To the Graduate Council:

I am submitting herewith a thesis written by Elizabeth A. Gilb entitled "The Cementoenamel Junction: Gap, Overlay and Edge to Edge Relationships." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Dr. Murray Marks, Major Professor

We have read this thesis
and recommend its acceptance:

Associate Vice Chancellor and
Dean of the Graduate School

The Cementoenamel Junction: Gap, Overlay and Edge to Edge Relationships

A Thesis

Presented for the

Master of Arts Degree

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Elizabeth A. Gilb

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DEDICATION

I would like to dedicate the following Master's thesis to my niece Marley Siobahn Gilb who has been a wonderful influence in my life and who has taught me about unconditional love. I regret ever leaving you and going to graduate school. Some day I hope that you will understand how important you really are to me. I love you.

ABSTRACT

The purpose of this research is to examine mineralized tissue relationships at the cementoenamel junction in the maxillary central incisor and the mandibular canine. There are three distinct relationships at the cervical region of the tooth: a gap junction is when the cementum and enamel fail to connect, an edge-to-edge when the cementum and enamel meet and an overlay when the cementum extends on to the enamel. There are four main research questions that have been addressed in this investigation; 1) Can a type of junction be correlated to racial affinity? 2) Is there a relationship between sex and junction type? 3) Is there a significant difference between adults and children? 4) Does dental hygiene or exposure to the oral cavity cause changes or damage to this structure? Population samples were utilized from a modern, historic and prehistoric time periods to address the above questions. Thin sections were analyzed at a magnification of 125X. The results verified a strong relationship between racial affinity and junction type. Sex was correlated to junction type on the labial surface of the canine only, while age and junction type showed positive statistical results for the both labial and lingual incisor. Dental hygiene and exposure (via age) to the oral cavity does not seem to result in a significant change at the cervical margin of the tooth. The goal of this research was to aid physical/forensic anthropologist in determining a biological profile of unknown individuals.

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CHAPTER 1

INTRODUCTION

A fundamental aspect of skeletal analysis, whether forensic or archaeological, is the estimation of sex and racial affinity of the individual or individuals in question. In many circumstances, physical anthropologists have to employ teeth to obtain the necessary data for comprising a biological profile of the skeletal remains. Numerous dental methods exist and new techniques for determining racial affinity and sex are currently being detailed in the anthropologic literature (See Axelsson and Kirveskari, 1977; Bang and Hasund, 1971; Biggerstaff, 1975; Blanco and Chakraborty, 1976; Dahlberg, 1985; Dennison, 1979; Ditch and Rose, 1972; Duffy et al., 1991; Falk and Corruccini, 1982; Garn et al., 1977; Garn, 1979; Garn et al., 1966; Haines, 1972; Hinkes, 1990; Kraus, 1951; Lavelle, 1984; Moorrees et al., 1957; Nichol et al., 1984; Owsley, 1982; Owsley and Webb, 1983; Pinto-Cisternas and Figueroa, 1968; Portin and Alvesalo, 1974; Reid et al., 1991; Rhine, 1990; Riesenfeld, 1956; Rosenzweig, 1970; Scott, 1980; Suzuki and Sakai, 1964).

Physical anthropologists have not utilized dental thin sections as a partner to skeletal analysis when establishing sex and racial affinity because they are labor intensive. Dental thin sections have been employed primarily in research involving age estimation using incremental lines in cementum and the transparency of root dentine (See Berg et. al., 1984; Drusini, 1991; Drusini et al., 1991; Grant and Bernick, 1972; Gustafson, 1950; Kashyap and Koteswara, 1990; Lipsinic et al., 1986;

Sivasankara-Pillai and Bhaskar, 1974). The cervical region of the tooth is microscopically observable by producing dental thin sections.

The cementoenamel junction is located at the cervical region of the tooth where the root cementum and coronal enamel meet (see Abrams, 1992; Avery, 1992). The junction is established after the last region of enamel is formed during amelogenesis (Avery, 1988). At the base of the enamel organ, the inner and outer enamel epithelial cells come together forming a double layer of cells termed Hertwig's sheath (Scott and Symons, 1974). This structure is where the cementoenamel junction occurs in the finished tooth as the inner eptihelial cells start the formation of cementum and the odontoblasts begin the development of root dentine (see Chapter 2).

Past studies of the cementoenamel junction have illustrated that there are three distinct relationships that occur between the enamel and cementum: overlap, when the cementum extends on to the coronal enamel, edge-to-edge, when the cementum and enamel connect at the cervical line, and a gap with an exposure of dentin resulting from cementum and enamel failing to meet at the cervical region (Bevenius et al., 1993; Grossman and Hargreaves, 1991; Jordan et al., 1992; Mayhall and Rose, 1984; Muller and van Wyk, 1984; Thorsen, 1917; Schroeder and Scherle, 1989).

The majority of past cementoenamel analysis has been performed by dental researchers and the results display significant percentage variation of these three types of relationships. Thorsen (1917) evaluated 65 Scandinavian teeth and recorded an edge-to-edge relationship occurring in 30%, an overlap in 60%, while a gap was observed in 10% (Bevenius et. al., 1993; Thorsen, 1917). Muller and van Wyk (1984) examined 152 teeth from the "Cape Peninsula Coloureds" population and their findings differed

from Thorsen's results: they observed an edge-to-edge relationship in 49.2%, overlap in only 34.1%, and a gap in 17.7%. Mayhall and Rose conducted the first research of the cementoenamel junction on two archaeological Native American populations from three cemeteries in Illinois (Study I) and the Libben site located in Ohio (Study II). Study I was comprised of 14 deciduous teeth and 37 permanent teeth, and Study II was composed of 67 permanent teeth (Mayhall and Rose, 1984). The results of the permanent teeth from Study I differed from past results of both Thorsen and Muller and van Wyk in that an edge-to-edge relationship occurred in 33%, an overlap in only 48% and a gap was recorded in 19%. The deciduous teeth from Study I also differed from past studies in that an overlap was only seen in 7.7%, while a gap appeared in 30.8% with 61.5% displaying an edge-to-edge relationship. An interesting finding from Study I is that the results are similar to the research of Ramsey and Ripa (1969) where 40 deciduous premolars showed an edge-to-edge relationship of 61.25%, overlap in only 7.5%, and a gap in 31.25%. The 67 permanent teeth in Study II showed relationship frequency results similar to Study I, with a gap in 18%, overlap in 53% and 29% displayed an edge-to-edge relationship. Other studies (Bevenius et al., 1993; Grossman and Hargreaves, 1991; Ramsey and Ripa, 1969; Schroeder and Scherle, 1989) show considerable variation in the cementoenamel junction, but the racial affinity and sex of the samples, were, unfortunately, not noted by the researchers (see Chapter 2).

While research regarding the cementoenamel junction has been conducted mainly by dental researchers, however, such findings might be applied anthropologically to estimate the racial affinity and/or sex of an individual. Past studies of the cementoenamel junction (Bevenius et al., 1993; Mayhall and Rose, 1984; Muller

and van Wyk, 1984; Thorsen, 1917) clearly demonstrate that there is variation in this structure. This variation may be due to genetic make-up. Yet, unfortunately, most studies have not considered sex as a variable. Anthropological studies have shown that the human dentition does display sexual differences (See Ditch and Rose, 1972; Garn et al., 1977; Owsley, 1982; Rosenzweig, 1970 among others) and the cementoenamel junction may be another target area of such diversity.

Age is yet another factor considered in this study. Research clearly demonstrates that there is variation between the three types of relationships exhibited at the cementoenamel junction in permanent and deciduous teeth (Mayhall and Rose, 1984; Muller and van Wyk, 1984; Ramsey and Ripa, 1969). Age will be analyzed to see if cementoenamel junction variation is a permanent boundary that does not become altered as a result of growth, development and aging of the oral tissues.

The goal of this study is to establish criteria that would determine the racial affinity and sex of unknown skeletal material based on the interpretation of cementoenamel variation. This study examines the cementoenamel junction utilizing thin sections of the maxillary central incisor and the mandibular canine viewed under a light microscope at 125X. The analysis includes examination of the relationship at the cementoenamel junction on both the labial and lingual surfaces of the tooth and measurement of gap distance or an overlay extension of the cementum. These criteria could be employed in studies involving archaeological or forensic case settings.

An examination of the cementoenamel junction was conducted on a modern European, historic African-American, and prehistoric Native American population samples to see if variation of this junction is related to racial affinity, sex and age (see

Chapter 3). In the past, several dental researchers (Bevenius et al., 1993; Muller and van Wyk, 1984) felt that exposure of the cementoenamel junction to the oral environment and oral hygiene methods could result in damage or changes in this region. Samples from prehistoric, historic, and modern time periods were analyzed to document the types of relationships between enamel and cementum. If similar relationships are exhibited at this junction, dental hygiene methods and exposure to the oral environment are probabely not causing change at this junction. The samples were analyzed in a blind test to reduce the observational biases resulting from known sample information.

CHAPTER 2

DENTAL DEVELOPMENT AND TOOTH HISTOLOGY

CROWN FORMATION

Dental development starts during the sixth embryonic week by the interaction of oral epithelial cells and the mesenchymal cells (Avery, 1992; Brand and Isselhard, 1990). Neural crest cells, i.e., mesenchymal cells of the head and neck, cause the epithelial cells to proliferate and form a unique layer in the stomodeum termed the dental lamina (Avery, 1992; Ranly, 1988). The lamina develops a ridge of epithelial cells known as the primary epithelial band overlying mesenchymal cells in both the maxilla and mandible. The epithelial cells accumulate into nodules that eventually give rise to the 20 primary tooth buds (Jordan et al., 1992; Scott and Symons, 1974; Weinstock, 1972). A tooth bud will develop three parts: the enamel organ which is responsible for the production of enamel, the dental papilla which produces dentin and pulp ingredients, and the dental follicle which serves as a fibrous membrane boundary protecting the developing tooth bud. The dental follicle initiates the covering of the root by cementum and the formation of the periodontal ligament once amelogenesis is completed. The enamel organ is derived from oral ectoderm while the dental papilla and the dental follicle are produced from mesenchymal cells (Avery, 1988; Ranly, 1988; Scott and Symons, 1974).

