CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTISTRY

GRADUATE STUDIES

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A LONGITUDINAL STUDY OF THE MATURE HUMAN DENTITION

-A Pilot Study.

by

Frances Karen Hamman

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science in Dentistry

Department of Orthodontics

School of Dentistry

CASE WESTERN RESERVE UNIVERSITY

August 13, 1993

A LONGITUDINAL STUDY OF THE MATURE HUMAN DENTITION -A PILOT STUDY

Abstract

by

Frances Karen Hamman

Presently, there are very few longitudinal studies of the aging dentition. Accordingly, the purpose and objective of this study was to evaluate changes seen in specific parameters of the dentition. To accomplish this, a longitudinal population of *orthodontically untreated* individuals between the ages of 17 and 74 were examined. Changes were evaluated from measurements of dental cast records of patients in the Bolton Brush Growth Study, Case Western Reserve University. Patients were selected from a population of mature individuals recalled for examination in 1982 (Behrent's Recall) and 1992 (Update 2000). The cases selected for measurement were chosen without regard to sex, facial profile, crowding of the mandibular anteriors, or Angle classification. Patients were selected if they possessed complete dental records of the adult dentition, had at least one record between age of 17 and 25, and a second record after age 46. Each dentition had to possess natural maxillary and mandibular first molars (i.e. no full coverage crowns). The parameters selected for measurement included: Decayed, Missing, and Filled Teeth; overbite, overjet, arch perimeter, intercanine distance, dental deflection, Angle classification, and deflection of the Angle molar relationship. The relationships of these parameters were then described and

compared. Descriptive statistics and the Wilcoxon Matched-Pairs Rank Test were employed to statistically analyze the change in the variables. In general the findings of this investigation suggest that:

1.) the majority of tooth loss/restoration seems to fall within a range of 6 to 15 teeth in a healthy mature dentition,

2.) the parameters of the dentition that *change significantly* over time include: overbite, maxillary and mandibular arch perimeter, mandibular intercanine distance, and dental deflection,

3.) and the parameters of overjet, maxillary intercanine distance, and molar deflection from Angle Classification show change over time, but this change seems to be evenly distributed and not statistically significant.

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LIST OF ABBREVIATIONS

1 or 2=	[After any abbreviation denotes Time 1 or Time 2]
3|3 L=	Intercanine Distance of Mandibular Arch
3|3 U=	Intercanine Distance of Maxillary Arch
3M=	Third molars M= missing I = impacted O = in occlusion
Angle=	Angle Classification
ADeflMR=	Angle Deflection of Right Molar
ADeflML=	Angle Deflection of Left Molar
DMFT=	Decayed, Missing, and Filled Teeth
DD=	Dental Deflection
OB=	Overbite
OJ=	Overjet
PL=	Mandibular Arch Perimeter
PU=	Maxillary Arch Perimeter
T1=	Time 1
T2=	Time 2

INTRODUCTION:

Aging...definition and description

Aging has many dimensions and can be characterized in many ways. It has been defined by Thorndike and Barnhardt (1972) as " a becoming old or older...the process of maturing." Stedman's Medical Dictionary(1982) defines it as

> "the process of growing old, especially by failure of replacement of cells in sufficient number to maintain function... the gradual deterioration of a mature organism resulting from time-dependent, irreversible changes in structure that are intrinsic to the particular species, and which eventually lead to decreased ability to cope with the stresses of the environment, thereby increasing the probability of death."

In other words, the effects of age and the aging process itself varies widely between individuals. It is rooted in genetics and is influenced by disease experience, nutrition, life style, and habits. We are all biologically unique and become more diverse as we age (Adams 1991). Yet, as Richard Adelman states, "one general feature that does seem to characterize all aging individuals is a progressive modified ability to adapt to changes in the surrounding environment (1989). One of features of the elderly patient which has changed dramatically over the last 25 years is the retention of a greater proportion of the the dentition. The severity of tooth loss has diminished steadily over the years and this has been supported in studies by the NIDR (1985-86), National Center for Health Statistics (NCHS) (Burnham 1974, Kelly 1979, and

Harvey 1981), and the U.S Department of Health, Education, and Welfare (Johnson et al., 1965). There are many possible reasons for this reduction in tooth loss and edentulism. For example, caries incidence decreased due to the immediate and long-term effects of flouridated public water systems; and improved public awarness concerning the importance of dental hygiene and regular dental health care. In addition, more attempts at "saving" teeth have been developed (i.e. root canals and prosthetic replacement), and dental care itself has virtually become "pain-free." Weintraub (1985) states that edentulism will continue to decline despite the aging of the population, and tooth loss of all kinds will decrease in all age groups over the long term.

This study is important to the field of dentistry. To date, there is a good basis of knowledge concerning aging teeth, tooth loss and edentulism. There are however, significant gaps in the knowledge concerning *change* in the aging dentition in the areas of arch perimeter, intercanine distance, incisor irregularity (dental deflection), overbite, overjet, and molar classification. The reason for these gaps is two-fold. First, there are very few comprehensive, longitudinal studies dating back to a time when patients would be in their adult years today. Hence, a source longitudinal population for adult information is lacking. The Bolton-Brush Growth Study is one of the few studies available that provides longitudinal information on today's adult dentition. In that this study began in the early 1900's, many of the patients are well into their adult years today. In addition, it was a well designed and meticulously carried out study for its time. Patients were recalled on a yearly basis in their early years providing an excellent source of adolescent information. The recall of the Bolton patients in the 1980's performed by Behrents (1985) opened the door for information on the adult patient.

The second reason for gaps in the knowledge of adult dentitional change has to

do with the historical focus of orthodontics. The field of orthodontics has changed drastically over the last 15 to 20 years. Twenty years ago, most practitioners would have stated that the majority of patients they treated were in the 11 to 15 year age range. In other words, orthodontics was targeted primarily to growing adolescents. Although the growing child is still the primary focus orthodontic treatment, the age range has broadened considerably. Both ends of the orthodontic treatment spectrum have diffused. For example, today there is a greater emphasis on early, Phase I type treatment in children ages 7 to 10. On the other end of the spectrum, adults from age 20 to 60 or older have become committed to improving their smile or functional status. William Proffit (1989) states it most succinctly,

> "Patients seek orthodontic treatment at older ages for two major reasons which themselves are correlated with age. At present, the majority of adult orthodontic patients are in the 25 to 40 age range. At this age, adults who desire orthodontic treatment usually are seeking a general improvement, not only in dental health and esthetics but also in their life situation. A typical situation might be the 32-year-old assistant professor who has always wanted to have his teeth straightened. Now he can afford it. Besides, he estimates that the chances of tenure and eventual department chairmanship might be better with teeth that no longer detract from his appearance. The number of people who seek orthodontic treatment for these reasons falls off sharply above age 40.
>
> The second major group of adults, the group who are becoming increasing important as the population ages, are those who seek orthodontics because they have specific health care needs for which orthodontic treatment is important. They seek orthodontic consultation because the periodontist told them that they may lose their teeth unless something is done, or the prosthodontist said that without orthodontics, there is no way to make a bridge. They tend to be in the 40 to 60 age range, although they can be younger or older. This is the group that will provide the greatest increase in the numbers of adult orthodontic patients in the future, simply because of the population bulge."

