A COMPARISON OF MAXILLARY ARCH FORM
BETWEEN GROUPS OF CEREBRAL PALSYED
AND NORMAL CHILDREN

by

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INTRODUCTION
In spite of a significant amount of attention to arch form in the dental and anthropometric literature, the basic problem of describing arch form still remains. There are the obvious pitfalls of subjective analysis in evaluating arch form according to conformity to geometric figures, e.g. ovoid, hyperbolic, or V-shaped. Although such terms are adequately descriptive, communication between investigators is hampered by individual variability in relating arch conformity to a geometric model. On the other hand, evaluation of arch form by means of measurement, although it is accurate, reproducible, and objective, cannot accurately describe individual variability.

Another problem in studying arch form is associated with clinical relationships. For instance, the complex relationship between arch form and muscle function is not well understood. Lear appropriately summarizes the status of research into this area.

It is obviously difficult to make meaningful inferences about the interaction between form and function when only selected functions are examined and the remainder of the physiologic spectrum of activity is overlooked.
Arch form has been used by many investigators as a diagnostic tool. Shapiro and Gorlin list ten congenital anomalies that demonstrate a consistent finding of a high palatal vault. Habits, heredity, and growth and development are other areas of clinical significance relevant to arch form.

The general objective of this study is to substantiate or invalidate the contention that a higher incidence of a particular maxillary arch form could be expected to exist in a sample of cerebral palsied children than in a normal sample. Theoretically, a particular type of maxillary arch expressed in the dimensions of arch and vault form might reflect several etiological factors. Noteworthy in the case of the cerebral palsied individual is the influence of varied aberrant patterns in the oral-facial musculature.

Within the limits of this study an effort will be made to determine whether maxillary dental arch form and palatal vault form may serve as consistent dental parameters of the cerebral palsy syndrome.

The specific objectives of this study are as follows:

1) To describe maxillary dental arch form by means of a numerical index computed from a length to width ratio.

2) To describe palatal vault form by means of the
angle of divergence of the palatal walls and by the actual depth of the palatal vault, both at the same reference point anterior-posteriorly.

3) To compare the maxillary dental arch form and palatal vault form of the cerebral palsied children with the normal children in their respective stages of tooth eruption. The cerebral palsied subjects will be divided into regional and descriptive classifications for comparison with the normal group and with each other.

4) To examine in both cerebral palsied and control groups the coincidence of maxillary dental arch form and palatal vault form with the occlusal discrepancies such as: unilateral posterior crossbite, bilateral posterior crossbite, anterior crossbite, and anterior open bite.

5) To establish the dental symmetry of the posterior reference points with respect to midpalatal raphe, all in the same anterior posterior plane and compare in both cerebral palsied and normal groups.
REVIEW OF THE LITERATURE
Cerebral Palsy

Definition

The clinical manifestations of cerebral palsy were first described by Little\textsuperscript{3} in 1861. A cross-legged gait, drooling, grimacing, and feeble-mindedness characterized the condition which he termed spastic rigidity.

Perlstein\textsuperscript{4} defined cerebral palsy as a condition characterized by paralysis, paresis, incoordination, dyskinesia, or any other aberration of the motor function due to the involvement of the motor centers of the brain. She further stated that many other defects may coexist as a result of the brain involvement, such as reduced intelligence, deficient personality, diminished sensation, epileptic diathesis, physical deformities, and social retardation.

The American Academy for Cerebral Palsy in 1956 defined the clinical entity as any abnormal alteration of movement or motor function arising from defect, injury, or disease to the nervous tissue contained in the cranial cavity.\textsuperscript{5}

Denhoff\textsuperscript{6} offered the most inclusive definition of cerebral palsy, which was based primarily on that of Perlstein.
He considered cerebral palsy one of several clinical syndromes which reflect cerebral dysfunction and whose distinguishing feature is abnormal motor function. Kaufman reinforced this concept in emphasizing that cerebral palsy should be considered as a syndrome with consistently occurring features rather than a distinct pathological entity. These two final concepts are fundamental in gaining insight into the individual who is afflicted with cerebral palsy.

Epidemiology

Accurate data concerning the current status of cerebral palsy in the United States and other parts of the world are scarce. Those studies that have been done demonstrate a high degree of inconsistency in their findings so as to make vast generalizations quite meaningless. The incidence ratio that is most accepted by investigators in the area of cerebral palsy has been seven afflicted individuals in one hundred thousand in the United States.\(^5,8\)

Cardwell\(^5\) in her text noted several epidemiological features of the cerebral palsy syndrome in the United States. She found that 22 to 30 per cent of the afflicted children in her investigation were born prematurely. She also found a higher incidence of cerebral palsy in the Caucasian race, with boys being afflicted with greater frequency than girls.
Classification

Classification of the various elements of the cerebral palsy syndrome is vital for communication between diagnosticians, therapists, and researchers. Unfortunately, no one of these elements alone provides a complete descriptive profile for an afflicted individual. In fact, in many instances, a multitude of descriptive criteria still leaves much to be desired in providing insight into the specific needs of such a person.

Perlstein comprehensively reviewed the criteria for classifying the elements of the cerebral palsy syndrome. This classification remains the basic descriptive tool of all professionals who deal with cerebral palsy. As the etiology, severity, and degree of involvement are included in her work, they will be dealt with in this section rather than separately.

I. Classification According to Anatomic Site of Brain Lesion

A. Pyramidal Tract Involvement - normal inhibitory effects are thwarted resulting in clinical spasticity.

B. Extrapyramidal Tract Involvement - involves the basic nuclear area and results in motion abnormality, e.g. athetosis, tremors, rigidities, etc.

C. Cerebellum Involvement - results in loss of balance and equilibrium, e.g. ataxic and atonicity.
II. Classification According to Clinical Symptoms

A. Spastic - abnormal stretch reflex is present resulting in more muscle contractures than in other forms; also have high incidence of convulsions, mental retardation, resistance to fast motion.

B. Dyskinesias - abnormal amount and type of motion; motions are uncontrollable, involuntary and incoordinated; tendency for degrees of tension and rigidity to occur during these motions.

1) Choreras - involuntary, uncontrolled, sudden, purposeless jerky movements: hyperkinesis.

2) Athetosis - differs from above in that more tension is involved; slower, writhing movement.

3) Dystonia - tension is the outstanding feature; hypertonicity; axial musculature is more involved.

4) Tremors - uncontrolled involuntary motion that is rhythmic; due to alternate agonist-antagonist contractions.

5) Rigidity - greater resistance to slow movements; antagonist - antigravity muscle involved; hypertonicity rather than excessive motion.

C. Ataxia - disturbance in sense of balance and equilibrium.

D. Mixed - combination of all.

III. Classification According to Topography

A. Paraplegia - legs only; practically always of spastic variety.

B. Diplegia - legs primarily and arms slightly; generally spastic.
C. Quadriplegia - all four extremities; usually mixed clinically.

D. Hemiplegia - half of body with arms more involved than body; usually spastic or mixed.

E. Triplegia - involves three extremities; both legs and one arm; generally spastic.

F. Monoplegia - one limb; extremely rare and usually ends up as a mild hemi or paraplegia.

G. Double Hemiplegia - cases of spastic quadriplegia with arms more involved than legs.

IV. Classification According to Muscle Tone

A. Isotonic - normal

B. Hypertonic - increased; "tension"

C. Hypotonic - decreased; "atonic"

V. Classification According to Severity of Involvement

A. Mild - ambulatory; no need of special care.

B. Moderate - handicapped but not entirely disabled; will need some special care.

C. Severe - non-ambulatory and restricted to bed or wheelchair.

VI. Classification According to Etiology

A. Prenatal - time of conception to onset of labor (30% of all C.P. cases)

1) Hereditary - static or progressive

2) Acquired in utero
   a) anoxia
   b) infection
   c) hemorrhage
   d) Rh factor or iso-immunization
   e) metabolic disturbance (maternal)
   f) gonadal irradiation
B. Natal - time of onset of labor to time of viability of delivered child (60%)

1) Anoxia
   a) mechanical obstruction
   b) atelectasis
   c) narcotism
   d) placenta previa or abrupto
   e) maternal anoxia or hypotension
   f) breech deliveries

2) Cerebral hemorrhage and contusion
   a) trauma
   b) sudden pressure changes
   c) prematurity
   d) bleeding due to hypoprothrombinemia or anemia

C. Postnatal - from time of birth of viable infant (10%)

1) Trauma
2) Infection
3) Toxicity
4) Vascular accidents
5) Anoxic
6) Neoplastic

Denhoff<sup>9</sup> considers cerebral palsy classification as involving theoretical and practical elements. The theoretical elements can be grouped into four criteria, the first of which involves anatomical classification. This is basically patterned after that offered by Perlstein.<sup>4</sup> The neuropathologic criterion presented by Benda includes spastic rigidity, pyramidal neuropathies, and mixed pyramidal-extra pyramidal neuropathies. The third and fourth criteria involve
pneumoencephalography and electromyography, respectively.

The practical elements submitted by Denhoff again conform to Perlstein's classification, namely symptoms, topography, muscle tone, and etiology. Denhoff summarizes the issue of classifying the cerebral palsied individual by endorsing the use of a variety of characteristics rather than general and nondescriptive labels. A practical classification must attempt to describe each individual rather than function as a taxonomy for labelling groups that share similar characteristics.

Dental Defects Associated With Cerebral Palsy Syndrome

Much attention has been directed to the dental status of cerebral palsied individuals. A number of findings have been thought to occur with sufficient frequency to qualify as possible dental characteristics of the syndrome. A close look at the literature, however, reveals a controversy.

Enamel hypoplasia in the primary and permanent dentition has been observed more often in cerebral palsied children than in normal children. Watson felt that a particular clinical pattern of hypoplasia was pathognomonic of infantile cerebral palsy of an Rh incompatibility origin. Herman and McDonald found a correlation between the time of possible etiologic incident producing the cerebral palsy syndrome and the time of occurrence of the hypoplasia.
The incidence of dental caries was quite high in the group of cerebral palsied subjects studied by Smark and Bernstein. The bulk of evidence, however, shows no variation in the dental caries index between groups of cerebral palsied and normal individuals.

Periodontal disease has consistently been reported more often in cerebral palsied children than in normal children, although variables such as institutionalization, systemic predisposing factors, dilantin medication, and relative abilities to perform oral hygiene procedures were not consistently measured.

Oral habits have been observed with greater frequency in cerebral palsied children than normal children. Bruxism, attrition, tongue thrusting, and mouth breathing have all been recorded to support this statement. Rosenbaum, on the other hand, found no statistically significant difference between the frequency of visceral swallowing or tongue thrust in experimental and control groups, although raw percentage values were slightly higher for the former group.

