study combining cephalometric and pantographic techniques, found an average eminence inclination of 53.6 degrees to the Frankfort plane.

In pantographic studies to record the angle of the eminence, it was noted by Isaacson (1959) that "it was necessary to relate the centers of rotation of the mandibular condyles to a third point so that a reference plane could be established." Isaacson chose the infraorbital notch of one of the orbits as his reference, establishing the axis-orbital plane. He reported an average eminence inclination of 35.6 degrees to this plane. Aull (1963) reported an average inclination of approximately 37 degrees to the axis-orbital plane with a range of 15-66 degrees. More recent investigations (Lundeen,1979; Widman, 1988), utilizing the lowest palpable point on the inferior rim of one of the orbits as a third reference point, reported average inclinations of 45 and 52.4 degrees respectively.

Embryology, Growth, and Developmental Changes

Embryologically, the first evidence of temporal bone development is seen at approximately the eighth gestational week (Furstman, 1963). At fourteen to fifteen weeks in utero, gradual formation of the glenoid fossa begins via intramembranous ossification (Morimoto et al, 1987). At approximately twenty-two weeks of prenatal age, the glenoid fossa and

articular eminence are well-formed. Furstman (1963), in a study of eighty fetal specimens, concluded that the glenoid fossa and articular eminence have established their basic morphologic pattern long before birth. Baume (1970), and Scott (1955), report that at birth, a rudimentary articular eminence is present and the articular fossa faces laterally and only slightly downward.

In the neonate, Wright and Moffett (1974) report that the overall appearance of the temporal components of the temporomandibular joint is one of vigorous osteogenesis, with several small areas of resorption seen on the roof of the glenoid fossa and the adjacent part of the articular tubercle. According to Wright and Moffett, during the first six to eight months of life, the articular tubercle enlarges slightly, with the height of the tubercle as measured from the depth of the glenoid fossa usually being less than 2 millimeters in the six month old infant. Between six months and two and one half years of age, the articular tubercle and glenoid fossa develop a more mature appearance. The height of the tubercle increases to approximately 4 or 5 millimeters, and the osseous cortex and trabeculae increase in density. Scott (1955) reported that the growth of the glenoid fossa is closely correlated with the growth of the head of the mandibular condyle. The head of the condyle attains its adult form at roughly six years of age, and about this time the articular eminence has become a well-developed ridge. The tubercle has enlarged, extending 5-6 millimeters below the roof of the fossa, and the slope of the eminence has steepened relative to that of the neonate. Wright and Moffett (1974) state that: "The basic morphologic pattern remains the

same throughout the period of mixed dentition and into adolescence except that the temporal components enlarge slightly and are reinforced by means of osseous compaction." These findings by Wright and Moffett are in agreement with Scott (1955) who reported that adult-like contour of the temporal part of the joint is established during the development of the primary dentition.

Several investigators have reported differing results regarding growth changes in the temporal components of the TMJ. Humphreys (1932) estimated that the tubercle does not assume its adult configuration until approximately twelve years of age, with the greatest growth in height occurring between ten and eleven years of age. Nevkari (1960) examined the growth in height of the tubercle radiographically, reflected as an increase in the depth of the fossa. He found a steady increase in the depth of the fossa from, an the average, 6 millimeters at age 6-8 years until somewhat more than 10 millimeters at age 20-25 years. Angel (1948) is in agreement with Nevkari, noting an increase in fossa depth from 3.3 millimeters in the lowest age group to 6.7 millimeters in adults in a cross-sectional study of dry skulls. Ricketts (1950), who studied the increase in the depth of the fossa using TMJ laminography during the growth period, found values intermediate to those reported by Angel and Nevkari. He also stated that: "The major part of the growth of the eminence apparently has occurred by the time the first molars are erupted, and there tends to be a slow but steady increase in height until adulthood". Oberg et al., (1971), in post-mortem studies of 115 joints, found the joint to increase in

size up to the age of twenty. During the latter part of the growth period growth occurred mainly in the medio-lateral direction.

As mentioned previously, there are conflicting reports regarding changes in the slope of the posterior surface of the articular eminence with advancing age. Ricketts (1950) failed to uncover any solid correlation. Ingervall (1972) and Angel (1948) reported increasing inclination with age.

In regard to functional mandibular development, Moyers (1969) reported that due to the limited early development of the articular eminence and glenoid fossa the infant's temporomandibular articulation is poorly defined. As discussed above, the temporal components of the TMJ mature concomitant with the development of the primary dentition. The arrival of the first incisor results in little change in neuromuscular function. However, as soon as the opposing incisor erupts, there is the possibility that the incisors may come into contact during random jaw movements. Moyers states:

> The instant these incisors touch, the first step in occlusal reflex learning has begun. One path of opening and closure is quickly learned which provides maximum function and minimum incisor interference.

Thus the anterior limits of jaw relationships are established first. With continued eruption of the dentition a similar interaction of occlusion and muscular function establishes lateral jaw movements (Moyers, 1969).

Materials and Methods

Sample Population

The sample population consists of a total of 50 children and adolescents presenting for orthodontic evaluation and treatment. Twelve of the subjects are from the private practice of Dr. Mark Hans. The remaining 38 subjects are from the orthodontic clinic at Case Western Reserve University. Twenty-three of the subjects are females, and 27 are males. Racially, the population consists of forty two Caucasians and eight individuals of African-American descent. The age range of the males is from 7 years and 7 months to 15 years and 5 months, with an average age of 11 years and 4 months. The females range in age from 6 years 11 months to 15 years 5 months, with an average age of 11 years and 9 months.

Axiographic Technique

The subject is first seated in the dental chair in an orthostatic position with a balanced tension between the head and neck musculature. A suitable clutch, which fixes the mandibular recording bow to the lower dentition, is chosen. A stick of periphery wax is placed across the incisal and occlusal surfaces of the lower teeth and across the clutch to facilitate its removal at the end of the procedure. The clutch is partially filled with fast setting plaster (Kerr #2 plaster, Great Lakes Orthodontics). The clutch is positioned in the mouth with the handle centered in the mid-sagittal plane. In order to minimize any vertical changes in occlusal dimensions,

the patient is instructed to bite on the clutch until it is fully seated. Clearance of the clutch is checked in mandibular movements after the plaster is set.

The next step is to position the cranial analyzer bow. The nasal support is adjusted to fit the subject's nasal bridge. The two lateral arms of the cranial bow are adjusted so that they are in contact with the skin, and that the posterior end of the sagittal recording flags lies just anterior to the tragus. The cranial bow is stabilized with an occipital elastic strap and an adjustable parietal strap. A piece of silicone putty (Citricon, Kerr) is placed under the nasal support to provide some relief from the pressure of the elastic occipital strap. Orbitale point is located by palpation of the anterior border of the orbit and the orbitale indicator is adjusted to register its location. Along with the emergence of the hinge axis of mandibular rotation on both sides, orbitale point will define a reference plane used to measure the slope and height of the articular eminence.

The mandibular recording bow is designed to be attached to the mandibular teeth through the aforementioned clutch. The mandibular bow is first initialized by placing it on a flat surface and adjusting the lateral arms to a neutral position. The mandibular bow is then placed on the shaft of the clutch, and the lateral arms are positioned against the sagittal flags with the posterior ends of the flags and recording arms coincident. The patient is asked to hold the arms in place while the parallelism of the transverse bar with the cranial bow is checked in the frontal and coronal planes. Any remaining stresses in the joints of the mandibular recording

bow are relieved by spinning the transverse bar, and the lateral arms are secured away from the flags at a distance predetermined by spacers.

Next, the hinge axis of mandibular rotation is located. The subject is guided through minor opening and closing movements from centric relation position. If the stylus on the mandibular recording bow is not on the hinge axis, its path will display an arc. The operator then adjusts the lateral arms horizontally and vertically until the stylus spins on its axis and no longer displays an arc. When this is achieved, the stylus is directly over the hinge axis, and the tracing of mandibular movements can begin.

Retractable pens are used to record tracings of mandibular movements. The patient is first guided to an unstrained centric relation position prior to beginning each tracing. Three sets of tracings are recorded for each condyle: (1) opening/closing (traced in black), (2) protrusion/retrusion (traced in red), (3) mediotrusion/medioretrusion (traced in blue). The use of different colored pens permits more accurate identification of the tracings during later analysis. Tracings are repeated until two sets displaying a reproducible pattern are obtained for each condyle. After this has been achieved, the equipment is removed from the patient with care in orded to maintain the relationships recorded by the cranial analyzer bow.

Finally, the axis orbital plane marker is clipped onto the ball of the orbitale indicator. The flexible arms of the plane marker are clamped to the sagittal flags so that they bisect the points coinciding with the emergence of the hinge axes bilaterally. The axis-orbitale reference line is drawn on both sets of right and left sagittal graph papers. At this point

the axiographic tracing procedure is complete and the tracings are ready for measurement and analysis.

Cephalometric Technique

The lateral cephalometric films were taken as part or routine pre-orthodontic records. Subjects from Case Western Reserve University were exposed using a 90 KVP 15 mA S.S. White x-ray unit in conjunction with a Wehmer cephalostat and Kodak T-Mat-G film. Films of the remaining subjects were exposed using a Moss Cephalometrix 90 KVP 15 mA unit and Kodak T-Mat-G film.

Clinical Exam Technique

1. Palpation of the head and neck musculature. Myofacial pain is evaluated by palpation of the head and neck muscles. The patient should be seated in a comfortable orthostatic position and bilateral muscles palpated simultaneously. The following muscle groups were palpated:

a. Temporalis-anterior, medial and posterior

b. Masseter

c. Lateral Pterygoid

d. Medial Pterygoid

e. Digastric

f. Neck

Digital pressure should be low initially and increase gradually. Pain elicited with minimal pressure is graded 3 or severe . Pain triggered by

moderate pressure is graded 2 or moderate. Minimal pain is graded 1. No pain elicited under a significant amount of digital pressure is graded zero.

2. TMJ palpation. The TMJ is palpated in two ways. Palpation sensitivity of the skin anterior to the tragus reveals a potential capsulitis of the external pole. Intrameatal pain to palpation may indicate retrodiscal inflammation. Both areas are palpated and graded from 0-3, with 0 denoting no pain , and 3 signifying severe pain.