With this need for adult treatment now so imminently upon the field of dentistry and orthodontics, it is necessary to broaden the knowledge concerning ***specific change*** in the adult dentition over time.

REVIEW OF THE LITERATURE

1. Overview of Aging

Aging is a gradual, continuous process... a "biologic continuum of life" (Behrents 1985). It has been well-established that there are basic histologic, biochemical, and physiologic alterations that are coincident with the aging process (Ferguson 1987; Tice and Setlow 1985; Reff 1985; Naeim and Walford 1985; Hausman and Weksler 1985; Harman and Talbert 1985; Kligman, Grove, and Balin 1985; and Bierman 1985). These alterations have an effect on the function of the aging individual as well as on the entire skeletal system.

The aging individual has been described in many ways. Oral physiology is generally believed to be age-stable in most healthy individuals (Ship 1992). However in the presence of medical disease and treatment, many functions can deteriorate. In addition, arthritic, visual, orthopedic, hearing, and speech impairments directly and indirectly impact on oral health. This impact is more significant for the elderly who have multiple medical problems. As Ship states (1992), nearly one half of the elderly have arthritis, establishing it as the most common chronic condition among older individuals. Sinclair (1978) describes the aging individual as one who has a diminished range of special senses--smell, sight, taste, and hearing; and one whose memory, ability to solve problems, and concentration level are diminished. Stern et al.,

(1980) further add that an aging individual sustains decreased breathing capacity, thermal regualtion, basal heat production, and general motor performance, including coordination, reaction time and strength. The *outward* changes of aging that are most often noted include changes in performance, superficial appearance, and function (Behrents 1985).

Enlow (1990) describes the aging process in terms of changes seen in the connective tissue. The dermis and hypodermis experience biochemical changes causing the skin to be less firmly bound to bone and facial muscles, thereby leading to the more leathery, wrinkled face of the aged person. The distribution and character of the collagenous matrix changes with advancing age. Individual fibers increase in massiveness and the skin decreases in resilience. Fibroblasts are reduced in number and cellular activities, including secretion and overall amount of proteoglycans, are diminished.

Age related changes in function and outward appearance have their basis in numerous osteologic and physiologic modifications. Exon-Smith (1985) in the Handbook of the Biology of Aging, states that many studies in experimental animals and human subjects have shown a decrease in the proportion of dietary calcium absorbed with increasing age. Additionally, aging is accompanied by the loss of bone tissue from the skeleton. This atrophy corresponds to the atrophy of other tissues which occurs with increasing age. Postmenopausal women in particular show the effects of bone porosity by a reduction in strength and reduced resistance to fracture. Rowe (1983), states that the radiographic density of the jaws parallel the rest of the changes seen in the skeleton. As one might imagine, there are many histologic changes that occur in aging bone as well. Tonna (1960) noted the changes in the osteocyte from a filamentous to a spherical shape, the lacunae become filled, indicating cell death, and

the total number of osteocytes decreases. The Haversian system also shows changes in configuration with age. Shikata et al., (1987) demonstrated that in addition to reduced calcified material, there are changes in the matrix with age, specifically the stabilization of collagen and a slower turnover rate in bone. Healing of fractures is a longer process in the older patient and the incidence of non-union fractures is higher. This delayed healing is most likely due to the reduction in blood supply and a less cellular periosteum. (Adams 1991).

Manson and Lucas (1962), Jowsey (1960,1963), Kerley (1965) and Enlow (1990) all describe alterations in the remodeling of bone. As Behrents (1985) points out, the findings in many of the bone turnover studies are somewhat inconsistent with each other; but all seem to show some degree of bone turnover at bony surfaces in the adult. Hence the adult individual, like the growing individual, is not a static entity.

It seems that "change" is the only "constant" in the aging process. Change occurs in essentially all cells and tissues of the body. It is apparent that "adulthood" is not a stable physiologic and morphologic period. In fact "...the only beginning may be birth with all processes continuing until the only ending, death" (Behrents 1985).

2. Age Changes in Oral Structures:
Bone, muscle, soft tissue, teeth

Some of the characteristic histologic and physiologic changes seen in aging bone also pertain specifically to alveolar bone. The loss of alveolar bone where teeth are missing is a well-known phenomenon. The rate of alveolar bone resorption varies considerably between individuals and not all of the factors relating to this loss are known. Even when teeth are present, there seems to be a gradual loss of bone at the alveolar crest (Adams 1991, Tallgren and Solow 1991). The amount of this loss seems

to be related to the periodontal status of the patient (Bailit et al., 1987, Axelsson et al., 1991), the presence or lack of cervical tooth restoration (Markitziu 1988), and the tooth root structure i.e. single or multi-rooted teeth (Rohner et al., 1983). Reduction in the height of aging alveolar bone however, is not necessarily related to occlusal wear (Baer 1963, Whittaker et al., 1985).

Karlsson et al., (1991) state that old age will inevitably result in a general deterioration of all motor functions, including oral motor function. The oral cavity has the sensory and muscular ability to perceive form, size, texture, and taste. These proprioceptive functions decline with age (McMillan et al., 1978). For example, Karlsson and Carlsson (1990) compared the characteristics of mandibular masticatory movement in young and elderly dentate subjects and clearly found a reduced vertical mandibular displacement and velocity in the elderly group. The groups compared had mean ages of 30 and 80 and possessed an almost complete dentition (mean 26.3 teeth present). The apparent difference in oral motor function for elderly and young subjects was described as being dependent on an age-associated "impairment" of both central and peripheral mechanisms. This degeneration of oral motor function, also seems to occur whether the subject is edentulous or not (Karlsson et al., 1991). Age-related changes such as decreased conduction velocity of the nerve impulse in sensory axons, as well as of motor fibers of peripheral nerves, might explain part of the reduced velocity. Campbell et al., (1973) found that an increase in age seems to be associated with a reduction of functional motor units, and a reduced mass of fast muscle fibers. Newton et al., (1987) also found that the cross-sectional area of the masseter and medial pterygoid muscle are significantly reduced with increasing age. In a similar study of oral motor function in the aging population, Baum and Bodner (1983) found

that lip posture, masticatory function, tongue function, and swallowing, all exhibited a high prevalence for altered motor performance with age. All of these changes in oral motor function however, have shown great individual variation with regard to the time when oral motor impairment occurs. At the age of 80 years, most individuals tend to show at least some functional deterioration (Karlsson et al., 1991). This reduction in masticatory efficiency in aged individuals, regardless of its cause, can lead to poor chewing habits and the possibility of digestive disturbances.

The soft tissues of the oral cavity also experience change with time. Connective tissue fibers, as mentioned earlier, become thicker with age and the turnover is slower. The salivary glands do not generally decrease in production of salivary flow simply due to the aging process. However, these glands can experience hypofunction due to radiation therapy and as a side effect of medications taken for blood pressure control, cardiovascular conditions, or anxiety states (Ferguson 1987).