Wessels reported a higher frequency of trauma to the maxillary anterior teeth in cerebral palsied children than in normal children. This was based on clinical observation rather than a controlled study.
Malocclusion has been quite controversial with respect to comparative frequency in cerebral palsied children versus normal children. A number of investigators feel that the cerebral palsy group carries the higher frequency.\textsuperscript{11,13,19,21,22,25,26} Others report that the frequency of malocclusion increases with age to a greater extent in cerebral palsied subjects.\textsuperscript{17,18,20} Open bite has been observed with greater frequency in cerebral palsied children by Koster and Allum.\textsuperscript{21,22} Posterior cross-bite has been reported to correlate to the affected side in the cases of spastic hemiplegia although this has not been substantiated by study.\textsuperscript{21} Watson\textsuperscript{10} and Rosenbaum\textsuperscript{23} found no difference in malocclusion frequency between afflicted and non-afflicted individuals. Rosenbaum\textsuperscript{23} in a well controlled study observed no significant difference in frequency of overjet, over bite, open bite, or midline deviation between the two groups.

**Dental Arch Form in Cerebral Palsy**

Dental arch form deformities occurring as a consistent dental finding of the cerebral palsy syndrome have received considerable attention, but the criteria have been somewhat subjective.

Jackson\textsuperscript{20} clinically evaluated 84 cerebral palsied children and compared the findings to those from 380 normal children. He felt that a greater, but unspecified, frequency
of arch form deformity occurred in the cerebral palsy group. He implied that the abnormal neuromuscular facial complex was the etiological factor.

Koster\textsuperscript{21} reported that spastic cerebral palsied children showed constricted maxillary and mandibular arches. No comparative figures with a normal group were available.

Trausch\textsuperscript{27} clinically examined 83 cerebral palsied children in an attempt to demonstrate a characteristic anatomical arch conformity. He concluded that the athetoid subjects demonstrated more arch deformation than other cerebral palsy types. Specific types of arch deformity were not qualified. He felt that eccentric muscle activity and dento-alveolar deviation were related in many of the afflicted subjects.

Siegel\textsuperscript{14} studied 65 cerebral palsied children and 65 normal children on the basis of clinical examination. He found that 54 per cent of the cerebral palsy group demonstrated high arch palates as opposed to 50 per cent in the normal group. He concluded that the differences between the two groups were minimal and therefore suggestive of an environmental rather than developmental etiology.

Album\textsuperscript{22} investigated the comparative dental findings of 55 cerebral palsied children versus 94 normal children. Through an evaluation of clinical examinations, study models,
and cephalometric lateral headplates, he found that the cerebral palsied children had smaller palates, especially in the breadth dimension, and demonstrated U-shaped forms. Album felt that the factors acting on the palates of the afflicted subjects to produce such a finding were mouth breathing, tongue size, tongue function abnormality, oral habits, and length-to-breadth growth abnormalities.

Kongo\textsuperscript{29} made a detailed anatomical study of the maxillary dental arch and the palate in a group of 577 cerebral palsied children and a group of 980 non-afflicted children who were either normal or deaf and dumb. He classified arch form visually by means of the following criteria.

1) Normal - parabolic, elliptic, circular square, circular-V

2) Abnormal - saddle shaped, contracted-V, V-shaped

He then determined dental arch width-to-length ratios for the first permanent molars, bicuspsids, and cuspids of each arch. He also measured palatal height and palatal volume. He noted that the abnormal arch form types were more common in the cerebral palsy group. Interestingly, the V-shaped arch form was seen exclusively in the cerebral palsy group. Other comparative findings in the cerebral palsied children were:

1) Greater magnitude of dental arch ratios, indicating a more ovoid form.
2) Less anterior-posterior length.

3) Less palatal height and less palatal volume.

All subjects in this study were Japanese, which may invalidate direct extrapolation of arch form characteristics to a different and mixed racial complex in the United States.

**Definition of Arch Form**

Defining arch form is a difficult task. The problem lies in determining which aspects of the dental arch are to be evaluated as representing the shape of the arch.

Basal bone is one such aspect that has been evaluated as representing arch form. Basal bone is considered to be the relatively stable skeletal component upon which the alveolar process and teeth are located. Scott\(^2\) felt that basal bone is constant in form in all mammals and therefore limited in representing arch form variability. Richardson and Brodie\(^3\) observed that the maxillary basal bone anterior to the permanent first molars became more ovoid and demonstrated less area with progressive growth.

The alveolar process has also been used to represent arch form. Scott\(^2\) indicated his preference for using alveolar process. He stated that the form of the dentition depended on the direction and extent of growth of the alveolar process. Richardson and Brodie\(^3\) felt that both alveolar
process and basal bone were valid representations of arch form but that no significant correlation existed between them with respect to growth.

The dentition has been most frequently used to represent arch form. The teeth not only give the most visual depiction of arch form but are also most readily measurable from an anthropomeric standpoint. Brash\(^{31}\) in his study of alveolar bone growth in pigs observed that the teeth moved outward toward the alveolar border in spite of the alveolar bone growth. Case\(^{32}\) felt that the form of the alveolar process was governed by the teeth. Boller\(^{33}\) observed that the tooth germs followed a regular pattern of development and had the inherent ability to locate themselves consistently in spite of apparent crowding in the alveolar process. Hrdlicka,\(^{34}\) Williams,\(^{35}\) and Sved\(^{36}\) supported the contention that the dentition is the most accurate representation of arch form.

The depiction of palatal vault form presents less ambiguity, although it is necessary to clarify the plane of reference at which it is described. Lebert\(^{37}\) clearly made this point in his study on the growth of the palate. The vault form can be described at an infinite number of points two-dimensionally in a transverse or sagittal plane.
Description of Arch Form

Subjective Criteria

Subjective criteria have been used commonly by both researcher and clinician in describing arch form. In spite of variability in individual concepts of a given visual template, subjective criteria are the most descriptive for a given sample. The disadvantages of this method are obviously limitations in reproducibility and accuracy.

Hrdlicka\textsuperscript{34} considered the dental arch to be one of five shapes: elliptoid, ovoid, U-shaped, narrow V-shaped, or circular horseshoe-shaped.

Sved\textsuperscript{36} classified arch form according to four basal temperaments which were supposedly physiologically descriptive for a given subject. The temperament was considered to be bilious, sanguinous, nervous, or lymphatic.

Izard,\textsuperscript{38} in an attempt to determine an ideal arch form, considered it to be a half-circle with variations of an elliptical figure. He termed these variations elliptical, ovoid, hyperbolic, parabolic, and U-shaped.

Barrow and White\textsuperscript{39} regarded the dental arch as tapered, trapezoid, square, ovoid, U-shaped, or hyperboloid in form. They reported that the trapezoid arch form was the most prevalent in their study sample, followed by ovoid and tapered, respectively.
Objective Criteria - Non-Measurement

Objective criteria for describing arch form have been more valid from a research standpoint. Investigators have attempted to give visual meaning to the form of the arch by using various instruments and methods.

Scott\textsuperscript{29} used a catenometer consisting of a chain with two ends suspended from an adjustable straight edge. Conceivably, any form of a half-circle could be duplicated.

Lebert\textsuperscript{37} used a Korkhaus symmetrograph to visualize the form of the palatal vault. The instrument consisted of a needle which followed the contours of a study cast and through linkage with a tracing device, inscribed a direct reproduction of these contours on a flat piece of paper. A number of investigators have used this principle in measuring dental arch widths and lengths.\textsuperscript{38,39,40,41,42}

Hyashi\textsuperscript{43} felt that the subjective arch form terminology of upsiloid, paraboloid, and elliptoid could be described and analyzed by means of a geometric formula. The specific form could be plotted as a mathematical function and the area under the curve calculated by means of the formula.

Lear\textsuperscript{42} used a continuous cast metallic bar that spanned the arch circumference at the cervical region of tooth from first molar to first molar. He then photographed the
circumferential bar and superimposed the halves for a comparison of symmetry.

Objective Criteria - Measurement

Arch dimension expressed by measurements continues to be a reliable method of characterizing arch form. The advantages of measurable criteria are obvious. The important consideration in dental arch measurements is determining those landmarks which will reflect the form most reliably.

Sved\textsuperscript{36} stated that these five points on the arch circumference are essential in determining arch form: the buccal grooves of the two first permanent molars, the incisal tips of the two cuspids, and the mesial contact point between the two central incisors. Angle\textsuperscript{44} subsequently endorsed these points as crucial in determining arch form.

Williams\textsuperscript{45} felt that the position of the six anterior teeth determines the shape and size of the mouth and should therefore serve as the points of reference for a given arch.

The dimensions of the dental arch have been expressed as either transverse widths or anterior-posterior lengths. The widths have been considered in the anterior and posterior regions. All measurements have been made either directly in the mouth of the subject or indirectly by means of study models, headplates, or orthographic projections.

Hendrikues\textsuperscript{46} used the method of direct intra-oral measurements in his study. Woods\textsuperscript{47} used anterior-posterior headplates to obtain his measurements.
In the cases where study models were measured, there was considerable variability of specific landmarks on the teeth used for references. A number of investigators used the buccal surfaces of the first permanent molars or primary second molars. Others have used the buccal cusp of molars. Lingual surfaces have also been used extensively and so has the peripheral outline of the alveolar process. Central fossae of the posterior teeth have been quite frequently utilized. Landmark areas on the cusps have been cusp tips and the lingual cervical region at the free gingival margin. It is evident that comparison of absolute dimension values between studies is difficult due to various landmarks used. Brawley and Sedwick emphasized this point in their investigation.

In addition to transverse and sagittal measurements, there has been significant attention to describing arch form by dimensional relationships usually involving ratios of arch width to arch anterior-posterior length. Hrdlicka utilized such a ratio and gave numerical meaning to Turner's terms of dolichouranic, mesouranic, and brachyuranic.

1) Dolichouranic - width/length (x 100) is less than 110, long, narrow arch.
2) Mesouranic - width/length \((X \times 100)\) is between 110 and 115; medium, typical arch.

3) Brachyuranic - width/length \((X \times 100)\) is greater than 115; short, broad arch.

Ashley-Montagu\(^64\) in his study of the form and dimension of the palate in the newborn made transverse width, anterior-posterior length, and vertical height measurements on the stone casts. He then considered numerical ratios to reflect the form of the arches in the various planes.