3. Auscultation of TMJ sounds. A stethoscope is used to amplify TMJ sounds. The subject is instructed to perform all mandibular movements. Clicking in opening or closing is noted and described as early, intermediate, or late (1,2,or 3). Upon closing, the grading is the same. Joint sounds in protrusion-retrusion and mediotrusion-medioretrusion are similarly noted.

4. Range of motion. Vertical overbite and horizontal overjet are measured with the posterior teeth in maximum intercuspation and recorded. Maximum vertical opening is determined by measuring the opening between the incisal edges and adding the amount of vertical overbite. In a similar fashion, maximum protrusion is equal to horizontal overjet plus maximal protrusion. Lateral excursions are referenced to the upper and lower midlines and recorded.

Axiographic Data

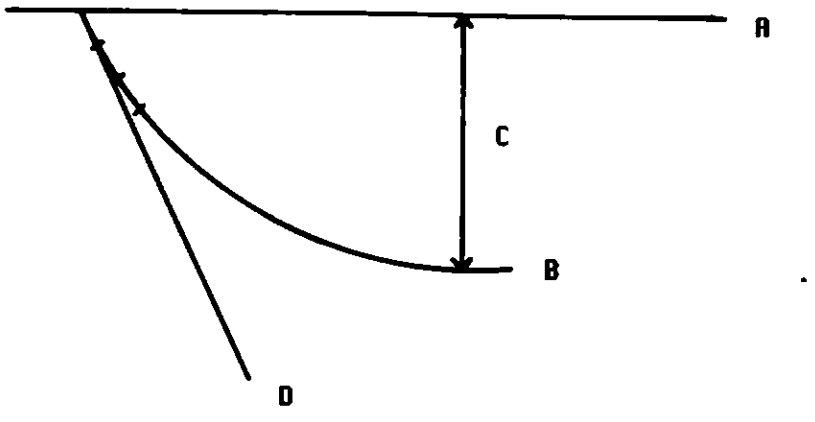
1. Data Acquisition. Approximately 20 of the axiographs were recorded by Dr. George Rozencweig in conjunction with his thesis work at Case Western Reserve University (Rozencweig, 1990). Because Dr.

Rozencweig trained the examiner in the techniques employed, minimal interoperator variability should be expected and the data pool may be considered as homogenous.

2. Angle of the articular eminence. The condylar path in protrusion has been shown to closely follow the form of the articular eminence (Corbett et al., 1971). From the axiographic tracings, the slope of the protrusive tracing is determined as follows. First, the tracings are enlarged three times on a photocopy machine in order to facilitate the measurement. The point corresponding to the emergence of the hinge axis is digitized (IBM computer, Dentofacial Planner software), as well as another point on the axis-orbital plane. Three points along the protrusive tracing at 1 millimeter intervals are also digitized, and the slope of each of the first three millimeters of the tracing for each condyle is computed individually, measuring the inside angle formed between the tracing and axis-orbital plane. These three measurements are then used to calculate the average slope of the first three millimeters of the tracings. A schematic of the measurement of the first millimeter of a typically enlarged tracing is seen in figure 1. Any difference between the right and left slopes is noted and the two measurements are averaged, resulting in an overall mean for the angle between the axis-orbital plane and the posterior slope of the articular eminence.

3. Tracing length and height. The length of the tracings in opening and protrusion are measured to the nearest millimeter using a flexible plastic ruler and recorded. The height of the articular eminence is also

Figure 1- Axiographic measurement



Legend

A: Axis-orbital plane

B: Protrusive tracing

C: Height measurement

D: Angle measurement

measured as the perpendicular distance from the axis-orbital plane to the lowest point along the protrusive tracing (see figure 1 for schematic of height measurement).

4. Interpretation of function. Functionally, the tracings are evaluated with regard to three criteria. First, the tracings are evaluated for any irregularities associated with internal derangement of the TMJ. Farrar (1978), and Slavicek (1988), described the pattern of tracings in the patient with internal derangement and reciprocal clicking. Namely, the tracing displays a characteristic irregularity as the condyle first reduces onto the disc during protrusion or on opening, then subluxates off of the disc during retrusion or closing (Bates et al., 1986; Farrar, 1978). If the meniscus is completely dislocated anteriorally without reduction, the clicking noise is not produced. The condylar path on opening is relatively steep, short, and divergent when compared with the condylar path in protrusion. A second method of evaluation involves the length of the tracings. Normal tracing length is 8-10 millimeters in protrusion and 12-14 millimeters in opening (Slavicek, 1988). The protrusive motion typically displays a shorter path because this movement is limited by the stylomandibular ligament. Any significant restriction of movement is considered to be a sign of dysfunction. Third, the tracings are evaluated with regard to condylar subluxation. Tracings which show condylar translation significantly beyond the height of the articular eminence are noted as evidence of condylar subluxation and recorded. Utilizing these criteria, the tracings are interpreted and assigned a designation of normal, internal derangement, or condylar subluxation.

Lateral Cephalometric Data

Using 0.003 inch frosted matte acetate with a 0.5mm lead mechanical pencil, the lateral cephalometric radiograph for each patient is traced. Sufficient landmarks were traced to allow identification of 37 registration points for digitization (see figure 11). In all tracings bilateral landmarks were bisected and the midpoint taken for cephalometric measurements. Digitization was accomplished using Dentofacial Planner software, which orients points on an x-y coordinate system. The program was modified with the aid of Dr. Stephen Parker to calculate the desired measurements. Landmarks used in measurement are defined as follows:

a. Mandibular plane: connects menton and gonion

b. Sella-nasion plane: connects center of sella turcica and nasion point

c. Frankfort horizontal plane: connects anatomical porion and most inferior point of orbit

d. Functional occlusal plane: occlusal plane constructed by bisecting the mesiobuccal cusp tips of the the first permanent molars and the first premolars (or first deciduous molars in the mixed dentition)

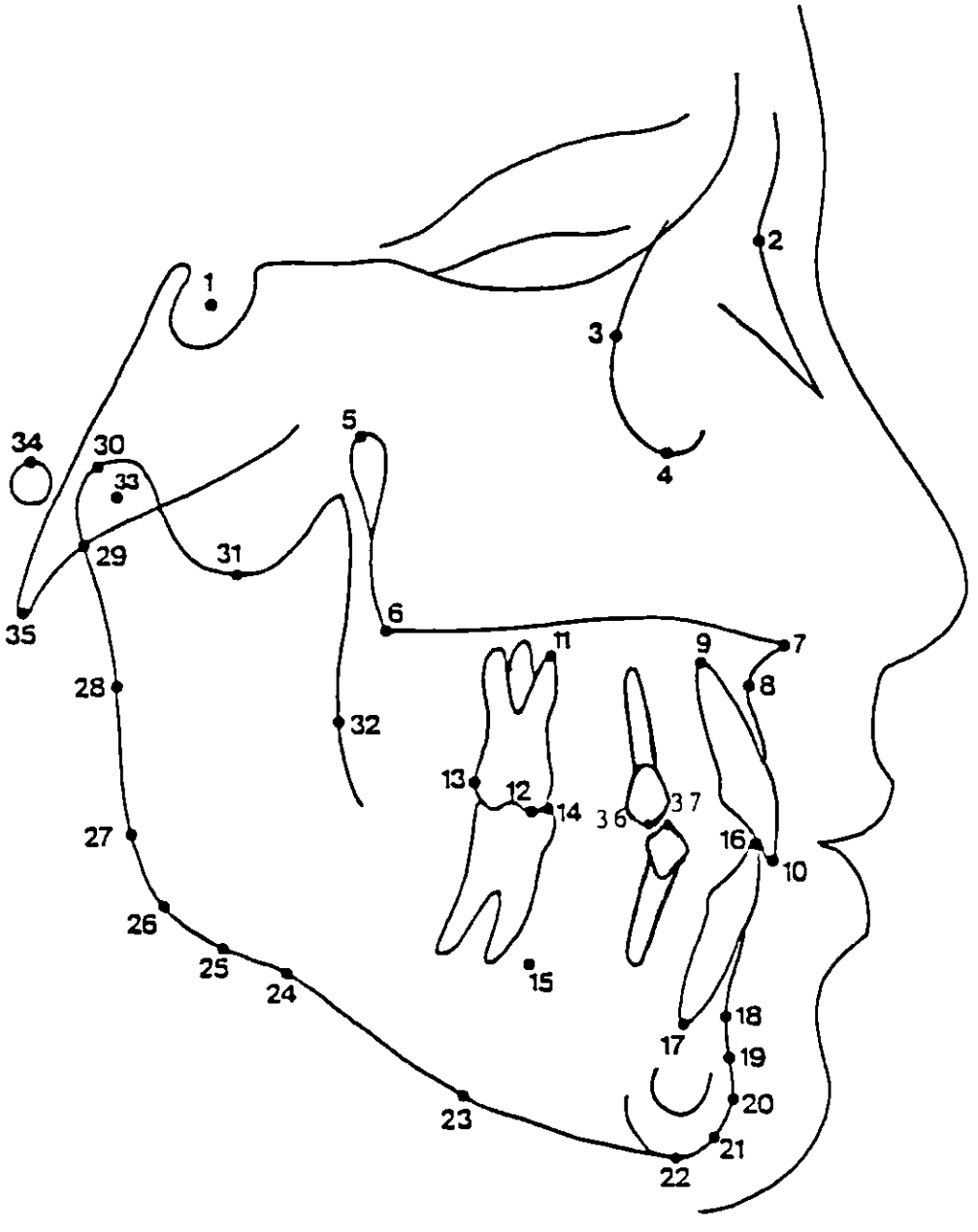
e. Palatal plane: plane from anterior nasal spine to posterior nasal spine

f. Maxillary incisor: long axis of most protrusive incisor

g. Mandibular incisor: long axis of most protrusive incisor

h. Basion-nasion plane: connects basion and nasion point

Figure 11: Cephalometric Landmarks
(from Dentofacial Planner manual, 1985)



The landmarks used in cephalometric digitization are defined in the following manner:

1. Sella, the center of sella turcica
2. Nasion, junction of the frontal and nasal bones at the naso-frontal suture
3. Orbital rim, the midpoint of the lateral orbital margin
4. Orbitale, the most inferior point on the infra-orbital margin mid-planed
5. Pterygo-maxillary fissure, at the eleven o'clock position mid-planed
6. Posterior nasal spine,tip
7. Anterior nasal spine, tip
8. A point, the deepest point in the concavity if the anterior maxilla
9. Upper incisor apex
10. Upper incisor tip
11. Upper molar root apex
12. Upper molar crown, the tip of the mesial cusp of the upper first molar
13. Upper molar distal contact
14. Lower molar crown, the tip of the mesial cusp of the lower first molar
15. Lower molar apex
16 Lower incisor tip
17. Lower incisor apex
18. B point, the deepest point in yhe concavity of the anterior mandible
19. Anterior genioplasty point
20. Pogonion, the most anterior point on the bony chin
21. Gnathion, the most antero-inferior point on the bony chin
22. Menton, the most inferior point on the bony chin
23. Posterior genioplasty point

24. Antegonial, depth of concavity of antegonial notch

25. Inferior gonion, point at a tangent to the inferior border near gonion

26. Gonion, midplaned point at the gonial angle loctated by bisecting the posterior and inferior borders of the mandible

27. Posterior gonion, a midplaned point at a tangent to the posterior border of the ramus near gonion

28. Posterior ramus, a point approximately halfway between gonion and articulare

29. Articulare, intersection fo the posterior border of the ramus with the inferior surface of the cranial base

30. Condylion, the most posterosuperior point of the mandibular condyle

31. Sigmoid, a landmark at the depth of the concavity of the mandibular sigmoid notch

32. Anterior ramus, a landmark located in the depth of the concavity of the anterior border of the mandibular ramus

33. Center of rotation, a landmark in the center of the mandibular condyle

34. Porion, the most superior point of the bony external auditory meatus

35. Basion, the most inferior point on the anterior margin of foramen magnum

36. Cusp tip of upper first bicuspid (or first deciduous molar)

37. Cusp tip of lower first bicuspid (or first deciduous molar)

NOTE: All bilateral structures were bisected during landmark determination.

The measurements computed in order to provide a representation of dentofacial morphology are presented below, followed by abbreviations used in data tables:

1. Facial proportions
    a. Basion-nasion plane to gnathion (mm) (Ba-Na-Gn)
    b. Nasion to menton (mm) (Na-Me)
    c. Basion-nasion plane to posterior nasal spine (mm) (BaNa-PNS)
    d. Nasion to anterior nasal spine (mm) (Na-ANS)
    e. Anterior nasal spine to menton (mm) (ANS-Me)
2. Cranial base length
    a. Sella to nasion (mm) (S-Na)
3. Maxillary and mandibular positions
    a. Sella-nasion-A point (degrees) (SNA)
    b. Sella-nasion-B point (degrees) (SNB)
    c. A point-nasion-B point (degrees) (ANB)
    d. Sella-nasion plane to mandibular plane (degrees) (S-N:GoMe)
    e. Frankfort horizontal plane to mandibular plane (degrees) (FH:GoMe)
4. Mandibular morphology
    a. Gonion to posterior nasal spine (mm) (Go-PNS)
    b. Articulare to B point (mm) (Ar-B)
    c. Articulare to pogonion (mm) (Ar-Pog)
    d. Gonion to pogonion (mm) (Go-Pog)
    e. Articulare to gonion (mm) (Ar-Go)
    f. Gonion to gnathion (mm) (Go-Gn)

g. Articulare-gonion plane to gonion-gnathion plane (degrees) (ArGo:GoGn)

5. Incisor relationships

a. Interincisal angle (degrees) (intinc)

b. Mandibular incisor to mandibular plane (degrees) (L1:GoMe)

c. Maxillary incisor to Frankfort horizontal plane (degrees) (U1:FH)

6. Occlusal and palatal plane inclination

a. Frankfort horizontal plane to functional occlusal plane (degrees) (OP:FH)

b. Palatal plane to Frankfort horizontal plane (degrees)

Clinical Exam Data

The information collected in the history and clinical examination will be categorized according to the following criteria:

a. Joint sounds: auscultation (positive or negative)

b. TMJ palpation: pain (positive or negative)

c. Muscle palpation: tenderness in at least one muscle of mastication as listed above (positive or negative)

Dental Cast Data

Dental casts obtained as part of pre-orthodontic records are evaluated with regard to the following criteria:

a. Presence or absence of transverse discrepancy (buccal crossbite tendency)

b. Presence or absence of incisor contact

c. Posterior tooth cuspal morphology- mandibular first molars subjectively evaluated and classified as flat, moderate, or steep

Statistical Comparisons/Data Analysis

1. Population characteristics vs. axiographic data. The angle and height of the articular eminence will be examined for relationship to the subject's sex utilizing a t-test analysis. If no significant difference is found between males and females for these measurements, then the data will be further analyzed as a single sample as described below. If a significant difference is found between the sexes, they will be subsequently analyzed as two separate groups.

Eminence morphology will also be evaluated for relationship to race. A t-test will be performed, and if any significant difference is uncovered between the two racial categories, they will be considered as separate groups. Because of the small size of the African-American sample, these subjects may have to be dropped from the study altogether

The relationship between eminence morphology and age will also be examined. The statistical method employed will be the correlation coefficient. Finally, descriptive statistics (mean and standard deviation) will be computed with regard to eminence morphology.

2. Eminence morphology vs. dentofacial morphology-cephalometrics. Cephalometric data will be analyzed for relationship to eminence morphology by computing correlation coefficients comparing the height and slope of the eminence to the cephalometric measurements listed above. Interincisal angle will be evaluated in three separate groups: the entire sample, those subjects with incisal contact as determined from cast analysis, and those subjects without incisal contact.

All other cephalometric measurements will be analyzed with respect to the whole sample only.

3. Eminence morphology vs. dentofacial morphology- dental casts. Eminence morphology will be examined for relationship to posterior tooth cusp morphology, presence or absence of transverse discrepancy, and presence or absence of incisor contact. The statistical method used will be analysis of variance testing.

4. Joint function vs. clinical exam data. The functional interpretation of the axiographic tracings will be evaluated for statistical correlation with the following clinical information: joint sounds , pain upon TMJ palpation, and pain upon muscle palpation. The statistical method used to compare these two sets of categorical data will be the Chi-square test.

Explanation of statistics

1. T-test. A t-test is used when comparing the means of two groups. The null hypothesis that is being tested is that the means of the groups in question are equal. The formula is as follows:

$$t = \frac{u_1 - u_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_1^2}{n_2}}}$$

where:

u= the group mean

σ^2= the group variance

n= the sample size

The p value derived from the t-test distribution is then used to determine whether or not to reject the null hypothesis. By convention, if the p value is less than .05, it is assumed that the null hypothesis is rejected and that

therefore the means of the two groups are significantly different from eachother. Because the 0.05 level is chosen, the rejection of the null hypothesis is made with 95% confidence that the difference between the two means is not due to chance alone.

2. Correlation coefficient. The correlation coefficient used in this investigation is Pearson's correlation coefficient. It is used to test the relationship between two variables across a group of measurements. The null hypothesis being tested is that there is no relationship between the two variables in question. The formula is as follows:

$$\text{Correlation Coeffficient} = \frac{\sum_{i=1}^{N} (X_i - \overline{X})(Y_i - \overline{Y})}{(N-1)\sigma_x\sigma_y}$$

where:

X&Y= individual measurement
$\overline{X}$&$\overline{Y}$= mean of measurement
N= sample size
σ= standard deviation

The p value derived from the correlation coefficient is then used to determine whether or not to reject the null hypothesis. By convention, if the p value is less than 0.05, it is assumed that the null hypothesis is rejected and that therefore the two variables are related. Because the 0.05 level is chosen, the rejection of the null hypothesis is made with 95% confidence that the relationship between the two variables is not due to chance alone.

A modified version of this test is the partial correlation coefficient, which measures the strength of two variables while controlling for the

effect of a third variable. This test was used in the current study in order to control for the subject's age when height of the articular eminence was being evaluated for correlation with other variables.

3. ANOVA testing. The one-way ANOVA test was used in this study to compare dependent, numerical variables (such as angle and height of the eminence) with independent, categorical variables (such as presence or absence of incisor contact on study models). The ANOVA tests the null hypothesis that there is no difference among the means of the groups in question. The formulas used in calculating the ANOVA test are as follows:

$$F = \frac{\text{Between groups mean square}}{\text{Within groups mean square}}$$

$$\text{Mean square} = \frac{\text{sum of squares}}{\text{degrees of freedom}}$$

$$\text{Sum of Squares} = \sum_{i=1}^{k} N_i (\bar{H}_i - \bar{H})^2$$

where:

$\bar{H}_i$ = mean of measurement in subgroup

$\bar{H}$ = mean of measurement in total group

N_i = sample size of subgroup

The p value derived from the F distribution is then used to determine whether or not to reject the null hypothesis. By convention, if the p value is less than 0.05, it is assumed that the null hypothesis is rejected and that therefore the two means are significantly different. Because the 0.05 level is chosen, the rejection of the null hypothesis is made with 95%

confidence that the difference between the two means is not due to chance alone.

4. Chi-square. The Pearson Chi-square test was used in this study in order to evaluate the relationship between categorical variables. The null hypothesis is that the variables in question are independent of each other. In this study, only 2 X 2 tables were used as only 2 variables were being compared at any one time. A sample 2 X 2 table and the formulae used to compute the Chi-square statistic are as follows:

2 X2 Chi-square table:

	1	2	
1	O_{11} E_{11}	O_{12} E_{12}	$Y_{1\cdot}$
2	O_{21} E_{21}	O_{22} E_{22}	$Y_{2\cdot}$
	$Y_{\cdot 1}$	$Y_{\cdot 2}$	$Y_{\cdot\cdot}$

$$X^2 = \sum_{i=1}^{2}\sum_{j=1}^{2} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$ where O_{ij}= observed values and E_{ij}= expected values

$$E_{ij} = (Y_{i\cdot})(Y_{\cdot j})/Y_{\cdot\cdot}$$ ($Y_{\cdot\cdot}$= total # of observations)

The p value derived from the Chi-square distribution is then used to determine whether or not to reject the null hypothesis. By convention, if the p value is less than 0.05, it is assumed that the null hypothesis is rejected and that therefore the two variables are independent of eachother. In hope of improving the approximation in the case of a 2 X 2 table where any cell's observed value is less than 5, Yate's correction for

continuity is often applied. Yate's correction involves subtracting 0.5 from positive differences between observed and expected frequencies and adding 0.5 to negative frequencies before squaring.