The first distinctive stage of tooth bud development is the bud stage. During this period of development the outer and inner epithelial cells and the stellate

reticulum of the enamel organ are formed above the dental papilla and migrate inferiorly. Continual growth of the tooth bud gives rise to the cap stage of development (Avery, 1992; Brand and Isselhard, 1990; Scott and Symons, 1974). The outer enamel epithelial cells develop from the basal layer of the oral epithelium and transform into low columnar cells. The inner enamel epithelial cells are also derived from the basal layer and they transform into a cuboid shape (Brand and Isselhard, 1990; Ranly, 1988). The stellate reticulum is located between the inner and outer enamel epithelium. The columnar epithelial layer is hydrophilic, i.e., water and glycosaminoglycans, and the future site of enamel formation.

The final stage of enamel organ development, i.e. , bell stage, is reached when the appearance of the stratum intermedium layer is observed between the inner epithelial layer and the stellate reticulum (see Figure 1) (Avery, 1992; Scott and Symons, 1974). As differentiation continues, the outer enamel epithelial layer acts as a protective layer for the enamel organ while the inner enamel epithelial cells elongate and transform into ameloblasts (Brand and Isselhard, 1990; Ranly, 1988). The cells of the dental papilla which are adjacent to the ameloblasts transform into low columnar cells termed odontoblasts. The odontoblasts migrate away from the trilaminar membrane of the dentoenamel junction and the ameloblasts begin to secret a matrix of mucopolysaccharide ground substance (Avery, 1988; Weinstock, 1972). The dentin matrix results in a change of nuclear polarity, among other organelle transformations that cause cells to undergo protien synthesis. The stellate reticulum now protects the inner epithelium layer and is nourishment to ameloblasts during amelogenesis (Ranly, 1988; Weinstock, 1972). The ameloblasts secrete a ground substance as they begin to

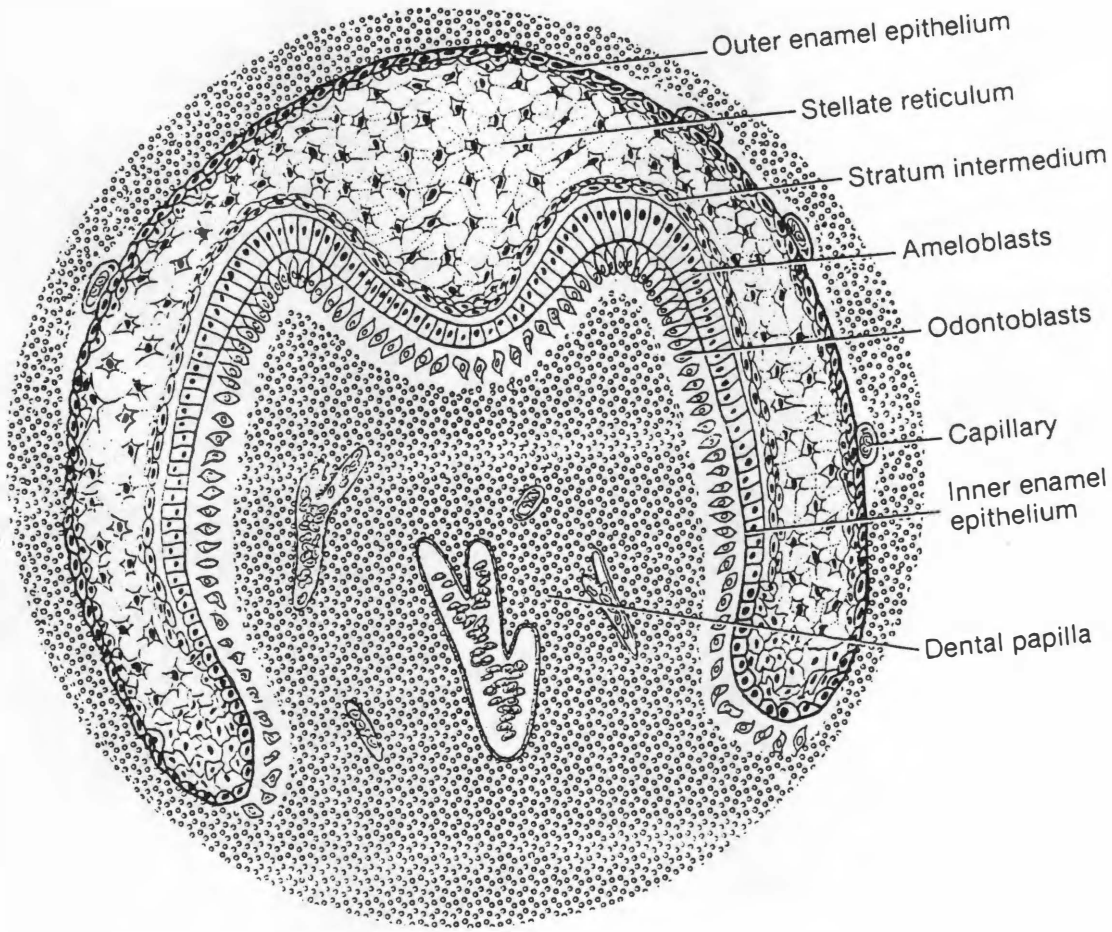


FIGURE 1. Cross-section of the bell stage of tooth development. (after Avery, 1992).

migrate towards the outer epithelial layer. Finally, the enamel and dentine matrix begins to mineralize (Avery, 1992; Brand and Isselhard, 1990). Crown mineralization of the dentin and enamel follows odontogenesis, they begin at the tip of the cusps and proceeding towards the cervical margin.

ROOT FORMATION

Root formation is instigated only after the crown is complete and begins to mineralize (Avery, 1992; Brand and Isselhard, 1990). After amelogenesis at the base of the enamel organ the inner and outer epithelial cells come together to develop Hertwig's sheath (Ranly, 1988; Scott and Symons, 1974). Hertwig's sheath determines the size, shape and number of roots that develop. This epithelial sheath starts at the cementoenamel junction where the ameloblasts have completed enamel crown formation overlaying the odontoblast layer that continues dentogenesis of the root. The root sheath will begin to curve horizontally into the pulp chamber at a 45 degree angle forming an epithelial diaphragm which will enclose the apical foramen and the pulp chamber during root formation (see Figure 2) (Brand and Isselhard, 1990; Ranly, 1988). At this time, odontoblasts continue dentin formation while the sheath cells undergo rapid mitotic division to produce an enameloid membrane termed intermediate cementum (Avery, 1992; Ten Cate, 1972). The formation of the enameloid membrane will cause Hertwig's sheath to disintegrate which produces epithelial rests (Avery, 1992; Scott and Symons, 1974). Epithelial rest cells disintegrate into the fibers of the dental follicle. In turn, mesenchymal cells from the dental follicle move between the epithelial rest vacancies on

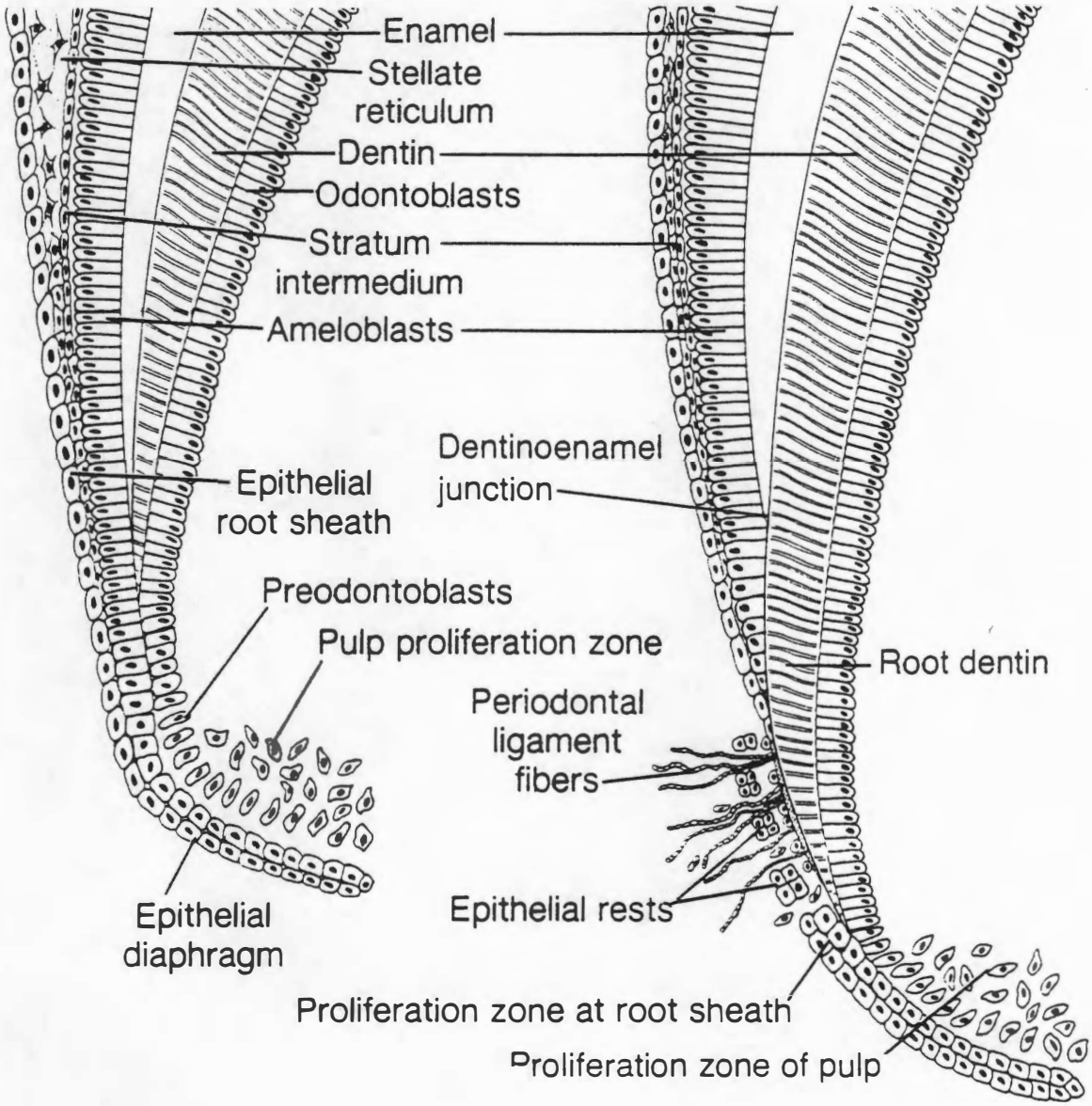


FIGURE 2: Root sheath development and epithelial diaphragm formation. (after Avery, 1992).