1) Palatal index = \[
\frac{\text{Maximum Palatal width}}{\text{Maximum Palatal length}} \times 100
\]

2) Palatal Height index = \[
\frac{\text{Maximum Palatal height}}{\text{Maximum Palatal width}} \times 100
\]

3) Palatal Curvature index = \[
\frac{\text{Anterior Palatal length}}{\text{Anterior Palatal width}} \times 100
\]

Observations on Maxillary Arch Form and Dimension

Maxillary Arch Growth and Development

In an excellent investigation by Kraus\(^67\) of the prenatal growth and morphology of the human palate, 151 embryos and fetuses ranging from seven to 18 weeks of age were examined microscopically. Kraus described prenatal palatal growth in seven stages, which are summarized below.

Stage I

(7-9 weeks): Separate but distinct ossification
centers for the premaxillary and maxillary processes are evident.

Stage II
(9 weeks): Ossification of the alveolar crypts of the central and lateral incisors is evident with the palatal area appearing triangular in shape.

Stage III
(10 weeks): The palatal processes of the maxilla develop medially and posteriorly. The posterior border of the horizontal plate becomes well defined.

Stage IV
(11 weeks): Alveolar growth proceeds inferiorly and the pterygoid-hamular areas become quite distinguishable.

Stage V
(13 weeks): The left and right palatal processes of the maxilla reach the midline. The anterior, middle, and posterior zones of the palatal surfaces are evident.

Stage VI
(14 weeks): The primary central incisors and first molars begin to calcify and the future incisive foramen becomes evident.
Stage VII
(17-18 weeks): Overall anatomical structures of the palate are more clearly defined. Kraus\textsuperscript{67} concluded that prenatal growth of the palate does not occur haphazardly but is rather a carefully coordinated and integrated pattern of acceleration and deceleration. He also noted that the proportions of the bony palate changed structurally and dimensionally throughout the growth period that he studied.

According to Salzman,\textsuperscript{68} the palatal processes of the maxilla grow backward laterally and posteriorly to the descending pterygoid process. He reported that the palatal length more than doubles itself during the total growth period. He also stated the generally accepted, though inconclusive observation that five-sixths of the mature width of the palatal arch is attained at four years of age with maximum breadth occurring at ten years of age. This observation was made earlier by Lewis.\textsuperscript{69}

Lebert,\textsuperscript{37} in his study of palatal growth changes, reported that the shape of the vault apex remained constant over the age range of five to 18 years. An increase in breadth at the apex was observed due to growth at the maxillary suture. The alveolar process increased in height and in breadth throughout the growth period studied.
Salzman reported that premature closure of the median maxillary suture would produce narrow palatal arches. If the vomer should be involved, unusually high palatal vaults would result. Neither of these observations was substantiated with studies.

Scott felt that the chief mechanisms separating the bones along the midsagittal suture were growth of the brain and growth of cartilage between the body and greater wing of the sphenoid.

According to Moyers, most primary dental arches are ovoid with less variation in form than adult arches. He felt that the maxilla increases markedly in height on its inferior border and grows vertically with the eruption of the permanent teeth.

Ashley-Montagu studied the palates of ninety newborn infants. He found minimal alveolar development in buccal segments and concluded that newborn palates were quite fleshy. The overall form of the palate was flat from a cross-sectional view anterior-posteriorly.

Bakwin and Bakwin, in their study of 422 infant palates, observed them to be broad and flat in form. The width-to-length relationship remained constant during the first year of life. Palatal dimensions in males were on the average larger than in females. Asymmetries were frequently observed and were associated with apparent facial asymmetry.
Goldstein and Stanton\textsuperscript{41} studied 300 children from one to 11 years of age. They found that the increase in anterior arch width proceeded at a faster rate than the increases in middle or posterior widths. Males demonstrated larger arches than females. The average growth increase per year in the breadth of the primary second molar region between two and nine years of age was calculated to be .33 mm in the maxilla. The shapes of the maxillary arches were most variable in this age group.

Barrow and White\textsuperscript{39} conducted a longitudinal study of 51 children from three to 17 years of age. They observed a 4 mm increase in maxillary intercanine width between the ages of five and nine years. Maxillary intermolar width at the primary second molar region increased 1.5 mm from five to 10 years of age. Maxillary intermolar width at the first permanent molar region increased 1.8 mm from seven to 11 years of age. There was a subsequent .4 mm decrease in width at this region in the age range of 11 to 15 years, due to mesial shift subsequent to the loss of the primary molars.

Lewis and Lehman\textsuperscript{55} observed the growth changes in the dental arches of 170 children by means of longitudinal records. They concluded that the primary arches became wider to allow increased size for the permanent incisors. The greatest increase occurred after six years of age in the intercanine region. They reported the mean maxillary width increases
to be 5.25 mm in the cusp region and 2.40 mm in the first
permanent molar region.

Hellman^5^9 studied facial growth by analyzing dry human
skulls. He observed steady growth of the palatal vault
height in all age ranges. The growth rate of the vault
height accelerated from early infancy through complete
primary eruption and from first permanent molar eruption to
second permanent molar eruption. However, it decreased in
the interim period between complete primary eruption and
first permanent molar eruption. Palatal width increased
3.4 mm in the primary second molar region and 3.13 mm in the
first permanent molar region. Palatal length increased
posteriorly with the eruption of the permanent molars and
resultant alveolar growth.

Meredith and Hopp^4^9 found a significant degree of vari-
ability in a study of arch width growth between the ages of
four and eight years. They observed that male arches were
1.9 mm wider, on the average, than female arches at the
region of the primary second molars. At four years of age,
the arches were 1.7 mm narrower than at eight years of age
in the same region.

Mills^5^3 measured dimensional changes of both arches
with respect to age. He found that arch breadth reached a
peak between 11 and 13 years of age. At age 19, the breadth
value was almost the same as at six and one-half years of age, indicating a decrease after the peak period.

Cohen\textsuperscript{54} made a longitudinal study of 28 children from three and one-half to thirteen and one-half years of age. The greatest lateral growth of the dental arches occurred in the intercuspid region and reached a maximum value during the five to eight year period in the maxilla. Little or no lateral growth was observed in the first permanent molar region. The arches of females tended to be more tapered than in males. Hendriques\textsuperscript{46} and Woods\textsuperscript{47} supported the findings of Cohen with respect to lateral growth of the maxillary arch.

Moorees\textsuperscript{73,74} in his extensive work in the area of growth changes of the dental arches noted that anterior posterior arch length was greatest at approximately 10 years of age. Intercanine distance was greatest at 14 years of age. He noted close correlation of these values in both sexes.

Relation of Arch Form to Other Variables

The part that heredity plays in determining arch form is well documented.\textsuperscript{29,30,34,38} Specific information as to its quantitative and qualitative role, however, is scarce and will probably remain so. Williams\textsuperscript{45} considered that arch form reflected racial types although well controlled substantiation was limited.
Congenital syndromes\textsuperscript{1} and neuromuscular handicaps such as cerebral palsy\textsuperscript{20,21,22,27,28} have been previously mentioned as influencing variables on arch form. Channing and Wissler\textsuperscript{58} studied the palates of normal and feeble-minded individuals in response to Down's report of the latter group demonstrating high V-shaped palatal vaults and narrow arches. Differences in degree but not in the kind of variability of arch form were found in the comparison of the two groups. The variability in the feeble-minded group was equally distributed between the extremes of arch shape. The authors concluded that there was no palatal form that was peculiar to idiocy.

Symmetry is another variable thought to influence dental arch form. Lundstrom\textsuperscript{75} made a detailed study of symmetry in 139 boys. He noted that the difference between the median palatal raphe and the actual center of the arch was quite small. The greatest values of asymmetry were in the first permanent molar region. Environmental causes for dental asymmetry were listed as oral habits, chewing patterns, loss of proper contact between teeth, extraction, and trauma.

In a study of dental symmetry in the maxillary arch, Lear\textsuperscript{42} noted that the dental midline did not consistently correspond to the median palatal raphe and ruled out sleeping posture as an etiological factor of facial and dental asymmetry.

Oral habits comprise another variable thought to affect dental arch form. Lerner\textsuperscript{76} serially analyzed 64 subjects to determine the effects of thumbsucking on the
dentition. He concluded that thumbsucking produced a specific kind of deformity, especially in the anterior aspect of the maxillary arch. He noted that the deformity was reversible in the primary dentition if the duration of the habit was less than four years.

Mouthbreathing has been implicated as having a profound effect on arch form. The bulk of evidence, however, does not substantiate this contention. A significant drawback in studying mouthbreathing is the difficulty of assessing it clinically. Rasmus emphasized this point in his study of the interrelation between mouthbreathing and malocclusion.

Tongue thrusting has been shown to influence the form of the dental arch, mainly by flaring the anterior segments. Anderson found tongue thrusting to be related to thumbsucking and to the presence of open bite. He also found less incidence of tongue thrusting with increase in age. Brauer and Holt gave a comprehensive classification of tongue thrust and implicated it as a cause of posterior crossbite, anterior crossbite, and anterior open bite. Hanson and Banard conducted an excellent study of tongue thrusting in preschool children. They noted a significant correlation between high narrow palates and tongue thrusting.

Open bite is an abnormality which definitely reflects an alteration in arch form and is indicative of a habit or
genetic pattern. Rogess\textsuperscript{83} seldom observed open bite in the primary dentition and felt that the condition was more prevalent in the mixed dentition. He attributed this increased prevalence to altered tongue restriction rendered by primary exfoliation. Subtelny\textsuperscript{84} reviewed the status of open bite and noted that it was more common in the younger age groups, i.e. 14 years and under. He felt that the tongue thrusting might be the result rather than the cause of open bite. He concluded that open bite could represent skeletal abnormalities as well as those of dental nature. Gellen\textsuperscript{85} supported this view in that he observed open bite in children with no history of oral habits.

Muscle function is still another variable thought to influence arch form. Baril and Moyers\textsuperscript{86} examined electromyographically the involvement of selected fifth and seventh cranial nerve muscles in a group of 24 thumb and finger suckers. They found the dominant muscles to be the orbicularis oris and the mentalis. The activity of these muscles was found to vary with each subject. They concluded that the neuromuscular behavior was not related to the skeletal or dental aspect of the malocclusions in their study. Kydd\textsuperscript{87} measured duration and magnitude of force exerted by the lingual and perioral musculature in treated open bite patients who had experienced relapse and those who had remained stable. Within the limits of his study, the tongue pressure in the relapse group was twice the value of the stabilized subjects.
Lear attempted to register lateral forces of orofacial musculature exerted on dental arches by means of a transducer. He was able to support his contention that arch form was determined by more than labiolingual muscle function. He felt that variables such as time of force per unit area and time duration in daily physiologic function were extremely important but could not be measured within the prescribed limits of a study.

Relation of Arch Form to Facial Structures

Considerable controversy has existed over the relationship between dental arch form and facial form.

Williams found no direct correlations between arch form and facial form.