RESULTS

The results of this study will be presented in 6 sections:

1. Descriptive statistics regarding articular eminence morphology and characteristics of the sample population.
2. Comparisons between eminence morphology and dentofacial morphology as reflected by cephalometric measurements.
3. Comparisons between eminence morphology and dentofacial morphology as reflected by dental study casts.
4. Comparisons between joint functional charasticstics and clinical exam data.
5. A comparison between joint functional characteristics and eminence morphology.
6. Error Study

Articular eminence morphological characteristics

A description of the sample population is provided in figure III and table I. Descriptive statistics for the angle and height of the articular eminence are presented in table II for the entire sample as a whole. T-tests were computed relating the angle and height of the articular eminence to the subject's sex, the results of which are presented in tables III and IV. These results indicate that no significant differences of means were found between female and male in either angle ($t(df=48)=-1.66$, $p>.10$) or height ($t(df=48)=-1.13$, $p>.26$).

Figure III
Age distribution

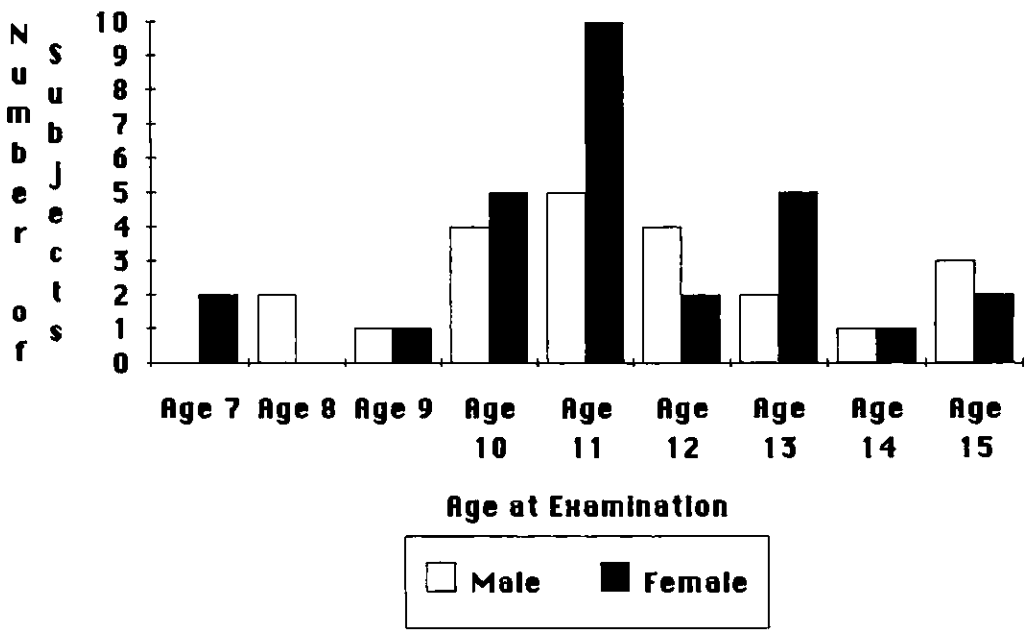


Table I
Sample description

Sample size	Males	Females
N= 50	N=22	N=28
Age Range	Age mean	Age std. dev.
6 yrs. 11 mos.- 15 yrs. 5 mos.	11.62 years	2.01 years

Table II
Descriptive statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Angle	45.01	4.77	35.05	56.75
Height	5.83	0.89	3.75	7.75

Table III
Angle of eminence vs. sex

Variable	Mean	Std. Dev.	Std. Error
Male N=22	43.772	4.992	1.064
Female N=28	45.986	4.434	0.838

t Value	df	p value
-1.66	48	.104

Table IV
Height of eminence vs. sex

Variable	Mean	Std. Dev.	Std. Error
Male N=22	5.671	1.056	.225
Female N=28	5.994	0.720	.136

t Value	df	p value
-1.13	48	.263

T-tests were also computed relating the angle and height of the eminence to the subject's race, the results of which are presented in tables V and VI. These results indicate that no significant differences exist between means of the African-American and Caucasian groups for either angle of the eminence (t(df=48)=-.86, p>.39) or height of the eminence (t(df=48)=-.16, p>.87).

Table V
Angle of eminence vs. race

Variable	Mean	Std. Dev.	Std. Error
White N=42	44.757	4.912	.758
Black N=8	46.350	3.932	1.390

t Value	df	p value
-.86	48	.392

Table VI
Height of eminence vs. race

Variable	Mean	Std. Dev.	Std. Error
White N=42	5.821	.899	.139
Black N=8	5.875	.866	.306

t Value	df	p value
-.16	48	.877

In order to evaluate the relationship between chronological age and the angle and height of the articular eminence, Pearson product moment correlation coefficients were computed. The results are summarized in table VII. These results indicate that age and angle of the articular eminence are not correlated ($r=-.19$, $p>.18$). However, age and height of the eminence are positively correlated (corr. coeff.$=.39$, $p<.01$). Therefore age was used as a covariant in subsequent analyses.

Table VII
Eminence morphology vs. age

Variable	Mean	Std. Dev.
Angle	45.012	4.769
Height	5.830	.8853
Age	11.620	2.012

Variable	Corr.Coeff.	p value
Angle	.1914	.183
Height	.3876	.005**

**=significant ($p \leq .01$)

Articular eminence morphology vs. dentofacial morphology- Cephalometric measurements

The mean and standard deviation of each of the cephalometric parameters previously described is presented in table VIII. The relationship of the angle of the articular eminence as compared to these lateral cephalometric measurements was evaluated by computing an individual correlation coefficient for each of these parameters. The only exception to this statistical treatment was the evaluation of interincisal angle, which was evaluated three separate times: once for the entire

sample, once for only those subjects with incisal contact, and once for those subjects without incisal contact. The results are summarized in table VIII. These results indicate that the only cephalometric measurement with statistical correlation to the angle of the eminence in this study is the angle between Frankfort horizontal plane and mandibular plane (gonion-menton). The two variables show negative correlation (r=-.299, p=.035).

Because height of the eminence and age are statistically correlated, partial correlation coefficients controlling for age were computed to examine the relationship between eminence height and cephalometric measurements. The results are summarized in table VIII. Essentially, there was no statistical correlation between the height of the articular eminence and the measurements from the lateral cephalometric x-ray, after controlling for the effectof age. Correlation coefficients between the height of the eminence and cephalometric measurements before age correction are seen in table VIII.

Table VIII - Data Summary

Measure	Mean	Standard Deviation	r : Angle of eminence	r : Height of eminence	r : Height of eminence- age corrected	Reliability (digitizing)	Reliability (tracing)
Ba-Na-Gn	94.55	6.48	-.0522	.1861	-.0935	.9966	.9785
Na-Me	113.87	7.24	-.2234	.0905	-.1749	.9988	.9422
S-Na	70.40	3.81	.0505	.2199	.1148	.9932	.9378
BaNa-PNS	23.79	2.95	-.0571	.2763	.1111	.9922	.7997
Na-ANS	50.24	4.35	-.1400	.1586	-.0077	.9986	.7715
ANS-Me	66.95	5.54	-.2115	-.0171	-.1866	.9976	.9034
SNA	82.98	3.47	-.0292	.1546	.1272	.9828	.8421
SNB	77.50	3.48	.1314	.1387	.0673	.9886	.7656
ANB	5.47	2.09	-.2715	.0215	.0950	.9922	.9314
PalPl:FH	5.43	2.96	-.0459	-.0818	-.0731	.9962	.7416
Go-PNS	38.78	3.51	.0311	.2359	.0465	.9914	.5896
Ar-B	93.70	6.32	.0857	.2497	.0367	.9954	.9662
Ar-Pog	101.31	6.52	.0638	.2596	.0165	.9970	.9801
S-N:GoMe	35.60	4.80	-.2250	-.2129	-.1729	.9914	.8834
FH:GoMe	24.80	3.64	*-.2290	-.2120	-.1750	.9692	.8211
Ar-Go	42.61	4.07	.0945	.2006	-.0154	.9978	.6146
Go-Gn	72.56	5.36	.0983	*.3130	.1182	.9950	.8244
ArGo:GoGn	126.53	4.90	-.2114	-.2557	-.1999	.9944	.7880
L1:GoMe	89.25	10.01	-.0465	**-.3727	-.2648	.9743	.7027
U1:FH	114.23	8.12	-.0254	.0376	-.0192	.9980	.9549
OP:FH	-7.09	3.39	.2134	*.2881	.1199	.9615	.8785
Go-Pog	72.27	5.26	.0948	*.3250	.1388	.9970	.8003
Intinc (all)	127.05	12.39	-.0555	-.1775	-.1161	.9980	.7027
Intinc (c+)	127.80	14.48	-.4126	-.2706	-.2326	NA	NA
Intinc (c-)	126.69	11.48	.1659	-.1175	-.0519	NA	NA

*=p≤.05
**=p≤.01

Frontal cephalograms would provide additional information in a morphological study of this nature. Unfortunately, few of the subjects in the study had a frontal cephalogram exposed as part of initial orthodontic records, therefore no analysis was possible.

Articular eminence morphology vs. dentofacial morphology- dental cast measurements

In comparing the angle of the eminence to the data from the dental casts, a one-way analysis of variance test was utilized. The results are summarized in table IX. No significant differences of means of eminence angle were found among the groups with and without incisal contact ($F=3.95$, $p>.05$), among the groups with and without transverse arch discrepancy ($F=1.0$, $p>.32$), or among the three different groups classified according to posterior tooth cusp morphology ($F=.11$, $p>.89$).

In comparing the height of the eminence to the dental casts, one way analysis of variance testing was utilized with chronological age as a covariate in the analysis. The results are summarized in table IX. No significant differences of means of eminence height were found between the groups with and without incisal contact ($F=.92$, $p>0.340$), between the groups with and without transverse arch discrepancy ($F=.31$, $p>0.58$), or among the three different groups classified according to posterior tooth cusp morphology ($F=.05$, $p>0.95$).