the root where they differentiate into cementoblasts after contacting the dentine (Brand and Isselhard, 1990; Ten Cate, 1972). The cementoblasts begin to secrete cementoid that will mineralize into mature cementum along the root surface (see Figure 3) (Avery, 1992; Scott and Symons, 1974). At the same time cementum is developing, the tissues of the dental follicle surrounding the developing tooth are forming the periodontal ligament. Then, periodontal fibers will attach into the alveolar bone and the cementoid to firmly anchor the tooth in each alveoli. The periodontal ligament attaches from the cementoenamel junction towards the apex and its development follows the formation of mature cementum along the root shaft (Avery, 1992; Ranly, 1988; Ten Cate, 1972).

PROPERTIES AND FUNCTIONS OF ENAMEL

Enamel develops through the process of amelogenesis which begins during the bud stage and concludes at the end of the late bell stage (Avery, 1992; Brand and Isselhard, 1990). It is a hard and brittle substance that covers the tooth surface. It is comprised of three main components: 96 % calcium phosphate, 4 % water and trace amounts of the protein enamelin (Poole and Stack, 1965). The main function of enamel is to protect the tooth crown exposed in the oral cavity and resist the strain of mastication. Enamel is able to protect the tooth crown because it is the hardest biological tissue in the human body. Enamel is able to sustain the stresses of mastication partially as a result of its structure of interlocking prisms or rods (Jordan et al., 1992). Each enamel rod develops from four ameloblasts and the structural formation in cross-section is a keyhole or racquet-shape with a head and tail differentiated by crystal

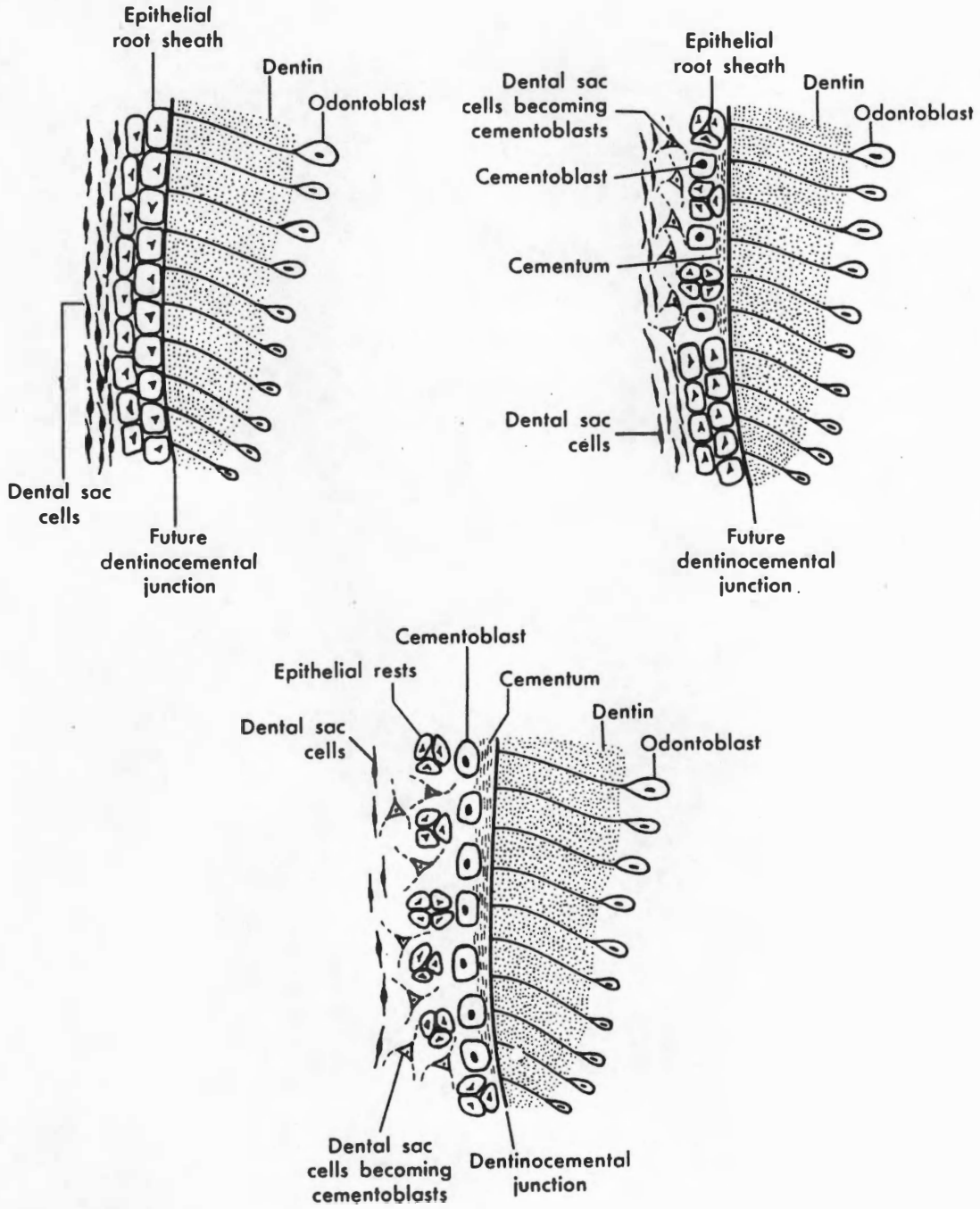


FIGURE 3: Developmental stages of cementum.
(after Brand and Isselhard, 1990).

orientation (Avery, 1988; Brand and Isselhard, 1990; Scott and Symons, 1974). The rods originate at the dentoenamel junction and extend to the enamel outer surface. Rods are developed almost perpendicular to the dentoenamel junction and become tortuous under the cusp tip. Groups of rods are slightly angled opposite the adjacent group. This configuration is what provides enamel the strength for mastication (Avery, 1988; Poole and Stack, 1965). Rods are deposited in weekly increments of 4 microns, appearing as dark lines termed striae of Retzius. Once amelogenesis is complete, no further deposition occurs (Avery, 1992; Weidmann and Hamm, 1965).

PROPERTIES AND FUNCTIONS OF CEMENTUM

The development of cementum is initiated after the bell stage of enamel formation. Cementum forms along the developing root shaft, keeping pace with dentinogenesis of the root (Avery, 1992; Schroeder and Listgarten; 1971). Biochemically, cementum is composed of an organic matrix of chondroitin sulfate, collagen and protein enamelin, while its mineral component is hydroxyapatite (Brand and Isselhard, 1990). Cementum has two main functions: it serves as an attachment site for periodontal ligament fibers and it protects the tubules of the root dentin (Jordan et al., 1992). There are two distinct layers of cementum covering the root. The first is termed intermediate cementum which derives from the root sheath cells forming into a homogeneous layer comprised primarily of enamelin. Since it is the first layer deposited onto the new root surface, it functions to seal the dentin tubules (Selvig, 1965). Intermediate cementum is completely developed before secondary cementum deposition

begins. Secondary deposition is directly over the intermediate cementum at a thickness of 30 to 60 microns. This layer is termed acellular cementum at the cementoenamel junction and increases to a thickness of 150 to 200 microns that becomes cellular cementum at the lower 1/3 of the root. Cellular differs from acellular in that it contains trapped cementoblasts and cementocytes that occur along the apical portion of the root (Brand and Isselhard, 1990; Selvig, 1965). Secondary cementum deposition also involves the formation of bundles of non-calcified fibers that function as the attachment sites of collagenous periodontal fibers known as Sharpey's fibers. Cementum grows continuously in appositional layers as a result of physical changes in pressure, stress, and trauma to the tooth (Gottlieb and Orban, 1938; Scott and Symons, 1974).

Researchers in both the fields of zooarchaeology and dentistry have observed that cementum thickness continually increases with age and they have used this in establishing age estimates (Broomell, 1898; Gustafson, 1950). The teeth are microscopically analyzed by preparing decalcified thin sections stained with either double hematoxylin or eosin (Lipsinic et al., 1986). Incremental lines in the cementum are used as an aging criterior for both animals and humans. Wildlife investigators were the first to routinely apply these lines in age determination and have utilized this method for many animal species, (i.e., deer, elk, ground squirrels, badgers, bison, and vampire bats) (Adams and Watkins, 1967; Crowe and Strickland, 1975; Keiss, 1969; Linhart, 1973; Low and Cowan, 1963; Novakowski, 1965). The zooachaeological method defines annulations in cementum as being paired dark and light bands that represent a one year life span (Davis, 1987). These bands have been attributed to the seasonal effects of nutrition, growth and hormones (Grue and Jensen, 1979). Dark bands represent

fall and winter while light bands are deposited during spring and summer months. These bands are counted to estimate the age (Grue and Jensen, 1979). In 1982, G. Scott was the first to correlate incremental lines in human cementum and age of tooth eruption to actual age of known individuals. Research is still being conducted to see if annulations in human cementum can be correlated with age estimates, but Lipsinic and his colleagues (1986) failed to achieve results observed by Scott's research. Incremental lines in cementum were found to be highly correlated to age in a study conducted on 80 teeth by Condon (1986) and his colleagues. Their results demonstrated that cementum annulation counts gave age estimates that only had a standard error ranging from 4.7 to 9.7 years.