Izard felt that a constant ratio existed between the length and width of the face and the length and width of the maxillary arch. He proposed a method of using the bizygomatic distance to determine the radius of an abstract normal dental arch for a particular individual.

O'Reilly stated that there was no relationship between the dental arch width and the bigonial or bizygomatic widths of the jaw.

Meredith et al found minimal correlation, or none at all, between transverse dimensions of the face and the maxillary arch. Adams later substantiated this fact.
in his study of the relationship between face widths and upper dental arch widths in five-year-old children.

Mills\textsuperscript{52} attempted to determine if differences in arch width, arch length, and tooth size exist between normal and crowded dental arches. He was unable to demonstrate a relation between severity of malalignment and maxillary and mandibular anterior posterior arch length. Second premolar widths decreased with increases in severity of malalignment.

Williams\textsuperscript{56} studied the correlation between palatal vault height, maxillary arch width, and anterior posterior arch length. He concluded that palatal height appeared to be independent of other variables and was probably suggestive of separate genetic control.
METHODS AND MATERIALS
Subjects

The experimental group of 98 subjects were randomly selected from congenital cerebral palsied children seeking medical and dental treatment at the Riley Children's Hospital Dental Clinic, the Riley Children's Hospital Cerebral Palsy Outpatient Clinic, and the Rotary Cerebral Palsy Clinic. Complete medical histories were available indicating the diagnosis and classification of the neuromuscular handicap. No attempt was made to grade the subjects as to severity of neuromuscular involvement, due to lack of reproducible and measurable criteria for judgment. The experimental sample consisted of 39 females and 59 males. The following chart shows the dispersion of subjects according to descriptive diagnosis and regional involvement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>D e</td>
<td>Spastic</td>
<td>53</td>
</tr>
<tr>
<td>s</td>
<td>Athetoid</td>
<td>16</td>
</tr>
<tr>
<td>c t</td>
<td>Ataxic</td>
<td>2</td>
</tr>
<tr>
<td>r i</td>
<td>Mixed</td>
<td>20</td>
</tr>
<tr>
<td>i v</td>
<td>Undiagnosed</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>98</td>
</tr>
</tbody>
</table>

| R e  | Diplegia | 18 | 17.3 |
| g n  | Hemiplegia | 28 | 28.5 |
| i a  | Paraplegia | 6  | 6.1  |
| o. l | Quadriplegia | 39 | 40.8 |
|      | Undiagnosed | 7  | 7.3  |
|      | Total       | 98 | 100.0 |
The control group of 76 subjects, 36 females and 40 males, were randomly selected from non-cerebral palsied children seeking dental treatment in the undergraduate Pedodontic Department of Indiana University School of Dentistry. Subjects in the control group were considered normal only on the basis of absence of any physical handicap.

All subjects had a full complement of maxillary teeth, except for normal exfoliation in the mixed dentition stages. In addition, absence of any previous orthodontic therapy was established in all cases. The age range was from three to 20. Each individual was recorded as to name, age, sex, and control or experimental group. In the case of the cerebral palsied children, the medical classification and regional involvement were included.

Collection of Study Models

Alginate maxillary impressions were obtained from 44 of the 98 cerebral palsied subjects. When possible, mandibular impressions were also obtained. The remaining subjects had maxillary and mandibular study models on file at the Riley Hospital Dental Clinic and the Rotary Cerebral Palsy Clinic. Alginate duplication impressions were made only of the maxillary original models of this latter group.

Maxillary and mandibular impressions were obtained on 29 of the 76 normal subjects. The remaining children had
study models available as part of their undergraduate pedodontic treatment records at the Indiana University School of Dentistry. These study models were secured by the investigator.

All alginate impressions were poured in plaster of Paris within an hour after being obtained to form dental casts. The superior art bases of the casts were trimmed parallel to the occlusal plane and the posterior art bases were trimmed at right angle to the occlusal plane. They were then smoothed, soaped, and marked to form the finished study models. The study models and the recorded subject information were grouped into three eruptive categories.

1) Primary dentition - full complement of primary teeth prior to the eruption of the first permanent molars.

2) Mixed dentition - eruption interval between the presence of the first permanent molars and the second bicuspids.

3) Permanent dentition - full complement of permanent teeth anterior to the first permanent molars.

These categories formed the basis of all comparisons of maxillary arch form and associated occlusal irregularities between the experimental and control group.
Study Model Analysis

The following information was recorded directly from the cerebral palsied and normal subjects, that is, either from the clinical visit at which the impressions were taken or from the original study models on record. In the latter case, past dental records were used to substantiate this information.

1) **Posterior crossbite:** This condition was felt to exist when any one or more opposing posterior teeth varied at least one-half a cusp in their interdigitational relationship buccolingually. An end-to-end relationship of the opposing primary molars, for example, was considered to be a posterior crossbite. A situation where the maxillary posterior tooth was completely buccal to the mandibular opposing tooth was considered as a crossbite. All posterior crossbites were qualified as being unilateral or bilateral.

2) **Anterior crossbite:** This condition was felt to exist when one or more teeth in the maxillary anterior segment were lingual to the opposing mandibular tooth.

3) **Anterior open bite:** This condition was felt to exist when there was one mm or more of space
between the incisal edges of the opposing anterior teeth with the remaining dentition in centric occlusion. These variables were felt to reflect to some degree the shape and dimensions of the maxillary arch, and that is why they were recorded and analyzed. The variables were all assessed by the same investigator.

Three posterior reference points were chosen on every maxillary study model. The central fossae of the primary second molars or the first permanent molars, depending on the dental eruptive stage observed, formed two of the points. (Fig. 1) The third was found by visually connecting the central fossae of the chosen molars by means of a symmetroscope, which is a plastic grid with a two mm square area in each division. A perpendicular (.036 steel wire) was dropped through the symmetroscope at the intersection of the visual intermolar line and the midpalatal raphe. (Figs. 2,3) This point was defined as A-point and together with the other two reference points formed the posterior boundary from which dental arch form was described. These points also formed the plane of reference for considering palatal vault form. All the maxillary study models were then measured directly by means of a Boley gauge to obtain the following dimensional variables.
1) **Intercanine Width** (Wc) - distance between the buccal-most aspect of the incisal tips of the primary or permanent cuspids. In the case of the edentulous cuspids areas, the transverse dimension between the distal surfaces of the two lateral incisors was used. (Fig. 4)

2) **Intermolar Width** (Wm) - distance between the central fossae of the second primary molars (We) or first permanent molars (W6). The central fossa of each molar was considered as the point of intersection between the transverse and buccal grooves of the occlusal surfaces. (Fig. 1)

3) **Length** (L) - the horizontal distance from A-point along the midpalatal raphe to the labial aspect of the central incisor mesial contact area. In the case where a large diastema persisted or the central incisors were tipped lingually, the labial aspect of the anterior alveolar process was used. (Fig. 5)

After measurement, the maxillary models were trimmed to the posterior reference plane connecting the central
fossae and A-point flush with the heel. (Fig. 6) The retrimmed models were placed heel down on a Xerox 3600-III copier in the middle one-third along the length of the field and reproduced. The palatal vault therefore appeared as a cross-sectional outline of the palate in one reference plane occurring at A-point. (Figs. 6,7) The distortion of the Xerox reproduction was calculated by comparison of photocopies of millimeter ruled graph paper with the originals. There was virtually no distortion in the width of the paper along the middle 80 mm band running the length of the paper. Beyond this 80 mm area, one mm of enlargement occurred at the width periphery. There was three mm of enlargement at the length periphery of the reproduced graph paper with the least amount within a 90 mm band running the width of the paper. Therefore, minimal distortion occurred in the middle 172 square mm of the reproduction. These observations are in agreement with those of Inder although he used a different machine. The Xerox photocopies of the palatal vault were used to measure the remaining variables.

4) **Palatal Vault Height** - the perpendicular distance between the intermolar line (Wm) and A-point. (Fig. 8)

5) **Palatal Vault Angle** - the angle formed by constructed tangents to the maximum amount
of surface outline of the palatal walls and extended to their point of intersection. (Fig. 8)

6) **Posterior Dental Symmetry** - the horizontal distance of the posterior molar reference point to the position of A-point along the intermolar line. (Fig. 8)

The palatal vault height and posterior symmetry were measured by means of a grid formed by an acetate photocopy of millimeter ruled graph paper. The section used had no discrepancy whatsoever when superimposed over the original graph paper. The palatal vault angle was measured by a protractor. (Fig. 8)

Standard degrees of error were computed in the selection of reference points and palatal surface tangents by analyzing two independent complete sets of measurements of 19 subjects within the same eruptive stage.

**Numerical Computation**

The dental form of each maxillary arch was described by an index number. This index number represented a ratio of transverse width to anterior-posterior length. The particular formula derivation for calculating this ratio was obtained from the work by Bell. He considered the dental arch index (D.A.I.) to be a product of two ratios, namely the degree of divergence \( W_o/W_m \) times the width to length
relation \((\frac{W_c}{L} + \frac{W_m}{L})\). The following is a mathematical representation of the derivation of the dental arch index and depicts the formula used for computation.

\[
D.A.I. = \text{Degree of Divergence} \times \frac{\text{Width}}{\text{Length}}
\]

\[
D.A.I. = \frac{W_c}{W_m} \times \frac{W_c + W_m}{L} = \frac{W_c}{W_m} \times \frac{W_c + W_m}{L}
\]

\[
D.A.I. = \frac{W_c (W_c + W_m)}{W_m L}
\]

This index reflects three features which form the basic determinants of any two dimensional dental arch form:

1) The divergence of the buccal segments of the arch, which is represented by the ratio of the anterior reference width to the posterior reference width \((\frac{W_c}{W_m})\).\(^{65}\)

2) The average width of the arch expressed by considering the anterior width and the posterior width \((W_c + W_m)\).\(^{65}\)

3) The anterior-posterior length of the arch \((L)\).\(^{65}\)

When the arch index numbers within a given subject group are small, they describe narrower, more tapering arch forms. Conversely, the larger numbers reflect a wider, more ovoid arch form.\(^{65}\) In this study, the numerical ranges were from 1.0 to 2.8. Visual meaning was given to this phenomenon by means of photographs of various arches demonstrating
the respective D.A.I. values in each dental eruptive stage. (Figs. 9-36) The direct proportional relationship between D.A.I. magnitude and the degree of tapering or ovoidness of the arch form is readily apparent. These numbers are not in themselves predictive of a particular type of form, i.e. they cannot be used as a template of arch form. They are merely descriptive tools within the scope of a given group of subjects and reflect relative trends in arch form characteristics.