Table IX
Eminence morphology vs. cast measurements

Variable	Angle of eminence F ratio (p value)	Height of eminence F ratio (p value)
Incisor Contact	3.948 (.053)	.917 (.343)
Transverse discrepancy	.995 (.324)	.306 (.583)
Posterior cusp Morphology	.113 (.893)	.046 (.95)

Joint function vs. clinical exam data

Only one joint in the sample produced tracings characteristic of internal derangement; therefore no analyses regarding this trait can be performed. This subject had an eminence angle of 42.28 degrees and an eminence height of 7.0 millimeters.

Ten subjects exhibited tracings characteristic of condylar subluxation in at least one joint. The incidence of subluxation is evaluated for relationship to data from the clinical exam using the Pearson Chi-square statistical analysis. Yates' continuity correction (used to correct the Chi-square test if the value of any cell is less than 5) was applied for all three categories of clinical exam measurements. The results are summarized in tables X, XI, and XII. The presence of condylar subluxation and muscle pain are shown to be independent of each other (Yates' correction for continuity=.0065, p>.94), as are subluxation and joint pain (Yates' correction for continuity=.26, p>.60) and subluxation and joint clicking (Yates' correction for continuity=.00, p>.99).

Table X: Subluxation vs. muscle pain

Pearson Chi-square		Muscle pain	
		-	+
Subluxation	-	29	8
	+	11	2

	Value	p value
Pearson Chi-square	.2338	.62866
Yates' correction	.0065	.9357

Table XI: Subluxation vs. joint pain

Pearson Chi-square		Joint pain	
		-	+
Subluxation	-	30	7
	+	12	1

	Value	p value
Pearson Chi-square	.9021	.3422
Yates' correction	.2602	.6011

Table XII: Subluxation vs. joint clicking

Pearson Chi-square		Clicking	
		-	+
Subluxation	-	34	3
	+	12	1

	Value	p value
Pearson Chi-square	.0022	.9620
Yates' correction	.0000	1.000

Joint function vs. eminence morphology

The subjects with condylar subluxation on one side only were selected in order to examine the relationship between eminence morphology and subluxation. Out of thirteen subjects exhibiting condylar subluxation, seven subjects exhibited subluxation on one side only. For these individuals, the means of eminence angulation and height were compared between left and right sides to determine if these values influence the incidence of subluxation. The statistical analysis used was the t-test. Although the mean of both angle and height of the eminence was lower for the left joint than for the right joint, the differences were not statistically significant (angle: $t(df=6)=-1.41$, $p>.21$: height: $t(df=6)=-.19$, $p>.85$). These results are summarized in tables XIII and XIV.

Table XIII
Subluxation vs. height of eminence

Variable	Mean	Std. Dev.	Std. Error
Axiograph height left	6.143	1.069	.404
Axiograph height right	6.214	.859	.325

t Value	df	p value
-.19	6	.853

Table XIV
Subluxation vs. angle of eminence

Variable	Mean	Std. Dev.	Std. Error
Axiograph slope left	44.124	5.651	2.136
Axiograph slope right	46.862	2.469	.933

t Value	df	p value
-1.41	6	.209

Error Study

In order to evaluate the error in the digitization process, 10 of the original cephalometric tracings were redigitized and the measurements of this group were compared to the original measurements utilizing the reliability coefficient test, which is computed by squaring the correlation coefficient of the means of the two groups. In a similar fashion, the tracing error was evaluated by retracing and redigitizing the same 10 headfilms. The results are presented in table XV. The closer the reliability coefficient is to one, the more reliable the measurement. The axiographic measurements were also repeated for 10 subjects and reliability coefficients computed. The results of the cephalometric reliability testing are seen in table VIII and the results of the axiographic reliability testing are seen in table XV.

Table XVII
Reliability of Axiographic Measurements

	Slope	Height
Reliability	.7479	.9492

DISCUSSION

The discussion of results of this study will be presented in the following five sections:

1. Articular eminence morphology and its relationship to various population characteristics.
2. Relationships between eminence morphology and dentofacial morphology as determined from cephalometric measurements and data from dental study casts.
3. Relationships between joint functional characteristics, clinical exam data, and articular eminence morphology.
4. Implications in TMJ function and dysfunction
5. Implications in orthodontic therapy

Articular eminence morphology

In this study, the overall mean for the articular eminence angle was 45.01 degrees measured against the axis-orbital plane, with a range of 35.05 to 56.75 degrees. This mean is in reasonable agreement with the findings of Lundeen (1979), who reported a mean of 45 degrees utilizing the axis-orbital plane as a reference. The current findings also differ from other previous studies utilizing the same reference plane. Isaacson (1959) reported a mean inclination of 35.6 degrees, Hull (1963) reported a mean of 37 degrees, and Widman (1988) reported a mean of 52.4 degrees. Possible explanations for this discrepancy would include differences in techniques used to locate and identify landmarks, as well as actual differences in the variance of the sample populations themselves.

The results of this study show no correlation between the angle of the eminence and the subject's age. This finding is in agreement with Ricketts (1950), who noted that his laminography study failed to produce any striking correlation between age and eminence steepness. The indication of the data in the present study is that the eminence and glenoid fossa have established their overall morphologic pattern early in life. If the angle of the eminence continued to change throughout the growth period, one would expect a positive correlation between angle and age, which was not the case in the current study. The exact stage of life at which this morphogenesis is complete has been discussed in previous literature with some disagreement. Wright and Moffett (1974) reported that the articular tubercle and glenoid fossa have developed a mature appearance by age two and one half years of age, while Scott (1955) reported that the establishment of more mature contours in the temporal components coincides with the development of the primary dentition. Both authors concur on the fact that once the eminence and fossa have obtained their definitive shape, they continue to enlarge slightly as skeletal maturation progresses. At any rate, based on the present study and previous literature it is reasonable to conclude that the overall angle of the eminence is well-established by the time the permanent dentition has erupted, and that little change in angulation occurs during the remainder of the growth period.

Ingervall (1972), however, presents results indicating that the average inclination of the condylar path increases with age. This differing conclusion may be due to the fact that he used a different methodology

(namely cephalometric radiography) in studying this phenomena, and also by the fact that he used the occlusal plane as the reference from which to measure eminence inclination. Utilization of dental landmarks to construct a reference plane allows mandibular and lower facial growth to potentially influence the resulting measurements. As the ramus continues to lengthen and facial growth proceeds, the dentoalveolar complex is displaced downward and forward relative to the glenoid fossa and articular eminence. If the direction of growth is more vertical than horizontal, the change in mandibular and lower facial morphology could be reflected in the occlusal plane and the resulting eminence angle referenced to it. Therefore, it is possible that Ingervall's results might truly reflect growth changes in the lower face and mandible rather than true changesin eminence inclination.

No significant difference in eminence inclination between the sexes was uncovered during in this study. This finding concurs with Ingervall (1972), who reported the same conclusion. In addition, this study failed to find any significant difference in eminence inclination between caucasians and African-Americans. African-Americans exhibit bimaxillary dentoalveolar protrusion , with a more proclined position of both maxillary and mandibular incisors. If eminence development were related to dental development in a gnathological sense, it would be expected that African-Americans would exhibit a flatter eminence angle which would correspond with a more acute interincisal angle and flatter incisal guidance in disclusion. The fact that this is not the case in the current study contradicts the concept of any developmental connection between the

eminence and occlusal relationships. However, this conclusion should be regarded as tentative, because the number of African-Americans in the sample was small (eight out of the total sample size of fifty). Further study with a larger sample of subjects of African-American descent would be required in order to evaluate the relationship between racial variation and eminence morphology.

Another possible explanation is that the African-Americans in the current study might not have exhibited characteristic African-American dentofacial morphology, but rather posessed characteristics resembling the Caucasian subjects in the study. In other words, the lack of ethnic variation may be a product of the fact that the sample of African-American subjects in the current study are not representative of the Afeican-American population as a whole. The only way to truly evaluate racial variations would be to repeat the study with larger samples selected for facial morphology representative of the "average" morphological characteristics of the ethnic groups in question.

With regard to eminence height, the mean value in this study was found to be 5.83 millimeters, with a range of 3.75 to 7.75 millimeters. The height of the eminence showed positive statistical correlation with age, a finding in agreement with Nevkari (1960), who found a steady increase in the depth of the glenoid fossa from 6 millimeters at age 6-8 years to more than 10 millimeters at age 20-25. Other previous studies by Wright and Moffett (1974), Angel (1948), Ricketts (1950), and Oberg (1971) reported similar conclusions regarding changes in eminence height with age. The fact that the eminence continues to increase in height should come as no

surprise. As skeletal maturation continues until after puberty, it would be remarkable if the height of the eminence did not show a concurrent enlargement. No significant differences in eminence height were revealed between subjects of different sex or race in the current study.

Relationships between articular eminence and dentofacial morphology

It has been suggested by several investigators that "improper" guidance of mandibular movements by the condyles and anterior teeth may cause a variety of stomatognathic dysfunctions such as occlusal wear, periodontal breakdown, tooth trauma, and TMJ disorders (Kaplan, 1963; Stallard and Stuart, 1963). Gnathologists suggest that the existence of a mutually protected occlusion where anterior and posterior disclusive angles fit certain criteria will decrease the likelihood of these problems (McHorris, 1979; Roth, 1981; Lucia, 1983). Numerous investigators have presented studies purporting an ideal relationship between the angle of the posterior slope of the articular eminence and various measures of incisor position and guidance, with little inter-investigator agreement on exactly what constitutes this "ideal" situation. Bell and Harris (1983) reported that the angle of the eminence should be 5.6 degrees greater than the lingual surfaces of the maxillary incisors as measured against the occlusal plane. McHorris (1979) stated almost exactly the opposite; his suggestion for the ideal relationship is when anterior disclusion is greater than posterior disclusion by 5 degrees. Maglione (1989), and Huffer et al., (1972) reported similar conclusions. Kohno and Nakano (1987), reported that the ideal relationship exists when the inclination of condylar and

incisal paths is approximately equal. Although the majority of these studies have evaluated subjects deemed to possess normal occlusions according to the criteria of the investigator, the underlying implication is that the morphology of the articular eminence and dentofacial structures are somehow developmentally or structurally related. The findings in the present study do not support this assumption. The only dentofacial parameter to show any statistical correlation to the angle of the articular eminence was the angle between the mandibular plane and Frankfort horizontal plane. The two showed an inverse relationship that was significant at the 0.05 level. This finding is in agreement with Widman (1988), who also found an inverse relationship between the angle of the eminence and the inclination of the occlusal plane. Widman concludes that his results suggest that brachycephalic facial types would tend to have a more vertical eminence morphology, while the converse would be true for those with a dolichocephalic facial morphology. In the present study, however, the finding of a correlation between mandibular plane/Frankfort horizontal and the articular eminence angle is contradicted by the fact that no statistical correlation exists when the mandibular plane is measured against sella-nasion plane, although the p value of 0.07 suggests that a larger sample might show statistical significance. There are two possible explanations for this disagreement. One is that the difference may reflect variations in cranial base morphology. Any differences in cranial base morphology between subjects in the study could directly influence the value for the measurement of mandibular plane to sella-nasion plane. For example, differences in flexure between

the middle and posterior cranial fossae would alter the location of the glenoid fossa and mandible relative to sella-nasion, resulting in an alteration in mandibular plane angle as well. Also, any difference in the location of the middle cranial fossa in the vertical plane would change the absolute inclination of sella-nasion plane, again resulting in a change in the value of the angle between mandibular plane and sella-nasion.