STUDIES OF THE CEMENTOENAMEL JUNCTION

Several researchers have investigated the cementoenamel junction and recorded variation between enamel and cementum (Bevenius et al., 1993; Muller and van Wyk, 1984; Schroeder and Scherle, 1989). Thorsen's (1917) ground sections of 65 Scandinavian teeth revealed that there were three distinctive relationships at the cementoenamel junction: overlap, when the cementum appears to extend onto the coronal enamel, edge-to-edge, when the enamel and cementum meet end to end at the cervical line, and a gap when there is an exposure of dentin at the junction as a result of cementum and enamel failing to intersect (see Figure 4, 5, 6, 7) (Avery, 1992; Jordan et al., 1992). Thorsen examined ground sections under a light microscope and recorded that the cementum overlays in 60%, an edge-to-edge relationship in 30% and a gap in 10% of the cases (Bevenius et. al., 1993; Thorsen, 1917).

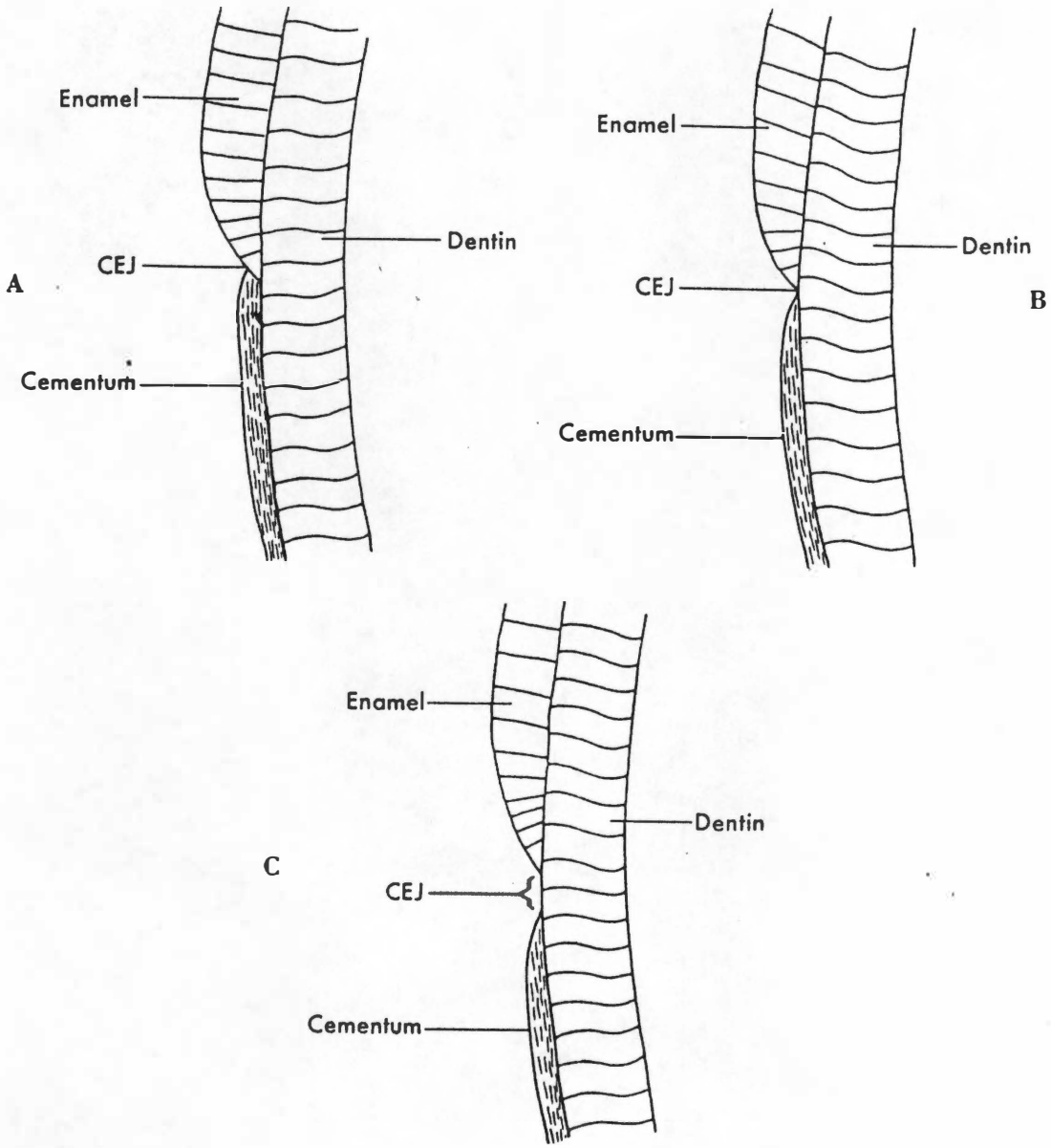


FIGURE 4: Relationships at the cementoenamel junction. A. Cementum overlaps enamel. B. Cementum and enamel meet at an edge to edge relationship. C. Cementum and enamel fail to intersect resulting in a gap relationship.
(after Brand and Isselhard, 1990)

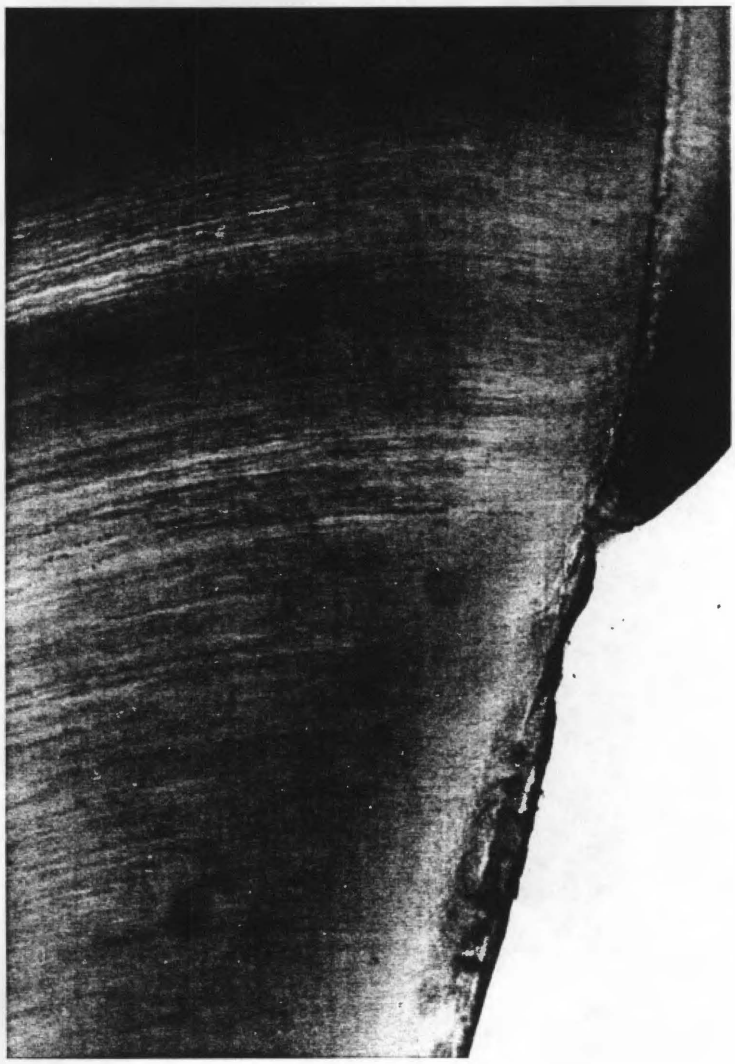


FIGURE 5: A gap relationship viewed under a light microscope at 125X.

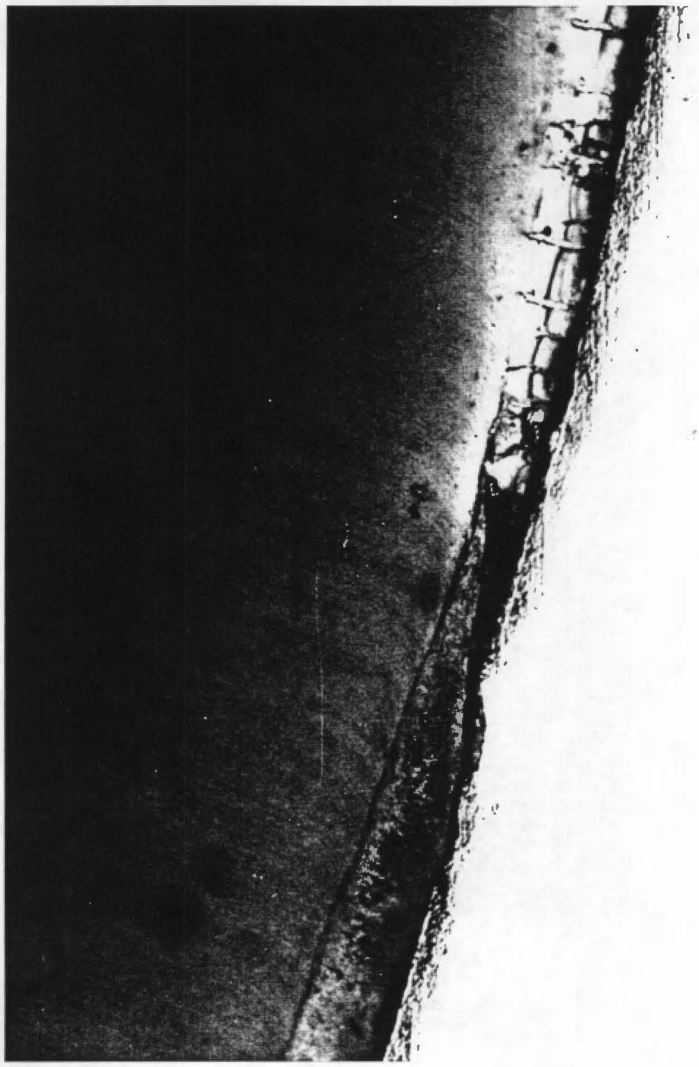


FIGURE 6: An overlay relationship viewed under a light microscope at 125X.