The palatal form of each maxillary arch was described by two variables: 1) the actual palatal height and 2) the angle of divergence of the palatal walls. Both of these assessments were made in a two-dimensional plane and, therefore, described the palatal form only at one anterior-posterior point of reference. Due to the fact that these variables were measured directly, as previously described, no numerical computation was necessary. However, it is important to recognize that, as in the case of the dental arch index number, palatal height and palatal angle are not templates. They are descriptive characteristics that vary relative to a given group and have the advantage over verbal descriptive characteristics of being definable, measurable, and reproducible.
RESULTS
Processing of Data

The data were recorded on standard IBM punch cards and submitted for statistical analysis to the Research Computation Center of Indiana University-Purdue University at Indianapolis. Because of the small sizes of both cerebral palsy and normal groups, males and females were treated together. In the case of the cerebral palsy subjects, diplegic and paraplegic classes were grouped together due to their individually small number of subjects. Ataxic and undiagnosed cerebral palsy classes were eliminated from statistical evaluation due to the small number of subjects.

Mean and standard deviation was computed for every control and experimental group in each of the three eruptive stages with respect to the following variables: 1) intercuspid width, 2) intermolar width, 3) anterior-posterior length, 4) dental arch index, 5) palatal height, and 6) palatal angle (Table I). Comparisons between groups were made statistically and will be subsequently described. Occlusal discrepancy occurrence in the form of posterior unilaterial crossbite, posterior bilateral crossbite,
anterior crossbite, and anterior open bite was tabulated and statistically compared between the experimental and normal groups. Posterior dental symmetry with respect to distance from the mid-palatal raphe was the final variable tabulated and statistically compared between the experimental and control groups.

Reliability of Measurements

Reliability estimates for each of the measured variables were made to determine the amount of error in the techniques of measurement used. Two separate series of measurements of intercuspid width, intermolar length, anterior-posterior length, palatal vault height, and palatal angle were made from the models and Xerox photocopies of 19 subjects. The one way analysis of variance was used to estimate reliability. The between-subject variance \((\sigma_s^2)\) and between-measurements-within-subject variance \((\sigma_e^2)\) were calculated and their mean square estimates were computed. Table II describes the subject groups for all variables considered in the analysis of variance for estimating the reliability in question. Total variation in a given sample was considered as the sum of subject variance \((\sigma_s^2)\) and error of measurement variance \((\sigma_e^2)\). Reliability of making a particular measurement by the investigator may be defined as follows:

\[
\text{Reliability} = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_e^2}
\]
The measurement error of the investigator may be defined as follows:

$$\text{Error} = \frac{\sigma^2}{\sigma_s^2 + \sigma_e^2}$$

Table III shows the percentages of reliability and error for each variable in question. The intercuspid width was 97.4 percent reliable, intermolar width measurement width was 99.3 percent reliable, anterior-posterior length measurement was 97.95 percent reliable, palatal angle measurement was 96.93 percent reliable, and palatal height measurement was 97.64 percent reliable. These values were considered quite acceptable in verifying the reproducibility of measurements obtained in this investigation.

Determination of Differences Between the Cerebral Palsy and Normal Groups at the Three Eruptive Stages

Differences between the cerebral palsy and normal groups at the three eruptive stages were determined by using the factorial analysis of variance. Table IV shows the distribution of the experimental and normal subjects according to eruptive stage, regional classification, and descriptive classification. Separate analyses were made for each variable studied: intercuspid width, intermolar width, anterior-posterior length, dental arch index, palatal height, and palatal angle (Table IV). Since the sample sizes were not
equal for the groups, the exact solution through the method of weight squares of means was used to obtain valid statistical comparisons. The results of this analysis appear in Tables V - XVII.

Cerebral Palsy Regional Classifications vs. Normal: The results of the analysis comparing the regional cerebral palsy classification with normal groups revealed no significant difference between them with respect to intercuspid width, palatal height, palatal angle, and dental arch index at a given eruptive stage (Tables V, VIII, IX, X). There was a highly significant difference between all six variables with respect to eruptive stage as illustrated by F-tests. The observed trends were consistent in all experimental and normal groups (Table I). Intercuspid width steadily increased with respect to progression from primary to permanent dentition. Intermolar width increased from primary to mixed dentition and remained relatively constant in the transition from the mixed to the permanent dentition. Anterior-posterior length followed the same trend as the intermolar width. Dental arch index was greatest in magnitude in the primary dentition. It became smaller in the mixed dentition, and then became larger again in the permanent dentition. Palatal height was constant for both primary and permanent dentitions and then took an upward trend in the permanent dentition. Palatal angle became more obtuse in the mixed dentition as opposed
to the primary dentition and was more acute in the permanent dentition than in either of the two other dentition stages.

With respect to intermolar width, differences between groups reached borderline significance \((F = 2.5, P = .05)\). (Table VI) Group-by-age interaction was significant at \(P < .025\). This indicated that differences between groups did not follow the same trend for each dental age. The Neuman-Keul's sequential range test was used for multiple comparisons among the groups. This method uses the studentized range "q" statistics. The results appear as follows:

1) At the Primary Dentition Stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>DP + PP</th>
<th>Normal</th>
<th>HP</th>
<th>QP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>38.10</td>
<td>37.51</td>
<td>33.11</td>
<td>31.34</td>
</tr>
</tbody>
</table>

Groups joined by a common line did not differ at a probability level of .05. Those groups not joined by a common line differed significantly from one another at \(P < .05\). Therefore, paraplegic plus diplegic (DP + PP) and normal groups differed significantly from the hemiplegic (HP) and quadriplegic (QP) groups in the primary dentition for the intermolar width variable. The latter two groups had the smaller dimension.

2) At the Mixed Dentition Stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>HP</th>
<th>DP + PP</th>
<th>Normal</th>
<th>QP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>46.00</td>
<td>44.54</td>
<td>44.17</td>
<td>43.52</td>
</tr>
</tbody>
</table>
All four groups did not differ from each other at a probability level of .05 during the mixed dentition stage for the intermolar width variable. This is illustrated by the continuous common line.

3) At the Permanent Dentition Stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>Normal</th>
<th>QP</th>
<th>HP</th>
<th>DP + PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>47.09</td>
<td>45.72</td>
<td>45.39</td>
<td>43.40</td>
</tr>
</tbody>
</table>

All four groups did not differ from each other at the probability level of .05 during the permanent dentition stage for the intermolar width variable. This is illustrated by the continuous common line.

With respect to anterior-posterior length, differences between the groups examined were significant at $P < .01$, $F = 4.11$ (Table VII). The non-significant interaction indicated that differences between groups followed a similar trend at all three eruptive stages. Therefore, multiple comparisons between groups were performed on all three eruptive stages together. The results are as follows:

<table>
<thead>
<tr>
<th>Group</th>
<th>QP</th>
<th>HP</th>
<th>DP + PP</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.39</td>
<td>31.99</td>
<td>31.76</td>
<td>31.06</td>
</tr>
</tbody>
</table>

The only significant difference at a probability level of .05 was between the quadriplegic (QP) and normal groups with respect to anterior-posterior length. This is illustrated by the continuous lines. The normal group had the smaller value.
Cerebral Palsy Descriptive Classification vs. Normal:
The results of the analysis comparing the descriptive cerebral palsy classification with normal groups revealed no significant difference between them with respect to intercuspid width, intermolar width, palatal height, palatal angle, and dental arch index. (Tables XI, XVI, XIV, XV, XVII). There was a highly significant difference between the three eruptive stages for all six variables. These differences have been discussed earlier.

A significant difference in anterior-posterior length was found between the spastic athetoid, mixed, and normal groups at \( P < .025 \) \( (F = 3.28) \) (Table XIII). Significant group-by-age interaction indicated varying trends of group differences at each eruptive stage. Neuman-Keul's test was used to compare any two among the four groups at the respective eruptive stages. 92

1) At the Primary Dentition Stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>Spas.</th>
<th>Mix.</th>
<th>Ath.</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>25.71</td>
<td>25.02</td>
<td>24.60</td>
<td>23.71</td>
</tr>
</tbody>
</table>

No significant difference was found between the four groups in the primary dentition stage with respect to anterior-posterior length. This is illustrated by the continuous common line.

2) At the Mixed Dentition Stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>Ath.</th>
<th>Mix.</th>
<th>Spas.</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>35.64</td>
<td>35.32</td>
<td>33.77</td>
<td>33.63</td>
</tr>
</tbody>
</table>
No significant difference was found between the four groups in the mixed dentition stage with respect to anterior-posterior length. This is illustrated by the continuous common line.

3) At the Permanent Dentition Stage:

<table>
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<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>35.00</td>
<td>34.03</td>
<td>32.76</td>
<td>31.23</td>
</tr>
</tbody>
</table>

A significant difference was found between the spastic and mixed cerebral palsy groups in the permanent dentition stage with respect to anterior-posterior length. The unconnected lines illustrate this point and it is seen that the spastic group demonstrates the higher length value.

Distribution of Cerebral Palsy vs. Normal Subjects With Respect to Dental Arch Index and Palatal Vault Angle: Numbers of experimental subjects were plotted against the range of values obtained for the dental arch indices and palatal vault angle measurements in order to graphically compare the distribution of both samples (Figs. 37 and 38). The graphs show that subject distributions followed a bell-shaped pattern in all eruptive stages and that the peak number of subjects occurred in the same value range for both cerebral palsy and normal groups in the two given variables.
Comparison of Occlusal Discrepancies to Arch Form Between Cerebral Palsy and Normal Groups

Cerebral palsy and normal groups were compared with respect to the occurrence of those occlusal discrepancies that were thought to have some influence on arch form, namely: posterior unilateral and bilateral crossbite, anterior crossbite, anterior open bite, and posterior dental symmetry. The tabulation of these variables for the experimental and control groups in the respective eruptive stages is depicted in Table XVII. The cerebral palsy group was not broken down into regional and descriptive categories for this comparison. Ataxic and undiagnosed subjects were included. Differences between the two groups were determined by means of the Chi-Square Test of Independence for 2 x 2 contingency table with Yates correction for continuity. Due to the small sample sizes and uneven distribution of the specific occlusal discrepancies, eruptive stages were not considered and all variables were treated together, with the exception of posterior dental symmetry. The following data were obtained:

<table>
<thead>
<tr>
<th>Subjects with occlusal discrepancies</th>
<th>Normal</th>
<th>C.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects without occlusal discrepancies</td>
<td>65</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>98</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 33.9 \text{ at } P < .001 \]
This indicates a highly significant difference, with the cerebral palsied group demonstrating a greater prevalence of occlusal discrepancies.

The same chi-square method was used to determine the difference between the cerebral palsy and normal groups with respect to posterior dental symmetry over the combined eruptive stages. The following data were obtained (Table XVII).