A second possible explanation for the difference between sella nasion and Frankfort horizontal to mandibular plane measurements is that because of the number of statistical correlations made in this study the significance of Frankfort horizontal plane is spurious. In either case, if the morphology of the eminence and dentofacial morphology were biologically related, one would expect to find significant correlations between other representative parameters. In the present study this is clearly not the case. None of the remaining 22 cephalometric and 3 dental cast measurements showed any relationship to the angle of the articular eminence. In addition, the height of the articular eminence bore no significant correlation to any of the dentofacial parameters when chronological age was used as a covariant in the statistical analyses.

A covariant is defined as a variable whose value is linearly related to another variable in question in the study. Thus, the covariant must be accounted for in further analyses to determine if statistical significance is due to the variable in question with the covariant held constant. For example, in this study the value of some of the cephalometric parameters increases as the subject matures. When age is not considered, it appears as though the height of the eminence is correlated with several of the

cephalometric measurements. However, when the statistics are adjusted with regard to the subject's age, no such correlations are seen.

These findings are in agreement with Ramfjord (1966) , who suggested that any relationship between anterior and posterior disclusive pathways is negligible, and Ingervall (1972), who also found no corriation between the inclination of the condylar and incisal paths.

Several investigators have provided evidence that some of the cephalometric parameters examined in the current study vary as the individual matures. In a cephalometric study utilizing metallic implants and following twenty-one subjects for a six year period around puberty, Bjork and Skeiller (1972) reported that general trends of growth indicated that mandibular and occlusal planes both rotate forward, essentially decreasing their angular measurements to other reference planes as the subject matures. Lande (1952) reported similar findings in a serial cephalometric study. Broadbent et al.,(1975) reported that there was no indication of a change in the inclination of Frankfort horizontal as an individual develops. Analysis of the growth templates developed from this study indicates a relative rotation of sella-nasion plane downward anteriorally when compared to the cranial base, probably due to an increase in size of the frontal sinuses and relative downward displacement of nasion point. It is unlikely that these trends would influence the results of the current study, due to the fact that the sample is randomly distributed across a fairly wide age range. In addition, only the height of the articular eminence showed correlation to chronological age, and when the age effect was controlled, the height of the eminence

was not correlated with any of the other dentofacial parameters in the study.

The morphology of the articular eminence was also compared to three characteristics as determined from the subjects' dental casts: presence or absence of incisor contact, presence or absence of transverse discrepancy, and posterior tooth cusp morphology. These parameters were chosen because the dental literature suggests that they might play a role in the development of the eminence. Gnathological concepts dictate that incisal guidance should be related to condylar guidance. Therefore one would expect to see a difference in eminence morphology between a group with and a group without incisor contact. No such difference was uncovered in the present study. Also, the concepts of gnathology hold that steeper condylar guidance should exist when posterior cusp morphology is steeper in order to rapidly disclude these teeth and avoid occlusal interferences. Again, if the eminence and teeth are related developmentally, one would expect to see a difference in eminence morphology among groups selected according to the steepness of the cusp morphology. This relationship was not detected in the present study. Similarly, one might expect that a constricted dental arch would result in a developmental change in eminence form if the teeth and eminence are interrelated developmentally. There was no difference in eminence morphology between groups sorted according to this characteristic in the present study. The overall conclusion to be drawn from the study of dental cast parameters is that the teeth and the articular eminence develop independently.

Relationships between joint functional characteristics, clinical exam data, and articular eminence morphology

The incidence of condylar subluxation was compared to three clinical exam findings: (1) presence or absence of muscle pain, (2) presence or absence of joint pain, and (3) presence or absence of joint clicking. It would be of interest if any of these parameters were dependent upon each other because this information could help identify the etiology of some types of TMJ dysfunction. The findings of this study lead to the conclusion that the parameters in question are independent of each other. Therefore, the presence of condylar subluxation may be more accurately characterized as a non-pathologic variation of condylar movement. Thirteen of the fifty subjects studied exhibited subluxation and no correlation to other indicators of joint dysfunction could be established. This indicates that joint subluxation in and of itself is non-pathologic. It may, however, reflect a laxity in the supporting structures of the joint (i.e. joint capsule, ligaments) that might predispose these subjects to further joint dysfunction later in life. For example, these subjects may experience increased incidence of disc displacement if the "looseness" of the joint is permanent and not subject to change as the subject matures.

Another question that arose during this study was whether or not the height or angle of the articular eminence had any relationship to the incidence of condylar subluxation. To test this relationship, subjects with subluxation on one side were selected and the means of the angle and height of the articular eminence would be compared between the affected

and unaffected sides. Unfortunately, only seven subjects in the sample fit this criteria. The results of the statistical analysis were not significant. However, a trend existed for the subluxation to occur on the side with the flatter eminence. Further study with a larger sample is indicated. If subluxation early in life is an indication that further TMJ dysfunction will occur , then articular eminence angle may become a useful predictor of future TMJ health. This information would be of considerable interest to orthodontists, because they tend to treat a large number of teenage clinically normal patients with clinically normal TMJs. Because epidemiologic studies indicate that one-third of all orthodontic patients will develop TMJ symptoms later in life, predictions of later TMJ health or disease have considerable value.

Unfortunately, the number of subjects in the sample exhibiting characteristics of internal derangement was too small to allow any statistical analysis. Of interest, however is the fact that although only one joint exhibited tracings characteristic of joint clicking, clicking was observed in four subjects during the clinical exam. There are two possible explanations for this discrepancy. First, the subjects might have an intermittent click that was not present during the axiography. This is unlikely, due to the fact that the clinical exam and axiography were performed at the same appointment for all subjects in the study. A second possible explanation for the discrepancy is that the clicking occurred early in the opening movement, and that it was not observed during the axiography due to the fact that the mandibular clutch of the axiograph opened the subjects' vertical dimension beyond the point at

which the click occurred. This discrepancy might have been avoided by the use of a custom made functional clutch for each subject which would be constructed at the subject's occlusal vertical dimension. The drawback of such a clutch is that it allows the posterior teeth to interdigitate. It was felt by the examiner that this would complicate instruction of the subjects in the mandibular movements desired, a task already difficult in children who often lack good coordination even when the posterior teeth are discluded. For this reason, the possible loss in accuracy of the tracings was deemed an acceptable compromise in order to assure that the overall tracing quality was acceptable.

Implications in TMJ function and dysfunction

Clinical symptoms of mandibular dysfunction affect more than three-fourths of a population of young adults in the United States (Solberg et al., 1979). However, the incidence of such problems is not nearly as common in children. The present study may shed some light on this difference. As has already been discussed, the height of the articular eminence increases with age. Because the eminence is not as well-developed in children , it is possible that this morphological characteristic increases the ability of the joint to withstand traumatic insults. In a child, when the eminence has not reached its full adult height, there is a certain amount of "play" in the temporomandibular articulation. A traumatic insult could thus be spread out over a greater area since the condyle has less restriction to movement. As the eminence increases in height towards adulthood (and the glenoid fossa is effectively deepened),

the condyle is, in effect, confined to a smaller functional area, and any traumatic insult would be more focused. Of course, this is speculative, and the etiology of TMJ dysfunction is probably multifactorial. However, it does seem possible that the change in eminence height with age could play a role in the increasing incidenc of TMJ dysfunction in adulthood.

The functional significance of the human articular eminence and the increase in height of the eminence with age is not clear. Examination of skull material from other primate species reveals that some posess a well-defined articular eminence and glenoid fossa while others do not. This difference in morphology would tend to indicate that there are different functional demands on this area between species. One possible explanation is that as evolutionary trends tended towards a more upright posture, the dentofacial complex assumed a more posterior and inferior position relative to the cranial base than was present in longer snouted mammals. Correspondingly, the dominant vectors of pull of the elevator muscles during mandibular function and mastication became anterior and superior as opposed to a more vertical direction of pull in snouted mammals. Although extremely speculative, this scenario could account for the existence of the articular eminence and glenoid fossa as a functional necessity in order to keep the anterior displacement of the mandible during mastication to a minimum. Without some restriction, the mandible would be free to translate anteriorally under the effects of the elevetor muscles, and the functional efficiency of the entire masticatory system would be compromised. Similarly, the finding of an increase in eminence height with age in the current study could be explained by heavier

functional demands concomittant with an increase in muscular size and strength as the individual matures, with a deeper fossa/higher eminence required in order to achieve the same amount of control of mandibular position during mastication.