FIGURE 7: An edge-to-edge relationship viewed under a light microscope at 125X.

Ramsey and Ripa (1969) analyzed the relation of enamel to cementum at the cementoenamel junction in 40 (21 maxillary and 19 mandibular) human deciduous premolar teeth. These teeth were ground sections of 80 microns and both mesial and distal surfaces were examined using light microscopy at 100X. They observed that an edge-to-edge relationship appeared in 61.25% of the sample, a gap occurred in 31.25% while an overlap only appeared in 7.5% (Ramsey and Ripa, 1969).

In 1984, Muller and van Wyk conducted similar research from a sample of "Cape Peninsula Coloureds" whose ancestry consisted of European, African and Malay descent. Their sample consisted of 152 teeth (incisors, canines, premolars, molars) that were extracted from 10 males and 15 females with age ranges of 16 to 67 (Muller and van Wyk, 1984). These teeth were thick sectioned at 150 microns for light microscopy. Observations were recorded for the buccal (108), mesial (125), distal (119) and lingual (117) surfaces. Their findings differed greatly from Thorsen's earlier research. They observed a gap relationship in 17.7%, an edge-to-edge in 49.2%, with 34.1% displaying an overlay. This research documented that when a gap was observed at the cementoenamel junction it was often located on the buccal or lingual surface of the incisors. Muller and van Wyk also concluded that there was no correlation between age and type of junction and no discernible trend in the junction within individuals or between individuals. The researchers stated that dental hygiene, (i.e., brushing and flossing) could not be the cause of variation at the cementoenamel junction.

Also in 1984, Mayhall and Rose investigated the cementoenamel junction of both mandibular and maxillary canine teeth from several prehistoric Native American samples. Two separate prehistoric samples were analyzed: Study I sample consisted of

14 deciduous teeth and 37 permanent teeth selected from three Late Mississippian cemeteries in Illinois. Study II was composed of 67 permanent teeth from the Late Woodland Libben site located in northern Ohio. The authors chose these samples because of their genetic homogeneity and the fact that these teeth were free of dental manipulation (Mayhall and Rose, 1984). They examined the cross-sections prepared at 100-150 microns at the labial and lingual cervical regions. Study I revealed that an edge-to-edge junction occurred in 33% of the cases with 19% having a gap relationship. Forty-eight percent exhibited an overlay. The deciduous teeth from Study I displayed very different results with an edge-to-edge relationship in 61.5%, an overlap in only 7.7% and a gap in 30.8%. These findings are similar to those by Ramsey and Ripa (1969) for deciduous premolars. In Study II, the findings showed that an edge-to-edge junction appeared in 29% of the sample and 18% had a gap relationship with 53% displaying cementum overlapping the enamel (Mayhall and Rose, 1984). When the junction could be read on both the lingual and labial surfaces, it was the same in 50% of the cases. There are three aspects that differed between the deciduous and permanent canines: the first is that the deciduous teeth had a lower frequency of cementum overlaying the enamel. Second, deciduous teeth showed a greater occurrence of enamel and cementum failing to meet. Third, enamel and cementum were thinner at the junction in the deciduous teeth. Mayhall and Rose concluded that the junction was independent of sex and age and that the frequency difference between the Scandinavian (Thorsen) and the Native American populations samples might reflect a genetic difference (Mayhall and Rose, 1984).

Schroeder and Scherle (1989) investigated the cementoenamel junction in order

to evaluate the relationship between enamel, dentin and cementum. Their sample consisted of eight deciduous premolars which were ground sectioned to 150 microns and examined using a light and scanning electron microscopy (SEM). Their study found an edge-to-edge relationship in 70% of the sample and an overlap in 29% while a gap relationship displayed an extremely low frequency of only 1% (Schroeder and Scherle, 1989).

Recently, Grossman and Hargreaves (1991) evaluated 18 sectioned teeth (5 incisors, 4 canines, 5 premolars and 4 molars) from one man using SEM. They found cementum overlapping the enamel in three distinctive forms:

> "the cementum overhung the enamel with a gap between the cementum and the underlying enamel, the cementum appeared directly attached to the underlying enamel, or the cementum formed a well defined groove prior to the overlap" (Grossman and Hargreaves, 1991).

Gaps of dentin exposure were measured between 10-60 microns, but their frequency were extremely low only appearing in 5 teeth (2 maxillary incisors, 1 mandibular premolar, 1 maxillary molar, and 1 mandibular molar). The study concluded that even though cementum overlapped the enamel in most of the cases, the cementoenamel junction displays irregular variation (Grossman and Hargreaves, 1991).

In 1993, Joan Bevenius and her colleagues conducted analysis of the cementoenamel junction in 50 deciduous unerupted premolar teeth. Ground sections were produced and then examined under light microscopy to insure that all of the soft tissue had been removed before the scanning electron microscopy. The SEM was set at 30 k/v and magnification of the junction was observed at 20X, 80X and 160X. Buccal, lingual and labial surfaces were inspected to document gap, overlap, or edge-to-edge

relationships. The study yielded the following results: an edge-to-edge relationship appeared on 130 surfaces (76.47% of the sample), while 24 surfaces displayed acellular cementum covering the enamel (14.12%), and a gap was recorded on 16 surfaces (9.41%) (Bevenius et. al., 1993). A gap was defined as only a ditch in the cementum, because exposure of dentin did not occur. Their results concurred with earlier studies regarding the morphological features of the cervical region. Their results differed from earlier reports that variation of this junction occurred at a short distance and they believed that this variation could have been the result of the junction being exposed in the oral cavity (Bevenius et. al., 1993).

In conclusion, the above examinations of the cementoenamel junction have been performed using light and scanning electron microscopy. The researchers concurred in that there are three distinct relationships between enamel and cementum: gap when enamel and cementum fail to meet, overlay when the cementum extends on to the enamel and edge-to-edge when the enamel and cementum connect end to end (Bevenius et al., 1993; Mayhall and Rose, 1984; Muller and van Wyk, 1984; Ramsey and Ripa, 1969; Thorsen, 1917; Schroeder and Scherle, 1989). The past studies illustrate variation in cementoenamel junction type between racial affinity and age (see Table 1) (Mayhall and Rose, 1984; Muller and van Wyk, 1984; Ramsey and Ripa, 1969; Thorsen, 1917).

Table 1: Percentage frequencies of past studies.

STUDIES	N	SAMPLES	OVERLAP	GAP	EDGE
Thorsen (1917)	65	European	60%	10%	30%
Muller and van Wyk (1984)	152	Cape Peninsula Coloureds	34.10%	17.70%	49.20%
Mayhall and Rose (1984)	14 deciduous teeth	Native American	7.70%	30.80%	61.50%
Ramsey and Ripa (1969)	40 deciduous teeth	Unknown	7.50%	31.25%	61.25%
Mayhall and Rose (1984)	37 Study I	Native American	48.0%	19.0%	33.0%
Mayhall and Rose (1984)	67 Study II	Native American	53.0%	18.0%	29.0%

CHAPTER 3

MATERIALS AND METHODS

The samples employed in this study consist of ground thin sections of either maxillary central incisors or mandibular canines. The samples were obtained from Dr. Murray Marks at the University of Tennessee, Knoxville. Dental ground thin sections were produced after the teeth were embedded in epoxy molds, and then cut labio-lingually at approximately 0.2 millimeters thick to preserve all enamel features (after Marks et al., 1996).

A modern population was analyzed to address the question if dental hygiene practices effected the types of relationships observed at the cementoenamel junction. This sample was selected from extractions obtained from the Knoxville Dental Clinic at U.T. Medical Center, Knoxville. The sample contains 23 maxillary incisors and 28 mandibular canines. While demographic information could not be obtained for the sample, it had been determined that 95% of the patients were of European descent.

Three historic African descent populations were examined. The first, Charity Hospital/Crypress Grove II Cemetery was excavated in New Orleans, Louisiana beginning in February of 1986 (Owsley et al., 1990). The cemetery was uncovered by road construction of Canal Boulevard. The cemetery was in use between 1849 and 1929 representing the Civil War, Reconstruction and Post-Reconstruction (Owsley et al., 1990). The burials were only 12 to 18 inches under the ground surface and were encased in either hexagon or rectangular coffins. When multiply burials were found the individuals were frequently housed in a rectangular

coffin (Owsley et al., 1990). The skeletal remains were in poor condition as a result of water table fluctuations, weight of motor vehicles and the construction of the road.

The teeth were removed from the mandible and maxilla of 255 individuals and washed in a solution of ethyl alcohol and water (Marks, 1993). The majority of the remains are incomplete and in extremely poor condition (Owsley et al., 1990). The dental thin section sample consisted of 58 teeth: 26 maxillary incisors and 32 mandibular canines. The teeth were selected from 34 burials; 19 males and 15 females as determined skeletally. Racial estimation concluded that 15 of the individuals were African-Americans, and 3 were of European descent. The samples was comprised of 34 adults with an average age between 18 and 35 years.