Aging teeth also possess a miriad of characteristics. The enamel of older teeth is somewhat darker than it is for younger teeth. This is most likely due to absorption of organic material from saliva and dietary sources over the years. Another reason for visible darkening of teeth is increased translucency of enamel allowing the yellow color of dentin to dominate. Longitudinal cracks in enamel are generally evident over time and can be due to mechanical stresses in the enamel or increased staining of the enamel lamellae with dietary substances (Adams 1991). Loss of enamel by abrasion, erosion, and/or attrition is another common finding in the mature dentition. The pattern and degree of enamel loss varies considerably from patient to patient depending on the diet, the occlusion or lack thereof, the musculature, disease processes, and everyday habits such as bruxism or clenching (Lewis and Smith 1973, Mair 1992, Pöllman et al., 1987, Seligman et al., 1988, Xhonga 1977). Occlusal wear reduces cusp height and

inclination, resulting in an increased food table area and loss of sluiceways (Murphy 1959, Hasund 1965, Seligman et al., 1988). The rate of attrition may be coordinated with other age changes such as continuous tooth eruption and gingival recession. Cementum is usually deposited in the apical region of the tooth as the tooth erupts, and there appears to be a continuous increase in the amount of cementum with age (Begg 1954, Ive et al., 1980, Whittaker et al., 1985). In cases where alveolar bone support is reduced, the clinical crown tends to become disproportionately long thereby creating excessive leverage on the bone. Attrition appears to reduce the clinical crowns and therefore preserve the balance between the teeth and their bony support (Begg 1954, Murphy 1964, Adams 1991). The deposition of secondary cementum is probably related, in part, to maintenance of the length of attachment of the periodontal ligament. Wear of teeth also occurs on the proximal surfaces and initiates a mesial migration of teeth (Murphy 1964, Witter et al., 1987). Dentin hypersensitivity does not seem to be a large problem in the aged. Even though dentin can be exposed on the occlusal or incisal aspects of the crown, or around the cervical margins of an aging teeth; the fact that aging dentin is highly mineralized secondary dentin, seems to reduce or eliminate some of the symptoms of hypersensitivity (Adams 1991). The aging pulp shows less cellularity, decrease in pulpal space, increased calcification, more fibrous tissue, and fewer nerve axons than a young tooth, thereby making dentin less sensitive (Bernick 1967, Grant and Bernick 1970).

The supporting tissues of the teeth undergo related changes with age. The periodontal ligament shows an increase in fiber bundle thickness (Lavelle 1968, Adams 1991), decreases in vascularity and mitotic activity (Adams 1991), and increases in arteriosclerotic change (Grant and Bernick 1970). Changes in the ligament and supporting tissues can be modified considerably in the presence of inflammatory

periodontal disease. The ligament is broken down progressively from the gingival margin allowing the epithelial attachment to migrate towards the apex of the tooth, leading to gingival recession. This can have implications on the incidence of caries. A common consequence of gingival recession, tooth retention, and continued eruption of the mature dentition, is the increased prevalence of root caries.

The relationship between age and prevalence and severity of periodontitis is complex. Previous literature stated that tooth loss in the elderly was primarily due to periodontal disease (Brekhus 1929, Allen 1944, Pelton 1954). Today, periodontitis is not considered a disease of aging (Burt 1992, Page 1984, Hunt et al., 1990, Adams 1991). The greater prevalence and severity in older people in most cross-sectional surveys do not reflect greater susceptibility. Rather, periodontitis develops from the accumulation and progression of lesions over time (Burt 1992). Most studies at this time seem to indicate that root caries may be the primary cause of tooth loss (Hand et al., 1991, Niessen and Weyant 1989, Bailit 1987, Brown and Meskin 1988, Kalsbeek et al., 1991).

3. Parameters of the Dentition and Their Changes with Age

> It is that the best balance, the best harmony, the best proportions of the mouth in its relation to the other features require that there shall be *the full complement of teeth, and that each tooth shall be made to occupy its normal position–normal occlusion.*
>
> -Edward H. Angle, 1903

Tooth alignment and intercuspation relate to many functional activities, the longevity of the dentition, and facial esthetics. (Moorrees et al., 1969) The occlusion of

the posterior teeth plays an essential role in the position and arrangement of the teeth following emergence, and the coordination of growth of the maxilla and mandible (van der Linden 1991). For many years, the growth of the dentition has fascinated and interested researchers in orthodontics. As a background to describing changes seen in the mature dentition, a brief review of the changes in the growing dentition is presented.

Development of the Arch- Adolescent Studies

Arch Length and Arch Width

There have been many longitudinal studies of the arch and its development from birth to late adolescence. In 1940, Joseph Cohen examined 28 children, 15 males and 13 females between the ages of 3 1/2 to 13 1/2 years. Over this growth period, he noted several conclusions as to tooth eruption and arch development or arch perimeter. First, he stated that the greatest lateral growth of the arch occurred in the cuspid area; this growth occurred primarily during the eruption of the permanent incisors. Second, the distance between the mandibular cuspids reached its maximum at age 8 1/2 and from then on, he felt that little increase occurred. Increase in distances between the maxillary cuspids was greatest between the ages of 5 and 8, and a slow, steady growth ensued from that point until about 12 years of age. In the time frame studied, Cohen also noted that there was little lateral growth of the arches between the first permanent molars and only a slight growth of the arches between the premolars. Additionally, there was a sex difference noted whereby the dental arches of females, especially the mandibular arch, tended to be wider in the posterior section than the males. The anterior section, however, was narrower in the female than the male. His small sample size may be the primary reason for this distinction. He concluded by stating there is a wide variation in

the development of the dental arches and it is common for individual children to depart from the patterns he described.

In a similar study, Barrow and White (1952) examined 528 sets of serial casts of 51 children, age 3 to 15, for changes in occlusal relationships during the period from completed primary dentition to the eruption of all permanent teeth except the third molars. They endeavored to measure the amount of growth occurring within and between the various areas of the primary and permanent dentitions. Their observations included the spacing and crowding of anterior teeth, classification of occlusion, arch form, depth of bite, dental arch width (measured at the canines, second primary molars, and first permanent molars), and dental arch length. In terms of crowding, there was consistently more crowding in the mandibular arch than in the maxillary arch. Occlusion was classified on the basis of molar relationship, and it was determined that those cases classified as "normal" or Class I according to Angle showed the least change in molar occlusion during the transition from primary to permanent dentition. The arch form was classified according to shape and it was explained that the primary arch before eruption of the first permanent molars is very short and trapezoidal in form. Examination of individual series of casts revealed that the form of the maxillary and mandibular dental arches changed only slightly during the period from the primary to the early permanent dentition. The depth of the bite was measured to be nearly constant throughout the primary and permanent dentitions. It was noted that the depth of the bite was established after the permanent incisors had erupted sufficiently so that the incisal edges of the mandibular anteriors came in contact with the lingual surfaces of the maxillary incisors. The width of the arch between the canines showed the following characteristics: (1) little intercanine arch width change from 3-5 years, (2) the intercanine width increased very rapidly from 5 to 8 or 9 years of age (4 mm in maxillary arch and