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>C.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetrical Cases</td>
<td>36</td>
<td>41</td>
</tr>
<tr>
<td>Asymmetrical Cases</td>
<td>40</td>
<td>57</td>
</tr>
</tbody>
</table>

\( \chi^2 = 0.78 \) (not significant)

No significant difference in prevalence of asymmetry was observed between the cerebral palsy and normal groups.
Figure 1. Boley gauge measurement of intermolar width ($W_m$) using central fossae as reference points.

Figure 2. Symmetroscope connecting the posterior reference points. A .036" steel wire is dropped at point of intersection with the midpalatal raphe (A-point).
Figure 3. View of .036" wire in place at A-point.

Figure 4. Boley gauge measurement of intercuspid width ($W_c$) using buccal-most aspect of incisal cusp tips as reference points.
Figure 5. Boley gauge measurement of anterior-posterior length (L) from A-point to labial-most aspect of alveolar ridge at mesial embrasure of maxillary central incisors.

Figure 6. Study models trimmed to posterior reference plane with the two central fossae and A-point flush with the heel. The respective Xerox copies of the palatal vaults are shown with the models.
Figure 7. Xerox copies of the respective study models' cross-sections demonstrating the palatal configurations.

Figure 8. Construction of the palatal wall tangent, the subsequent angle of divergence of the palatal walls measured, and the determination of the distance of the molar reference points from A-point along the intermolar line. Palatal vault height was measured directly as perpendicular distance from A-point to intermolar line by means of grid.
Figure 9. Primary dentition arch:  
D.A.I. = 1.598.

Figure 10. Primary dentition arch:  
D.A.I. = 1.617.

Figure 11. Primary dentition arch:  
D.A.I. = 1.719.

Figure 12. Primary dentition arch:  
D.A.I. = 1.803.
Figure 13. Primary dentition arch:
D.A.I. = 1.956.

Figure 14. Primary dentition arch:
D.A.I. = 2.003.

Figure 15. Primary dentition arch:
D.A.I. = 2.155.

Figure 16. Primary dentition arch:
D.A.I. = 2.229.
Figure 17. Primary dentition arch:  
D.A.I. = 2.337.

Figure 18. Primary dentition arch:  
D.A.I. = 2.455.

Figure 19. Primary dentition arch:  
D.A.I. = 2.566.

Figure 20. Primary dentition arch:  
D.A.I. = 2.800.
Figure 21. Mixed dentition arch:
D.A.I. = 1.398.

Figure 22. Mixed dentition arch:
D.A.I. = 1.468.

Figure 23. Mixed dentition arch:
D.A.I. = 1.581.

Figure 24. Mixed dentition arch:
D.A.I. = 1.657.
Figure 25. Mixed dentition arch:  
D.A.I. = 1.732.

Figure 26. Mixed dentition arch:  
D.A.I. = 1.858.

Figure 27. Mixed dentition arch:  
D.A.I. = 1.930.

Figure 28. Mixed dentition arch:  
D.A.I. = 2.240.
Figure 29. Permanent dentition arch:
D.A.I. = 1.579.

Figure 30. Permanent dentition arch:
D.A.I. = 1.608.

Figure 31. Permanent dentition arch:
D.A.I. = 1.730.

Figure 32. Permanent dentition arch:
D.A.I. = 1.865.
Figure 33. Permanent dentition arch: 
D.A.I. = 1.934.

Figure 34. Permanent dentition arch: 
D.A.I. = 2.021.

Figure 35. Permanent dentition arch: 
D.A.I. = 2.083.

Figure 36. Permanent dentition arch: 
D.A.I. = 2.403.
Figure 37. Graph showing distribution of cerebral palsy and normal subjects with respect to dental arch index number in each eruption stage.
NORMAL vs. CEREBRAL PALSY
DENTAL ARCH INDEX

Permanent Dentition

Mixed Dentition

Primary Dentition

NUMBER OF SUBJECTS IN EACH ERUPTION STAGE

D. A. I.
Figure 38. Graph showing distribution of cerebral palsy and normal subjects with respect to palatal vault angle in each eruption stage.
NORMAL vs. CEREBRAL PALSY
PALATAL VAULT ANGLE

Permanent Dentition

Mixed Dentition

Primary Dentition
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>28.82</td>
<td>2.70</td>
<td>37.50</td>
<td>2.55</td>
<td>23.71</td>
<td>1.46</td>
<td>2.189</td>
<td>1.37</td>
<td>75.86</td>
</tr>
<tr>
<td>Di. &amp; Para.</td>
<td>30.16</td>
<td>1.84</td>
<td>38.10</td>
<td>3.03</td>
<td>25.83</td>
<td>3.74</td>
<td>2.125</td>
<td>0.75</td>
<td>82.66</td>
</tr>
<tr>
<td>Hemi.</td>
<td>29.02</td>
<td>1.79</td>
<td>33.11</td>
<td>9.73</td>
<td>25.91</td>
<td>2.75</td>
<td>2.010</td>
<td>1.39</td>
<td>73.66</td>
</tr>
<tr>
<td>Quad.</td>
<td>28.50</td>
<td>4.73</td>
<td>31.34</td>
<td>10.15</td>
<td>25.65</td>
<td>1.96</td>
<td>1.961</td>
<td>1.11</td>
<td>71.66</td>
</tr>
<tr>
<td>Spastic</td>
<td>28.93</td>
<td>1.92</td>
<td>36.86</td>
<td>2.81</td>
<td>25.70</td>
<td>2.25</td>
<td>2.022</td>
<td>1.30</td>
<td>76.84</td>
</tr>
<tr>
<td>Athetoid</td>
<td>30.45</td>
<td>2.05</td>
<td>37.45</td>
<td>1.48</td>
<td>24.60</td>
<td>2.54</td>
<td>2.266</td>
<td>0.70</td>
<td>85.75</td>
</tr>
<tr>
<td>Mixed</td>
<td>26.92</td>
<td>3.06</td>
<td>33.70</td>
<td>4.50</td>
<td>25.02</td>
<td>1.92</td>
<td>1.968</td>
<td>0.50</td>
<td>66.10</td>
</tr>
<tr>
<td>Normal</td>
<td>32.55</td>
<td>2.78</td>
<td>44.17</td>
<td>2.45</td>
<td>33.63</td>
<td>2.01</td>
<td>1.784</td>
<td>1.96</td>
<td>85.25</td>
</tr>
<tr>
<td>Di. &amp; Para.</td>
<td>32.72</td>
<td>2.43</td>
<td>44.53</td>
<td>3.72</td>
<td>33.51</td>
<td>3.56</td>
<td>1.696</td>
<td>3.10</td>
<td>84.10</td>
</tr>
<tr>
<td>Hemi.</td>
<td>34.23</td>
<td>2.07</td>
<td>46.00</td>
<td>2.93</td>
<td>34.32</td>
<td>1.32</td>
<td>1.699</td>
<td>1.66</td>
<td>84.08</td>
</tr>
<tr>
<td>Quad.</td>
<td>32.59</td>
<td>2.85</td>
<td>43.51</td>
<td>2.52</td>
<td>35.45</td>
<td>2.00</td>
<td>1.618</td>
<td>2.09</td>
<td>81.47</td>
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<tr>
<td>Spastic</td>
<td>32.82</td>
<td>2.12</td>
<td>46.51</td>
<td>10.87</td>
<td>33.76</td>
<td>2.67</td>
<td>1.699</td>
<td>2.64</td>
<td>83.88</td>
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<td>Athetoid</td>
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<td>46.27</td>
<td>2.30</td>
<td>35.64</td>
<td>2.14</td>
<td>1.612</td>
<td>2.27</td>
<td>81.07</td>
</tr>
<tr>
<td>Mixed</td>
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<td>1.80</td>
<td>43.46</td>
<td>3.63</td>
<td>35.31</td>
<td>1.46</td>
<td>1.656</td>
<td>1.73</td>
<td>80.27</td>
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<tr>
<td>Normal</td>
<td>35.40</td>
<td>2.71</td>
<td>47.08</td>
<td>3.86</td>
<td>32.76</td>
<td>2.13</td>
<td>1.899</td>
<td>2.16</td>
<td>72.50</td>
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<tr>
<td>Di. &amp; Para.</td>
<td>33.47</td>
<td>5.01</td>
<td>43.40</td>
<td>3.14</td>
<td>34.52</td>
<td>2.95</td>
<td>1.697</td>
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<td>58.75</td>
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<td>3.00</td>
<td>45.38</td>
<td>4.92</td>
<td>35.81</td>
<td>2.37</td>
<td>1.744</td>
<td>2.98</td>
<td>67.71</td>
</tr>
<tr>
<td>Quad.</td>
<td>34.67</td>
<td>3.47</td>
<td>45.72</td>
<td>4.93</td>
<td>33.03</td>
<td>4.34</td>
<td>1.858</td>
<td>1.80</td>
<td>66.73</td>
</tr>
<tr>
<td>Spastic</td>
<td>34.50</td>
<td>4.17</td>
<td>45.47</td>
<td>4.13</td>
<td>35.05</td>
<td>2.56</td>
<td>1.734</td>
<td>2.84</td>
<td>66.33</td>
</tr>
<tr>
<td>Athetoid</td>
<td>34.85</td>
<td>3.54</td>
<td>44.91</td>
<td>2.87</td>
<td>34.02</td>
<td>2.90</td>
<td>1.841</td>
<td>1.82</td>
<td>66.42</td>
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<tr>
<td>Mixed</td>
<td>34.95</td>
<td>1.39</td>
<td>44.65</td>
<td>6.34</td>
<td>31.22</td>
<td>7.21</td>
<td>1.954</td>
<td>2.13</td>
<td>66.00</td>
</tr>
</tbody>
</table>
Table II

Analysis of Variance for Estimating Reliability of Measurement

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td>18</td>
<td>$\sigma_e^2 + 2\sigma_s^2$</td>
</tr>
<tr>
<td>Between Measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td>19</td>
<td>$\sigma_e$</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