The second African-American sample was from First African Baptist Church, 8th Street Cemetery located at 8th and Vine in Philadelphia, Pennsylvania (Marks, 1993). The site was unearthed in 1980 when a coffin was located at a depth of six feet and construction workers believed that more graves would be discovered (Parrington and Roberts, 1990). The site was then excavated in 1983 as a result of construction work on the Philadelphia Center City Commuter Rail Tunnel. John Milner Associates, Inc. was contracted to excavate the cemetery. Heavy machinery was used until several burials were located at the depth of 8 feet, the archaeologists then resorted to hand excavation (Angel et al., 1987). Evidence of coffins was observed for the majority of the burials, including intact "pinched toed" coffins, coffin nails and soil stains. Several of the graves revealed multiple burials and in some cases as many as eight individuals were contained in one grave at depths over seven feet. Multiple graves are believed to have been family plots (Parrington and Roberts, 1990). Historic research reported that the 8th Street

Cemetery was used by the First African Baptist Church congregation of Reverend Henry Simmons during years of 1823 to 1842 (Marks, 1993).

The burials of the First African Baptist Church were located approximately 5 feet under the ground surface and represented the skeletal remains of 140 individuals (Marks, 1993). Skeletal analysis was first conducted by John Milner Associates, Inc. with further research managed at the Smithsonian by Dr. Lawrence Angel and his associates (Parrington and Roberts, 1990). The skeletal research was conducted on the sample and death ratios were computed. The results revealed that females died more frequently than males as a result of a poorer quality of diet which was demonstrated by the number of dental lesions. Females also suffered stress from pregnancies, childbearing and childrearing (Marks, 1993). A thin section sample of 56 maxillary incisors and 54 mandibular canines was produced from 65 burials. The population sample was composed of 29 males, 33 females and 3 individuals who's sex could not be determined. There were 49 adults between 20 and 60 years and 15 subadults ranging in age from 14 months to 19 years.

Cedar Grove Historic Cemetery (3LA97 #528) was located on the south bank of the Red River near Texarkana, Arkansas (see Trubowitz, 1985). This is the third African-American sample used in this study. Salvage excavation was carried out in 1980 during the prehistoric cemetery excavation. In 1982, the Arkansas Archaeological Survey was contracted to excavate, analyze and relocate 79 graves representing 80 individuals (Rose and Santeford, 1985). The excavation was sponsored by the U.S. Army Corps of Engineers, New Orleans District, in attempt to prevent cropland destruction by the Red River. The cemetery was located west of the levee and displayed rows of graves

oriented southwest and northeast from the east side of the cemetery to the west (Trubowitz, 1985). The Black historic cemetery was in use during 1890 to 1927 which represents the post-Reconstruction (1878-1930). It is believed that the cemetery was probably in use from as early as 1835 (see Rose and Santeford, 1985).

Analysis of the remains from Cedar Grove Cemetery was conducted on site as a result of the 24-hour reburial limit. Only information regarding paleopathology, genetic affiliation and demographics were recorded (Guendling et al., 1985). The remains of 80 individuals were analyzed for sex, age and race. A death ratio was calculated and it appears that females died earlier then males probably as a result of pregnancy, childbirth, childrearing and infectious disease (Guendling et al., 1985). Genetic affiliation data was collected when possible, and there was a large African descent group represented with an admixture of traits from both European as well as Native Americans. A thin section sample was drawn from 41 of the burials: containing 32 maxillary incisors and 33 mandibular canines. There are 12 individuals classified as males, 16 females, and sex could not be determined for 13 individuals. The age break down of the sample contains: 26 adults with an average age ranging between 22 to 55+ years, 13 subadults with an average age ranging between 11 months to 17 years, and 2 individuals of unknown age.

The Native American sample was drawn from the Libben Site located along the Portage River in Ottawa County, Ohio (see Lovejoy et al., 1977). The site lies approximately six miles from lake Erie and during the time of occupation (Late Woodland) this region was called the "Great Black Swamp". Excavation was conducted during 1967 and 1968 under the direction of Dr. Prufer (Harrison, 1978). Artifact

remains indicate that the culture affiliation was with the Western Basin Tradition of southern Michigan with occupation for a time span of 250 to 300 years (Harrison, 1978). The Libben site has been dated between A.D.800 and 1100 by the use of radiocarbon techniques (Lovejoy et. al., 1977). Combined floral and faunal remains and on-site butchery of large animal species indicate that the site was probably occupied year-round (Duray, 1992). The population survived on a rich diet of animal protein (fish, bird, mammals) while the gathering of wild vegetable foods, wild rice and corn help the population to reach their needed calorie intake (Harrison, 1978).

The Libben site yielded an extremely well-preserved skeletal sample of 1327 articulated individuals, making this one of the largest intact prehistoric sample uncovered in North America (Duray, 1992). Demographic analysis of the skeletal population indicates a mean life expectancy at birth of 20 years, mean family size of 3.8 individuals and a generation length of 26.6 years (Harrison, 1978). Infant mortality was low and adult male mortality was consistently higher than that of females (Lovejoy et al., 1977). Sex ratio studies demonstrate that there were 97 males per 100 females among adults, with sex ratio at birth of 105 males per 100 females (Howell, 1982). Village size was estimated at 88 to 106 individuals per given time period (Howell, 1982). The thin section sample contains 41 maxillary incisors and 139 mandibular canines, obtained from Dr. Jerome C. Rose of the University of Arkansas. The sample was drawn from 180 burials, 21 were determined to be males, 19 were identified as females and 140 individuals could not be classified. The sample represents individuals from childhood to adult: 45 individuals were adults ranging in age from 20 to 48, 127 subadults ranging in age from 7 to 19 years and 8 individuals whose age could not be determined.

METHODS

Thin sections were analyzed at Dr. David Gerard's laboratory in the Department of Medical Biology at the University of Tennessee Medical Center, Knoxville. A magnification of 125X was chosen using the *Wild Macroskop M420* mounted with a *Wild MPS S1 S Spot 35* millimeter camera. The samples consisted of either the maxillary central incisor or the mandibular canine. The relationship at the cementoenamel junction was recorded for both the lingual and labial sides of the tooth. If the cementum and enamel failed to meet or if the cementum extended onto the enamel a measurement was recorded for this distance. For each sample, statistical analysis was conducted using SAS program provided through a Vax account at the University of Tennessee. Frequency tables were produced for each population by the 4 surfaces examined (labial incisor, lingual incisor, labial canine, and lingual canine). Chi square tests of Independence were computed for each of the 4 surfaces to see if there was a correlation between race, sex and age and 3 types of relationships found at the cementoenamel junction.

CHAPTER 4

RESULTS

Statistical analysis was performed for the maxillary incisor and mandibular canine. Both teeth were observed on the labial and lingual surfaces and the results for each of four surfaces (labial incisor, lingual incisor, labial canine, lingual canine) were run in a statistical program using SAS (After Schlotzhauer and Littell, 1987). The research hypothesis is that there is a relationship between type of cementoenamel junction and either sex, age or race. The null hypothesis is that there is no relationship between them. Frequency tables were calculated with the variables being the 3 types of relationships at the cementoenamel junction and the five population samples. Chi square tests of independence were performed because of the categorical nature of this data. The data was analyzed to determine if a pattern exists between the variables of sex, age and race and the type of relationship at the cementoenamel junction.

FREQUENCY TABLE RESULTS

Frequency tables were constructed for each of the four surfaces that were analyzed. The tables were arranged so that the type of junction (gap, overlay, edge-to-edge) was a variable and the population samples (Cedar Grove Historic Cemetery, First African Baptist Church, Libben Site, Charity Hospital/Cypress Grove II Cemetery, Modern) were the other variable. The results of the frequency tables illustrate that the population samples seem to show similar percentage

frequencies in all four of the surfaces; The Cedar Grove, First African Baptist Church, and the Charity Hospital/Cypress Grove II samples all display a high percentage of edge-to-edge relationships at the cementoenamel junction, while the Libben population sample displays a lower edge-to-edge frequency and a higher percentage of overlays (See Table 2, Table 3, Table 4, Table 5). The Modern population sample seems to display a high frequency of edge-to-edge junctions, but the percentage frequency for overlays and gaps were very similar (See Table 2, Table 3, Table 4, Table 5).

It should be noted that some of the dental thin sections could not be read because there was damage at the cementoenamel junction of the tooth. The unreadable surfaces were recorded as follows: the Cedar Grove sample contained 24, the First African Baptist sample had 26, the Libben sample contained 154, the Charity Hospital/Cypress Grove sample had 93 and 149 surfaces were damaged in the Modern sample. The reason for the high frequency of unreadable surfaces for the Libben sample is that the majority were deciduous teeth where cementum had not been developed. The Charity Hospital/Cypress Groove sample consisted of several teeth that were in poor condition as a result of caries and dead tracks located at the cementoenamel junction. As a result of modern dental practices and procedures the Modern sample had many teeth that were damaged at the cervical region of the tooth.

CHI SQUARE TEST OF INDEPENDENCE FOR SEX

Chi square tests for independence were computed for the four surfaces analyzed to see if sex was dependent on the junction type. The variable sex was drawn from all of

Table 2: Frequency table of the labial incisor.

Percentage of Relationship by Sample for the Labial Incisor

Sample	N	Gap	Overlay	Edge to Edge
Cedar Grove	23	13.04 %	0.000 %	86.96 %
First African Baptist	47	12.77 %	2.130 %	85.11 %
Libben	3	0.000 %	33.33 %	66.67 %
Charity Hospital	9	0.000 %	22.22 %	77.78 %
Modern	17	17.65 %	11.76 %	70.59 %

Table 3: Frequency table of the lingual incisor.

Percentage of Relationship by Samples for the Lingual Incisor

Sample	N	Gap	Overlay	Edge to Edge
Cedar Grove	23	4.350 %	17.39 %	78.26 %
First African Baptist	47	10.64%	0.000 %	89.36 %
Libben	3	0.000 %	0.000 %	100.0 %
Charity Hospital	9	0.000 %	11.11 %	88.98 %
Modern	17	17.65 %	23.53 %	58.82 %

Table 4: Frequency Table of the labial canine.