3mm in mandibular arch), (3) in most cases the maxillary and mandibular intercanine arch widths steadily decreased in amounts varying between 0.5mm and 1.5mm after 14 years of age. The dental arch width between the second primary molars showed that from 5 to 10 years of age, the width of both arches increased approximately 1.5mm. From 7 to 11 years of age the average increase in intermolar width (between permanent first molars) was 1.8mm in the maxillary arch and 1.2mm in the mandibular arch. From 11 to 15 there was an average decrease in intermolar width of 0.4mm in the maxilla and 0.9mm in the mandible. This decrease in intermolar width following the 11 year measurement was due to mesial drift of the first permanent molars after the loss of the primary molars. From 15 to 17 years of age, more than half of Barrow and White's cases showed a continued decrease in intermolar width. Dental arch length showed similar changes. Between 6 and 12 years there was an average increase in arch length of 1mm in the maxilla and a decrease of 1.12mm in the mandible. Further decreases in both arches continued from age 12 to 17. Barrow and White cited three main reasons for the decrease in arch length: (1) closure of interproximal spacing of posterior teeth, (2) lingual movement of anterior teeth, especially the maxillary incisors, and (3) normal wear of the proximal contact surfaces of all teeth. In general, they concluded by stating that "the permanent teeth through the years move and wear in many ways resulting in a shortening of the dental arches."

Longitudinal studies of the developmental changes in dental arch perimeter by Nance (1947), Speck (1950), Knott (1961,1972), DeKock (1972), and Foster et.al. (1977), showed similar results and measurements stating that dental arch perimeter experiences the greatest lateral growth in the cuspid area; growth occurs primarily during the eruption of the permanent incisors; there is wide variation in the development of the dental arches; and over time it seems that arch perimeter tends to decrease. Fisk (1966)

and Lundström (1969) added that some mesial migration of the buccal segments contribute to the overall decreases in arch length. Sillman (1964) included patients from birth to age 25 in his study. Essentially, he found no evidence of significant increases in arch length or width beyond age 13 or fourteen.

The development of dental arch width has also been a topic of considerable interest over the years. Virginia Knott (1961, 1972) collected the dental arch widths of orthodontically untreated subjects (n= 21 males and 14 females) aged 4 to 26 at four consecutive stages of the dentition. Her sample was taken from serial records collected at the University of Iowa between 1946 and 1960, and 1968 and 1971. The dental widths measured on each arch included the: 1.) maximum rectilinear distance between the lateral incisors, 2.) maximum distance between the canines, and 3.) the maximum rectilinear distance between the deciduous second molar teeth or second premolar teeth. These measurements were made on maxillary and mandibular casts at four stages of dental development designated as: deciduous, mixed, permanent, and young adult; with the approximate ages of 5-6, 9-10, 14, and 26, respectively. The findings of this longitudinal study showed that the average size of the dental arch was greater for males than females, and that the changes between the stages in the arch widths were distributed similarly for males and females. In the transition between complete deciduous dentition to permanent dentition (young adulthood), the least mean change in arch width was registered from the mandibular deciduous second molars to the width of their successors. Additionally, for most of the individuals, the maximum intercanine distance of both arches showed little change after the "permanent dentition stage" was attained. In the mandibular arch, any increases in the intercanine width occurred largely before eruption of the permanent canine teeth.

Similar findings were seen in the deciduous dentitions of subjects involved in studies of dental arch widths by O'Reilly (1951), whose sample of 130 orthodontically untreated children from the University of Iowa included dental casts and radiographs. DeKock (1972), who investigated the longitudinal arch width changes in subjects age 12-17 and age 26 (n=16 males and 10 females) found similar results for the "permanent dentition stage" as described by Knott. Guy Woods Jr. (1950) reported similar results in his radiographic study of arch width dimensions. The sample he utilized consisted of 28 patients (n=14 males and 14 females), 25 of which were orthodontically untreated Class I malocclusions, one untreated Class II, one untreated Class III, and one treated Class I malocclusion. The patient age range was between 3 and 15. He found the following concerning the dentition: 1.) the maxillary intercanine width increased gradually during the growth period [no specific time frame noted] except for a decrease between ages 7 and 12; 2.) the mandibular intercanine width remained the same during the ages of 3 to 15 except for a decrease in width between ages 6 and 11; 3.) the width between the maxillary first molars increased until the teeth came into occlusion and then continued to increase at a much slower rate; and 4.) the widths between the mandibular first molar decreased gradually until the teeth came into occlusion. After the teeth came into occlusion, he stated that increases or decreases in width remain constant. He also found that the principal difference between the sexes was one of size, with the females being slightly smaller than the males, in all dimensions.

In addition to the development and change of the arch width and perimeter, the literature also states that there is a strong tendency for the orthodontically untreated mandibular arch to become more crowded after the eruption of the second permanent molars. Authors such as Moorees et al., (1979), Richardson (1986), Lundström

(1969), Sinclair and Little (1983), and Bishara et al., (1989) have all reported increases in crowding within the age range of 12 to 27. Robert M. Little (1975), well-known in the field of mandibular anterior alignment, developed an index for what he felt to be the most frequently occurring characteristic of malocclusion: anterior dental crowding. The Irregularity Index was designed to provide a quantitative score of mandibular alignment. Several other examiners have developed indices to illustrate the malalignment of crowded anteriors. For example, the Handicapping Labio-lingual Deviation Index (HLD Index) developed by Draker (1960), the Treatment Priority Index (Salzmann, 1970), the Index of the American Association of Orthodontists (Salzmann 1968), and the Ackerman-Proffit Rating Scale have been utilized by researchers and clinicians alike to evaluate and diagnose the amount and severity of dental crowding. Other methods of establishing anterior tooth malalignment have been proposed by Barrow and White (1952), Björk and colleagues (1964), Grewe and Hagan (1972), and VanKirk and Pennell (1959). Dental crowding and its relationship to mesiodistal crown diameter was also studied by Radnzic (1988), Doris et al., (1981) and Howe et al., (1983). They independently found no significant correlations between cumulative mesiodistal crown width and dental crowding. This suggests a complex interrelationship among cumulative mesiodistal crown widths and various arch dimensions.