Table III

Reliability and Error Estimates for Measurement Methods Used in Study

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean Square</th>
<th>$\sigma_s^2$</th>
<th>$\sigma_e^2$</th>
<th>Reliability $\frac{\sigma_s^2}{\sigma_s^2 + \sigma_e^2}$</th>
<th>Error $\frac{\sigma_e^2}{\sigma_s^2 + \sigma_e^2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wc Bet.Subj.</td>
<td>6.684</td>
<td>3.298</td>
<td>0.089</td>
<td>0.97365</td>
<td>0.026341</td>
</tr>
<tr>
<td></td>
<td>0.089</td>
<td></td>
<td></td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>Wm Bet.Subj.</td>
<td>8.276</td>
<td>4.124</td>
<td>0.028</td>
<td>0.99321</td>
<td>0.00678</td>
</tr>
<tr>
<td></td>
<td>0.028</td>
<td></td>
<td></td>
<td>0.67%</td>
<td></td>
</tr>
<tr>
<td>L Bet.Subj.</td>
<td>19.414</td>
<td>9.606</td>
<td>0.020</td>
<td>0.97953</td>
<td>0.0247</td>
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<td>0.020</td>
<td></td>
<td></td>
<td>2.47%</td>
<td></td>
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<tr>
<td>Pal.Ang. Bet.Subj.</td>
<td>123.331</td>
<td>62.655</td>
<td>0.19802</td>
<td>0.9693</td>
<td>0.0306</td>
</tr>
<tr>
<td></td>
<td>0.19802</td>
<td></td>
<td></td>
<td>3.06%</td>
<td></td>
</tr>
<tr>
<td>Pal.Hgt. Bet.Subj.</td>
<td>3.233</td>
<td>1.636</td>
<td>0.0394</td>
<td>0.9764</td>
<td>0.2355</td>
</tr>
<tr>
<td></td>
<td>0.0394</td>
<td></td>
<td></td>
<td>2.35%</td>
<td></td>
</tr>
</tbody>
</table>

$\sigma_s^2$ = variance attributable to differences between subjects

$\sigma_e^2$ = variance attributable to error of measurement
### Table IV

**Sample Sizes**

<table>
<thead>
<tr>
<th>Dental Age</th>
<th>Diplegia &amp; Paraplegia</th>
<th>Hemiplegia</th>
<th>Quadriplegia</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Mixed</td>
<td>14</td>
<td>12</td>
<td>17</td>
<td>49</td>
</tr>
<tr>
<td>Permanent</td>
<td>4</td>
<td>7</td>
<td>13</td>
<td>8</td>
</tr>
</tbody>
</table>

### By Descriptive Classification

<table>
<thead>
<tr>
<th>Dental Age</th>
<th>Spastic</th>
<th>Ataxic</th>
<th>Athetoid</th>
<th>Mixed</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>15</td>
<td>2</td>
<td></td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Mixed</td>
<td>26</td>
<td>2</td>
<td>7</td>
<td>11</td>
<td>49</td>
</tr>
<tr>
<td>Permanent</td>
<td>12</td>
<td>7</td>
<td></td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

### Cerebral Palsy Groups With Respect to Regional Classification

#### Table V

**Analysis of Variance for Intercuspid Width (W<sub>c</sub>)**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>4.168</td>
<td>0.49 (n.s.⁺)</td>
</tr>
<tr>
<td>Between dental ages</td>
<td>2</td>
<td>276.585</td>
<td>32.79 (P&lt;.001)</td>
</tr>
<tr>
<td>Group X age interact.</td>
<td>6</td>
<td>5.346</td>
<td>0.63 (n.s.)</td>
</tr>
<tr>
<td>Error</td>
<td>155</td>
<td>8.435</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>166</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table VI

**Analysis of Variance for Intermolar Width (W<sub>m</sub>)**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>51.096</td>
<td>2.65 (p=.05)</td>
</tr>
<tr>
<td>Between dental ages</td>
<td>2</td>
<td>1262.211</td>
<td>65.52 (P&lt;.001)</td>
</tr>
<tr>
<td>Group X age interact.</td>
<td>6</td>
<td>51.390</td>
<td>2.67 (P&lt;.02)</td>
</tr>
<tr>
<td>Error</td>
<td>155</td>
<td>19.263</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>166</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

⁺n.s. = non significant
Table VII

Analysis of Variance for Arch Length (L)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>25.59</td>
<td>4.11 (p&lt;.01)</td>
</tr>
<tr>
<td>Between dental ages</td>
<td>2</td>
<td>1039.62</td>
<td>167.06 (p&lt;.001)</td>
</tr>
<tr>
<td>Group X age interact.</td>
<td>6</td>
<td>10.75</td>
<td>1.73 (n.s.)</td>
</tr>
<tr>
<td>Error</td>
<td>155</td>
<td>6.22</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>166</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table VIII

Analysis of Variance for Palatal Height

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>0.15</td>
<td>0.04 (n.s.)</td>
</tr>
<tr>
<td>Between dental ages</td>
<td>2</td>
<td>177.25</td>
<td>43.52 (p&lt;.001)</td>
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<tr>
<td>Group X age interact.</td>
<td>6</td>
<td>1.07</td>
<td>.26 (n.s.)</td>
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<tr>
<td>Error</td>
<td>155</td>
<td>4.07</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td></td>
<td></td>
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</tbody>
</table>

Table IX

Analysis of Variance for Palatal Angle

<table>
<thead>
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<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>146.12</td>
<td>1.08 (n.s.)</td>
</tr>
<tr>
<td>Between dental ages</td>
<td>2</td>
<td>2999.32</td>
<td>22.21 (p&lt;.001)</td>
</tr>
<tr>
<td>Group X age interact.</td>
<td>6</td>
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<td>.99 (n.s.)</td>
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<tr>
<td>Error</td>
<td>155</td>
<td>135.04</td>
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Table X

Analysis of Variance for Dental Arch Index (D.A.I.)

<table>
<thead>
<tr>
<th>Source of Variation</th>
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<th>F</th>
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</thead>
<tbody>
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<td>Between groups</td>
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<td>0.1131</td>
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<td>Between dental ages</td>
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<tr>
<td>Error</td>
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<tr>
<td>Total</td>
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Cerebral Palsy Groups With Respect to Descriptive Classification

### Table XI

Analysis of Variance for Intercuspid Width ($W_c$)

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<th>Source of Variation</th>
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</thead>
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<tr>
<td>Between groups</td>
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<td>2.88</td>
<td>0.38 (n.s.)</td>
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<tr>
<td>Between dental ages</td>
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<td>217.22</td>
<td>28.60 (p&lt;.001)</td>
</tr>
<tr>
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<td>4.81</td>
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<tr>
<td>Error</td>
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<td>7.59</td>
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<tr>
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### Table XII

Analysis of Variance for Intermolar Width ($W_m$)

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<td>Between dental ages</td>
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### Table XIII

Analysis of Variance for Arch Length ($L$)

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<tr>
<td>Between groups</td>
<td>3</td>
<td>18.57</td>
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### Table XIV

Analysis of Variance for Palatal Height

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</thead>
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<td>0.23</td>
<td>0.06 (n.s.)</td>
</tr>
<tr>
<td>Between dental ages</td>
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<td>37.47 (p&lt;.001)</td>
</tr>
<tr>
<td>Group X age interact.</td>
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<td>2.22</td>
<td>0.54 (n.s.)</td>
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<tr>
<td>Error</td>
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<td>4.13</td>
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<td>Total</td>
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Table XV

Analysis of Variance for Palatal Angle

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<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
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</thead>
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<tr>
<td>Between groups</td>
<td>3</td>
<td>216.97</td>
<td>1.56 (n.s.)</td>
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<tr>
<td>Between dental ages</td>
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<td>1983.00</td>
<td>14.21 (p&lt;.001)</td>
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<td>97.48</td>
<td>0.70 (n.s.)</td>
</tr>
<tr>
<td>Error</td>
<td>154</td>
<td>139.51</td>
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<tr>
<td>Total</td>
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Table XVI

Analysis of Variance for Dental Arch Index (D.A.I.)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
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<tbody>
<tr>
<td>Between groups</td>
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<td>0.0972</td>
<td>2.27 (n.s.)</td>
</tr>
<tr>
<td>Between dental ages</td>
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<td>1.4938</td>
<td>34.99 (n.s.)</td>
</tr>
<tr>
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<td>0.0788</td>
<td>1.85 (n.s.)</td>
</tr>
<tr>
<td>Error</td>
<td>154</td>
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<tr>
<td>Total</td>
<td>165</td>
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Table XVII

Normal Groups - Occurrence of Occlusal Discrepancies vs. Cerebral Palsy

<table>
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<td>Norm. C.P.</td>
<td>Norm. C.P.</td>
<td>Norm. C.P.</td>
<td>Norm. C.P.</td>
<td>Norm. C.P.</td>
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</table>

| Primary Dent. | 1 | 7 | 1 | 2 | 1 | 3 | 13 | 11 | 15 |
| Mixed Dent.   | 1 | 6 | - | 1 | 7 | 6 | 3  | 11 | 24 | 21 |
| Permanent Dent.| - | 9 | - | 4 | - | 3 | -  | 6  | 1  | 5  |

| Total          | 2 | 22 | 1 | 7 | 8 | 9 | 6  | 30 | 36 | 41 |
DISCUSSION
Describing and assessing arch form pose problems for both clinician and researcher. The need for accuracy and reproducibility has often been stressed in the literature, and the purpose of the present study was to help meet that need by comparing the maxillary arch form and palatal vault form in cerebral palsied and normal children.

Concerning the classification difficulties encountered with cerebral palsied individuals, most authors feel that a descriptive profile of each afflicted individual is more informative than an objective taxonomy. The classifications used in this study were similar to those which others have used in dealing with the subject of cerebral palsy. The spastic and the mixed descriptive groups formed the majority of cerebral palsy subjects in this study sample. Ataxic individuals represented the smallest group. This distribution is consistent with the incidence reports mentioned by Cruikshank. With respect to cerebral palsy regional classification, the quadriplegic group had the most subjects and the paraplegic group had the fewest. Lack of index reports with respect to regional involvement prevents any
assessment of whether this study sample is representative of the general cerebral palsy population.

Describing arch form by means of an index number involving reproducible measurements has obvious advantages. The method used in this study proved to be reliable from a statistical standpoint, and the landmarks used were valid. However, an index ratio method of describing arch form cannot reflect irregularities which are readily observable upon visual examination but do not involve the specific landmarks used. Other reproducible variables, such as area measurements and arch segment angle determinations, would contribute more information on the form of a dental arch.

Using the angle of divergence of the palatal vault walls, in addition to the fact that it is measurable and reproducible, permits visual depiction of the vault form from a cross-sectional view. An acute vault angle conveys the idea of a tapered or V-shaped vault form and conversely, an obtuse angle suggests a more ovoid form. Xerox photographs of the study cases were of inestimable value in this procedure. Vault angle alone, however, leaves much to be desired as a means of describing vault form. Contributions from other variables such as palatal vault volume and cross-sectional palatal vault area would improve the descriptive profile of vault form.
Intercuspid widths did not differ significantly between the cerebral palsy and normal groups within any of the three eruptive stages. The developmental trends indicated by the similar significant differences between eruptive stages for all groups suggested that the transverse growth of the maxillary anterior segment was not affected by the cerebral palsy condition. The observed intercuspid growth trends were in agreement with similar reports in the literature.39,54,55,73,74

In the primary dentition stage, differences in intermolar width between regional cerebral palsied and normal groups reached borderline significance. The hemiplegics and quadriplegics had smaller intermolar dimensions than the normal group. The paraplegic-diplegic combined group did not differ from the normal with respect to this variable. This is interesting since hemiplegics and quadriplegics have more extensive brain damage and are almost invariably more physically handicapped than the latter groups.4 Why this intermolar difference was not observed in the mixed and permanent dentition remains unknown.