Implications in orthodontic therapy

As discussed above, the results of this study and previous literature indicate that the overall angle of the articular eminence is well-established early in life, at least by the time the permanent dentition erupts. Further change in eminence morphology seems to be limited to general enlargement only. In this author's opinion, the functional relationship referred to in gnathological concepts as posterior disclusion is also established at this early age. Condylar guidance or posterior disclusion is determined by the angle of the eminence because the posterior teeth usually disclude in the first few millimeters of mandibular movement. This is long before the condyle has reached the height of the eminence. Therefore, it seems reasonable to assume that the pattern of mandibular movement (as guided by the articular eminence) matures concurrently with the eminence. This occurs prior to the eruption of the permanent dentition and maturation of the dentofacial complex. If (as gnathological concepts indicate) the eminence and dentofacial structures are developmentally related, one would expect the permanent dentition to erupt into positions that would complement eminence function and that facial development would also follow accordingly. The resulting occlusion and facial morphology would be intimately "matched" to the eminence,

and different eminence morphologies should result in characteristic dentofacial morphologies. This scenario does not exist in the current study. Therefore, the results of this study strongly suggest that no developmental relationship exists between the articular eminence and the dentofacial complex. However, the sample in the current study consisted entirely of subjects with malocclusion, both skeletal and dental in nature. By definition, these children and adolescents display facial growth and occlusal development that is far from ideal; it is for exactly this reason that they presented seeking orthodontic treatment in the first place. Thus, the results of this study do not preclude harmony between anterior and posterior disclusion as a treatment goal in orthodontics. Fortunately, most orthodontic therapy takes place after the age of six or seven years. If harmony between condylar and incisal guidance is a treatment goal, at least the results of this study indicate that the angle of the eminence is no longer changing by this age.

The question that arises in evaluating the results under discussion is whether or not these results would be any different if the sample population consisted of a group of adolescents that would be considered to have an ideal, normal occlusion and facial profile. Current thinking in orthodontics dictates that "normal" occlusion exists when the posterior teeth exhibit good interdigitation and the anterior teeth are in contact when the patient closes into maximum intercuspation with overjet and overbite measuring approximately two millimeters. Functionally, a "normal" occlusion is one free of interferences to various movements during function while providing the contacts necessary for mastication. A

"normal" facial profile would be considered to be an esthetically pleasing face in which there is skeletal balance between the maxilla and mandible and the rest of the facial structures, with no one facial component overly protrusive or retrusive. Selecting a sample based on these criteria could result in a group of subjects with similar craniofacial characteristics in general, and relationships within the group would not be applicable to a population not pre-selected in the same manner. This teleological type of experimental design necessarily produces positive correlations.

Another finding of this study that has potentially important implications to the practice of orthodontics is the relationship between the angle of the articular eminence and mandibular plane angle. It is a commonly held belief among orthodontists that patients with low mandibular plane angle should be finished with increased torque in upper and lower incisors. This results in a more acute interincisal angle and flatter incisal guidance. The finding in the current investigation of an inverse correlation between eminence angle and mandibular plane angle leads one to the exactly opposite conclusion. If reasonable agreement between anterior and posterior disclusion is a goal of orthodontic treatment, then low angle, brachycephalic individuals (with correspondingly steeper eminence angle) should actually be finished with <u>less</u> incisor torque. This would result in a more obtuse interincisal angle and steeper incisal guidance. The converse situation would apply to dolichocephalic individuals with their characteristic higher mandibular plane angle.

A final noteworthy point involves the actual values of eminence inclination of subjects in the study. In this author's opinion, it is important to emphasize that the data shows considerable variation in the angle of the articular eminence among the sample population (mean=45.01 degrees, range=35.05 to 56.75 degrees). These findings underscore the need to treat each orthodontic patient as an individual. They indicate that treating all patients to standardized, normal cephalometric values is probably not in the best interest of the patient. Rather, decisions on how to finish a patient's occlusion should be multifactorial, based upon the complex interplay between esthetics, morphology, and function.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to examine the relationship, if any, that exists between the morphology of the articular eminence of the temporal bone and the morphology of the dentofacial complex. Fifty children and adolescents presenting for orthodontic treatment were studied. The following sets of data were gathered on each subject: (1) axiographic tracings of mandibular border movements, (2) lateral cephalometric radiograph, (3) dental study casts, and (4) clinical examination data. The angle and height of the articular eminence were compared to the cephalometric and dental cast data to evaluate morphological tendencies, and to the clinical exam data to compare eminence morphology to functional characteristics of the TMJ. The results of this present study may be summarized as follows:

Regarding children and adolescents with developing malocclusions:

1. The angle of the posterior slope of the articular eminence of the temporal bone is not related to age or gender.

2. The height of the articular eminence is not related to gender, but shows positive correlation with chronological age.

3. Mandibular plane angle was inversely correlated with the angle of the articular eminence.

4. The incidence of condylar subluxation is independent of the presence or absence of pain upon palpation in the muscles of mastication , pain upon palpation of the TMJ, and TMJ clicking.

5. The incidence of condylar subluxation may be related to the height and angle of the articular eminence. Further study with a larger sample is indicated.

The results of this study indicate that the articular eminence and dentofacial complex are independent of each other developmentally. This study utilized a random sample of subjects with malocclusion seeking orthodontic treatment. This distinguishes this study from previous gnathological studies where the sample was selected based on outcome criteria. Outcome biased experimental designs necessarily produce positive correlations.

Axiography is a valuable research tool to examine longitudinal changes in TMJ function. Further application of this methodology to the areas of growth and development is clearly indicated. Options for further axiographic study of the TMJ would include: (1) examining the relationships between head form and joint morphology and (2) a prospective longitudinal study on condylar subluxation. The relationship between eminence morphology and subluxation needs to be examined. The presence of unilateral or bilateral subluxation as an indicator of future TMJ health could also be studied with a prospective longitudinal experimental design.

APPENDIX I
MASTER PATIENT LIST

Nb	last	first	m/f	Origin	Birthdate	Exam date
103	Reagan	M	m	Case	6/7/81	12/13/89
104	Bostwick	R	f	c	2/15/81	12/6/89
105	Cohen	R	m	c	9/1/78	11/10/89
109	Hobe	A	f	c	5/27/79	11/16/89
112	Wisolki	B	f	c	7/24/79	11/28/89
113	Cunningham	C	m	c	8/14/77	9/7/89
117	Clepluch	K	f	c	4/21/82	11/21/89
118	Minich	L	f	Hans	12/12/78	2/26/90
119	Bostwick	E	f	c	1/18/78	12/6/89
120	Hutchinson	B	m	c	9/11/79	11/30/89
122	Isler	A	f	c	12/1/77	2/9/89
135	Glowe	A	f	c	9/18/78	11/22/89
136	Burke	D.	m	c	11/24/78	12/14/89
139	Wiersma	J.	f	c	6/2/76	10/6/89
142	Reagan	B.	f	c	12/20/79	12/13/89
145	Rodriguez	R.	m	c	10/26/74	11/8/89
151	Legg	K.	f	h	9/25/79	4/27/90
152	Smith	J.	m	h	12/26/76	4/27/90
153	Price	K.	f	h	10/10/75	3/23/90
155	Timko	T.	f	h	5/28/79	3/23/90
156	Lewis	H.	f	c	8/23/78	8/22/90
159	Dixon	D.	f	c	6/1/79	5/30/90
169	Ouversloot	J.	m	c	2/16/75	5/2/90
170	Morris	T.	m	c	8/11/79	7/10/90
171	Dotson	M	m	c	4/25/80	6/22/90
172	Croston	S.	f	c	9/11/75	6/19/90
174	Sechler	S.	m	c	3/15/80	9/18/90
176	Stouffer	M.	m	c	9/24/76	9/11/90
177	Traylor	J.	m	c	3/21/79	1/1/91
178	Korte	J.	f	c	8/5/81	1/17/91
179	Batts	C.	f	c	11/15/80	1/16/91
180	Shaw	L.	m	c	12/26/79	11/9/90
181	Murton	E.	f	h	7/30/79	1/11/91
182	Baugher	M.	f	h	2/15/83	1/11/91
183	Bosch	E.	f	h	9/21/79	1/10/91
184	Chinavong	J.	f	h	3/6/80	1/10/91
185	Rosboril	C.	f	c	8/13/77	1/22/91
186	Williams	D	m	c	8/19/77	1/30/91

187	Patterson	D	m	c	8/10/75	1/30/91
188	Puening	E	m	h	12/19/79	2/2/91
189	Kreuzer	S	f	h	12/15/77	2/2/91
190	Mantz	M	m	h	6/30/82	2/2/91
191	Hudak	D	f	c	10/23/77	2/6/91
192	O'Braza	A	m	c	4/3/79	2/6/91
193	Fletcher	R	m	c	8/19/78	2/13/91
194	Norek	C	f	c	3/23/78	2/13/91
195	Sherman	L	f	c	10/3/78	2/13/91
196	Barvincak	K	f	c	1/1/80	2/20/91
197	Ohirogge	D	m	c	9/28/80	2/27/91
198	Alexander	T	f	c	12/14/79	2/28/91

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AJO ABSTRACT

Comparison Between Dentofacial and Temporomandibular Joint Morphology-Children and Adolescents. D. KRUSE. Case Western Reserve University, Cleveland, Ohio.

Previous studies have reported that the morphology of the articular eminence of the temporal bone is related to various dental and skeletal parameters as well as chronological age in populations selected with "normal" occlusions. The purpose of this study was to determine if any such relationship exists in a sample of children and adolescents with developing malocclusions.

Fifty patients, 10 to 16 years of age, from Case Western Reserve University's Orthodontic clinic were randomly selected for study. Dental study models and a lateral cephalogram were obtained for each subject as part of routine orthodontic records. In addition, axiographic tracings of condylar movements were recorded and a measurement of the height and angle of the posterior slope of the articular eminence derived. These parameters were statistically compared to population characteristics and representative cephalometric and dental cast measurements. The findings of this study demonstrate that the angle of the posterior slope of the articular eminence is not related to age or gender. The height of the eminence is not related to gender, but is positively correlated with the subject's age ($r=.388$, $p<.01$). Of the 62 comparisons between eminence morphology and the cephalometric and dental cast parameters studied, only mandibular plane angle was weakly correlated with the angle of the posterior slope of the eminence ($r=-.229$). These results indicate that morphology of the temporomandibular joint is not related to facial morphology or occlusion of the teeth.

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AJO PUBLICATION

ABSTRACT

The purpose of this study was to determine if a relationship exists between the morphology of the articular eminence of the temporal bone and various dental, skeletal, and population characteristics in a sample of children and adolescents with developing malocclusions. Fifty patients, 10 to 16 years of age, from Case Western Reserve University's Orthodontic clinic were randomly selected for study. Dental study models and a lateral cephalogram were obtained for each subject as part of routine orthodontic records. In addition, axiographic tracings of condylar movements were recorded and a measurement of the height and angle of the posterior slope of the articular eminence derived. These parameters were statistically compared to population characteristics and representative cephalometric and dental cast measurements. The findings of this study demonstrate that the angle of the posterior slope of the articular eminence is not related to age or gender. The height of the eminence is not related to gender, but is positively correlated with the subject's age ($r=.388$, $p<.01$). Of the 62 comparisons between eminence morphology and the cephalometric and dental cast parameters studied, only mandibular plane angle was weakly correlated with the angle of the posterior slope of the eminence ($r=-.229$, $P<.035$). These results indicate that morphology of the temporomandibular joint is not related to facial morphology or occlusion of the teeth.