Mandibular Incisor Crowding

The relationship between mandibular incisor crowding and lateral craniofacial morphology has also gathered considerable interest over the years. Fisk, in 1966, felt there was a correlation between mandibular anterior crowding and the growth vector of the mandible. Leighton and Hunter (1982) also supported this view. Lundström (1969) and Richardson (1986), on the other hand found no correlation

among arch dimension changes, incisor position changes within the mandible, and the direction of mandibular growth. All of these were longitudinal studies. Rainer Miethke and A. Behm-Menthel (1988) designed a cross-sectional study to examine the possibility of a correlation between mandibular incisor crowding and incisor position relative to craniofacial morphology. A correlation analysis and a factor analysis of their data supported previous findings by other authors that, no correlations exist between the parameters of mandibular incisor crowding and vertical skeletal morphology; rather, mandibular incisor crowding is a local, independent, and genetically determined discrepancy between tooth width and size of supporting bone. Regardless of the influence of mandibular growth (or lack thereof), the fact remains that mandibular incisor crowding or malalignment is of considerable importance in examining and treating the dentition.

The dentition, therefore seems to show reduced spacing between teeth with age and an increase in crowding in both the deciduous and permanent dentitions over time. Measurements on arches have shown that the trend is primarily due to a reduction in anterior-posterior dimension rather than in the transverse dimension. This observed shortening may be ascribed in part to certain local factors i.e., mesial migration of the teeth, or lingual tipping of the anteriors. This phenomenon has been substantiated by Cohen (1940), Nance (1947), Speck(1950), Woods (1950), Barrow and White (1952), Knott (1961, 1972), Vego (1962), Sillman (1964), Fisk (1966), Lundström (1969), Moorrees (1969), DeKock (1972), and Foster et al., (1977). Mandibular incisor crowding or malalignment is a topic of considerable importance when considering the dentition, and many indices and methods have been developed throughout the years to measure its severity .

Third molars have also been attributed to having an effect on the spacing or crowding of the dentition. The belief that mesial forces from unerupted third molars tend to crowd the mandibular anterior teeth remains a controversy in dentistry today. Vego (1962) found an increased amount of crowding in subjects with erupting third molars compared to subjects with a congenital absence of third molars. Similarly, Lindqvist and Thailander (1982) found less tooth crowding on the side where erupting third molars had been extracted, than on the contralateral, non-extraction side. The Belfast third molar studies conducted by Richardson (1979, 1986, 1992) further indicated evidence in support of the "pressure from behind" theory.

On the other hand, Björk and Skieller (1972) found no clear evidence that crowding was caused by erupting third molars. Kaplan (1974) concluded that the presence of unerupted third molars does not produce a greater degree of mandibular anterior crowding after orthodontic retention. Ades et al., (1990) reported no postretention differences in mandibular crowding among subjects with functional third molars, absence of third molars, third molar impaction, or third molar extraction. Southard et al., (1991) in a study of mesial force exerted by unerupted mandibular third molars, found that the removal of third molars for the exclusive purpose of relieving interdental pressure and thereby preventing mandibular incisor crowding was unwarranted. The significant point here, is that there appears to be a natural tendency for incisors to crowd in adults-many times, long after the pressure of erupting third molars would be exerted (Southard 1992). Additionally, this natural tendency for crowding seems to occur when third molars are present, absent, or impacted. It is obvious there is a general lack of agreement regarding the influence of third molars on dental crowding. This thesis will not attempt to sway the argument in either direction; rather it will serve only to provide additional information on the presence or absence of

third molars in this adult sample. As will be noted later, the sample size of this thesis is too small to lead to significant conclusions as to the influence of third molars on mandibular incisor crowding, or correlations between third molars and changes in the adult dentition.

Specific Studies of the Adult Dentition

It is uncertain to what extent the various traits of the malocclusion remain stable over time (Helm and Petersen 1989). Also, it is often difficult to delineate occlusal changes in the adult since extraction or restoration itself involves an alteration of the occlusion and influences the subsequent occlusal changes. Another difficulty in a serial investigation of the adult dentition lies in the fact that it is best carried out on dentitions with complete arches where very little, if any prosthetic restorative work has been performed. Moreover, changes in the adult dentition occur slowly. It is because of these, and many other problems that the adult dentition has not been examined extensively. Generally, the changes seen in a mature dentition include tooth loss, increasing numbers of filled teeth, tooth migration, and attrition, both occlusally and interstitially. As Beyron (1954) states,

> "...a single examination provides but a cross section, a momentary picture of a lengthy process. Knowledge of the changes that various types of adult occlusion undergo is of importance then for the evaluation of "momentary" occlusion, for treatment planning and for prognosis of occlusal correction and rehabilitation."

A severe compromise to dental function is tooth loss. Therefore, reductions in caries and periodontitis, two of the most common causes for tooth loss, are extremely important indicators of improved oral health, and are a primary focus of health

promotion efforts. Many recent studies provide evidence that the oral health in the United States is improving. Across the nation, the incidence and extent of decay in children and young adults is declining (Brunelle 1989, Graves et al., 1986). Miller (1987) reports that in older adults, untreated caries, the amount of advanced periodontitis, tooth loss, and edentulism are declining. These facts are supported by Weintraub and Burt (1985), Graves and Stamm (1985), and Johnson et al., (1965). In a study of 572 adult patients with an average age of 60.1, Brown and Meskin (1989) state that there is very little recent evidence that periodontal diseases are a major cause of tooth loss. Rather, caries was found to be the major cause of tooth loss in the adult population. Findings reported in studies by Hunt et al., (1990), Bouma et al., (1987), and Miyazaki et al., (1991) support Brown and Meskin's conclusion.

Recent studies by Bjertness (1991), Palmqvist et al., (1991), and Johnson et al., (1992) have investigated additional factors in the aging dentition. Epsen Bjertness designed a study to analyze the relative importance of oral hygiene and other selected independent variables on the number of carious surfaces in a random sample of 142, 35 year old Oslo, Norway citizens. In addition to oral hygiene status (OHI-S), the independent variables of frequency of tooth cleaning, regular dental visits, years at school, sex, and number of filled and missing surfaces were included in the analysis. It has been well established that plaque has to be present on a tooth surface to promote caries, but the relationship between oral hygiene and caries remains controversial (Bjertness, 1991; Loe et al., 1972). The results of the study showed oral hygiene status, regular dental visits, and years at school to be statistically significant relative to the number of carious surfaces present. As one might suspect, the better the OHI-S score (low value), the more frequent the dental visits, and the more educated the individual, the fewer the carious lesions observed. The educational level may not

always indicate the positive results described in this study. Bjertness also pointed out that other factors must be taken into consideration when examining the aging dentition, such as dietary habits (Johnson et al., 1992), oral microflora, salivary factors, cognition, motor function, and behavioral factors.