No significant differences in intermolar width were observed between the descriptive cerebral palsy and normal groups. This finding does not agree with that of Album,22 who reported smaller intermolar dimensions in his seven
to 10-year-old subject sample. The developmental trends were the same for all groups with respect to intermolar width, but did not follow the pattern of decrease from mixed to permanent stages that was reported by Barrow and White, Mills, and Cohen. This difference may be due to several factors. The present study is cross-sectional whereas the others mentioned were longitudinal. Strict comparison between the two in terms of developmental trends is hazardous. Another factor is the age grouping of subjects. Mills, for instance, found differences in molar breadth values between 13 and 19 years of age, whereas the present study grouped these age extremes in one category.

Anterior-posterior length values differed significantly between the regional cerebral palsy and normal groups when all three eruptive stages were grouped together. The quadriplegic group demonstrated a longer maxillary arch than the normal. As previously mentioned, the quadriplegic individuals are considered to be more severely afflicted than the other groups, which lends significance to this finding. The other regional groups did not differ from the normal. Among the descriptive cerebral palsy groups, the spastics had longer maxillary arches than the normal. These findings conflict with those of Kongo who found shorter anterior-posterior lengths in his cerebral palsy group than in his control group. He did not discriminate
between his descriptive and regional cerebral palsy groups with respect to his findings. The developmental trends of this variable with respect to eruptive stages followed the same pattern in all groups studied and correlated well with those reported by Moorees. It must be pointed out that the age groupings in this study were much broader and, therefore, less expressive of variation with respect to smaller age increments.

The dental arch index numbers did not differ significantly between cerebral palsied and normal groups in any of the three eruptive stages. Since maxillary dental arch form was expressed by this number, variation in arch form did not appear to be altered in a sample solely on the basis of their being cerebral palsy subjects. In addition, no particular trend was measured in any of the cerebral palsied groups to warrant the ascription of a particular maxillary arch configuration to that group. These findings do not support those of Koster and Album but do support those of Siegel. Other authors have reported more arch deformation in cerebral palsy subjects than in normal individuals. Specific types of arch deformation were not qualified, however, and the dental arch index number in the present study did not measure this variable. The significant differences in the dental arch index numbers which
were observed in all groups with respect to eruptive stages indicate a greater tendency toward ovoidness, i.e., larger values, in the primary dentition. This correlates well with the observations of Moyers and Bakwin.

Surprisingly, there was also a tendency toward more ovoidness in the permanent dentition than in the mixed dentition. With the continued lengthening of the arch posteriorly due to the eruption of the second molars and growth at the tuberosity areas, lower index numbers suggestive of a tapering effect would be expected.

Palatal height dimensions did not differ significantly between any of the cerebral palsy and normal groups in any of the stages. This finding supported the observations of Siegel and conflicted with those of Kongo, who found that the cerebral palsy subjects in his study had less palatal height dimensions. The developmental trends of increased palatal height with age in all groups studied supports the findings of Lebert, Hellman, and Moyers.

Palatal vault angle values did not differ significantly between any of the cerebral palsy and normal groups within the respective eruptive stages. This indicated that palatal vault form of the cerebral palsied subjects was no more or less tapered than in normal subjects, nor was there a vault configuration that was peculiar to any of the cerebral palsied groups investigated. Since no correlatable
subjective terminology has been ascribed to a particular angle, the findings of the present study could not be compared directly with those of other studies mentioned in the literature review. From a developmental standpoint, significant differences were evident in similar patterns for all groups studied. Palatal angles were more obtuse in the mixed dentition than either the primary or permanent dentition. Greatest palatal angle acuity was observed in the permanent dentition, indicating a tendency toward a more tapering vault form with age.

Significant differences between cerebral palsy and normal groups were demonstrated with respect to prevalence of the occlusal discrepancies of unilateral and bilateral posterior crossbite, anterior crossbite, and anterior open bite. A direct correlation between those discrepancies and maxillary dental arch form and palatal vault form was not made. Therefore, the ability of those variables to reflect a change in arch form could only be inferred rather than statistically established. Such an inference can be justified with respect to open bite. Cross-bite presents more of a problem. The significance of these discrepancies cannot be thoroughly assessed without attention to their etiology. This very important variable was not evaluated in the present study. In considering the data, it is
interesting that the frequency of each discrepancy was greater in the cerebral palsy groups than in normal groups, which supports the finding of Koster\textsuperscript{21} and Album\textsuperscript{22} and conflicts with that of Rosenbaum.\textsuperscript{23} (Table XVII)

No significant difference between cerebral palsy groups and normal groups was demonstrated with respect to posterior dental asymmetry. This was a fourth occlusal discrepancy which was thought to reflect arch form variation. The same criticisms of the other occlusal variables hold true for asymmetry evaluation.

It would appear that from the analysis of the data collected in this study, maxillary arch form cannot be considered as a diagnostic tool in cerebral palsy individuals. Values of arch form and dimension did not show enough consistent differences between cerebral palsy groups and normal groups to warrant generalizations about maxillary arch form peculiarities in cerebral palsy children. It may be that this finding could still be contested and it is the hope of the author that more studies will be conducted in this area. The limitations of the present investigation are evident, such as small sample size, lack of attention to arch form differences due to sex, inability to measure arch from variables longitudinally, and lack of attention to etiological factors which could correlate with high and low maxillary arch form values. However, this study has
described a reliable method of objectively describing dental arch form and palatal vault form. It has also, within its limitations, attempted to evaluate the differences in maxillary arch form between groups of cerebral palsy and normal subjects and in doing so has provided additional information on this controversial subject.
SUMMARY AND CONCLUSIONS
Reports in the literature on arch form in cerebral palsy individuals, along with clinical observations by the author, led to this comparative study of the maxillary arch form in groups of cerebral palsy and normal children.

Maxillary study models of 98 cerebral palsy children and 76 normal children were compared for differences in arch form in two planes: the horizontal plane represented by dental arch form and the vertical plane represented by palatal vault form. Dental arch form was described by an index number calculated from intercuspid, intermolar, and anterior-posterior length measurements. Palatal vault angle represented the angle of divergence of the palatal wall tangents constructed on Xerox photocopies of the study model cross-sections. In addition to these two values, all dimensional measurements and the occlusal discrepancies of posterior crossbite, anterior crossbite, anterior open bite, and dental asymmetry were statistically treated for between-group differences in the primary, mixed, and permanent dentitions.

From the observations made in this study, the following conclusions were made:
1. The method of describing maxillary dental arch form and palatal vault form used in this study was acceptable and reliable.

2. There were no significant differences in maxillary dental arch form and palatal vault form between the cerebral palsy and normal children in this study with respect to dental arch index and palatal vault angle values. No particular type of dental arch form or palatal vault form was peculiar to any of the cerebral palsy groups studied.

3. There were no significant differences in palatal vault height as measured in this study between cerebral palsy and normal children.

4. Hemiplegic and quadriplegic cerebral palsy children demonstrated significantly narrower intermolar breadth dimensions than did the normal subjects in the primary dentition.

5. Quadriplegic cerebral palsy children demonstrated significantly longer maxillary dental arches anterior-posteriorly than did the normal children in the combined eruptive stages.

6. Spastic cerebral palsy children demonstrated significantly longer maxillary dental arches
anterior-posteriorly than the normal children in the permanent dentition. The mixed cerebral palsy group demonstrated a significantly shorter arch length than the normal group in this same eruptive stage.

7. The occlusal discrepancies of unilateral and bilateral posterior crossbite, anterior crossbite, and anterior open bite were found with greater frequency in the cerebral palsy sample than in the normal sample.
REFERENCES


CURRICULUM VITAE
Clifton Orrin Dummett, Jr.

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<td>February 14, 1944</td>
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</tr>
<tr>
<td>June, 1961</td>
<td>Graduated from Lenox Preparatory School, Lenox, Massachusetts</td>
</tr>
<tr>
<td>June, 1965</td>
<td>A.B. Degree, Earlham College Richmond, Indiana</td>
</tr>
<tr>
<td>June, 1969</td>
<td>D.D.S. Indiana University-Purdue University School of Dentistry</td>
</tr>
<tr>
<td>September, 1969</td>
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<td>Entered Indiana University-Purdue University at Indianapolis Graduate School of Dentistry and Fellow of the United Cerebral Palsy Education and Research Foundation, Indianapolis, Indiana</td>
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<td>August, 1969</td>
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Professional Organizations

American Dental Association

American Society of Dentistry for Children
ABSTRACT
A COMPARISON OF MAXILLARY ARCH FORM
BETWEEN GROUPS OF CEREBRAL PALSIED
AND NORMAL CHILDREN

Clifton Orrin Dummett, Jr., D.D.S.
Indiana University-Purdue University at Indianapolis
School of Dentistry
Indianapolis, Indiana

The purpose of this study was to compare the maxillary dental arch form and palatal vault form between 98 cerebral palsied and 76 normal children. All subjects were divided into three categories based on their dental eruption. The cerebral palsy subjects were further divided into the regional classifications of diplegia, paraplegia, hemiplegia, and quadriplegia, and the descriptive classifications of spasticity, athetosis, and mixed.

The maxillary dental arch form was described by an index number which reflected intercusp width, intermolar width, anterior-posterior length, and degree of divergence of the posterior segments. The palatal vault form was described by the angle of divergence of the palatal walls at an established reference point from a cross-sectional view. All measurements were made from study models and Xerox photocopies of study model cross-sections. In addition, those occlusal discrepancies that were thought to influence
arch form, i.e., posterior unilateral and bilateral crossbite, anterior crossbite, anterior open bite, and posterior dental asymmetry were tabulated.

Statistical analysis of the results revealed no significant difference in maxillary dental arch form between the cerebral palsied and normal children. The same held true for palatal vault form. Significant differences did occur between primary, mixed, and permanent dentitions for both cerebral palsied and non-handicapped groups. The results suggest that the neuromuscular handicap has little effect on the form of the maxillary dental arch. On the basis of this study, it appears that there is no particular type of maxillary arch form that is peculiar to cerebral palsy.