Percentage of Relationships by Samples for the Labial Canine

Sample	N	Gap	Overlay	Edge to Edge
Cedar Grove	24	8.330 %	4.170 %	87.50 %
First African Baptist	43	9.300 %	2.330 %	88.37 %
Libben	30	20.00 %	16.67 %	63.33 %
Charity Hospital	10	10.00 %	10.00 %	80.00 %
Modern	9	33.33 %	11.11 %	55.56 %

Table 5: Frequency Table of the lingual canine.

Percentage of Relationships by Sample for the Lingual Canine

Sample	N	Gap	Overlay	Edge to Edge
Cedar Grove	24	0.000 %	12.50 %	87.50 %
First African Baptist	43	4.650 %	4.650 %	90.70 %
Libben	30	10.00 %	30.00 %	60.00 %
Charity Hospital	10	0.000 %	0.000 %	100.0 %
Modern	9	22.22 %	11.11 %	66.67 %

the population samples where known sex had been determined through anthropological methods. The Chi square test for the labial surface of the incisor yielded a probability of 0.031 which conveys that there is not a strong relationship between sex and the type of junction. The results for the lingual incisor also gave negative values with an even lower probability of 0.250. The labial canine gave a different conclusion with a high probability of 0.000 which means that there is a strong relationship between type of junction and sex (See Table 6 and Table 7). Females displayed a higher frequency of gap relationships (88.46%), while males exhibited a higher frequency of overlays (68.42%). The lingual canine results did not concur with the labial canine, for the probability of 0.616 showed that a relationship did not exist between sex and type of junction. In conclusion, the statistical analysis for the relationship between sex and type of junction for the labial incisor, lingual incisor and lingual canine have probabilities that support the null hypothesis that there is not a relationship between type of junction and sex. The labial canine differed from the other surface results in that it did not give support to the null hypothesis. The calculated Chi square value of 16.839 and a extremely high probability of 0.000 illustrates that obtaining such a value by chance is enough evidence to reject the null hypothesis and support the research hypothesis.

CHI SQUARE TEST OF INDEPENDENCE FOR AGE

A Chi square test of independence was computed for each of the four surfaces, with the categorical variables being junction type and age. The variable age was drawn from known age individuals from the five population samples. The labial incisor results

Table 6: Chi square results of the labial canine for the variable sex.

Percentage of Relationships by Sex for the Labial Canine

Sample	N	Gap	Overlay	Edge to Edge
Females	107	21.50 %	5.610 %	72.90 %
Males	91	3.300 %	14.29 %	82.42 %

Table 7: Chi square results for the labial canine showing overall percentages.

Comparing Sex Variation by use of the Overall Percentages

Sample	N	Gap	Overlay	Edge to Edge
Females	107	88.46 %	31.58 %	50.98 %
Males	91	11.54 %	68.42 %	49.02 %

* Statistic:

Chi square value = 16.839
Probability = 0.000
Degree of Freedom = 2

show a Chi square value of 17.531 and a high probability 0.000 which indicates that there is a strong relationship between age and type of junction. The results demonstrate that the subadults are lacking a gap junction, while the adults show a high frequency of edge-to-edge junctions (See Table 8 and Table 9). The lingual incisor results did concur with the positive results seen for the labial incisor. The high probability of 0.007 and the high Chi square value of 9.936 does not give support to the null hypothesis that there is no relationship between type of junction and age (see Table 10 and Table 11). The labial canine results give evidence to support the null hypothesis. It showed a low probability of 0.120 and a low Chi square value of 4.244. The lingual canine results also show a low probability of 0.261 and a low Chi square value of 2.687. In conclusion, it is apparent that both the labial incisor and lingual incisor statistical results give support to the research hypothesis that there is a relationship between age and type of junction. Further analysis was run to make sure that this probability was not biased from the population samples age ranges, but no evidence was found to support this bias. The age categories were comprised of adults and children from the all of the population samples except for the modern sample, where age was not known.

CHI SQUARE TEST OF INDEPENDENCE FOR RACE

Chi square tests for independence were run to see if there was a relationship between racial affinity and type of junction. The category race was drawn from the 5 population samples: a modern European descent group, three historic African Americans groups and a Native American group. The results for the labial

Table 8: Chi square results of the labial incisor for the variable age.

Percentage of Relationships by Age for the Labial Incisor

Sample	N	Gap	Overlay	Edge to Edge
Adults	131	11.45 %	7.630 %	80.92 %
Subadults	44	0.000 %	29.55 %	70.45 %

Table 9: Chi square results for the labial incisor showing overall percentages.

Comparing Age Variation by use of the Overall Percentage

Sample	N	Gap	Overlay	Edge to Edge
Adults	131	100.0 %	43.48 %	80.92 %
Subadults	44	0.000 %	56.52 %	22.63 %

* Statistic:

Chi Square value = 17.531
Probability = 0.000
Degree of Freedom = 2

Table 10: Chi square results of the lingual incisor for the variable age.

Percentage of Relationships by Age for the Lingual Incisor

Sample	N	Gap	Overlay	Edge to Edge
Adults	131	6.870 %	6.100 %	87.02 %
Subadults	44	4.550 %	22.73 %	72.73 %

Table 11: Chi square results of the lingual incisor showing overall percentages.

Comparing Age Variation by use of the Overall Percentage

Sample	N	Gap	Overlay	Edge to Edge
Adults	131	81.82 %	44.44 %	78.08 %
Subadults	44	18.18 %	55.56 %	21.92 %

Statistic:

Chi square value = 9.936
Probability = 0.007
Degree of Freedom = 2

incisor show support for the research hypothesis with a high probability of 0.000 and a high Chi square value of 64.408 (See Table 12 and Table 13). The African-American samples show the highest occurrence of edge-to-edge relationships (62.07%) while the Native American sample exhibits the highest percentage of overlays (56.52%) .The lingual incisor gave a high probability of 0.000 and a high Chi square value of 35.158 (See Table 14 and Table 15). The modern European sample displays the highest overall percentage for a gap relationship while the African-American samples still display the highest occurrence of an edge-to-edge junction. These results also give strong support for the research hypothesis that there is a relationship between type of junction and racial affinity. The results for the labial canine display a slightly lower probability of 0.020 and a lower Chi square value of 11.658, but this could be a result of the low sample size for each of the categories of race (See Table 16 and Table 17). The lingual canine results concur with the positive results of the labial and lingual incisor. A high probability of 0.000 and a high Chi square value of 35.674 gives support to the research hypothesis (See Table 18 and Table 19). The African-American sample again shows the highest degree of edge-to-edge relationships, while the Native American sample has a high occurrence of overlays. In conclusion, three of the four surfaces (labial incisor, lingual incisor, lingual canine) show a positive correlation between type of junction and racial affinity with a high probability of 0.000 and high Chi square values. The African American samples show the highest occurrence of edge-to-edge junctions in all of the four surfaces. The Native American sample displays the highest degree of overlay junctions except for the lingual incisor where the percentage is the same in the Native American sample and the modern European sample. The incisor results for the Native American sample did

Table 12: Chi square results of the labial incisor for the variable race.

Percentage of Relationships by Race for the Labial Incisor

Sample	N	Gap	Overlay	Edge to Edge
European	70	21.43 %	0.000 %	78.57 %
Afro-American	133	11.28 %	7.520 %	81.20 %
Native American	24	0.000 %	54.17 %	45.83 %

Table 13: Chi square results for the labial incisor showing overall percentages.

Comparing Race Variation by use of Overall Percentages

Sample	N	Gap	Overlay	Edge to Edge
European	70	50.00 %	0.000 %	31.61 %
Afro-American	133	50.00 %	43.48 %	62.07 %
Native American	24	0.000 %	56.52%	6.320 %

* Statistic:

Chi Square value = 64.408
Probability = 0.000
Degree of Freedom = 4

Table 14: Chi square results of the lingual incisor for the variable race.

Percentage of Relationships by Race for the Lingual Incisor

Sample	N	Gap	Overlay	Edge to Edge
European	70	21.43 %	14.29 %	64.29 %
Afro-American	133	8.270 %	6.020 %	85.71 %
Native American	24	0.000 %	41.67 %	58.33 %

Table 15: Chi square results for the lingual incisor showing overall percentages.

Comparing Race Variation by use of the Overall Percentages

Sample	N	Gap	Overlay	Edge to Edge
European	70	57.69 %	35.71 %	26.01 %
Afro-American	133	42.31 %	28.57 %	65.90 %
Native American	24	0.000 %	35.71 %	8.090 %

* Statistic:

Chi Square value = 35.158
Probability = 0.000
Degree of Freedom = 4

Table 16: Chi square results of the labial canine for the variable race.

Percentage of Relationships by Race for the Labial Canine

Sample	N	Gap	Overlay	Edge to Edge
European	6	16.67 %	16.67 %	66.67 %
Afro-American	72	8.330 %	4.170 %	87.50 %
Native American	31	25.81 %	16.13 %	58.06 %

Table 17: Chi square results for the labial canine showing overall percentages.

Comparing Race Variation by use of the Overall Percentages

Sample	N	Gap	Overlay	Edge to Edge
European	6	6.670 %	11.11 %	4.710 %
Afro-American	72	40.00 %	33.33 %	74.12 %
Native American	31	53.33 %	55.56 %	21.18 %

* Statistic:

Chi Square value = 11.658
Probability = 0.020
Degree of Freedom = 4

Table 18: Chi square results of the lingual canine for the variable race.

Percentage of Relationships by Race for the Lingual Canine

Sample	N	Gap	Overlay	Edge to Edge
European	30	16.67 %	16.67 %	66.67 %
Afro-American	128	3.130 %	5.470 %	91.41 %
Native American	99	14.14 %	27.27 %	58.59 %

Table 19: Chi square results for the lingual canine showing overall percentages.