Palmqvist et al., (1991) performed a questionnaire study on 3000 randomly sampled individuals aged 45-69 years of age living in Orebro, Sweden. The purpose of the study was to describe dental conditions in that population and to note differences in dental conditions between various socioeconomic groups. The distribution in dental categories was studied for subjects grouped by age (45-49 years; 50-54 years; 60-64 years; 65-69 years), gender, marital status (married; unmarried; divorced; widowed), place of residence (city; village; rural), individual income, and education (short-up to 9 years; medium-10-12 years; long-more than 12 years). In general, the results were as follows: (1) the percentage of subjects having all teeth present decreased with increasing age, whereas the percentage of those totally edentulous in one or both jaws increased with age; (2) married men showed better dental conditions than other men; (3) widowed women showed the poorest dental conditions compared with both the married and unmarried women; (4) unmarried women tended to have better dental conditions than even the married women, but this was not statistically significant and; (5) subjects in lower income groups reported poorer dental conditions than those in higher income groups. Those with the short education had the poorest dental conditions while those with the longest education had the best. This finding would tend to support the results by Bjertness (1991). Compared to earlier studies by Palmqvist's colleagues, this study found that there was an overall improvement of dental conditions. In the early 1960's , 53% of the Swedish population in the 45-64 year age group were totally edentulous. In 1983-84, the corresponding figure was 18% for the age group 50-69 years, and in this

study the totally edentulous subjects constituted 6% and 11% of the age groups 45-64 and 50-69 years, respectively. It may be possible then to extrapolate an overall improvement of the aging dentition as a function of medical technology, dental education and advances in dentistry itself.

Beyron (1954) reported a serial investigation of occlusal changes in the adult dentitions. He used the term "occlusal changes" to mean the formation of facets of attrition on the occlusal surfaces and changes in position and inclination of the teeth. The investigation concerned itself primarily with the following questions: What are the appearance and localization of the occlusal changes? What are the factors that influence the appearance and localization of these changes? Since attrition occurs frequently on the tooth surfaces that are in contact in eccentric positions of the mandible, this study set out to investigate each individual type of mandibular movement, especially of contact gliding. They were concerned with changes in the occlusal surface and the position of the teeth in connection with the stresses on the supporting tissues. Their study sample consisted of 138 patients with complete or almost complete dentitions. Patients were excluded if (1) the dentitions required extractions or fairly extensive restorative treatment, (2) the patients gave evidence of bruxism or a similar condition, or (3) the dentitions were such that maximum intercuspation did not accord with centric relaxed mandibulocranial relation (centric relation). The final study group consisted of 44 clinically healthy adults, varying in age from 23 to 36 years. In this age range, it was thought that characteristic attrition usually begins, but has not yet reached an extreme stage. No clinical symptoms of periodontal disease were present at the initial examination. The dentitions were complete or almost complete, and only minor restorations had been carried out before the initial examination. There were various types of occlusion, including local malpositions. The occlusal contact in all dentitions

was such that maximum intercuspation accorded with centric relation. In eccentric relations, the occlusal contact varied considerably. The method employed by Beyron consisted of (1) an oral examination of occlusion, (2) analysis of occlusion in an adjustable articulator and, (3) study of mandibular movements. Each dentition was studied during incision and mastication, both with and without food. Special emphasis was placed on the gliding movements with the teeth in contact. Observation of these "movement patterns" was recorded for each patient and was marked according to whether pronounced (long) or restricted (short) gliding movements occurred, and whether pronounced movements in one direction were prodominant while movements in other directions were restricted. The examination procedure was repeated for each patient at intervals of 2 to 3 years for periods of 8 to 12 years. Therefore, the evaluation of the dentition of each subject was based on a series of clinical observations and a series of casts mounted on the articulator. The results were grouped according to movement patterns: multidirectional gliding movements, predominating bilateral movements, predominating sagittal movements, predominating unilateral movements, and predominating unilateral movements with an anterior component. Specific observations were made for each of the types of movement, but some general conclusions were drawn as to changes in the dentition. For the most part, all teeth showed attrition. The contact surfaces had increased, and contact was extended to include more teeth in both lateral and protrusive positions. Some cases (predominating bilateral and sagittal movements) showed a slight tipping of the cuspids and lateral incisors labially in the maxilla and lingually in the mandible. In general, occlusal changes as studied by Beyron seemed to develop in accordance with the individual pattern of gliding movements with the teeth in contact. The most notable changes included attrition, tipping, and migration of teeth. The effect of attrition varies from

favorable to unfavorable, and depends on the form and the amount of attrition that occurs.

A study by Helm and Petersen (1989) examined the individual changes in malocclusion from adolescence to adulthood. The aim of this longitudinal study of 176 subjects, was to assess whether certain, pronounced traits of the malocclusion changed from adolescence to age 35-39 years. The criteria for selection included at least one of the following pronounced traits of malocclusion at the initial examination: extreme maxillary overjet (>9mm); mandibular overjet; deep bite (>7mm); frontal open bite; crossbite in the canine/premolar and molar segments, uni- or bi-laterally; maxillary or mandibular crowding (>2mm) in incisor and at least one lateral segment; maxillary spacing (>2mm) in incisor segment and/or medial diastema; and congenital absence of one or both maxillary lateral incisors. In 1965/66, 148 patients exhibited more than one of the above traits of malocclusion and a comparison group consisted of 28 subjects with "no malocclusion." At the final recall, 10% of the patients had undergone orthodontic treatment. The changes observed over the next 2 decades were as follows: extreme maxillary overjet persisted; deep overbite remained constant, with a tendency towards increasing frequency and severity; open frontal bite showed a slight tendency to disappear with time; and cross-bites remained constant. Changes occurred in parameters that measured spacing and crowding as well. Maxillary crowding that exceeded 2 mm was persistent, with no clear tendency for increasing or decreasing occurrence; while mandibular crowding showed a clear trend to either persist or become more common between subjects. In particular, crowding in the mandibular incisor segment showed increased frequency. Of the original 148 subjects with a malocclusion present in 1965/66, 139 "maintained" their malocclusion, while 9 showed no malocclusion. Of the 9 showing no malocclusion in 1986/87, 3 received orthodontic treatment, 5 exhibited

only 2mm. (or more) of maxillary spacing which seemed to resolve itself, and one subject remained unaccounted for. Of the original 28 subjects in the control group, (originally selected to have none of the outlined traits of malocclusion) 27 exhibited no change in malocclusion, while one subject developed a malocclusion. No description was given as to the extent or severity of malocclusion that developed in that subject. Overall then, the study concluded that deep overbite and anterior crowding in the mandible tend to increase in frequency, and the occurrence of other traits of the malocclusion are remarkably stable over time. In that most of the patients had not completed their growth in 1965/66 (mean age 15-19), late growth changes and tooth eruption must be taken into account when considering the results of the study.