INTRODUCTION

Previous studies have reported that the morphology of the articular eminence of the temporal bone is related to various dentofacial and population characteristics.[1-5] The most notable area of focus in these investigations has been an attempt to delineate a relationship between anterior disclusion (incisor positions) and posterior disclusion (condylar path down the articular eminence). These studies commonly conclude by reporting the "ideal" relationship uncovered, implying a developmental connection between the teeth and face and the TMJ components in question. However, the population samples in these investigations were selected for having met the authors' criteria of normal occlusion.

This study was designed to evaluate the relationship between articular eminence and dentofacial morphology in a randomly selected sample of children and adolescents with developing malocclusions. In addition, the relationship of eminence morphology to age, gender, and race was also examined.

MATERIALS AND METHODS

The sample population consisted of fifty children and adolescents presenting for orthodontic treatment, age 7 years 7 months to 15 years 5 months. The mean age was 11 years 4 months. Twenty-three of the subjects were females and twenty-seven were males. Racially, the population consisted of forty-two Caucasians and 8 individuals of African-American descent.

Dental casts and a lateral cephalometric radiograph were obtained for each subject in conjunction with routine orthodontic pre-treatment records. From these, the following data was collected:

A. Cast Data

1. Presence or absence of incisor contact.
2. Presence or absence of transverse discrepancy (buccal crossbite tendency).
3. Posterior cusp/fossa morphology: mandibular first molars subjectively evaluated and classified as flat, moderate, or steep.

B. Lateral Cephalometric Measurements

1. Facial proportions
    a. Basion-nasion plane to gnathion (mm)
    b. Nasion to menton (mm)
    c. Basion-nasion plane to posterior nasal spine (mm)
    d. Nasion to anterior nasal spine (mm)
    e. Anterior nasal spine to menton (mm)

2. Cranial base length
    a. Sella to nasion (mm)

3. Maxillary and mandibular positions
    a. Sella-nasion-A point (degrees)
    b. Sella-nasion-B point (degrees)
    c. A point-nasion-B point (degrees)
    d. Sella-nasion plane to mandibular plane (degrees)
    e. Frankfort horizontal plane to mandibular plane (degrees)

4. Mandibular morphology
    a. Gonion to posterior nasal spine (mm)
    b. Articulare to B point (mm)
    c. Articulare to pogonion (mm)
    d. Gonion to pogonion (mm)
    e. Articulare to gonion (mm)
    f. Gonion to gnathion (mm)
    g. Articulare-gonion plane to gonion-gnathion plane (degrees)

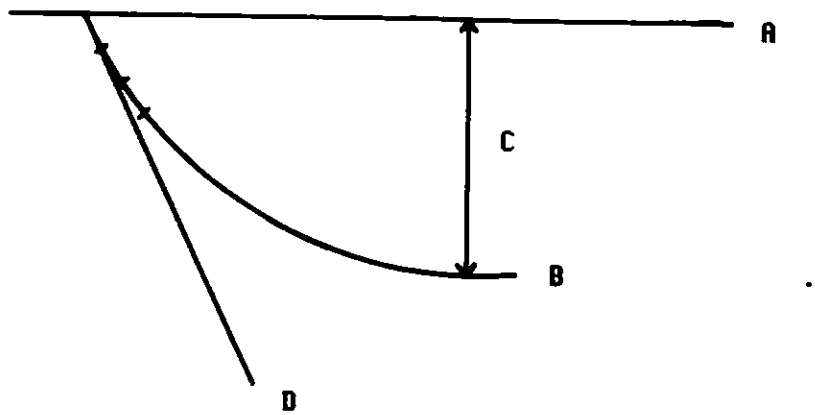
5. Incisor relationships
    a. Interincisal angle (degrees)
    b. Mandibular incisor to mandibular plane (degrees)
    c. Maxillary incisor to Frankfort horizontal plane (degrees)

6. Occlusal and palatal plane inclination
    a. Frankfort horizontal plane to functional occlusal plane (degrees)
    b. Palatal plane to Frankfort horizontal plane (degrees)

In addition, axiographic tracings of both joints were recorded for each subject. Utilizing the axis-orbital plane as a reference, the slope of the first 3 millimeters of the protrusive tracing was measured and an average for both joints computed. An estimate of the height of the eminence was determined by measuring the from the lowest point on the protrusive tracing to the axis-orbital pland perpindicularly, and an average of both joints computed (see figure I). The following statistical comparisons were made:

1. Articular eminence morphology vs. gender utilizing t-test statistical analysis
2. Articular eminence morphology vs. age utilizing correlation coefficient analysis
3. Articular eminence morphology vs. race utilizing t-test statistical analysis
4. Articular eminence morphology vs. dentofacial morphology as determined cephalometrically utilizing correlation coefficient analysis
5. Articular eminence morphology vs. dentofacial morphology as determined from dental casts utilizing one-way analysis of variance testing

Figure I Axiographic measurements



RESULTS

The overall values for height and angle of the articular eminence as determined from the axiographic tracings are presented in table I.

Table I

Variable	Mean	Std. Dev.	Minimum	Maximum
Angle	45.01	4.77	35.05	56.75
Height	5.83	0.89	3.75	7.75

No significant mean differences were found between groups separated according to gender in angle ($t=-1.66$, $p>.104$) or height ($t=-1.13$, $p>.263$) of the articular eminence. No interracial differences in mean of angle ($t=-.86$, $p>.39$) or height ($t=-.16$, $p>.87$) of the eminence were revealed.

The results also indicated no correlation between the subjects' age and the angle of the articular eminence ($r=-.19$, $p>.18$). However, chronological age and the height of the articular eminence were positively correlated ($r=.39$, $p<.01$). Therefore, age was considered as a covariant in other statistical comparisons involving the height of the eminence.

Cephalometrically, the only statistically significant finding with regard to the angle of the articular eminence was a weak inverse correlation with mandibular plane angle ($r=-.229$, $p<.035$). No significant correlations were uncovered in comparing the cephalometric measurements to the height of the articular eminence (see table II).

In comparing the angle and height of the articular eminence to the dental cast parameters, one-way analysis of variance testing was utilized. No significant differences of means of eminence angle were found among the groups with and without incisal contact ($F=3.95$, $p>.05$), among the groups with and without transverse arch discrepancy ($F=1.0$, $p>.32$), or among the three different groups classified according to posterior tooth cusp morphology ($F=.11$,

p>.89). No significant differences of means of eminence height were found between the groups with and without incisal contact (F=.92, p>0.340), between the groups with and without transverse arch discrepancy (F=.31, p>0.58), and among the three different groups classified according to posterior tooth cusp morphology (F=.05, p>0.95) (see table III).

Table II - Data Summary

Measure	Mean	Standard Deviation	r : Angle of eminence	r : Height of eminence	r : Height of eminence- age corrected	Reliability (digitizing)	Reliability (tracing)
Ba-Na-Gn	94.55	6.48	-.0522	.1861	-.0935	.9966	.9785
Na-Me	113.87	7.24	-.2234	.0905	-.1749	.9988	.9422
S-Na	70.40	3.81	.0505	.2199	.1148	.9932	.9378
BaNa-PNS	23.79	2.95	-.0571	.2763	.1111	.9922	.7997
Na-ANS	50.24	4.35	-.1400	.1586	-.0077	.9986	.7715
ANS-Me	66.95	5.54	-.2115	-.0171	-.1866	.9976	.9034
SNA	82.98	3.47	-.0292	.1546	.1272	.9828	.8421
SNB	77.50	3.48	.1314	.1387	.0673	.9886	.7656
ANB	5.47	2.09	-.2715	.0215	.0950	.9922	.9314
PalPl:FH	5.43	2.96	-.0459	-.0818	-.0731	.9962	.7416
Go-PNS	38.78	3.51	.0311	.2359	.0465	.9914	.5896
Ar-B	93.70	6.32	.0857	.2497	.0367	.9954	.9662
Ar-Pog	101.31	6.52	.0638	.2596	.0165	.9970	.9801
S-N:GoMe	35.60	4.80	-.2250	-.2129	-.1729	.9914	.8834
FH:GoMe	24.80	3.64	*-.2290	-.2120	-.1750	.9692	.8211
Ar-Go	42.61	4.07	.0945	.2006	-.0154	.9978	.6146
Go-Gn	72.56	5.36	.0983	*.3130	.1182	.9950	.8244
ArGo:GoGn	126.53	4.90	-.2114	-.2557	-.1999	.9944	.7880
L1:GoMe	89.25	10.01	-.0465	**-.3727	-.2648	.9743	.7027
U1:FH	114.23	8.12	-.0254	.0376	-.0192	.9980	.9549
OP:FH	-7.09	3.39	.2134	*.2881	.1199	.9615	.8785
Go-Pog	72.27	5.26	.0948	*.3250	.1388	.9970	.8003
Intinc (all)	127.05	12.39	-.0555	-.1775	-.1161	.9980	.7027
Intinc (c+)	127.80	14.48	-.4126	-.2706	-.2326	NA	NA
Intinc (c-)	126.69	11.48	.1659	-.1175	-.0519	NA	NA

*=$p \leq .05$
**=$p \leq .01$

Table III
Eminence morphology vs. cast measurements

Variable	Angle of eminence F ratio (p value)	Height of eminence F ratio (p value)
Incisor Contact	3.948 (.053)	.917 (.343)
Transverse discrepancy	.995 (.324)	.306 (.583)
Posterior cusp Morphology	.113 (.893)	.046 (.95)

DISCUSSION

In contrast to previous studies, the current study failed to elucidate any significant relationship between the morphology of the articular eminence and that of the face and teeth. Of the 62 comparisons between eminence morphology and the cephalometric and dental cast parameters studied, only mandibular plane angle was weakly correlated with the angle of the posterior slope of the eminence ($r=-.229$, $P<.035$). These results indicate that morphology of the temporomandibular joint is not related to facial morphology or occlusion of the teeth.

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