Comparing Race Variation by use of the Overall Percentages

Sample	N	Gap	Overlay	Edge to Edge
European	30	21.74 %	12.82 %	10.26 %
Afro-American	128	17.39 %	17.95 %	60.00 %
Native American	99	60.87 %	69.23 %	29.74 %

* Statistic:

Chi square value = 35.674
Probability = 0.000
Degree of Freedom = 4

not demonstrate gap junctions while the canine surfaces show high degrees of gaps with overall percentages higher then any other group. The European sample results show the most variation between type of junction and the surface analyzed. There does not seem to be a consistent trend as to what type of junction is seen most frequently in the European sample.

CHAPTER 5

DISCUSSION

Several researchers have investigated the cementoenamel junction and have recorded various percentage frequencies for each type of junction (Bevenius et al., 1993; Grossman and Hargreaves, 1991; Mayhall and Rose, 1984; Muller and van Wyk, 1984; Ramsey and Ripa, 1969; Schroeder and Scherle, 1989; Thorsen, 1917). What follows is a summary of how the results from this study correlates with past results.

The modern sample results were compared to Thorsen's study because both of the samples were from European descent groups. The current sample differs greatly from Thorsen in that the highest frequency percentage is an edge-to-edge junction (65%), where Thorsen's sample showed the highest frequency in overlays between enamel and cementum (60%). Thorsen also observed that edge-to-edge junction was the next highest occurring in 30%. The study sample displayed the gap junction (21%) more frequently then an overlay (12%). Several reasons may explain this inconsistency. First, Thorsen's research was conducted in 1917, technological advancements in microscopy and new procedures for producing thin sections of teeth could be a factor. Also Thorsen does not indicate what type of teeth he examined and if the same teeth were not employed, this again could account for the frequency variations.

The Native American sample results were compared to Mayhall and Rose's findings on those two Native American samples. They observed that an overlay junction occurred in approximately 51% of their samples, while an edge-to-edge and gap relationships resulted in 31% and 18%, respectively (See Table 1). The current sample

displayed slightly different results in the edge-to-edge junction in approximately 55%, with overlay occurring in 35% and gap in 10% (See Tables 12-18). The current research results do concur with Mayhall and Rose's earlier findings, where the overlay junction was most frequent in the Native American sample when compared to the other groups (See Tables 12-18).

The African-American samples could not be compared to past research since no previous study has examined such groups. The only research that had an African descent component was in the Muller and van Wyk study of the "Cape Peninsula Coloureds" population containing an admixture of European, African and Malay descent. Their findings did illustrate that an edge-to-edge junction had the highest frequency of 49.29%, but the current samples contained an edge-to-edge relationship in approximately 80% or more. The African-American samples displayed the highest degree of edge-to-edge relationship when they were compared to the other population samples from European and Native American descent groups (See Tables 12-18).

Past research has addressed the question of age and if there is variation between adults and children in type of junctions (Mayhall and Rose, 1984; Muller and van Wyk, 1984; Ramsey and Ripa, 1969). Other research has focused on deciduous teeth and these results display differences when compared to adult samples (Bevenius et al., 1993; Schroeder and Scherle, 1989). Ramsey and Ripa (1969) were the first to analyze deciduous teeth with a sample of 40 (21 maxillary and 19 mandibular) premolars. Their results reported an edge-to-edge relationship in 61.25%, a gap in 31.25% and an overlay in only 7.5%. Mayhall and Rose investigated 14 deciduous canine teeth from a Native American sample and their results concurred with Ramsey

and Ripa's findings. They observed an edge-to-edge in 61.5%, a gap in 30.8% and an overlay in only 7.7%. Schroeder and Scherle (1989) analyzed eight deciduous premolar teeth and recorded an edge-to-edge in 70%, a gap in only 1% and an overlay in 29%. Bevenius and her colleagues (1993) examined 50 intact premolar teeth and found an edge-to-edge junction in 76.47%, a gap in 9.41% and an overlay in 14.12%.

This research evaluated both permanent and deciduous teeth and the results concur with previous research that deciduous teeth show a high frequency of edge-to-edge relationships. Positive statistical results were seen for both the labial and lingual incisor for the variable of age. The deciduous teeth displayed an edge-to-edge relationship in about 70% , a gap was observed only on the lingual incisor in 4.55% and an overlay was recorded for approximately 25% of the sample (see Tables 8-11). When the deciduous sample was statistically compared to the adult sample, it was noted that the deciduous teeth display a higher overall frequency of overlays while the adults displayed a higher frequency of edge-to-edge relationships and gaps (see Tables 8-11).

From the research conducted at the cementoenamel junction it is apparent that there seems to be a difference between adults and children in regards to type of junction. The difference between all of the studies could be the result of genetic variation because race was only noted for Mayhall and Rose's analysis and the current research project. More research will have to be conducted regarding age changes and how this could effect the cervical region of the tooth. The current study utilized prehistoric and historic populations with the oldest age ranging in the fifties. This age at death would not reflect a high degree of damage or change as a result of the aging process.

Sex was another factor considered in this study. The only other research to examine this variable was Mayhall and Rose (1984). They concluded that sex was not correlated with a junction type. The current project results showed a positive correlation between sex and type of junction on the labial canine surface. Females displayed a significantly higher frequency of gaps compared to males and males showed a significantly higher degree of overlays then females (See Table 6 and Table 7).

Some researchers in the past hypothesized that dental hygiene practices such as brushing and flossing and exposure to the oral cavity could result in changes at the cementoenamel junction (Bevenius et al., 1993; Muller and van Wyk, 1984). Modern, historic and prehistoric samples were analyzed to see if the same types of junctions were visible at the cervical region of the teeth. It was postulated that if oral hygiene does cause changes in this junction then the modern sample, as a result of modern dental practices, would not have the same types of junctions. Since the results from this study verify that the same types of junctions were observed, then it is believed that dental hygiene is not causing a great deal of change at the cementoenamel junction. In response to the question of exposure to the oral cavity, again the modern sample was utilized because prehistoric and historic sample displayed a line of supragingival calculus above the cementoenamel junction that would verify that the junction was not exposed in the oral cavity. The modern sample again displayed the same three types of junctions as seen in the prehistoric and historic samples. In conclusion, it appears that exposure to the oral cavity does not seem to cause a great amount of change between the relationship of cementum and enamel at the cervical region of the teeth.

CHAPTER 6

CONCLUSION

The goal of this study was to establish criteria that could be utilized by physical/forensic anthropologists in comprising a biological profile of unknown individuals. The research design entailed examination of the cementoenamel junction of the labial and lingual surfaces of the maxillary central incisor and the mandibular canine. The teeth were thin sectioned so that the labial and lingual surfaces would be more easily visible under a light microscope at 125X. There are three distinctive relationships that can occur at the cervical region of the tooth: a gap when cementum and enamel fail to meet, overlay when cementum extends onto the enamel and an edge-to-edge junction when the cementum and enamel meet.

Four questions that were addressed: 1) if racial affinity could be correlated to junction type, 2) if sex could be determined by the type of junction, 3) if there were relationship differences between adults and children, 4) if dental hygiene methods and exposure of this structure to the oral cavity resulted in damage or changes to the cementoenamel junction.

Frequency tables and Chi square tests for independence were conducted for each of the four surfaces (labial incisor, lingual incisor, labial canine, lingual canine). Statistical analysis computed by the SAS program determined that there is a very strong positive correlation between racial affinity and junction type present on all four surfaces by the probability of 0.000 and high Chi square values. The labial canine gave positive results, of a high probability of 0.000 and a high Chi square values of 16.893, in determining if the variable sex was correlated with junction type. Females

as a group displays a higher frequency of gaps and males exhibit more overlays at the cementoenamel junction. The labial and lingual incisor results confirmed that there was a correlation between age and type of junction. Adults display a higher frequency of gap relationships while the children had a higher frequency of overlays. This relationship between age and type of junction was verified by the high probabilities. Dental hygiene and exposure to the oral cavity was addressed by utilizing population samples that represented prehistoric, historic and modern time periods. The modern sample results illustrate that dental hygiene and exposure to the oral cavity do not result in a large amount of damage or change to the cementoenamel junction since the same three types of relationships were observed.

The above research results verify that there are frequency percentage differences at the cementoenamel junction (junction type) that have been statistically correlated to race, sex, and age. The results also confirmed that dental hygiene and exposure to the oral cavity do not seems to cause damage or change to the cervical region of the tooth. The goal of this research was to aid physical anthropologists in either an archaeological or forensic setting in determining the racial affinity, sex and age of unknown individuals. Hopefully, the above research criteria and valid statistical results will help them achieve their goal in comprising a biological profile of unknown skeletal material.

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Vita

My name is Elizabeth Anne Gilb and I was born on April 5, 1968, in Cincinnati, Ohio. I attended schools in the Greenhills School District; Beechwoods Elementary, Greenhills Middle School and Greenhills High School. In 1987, I graduated from high school and moved to San Diego, California. I attended my freshmen year of college in 1988 at San Diego State University. In 1989, I returned to Cincinnati and started to attend the University of Cincinnati with a declared major in Anthropology. During my undergraduate career, I worked for 2 years in the osteology lab under the direction of Pat Tench. My duties included cleaning, inventorying, and sex, age and stature determination for the skeletal remains from the Stateline Site. In 1993, I received my Bachelor's degree and was excepted into the graduate program at the University of Tennessee. During my graduate career, I have had the opportunity to work at Dr. William Bass's Anthropological Research Center where I retrieved, processed and inventoried skeletal remains for the donated collection. I completed a 2 month internship with the Knoxville Police Department in the Crime Lab under the direction of Lanny Janeway. I was taught the procedures for the collection of physical evidence such as, blood samples fingerprints, rape kits and ballistics. I have also worked for the University of Tennessee Transportation Department as a field technician for the archaeological contract firm directed by Charles Bentz. I have worked on both historic and prehistoric sites and have developed skills in excavation, mapping, water screening, floatation, dry screening, sorting and size grading, and artifact analysis.