From a cephalometric standpoint, the dentition also demonstrated considerable activity in terms of adjustment and compensation with age, according to Behrents (1985). The teeth and surrounding alveolar structures moved away from the cranial base. This process was related to sex of the individual and showed continued movement with age. Down's occlusal plane, relative to Frankfort plane, showed a significant trend to an increasing angle or steeper occlusal plane. In relation to the palatal plane, the S-N plane, PM vertical plane, and functional occlusal plane show a decreased angulation in males and stability in females. Therefore, while the female occlusal plane tends to be steeper to begin with, it remains fairly stable throughout time. Males, however, show a consistent change toward a flatter occlusal plane. The axis of the maxillary incisors, when measured according to nasion-A point, S-N plane, palatal plane, and mandibular plane indicates that the maxillary incisor is constantly uprighting with age. The axis of the maxillary molar relative to palatal plane shows a distinct uprighting in the male and a tendency toward a more distal inclination in the female. The axis of the mandibular incisor showed a consistent inclination when measured to nasion-

pogonion, A point-pogonion, Frankfort plane, S-N, palatal plane, Down's occlusal plane, and mandibular plane. The female exhibits a strong tendency for anterior inclination of the mandibular incisor in relation to maxillary facial structures. Relative to the mandible however, they are more upright than males. This finding was consistent with the relatively retruded mandible seen in females where mandibular anteriors tilt foreward in an effort to maintain contact as the mandibular plane rotates clockwise. It may be stated then that the maxillary incisors upright in both sexes with age and the mandibular incisor tilts anteriorly primarily in the female. The interincisal angle therefore changes significantly in the male but remains stable in the female. The mandibular molar relative to the mandibular plane, moves complementary to the maxillary molar, with the molar becoming more upright in the male and tipping mesially in the female.

Some of the movements described above may be the result of the teeth being carried by bones as they remodel foreward, but it is also due to the fact that the teeth themselves adjust via attrition and wear, and continue their eruption as the alveolus changes with time. The maxillary arch measured from palatal plane showed positive increases in the height of the alveolus anteriorly and posteriorly, and continued eruption of the anterior and posterior teeth. Similar alveolar and eruptive changes occurred in the mandibular arch. Attritional changes in the teeth have been noted by Hasund (1965), Murphy (1959), and Manson and Lucas (1962).

4. Adult Craniofacial Growth

There are numerous studies on the morphologic changes of the craniofacial skeleton. Generally, these studies center on the growth seen in children. In recent years however, there has been greater interest in the possibility of craniofacial change in the adult.

Changes in the human skull have been reported as early as 1858, by Humphrey, who stated that the cranium becomes thicker with age. Additionally, in 1864, he stated that the loss of teeth results in a change of function and a widening of the gonial angle. Boersma (1974) studied lateral radiographs of the heads of persons between 58 and 91 years, and found slight dimensional changes in the nasal floor, cranial base angle, and anterior cranial base. In that this study made no reference to the state of the dentition, and matched its subjects only on age and sex, interpretation may be somewhat limited. Boersma did note that the length of the nasal floor showed significant increases in the aging female in comparison to men. Overall, the study demonstrated that women generally are smaller than men, and the differences between men and women tend to become more pronounced with age. Harry Israel, also a proponent of continued growth in adulthood, carried out a series of studies in the late sixties and seventies. The results of his work were somewhat scrutinized by fellow researchers because his lack of precision and consistency in record gathering made the results of his study seem unreasonable. In short, he felt that the entire craniofacial system was involved in a process of symmetrical, "magnifying" enlargement throughout time. As Behrents stated (1985) concerning Israel's work, "it is likely that biology was assessed but was difficult to accurately quantify". Behrents (1985) states,

> "With biologic changes occurring throughout the body and with certain disease states and therapeutic interventions such as orthodontics effecting changes, it is perhaps illogical to suggest that the craniofacial complex with its elaborate sensory systems would be completely dormant and nonadaptive throughout the post-adolescent ages."

In order to explain the changes seen in the craniofacial complex of the adult, Behrents uses the term "adult conformational adaptation" to aid the reader in qualifying and envisioning the actual nature of the changes he felt were occurring. Through the use of cephalometrics, Behrents investigated the growth of individuals primarily between the ages of 17, 25, 30, 35, and 40 with some individuals extending into their early eighties. The medical and dental health of his sample population was good. Only two patients had dentures in one arch. The number of missing teeth was low, and the incidence of prosthetic replacement of any missing individual dental units was high. Most of the subjects were receiving regular dental care and the amount of active dental and gingival disease was negligible. The sample consisted of orthodontically untreated individuals only.

The results of his study showed that in the 17 year age group (n=113), 64 of the possible 70 cephalometric distance measures were significantly enlarged when compared to the standards, and 48 of the possible 69 angular measures were changed significantly. Both males and females demonstrated significant changes. Before this study, females were thought to have stopped growing by age 16. The findings that both distance and angular values changed during the time intervals studied, indicated that both enlargement and change in shape and position occurred. In other words, "differential growth" appeared to be happening. In the 25 year age group (n=56), 60 of the 70 distance measures and 32 of the 69 angular values were significantly changed. Again, this suggested that adults continued to change beyond age 25. In the 30 year age group (n=27), 56 of the 70 distance measurements changed while 28 of the 69

angular measurements changed significantly. The changes seen in the 35 year age group (n=10) were similar. The changes in these latter age groups however, would not seem related to late maturation as an extension of adolescent growth, as it might in the 25 year age group. The age group consisting of individuals beyond age 40 (n=4) showed 22 of the 70 distance measures and 11 of the 69 angular measures to have changed significantly from initial to final cephalometric recordings.

The main point of the above findings is that everyone is continuing to change, and maturation of characteristics occurs throughout adult life, perhaps until death. Further study at very old ages could illustrate a more defined "end" or "plateau effect" on growth.

Sexual dimorphism was also examined in Behrents study. In general, females were smaller than males although both groups change with time. Specifically, the major features differentiating males and females involve size and the shape of the maxillary facial area around the eyes. Behrents postulated that females "restart" growth coincident with pregnancy, i.e. a "female post-fertilization growth acceleration".

Other aspects of the craniofacial complex were also considered by Behrents: cranial base, midface, mandible, dentition, and others. Overall, the cranial base appeared to be stable with age except at its extreme extensions. The occipital condyle area appeared to change slightly with age as the region involving Bolton point moved downward and foreward (especially in the male). This effect, although small, was consistent across age and would affect cranial base orientations such as Frankfort plane. Basion continued to elongate in its original direction, remodeling downward and backward, without a change in cranial base angle. The anterior cranial base from sella to the endocranial surface of the frontal bone was stable. The frontal sinus showed

considerable enlargement over time, and there were some notable changes in the glabellar region of the frontal bone. (Behrents 1985)

The midface showed a number of subtle changes with age. The posterior aspect of the palate showed a remodeling both posteriorly and inferiorly. The fronto-maxillary nasal suture showed a continued foreward movement anteriorly with no angular change relative to cranial base. In all ages studied, the tip of the nasal bone moved anteriorly, elevating slightly in the male with age. Orbitale consistently moved foreward, away from sella throughout age, and was farther foreward in males. The key ridge was also seen to move foreward at all ages, and A point was continually moving away from the cranial base. In addition, the maxilla (at A point) was seen to come foreward, consistent with the anterior movement at nasion. The changes observed in the midface were felt to be related to an increase in the nasorespiratory area due to increased physiologic demands of increased age and decreased pulmonary efficiency.

The mandible demonstrated considerable change with age. Menton moved downward throughout all age spans, in males and females, with males showing larger values of change. Gnathion and pogonion also moved downward with time. B point moved away from the cranial base (greater in male) with a clockwise change in angulation in the female. Clearly, the mandible moved downward in both sexes. It was additionally stated that in males, the chin landmarks move down and foreward, and in the female they move more or less straight down with age. The anterior and posterior border of the ramus moved foreward in the male, but remained stationary in the female. The coronoid process moved away from the cranial base with time, but maintained its angular relationship to the mandible proper. The effective length of the mandible, the body, and the ramus all tended to increase in length throughout all age spans.

The dentition is not dormant during the aging process, and changes seen here generally coincide with changes in the corresponding osseous structures. As Behrents states, it is likely that in his dentally healthy population, the changes observed reflect more or less healthy dental changes with age.

It is obvious that there are several factors influencing the development, progression, and character of the adult dentition. The amount of literature concerning *change* in parameters of the mature, adult dentition is negligible. This thesis will attempt to delineate some of the variables of the dentition that change as individuals age, and will attempt to quantitatively measure visible changes in the dental arches.

STATEMENT OF THESIS

The purpose of this study was to identify particular changes seen in the dentition of a longitudinal population of *orthodontically untreated* individuals between the ages of 17 and 74. The hypothesis of this study is that there are measurable changes in the adult dentition. The null hypothesis of this study is that no change occurs in the permanent dentition after age 18. The aim of this examination of the adult human dentition is to disprove the null hypothesis and identify particular changes seen in the dentition of an adult sample. The research hypothesis was performed by means of evaluating dental casts at ages corresponding to an early adult dentition and a mature adult dentition. The specific parameters of the dentition that were quantitatively evaluated include: Decayed, Missing, and Filled Teeth, overbite, overjet, maxillary and mandibular arch perimeter, maxillary and mandibular intercanine distance, dental deflection, Angle classification, and molar deflection from Angle classification. Sex, age, and Angle classification were taken into account in consideration of each of the variables. Attempts were made to accurately identify specific changes occurring in a healthy, mature human dentition.

The long term objective of this study is to provide a basis for further investigation into the changes of the adult dentition. Information accumulated in this study is important for future research concerning the nutritional habits and

environmental influences governing a modern aging lifestyle. In addition it is hoped that studies such as this one will initiate further investigation into the factors that lead to the survivability of the mature human dentition.

METHODS AND MATERIALS

Source: The study models and radiographs utilized in this investigation were obtained from the Bolton-Brush Growth Study Center at Case Western Reserve University, School of Dentistry. Specifically, longitudinal study models of orthodontically untreated individuals from the original Bolton-Brush population were used. This group includes subjects studied by Behrents (1980's), as well as subjects seen during the pilot recall of the Bolton population (Update 2000) in 1992 (Figure 1).

Sample: A longitudinal sample of fifty orthodontically *untreated* subjects between the ages of 17 and 74, were evaluated to determine the amount and severity of tooth loss, how tooth loss has affected the remaining dentition, and what parameters of the dentition remain stable over time.

Background of the Sample: In the late 1920's, the Bolton-Brush study set out to examine normal facial growth in children. The original population consisted of 4,570 healthy children from families with moderate income and good access to health care. The study was designed to evaluate patients yearly, from babyhood to early adulthood, or approximately age 18. Examinations consisted of the following:

- physical examination and health inquiry
- mental tests
- nutrition history
- information regarding genetic and environmental factors
- dental examination, dental casts, and cephalometric radiographs

Some of the patients obtained orthodontic treatment while others did not. The majority of patients came in once a year until they reached maturity. There were however, subjects that were difficult to follow into the older adolescent years.

In the 1980's, Rolf Behrents initiated a recall of the original Bolton-Brush patients. By this time, the subjects were between the ages of 40 and 75 and could furnish valuable information concerning the aging process. At the recall visit, Dr. Behrents collected information on the subject's health, nutritional history, and dental status; and obtained dental x-rays and casts. This recall located approximately 214 individuals, 113 of which were orthodontically untreated. In that many of the patients were located via long distance correspondence, attempts were made to obtain as much information as possible from attending dentists and orthodontists. While x-rays are fairly easy to obtain and mail, study models are not as easily procured. In other words, not all the recall patients located had a set of study models available for examination. This limited the number of 1982 recall patients available for this research study. In short, of the 113 orthodontically untreated individuals, only 69 patients possessed a set of study models in the 44 to 74 year age range. All of these patients had a complete series of x-rays in the older age range.

In 1992, the final recall of the Bolton-Brush Growth population was initiated. To date, approximately 100 patients have been located. A thorough dental examination was performed, cephalometric x-rays were taken, and impressions for dental casts were obtained. In addition, an extensive health and nutrition questionnaire was administered to each of the patients. Forty-one of the 100 patients (1992 recall) were orthodontically untreated; and each one had a complete series of x-rays in the older age range and a set of study models.

At this point, the orthodontically *untreated* adult patients (69 from 1982 and 41 from 1992) were longitudinally matched with their earlier, young adult dental records taken during the original Bolton Study. In order to be included in the study, the patient had to meet the following criteria:

1.] Each subject had complete dental records of the adult dentition: at least one record between the age range of 17-25 [Time 1: 1934-1952], and a follow-up record of an "aged" or mature dentition between the age range of 44-74 [Time 2: 1982-1992].

2.] Each subject had a radiographic history in each age group [Time 1 and Time 2]; and all casts to be examined were in excellent condition (no air bubbles, proximal fractures, etc.).

3.] Each dentition had natural maxillary and mandibular first molars at the first examination [Time 1]; and natural maxillary and mandibular first molars in at least one quadrant of the dentition at the second examination [Time 2].

The final sample included 50 orthodontically untreated subjects between the ages of 44 to 74, with complete dental records and an early adult dentition time period (see Figure 1).

In regards to this research sample, it is important to remember that the recalls of 1982 and 1992 contained patients that were available for examination. Long term follow-up in any longitudinal study is difficult and time-consuming. Therefore, it must be remembered that this research population is a convenience sample, not a truly random sample of an adult population.

Research Sample:

In that tooth loss can have dramatic effects on many parameters of the dentition (Burt 1992, Behrents 1985), the study sample was divided into a large group and a subset group. Group One consisted of fifty patients with no limitations on the number and

kind of teeth missing. Group Two, a subset group, consisted of forty-two patients. It was divided and ranked according to the amount of tooth loss and specific teeth that were missing (Table 1):

Table 1. --Rank designated to patients according to the number of teeth missing at [Time 2].

Rank	# of teeth missing [Time 2]
1	no teeth missing
2	≤3 teeth missing-no 1st molars are missing
3	≤3 teeth missing-only one is a first molar
4	≥3 teeth missing, or more than one first molar is missing

This design for "rank" based on tooth loss was modeled after a study of tooth loss patterns by L. Jackson Brown and Lawrence H. Meskin (1988). All 42 patients in Group Two were examined for *change* in parameters of the dentition and exhibited no teeth missing at [Time 1], and a rank of 1 or 2 at [Time 2]. The elimination of patients with excessive tooth loss would aid in reducing any possible confounding effects that might occur in variables subject to drift and rotation. Therefore, Group 1 data only provides information on decayed, missing, and filled teeth, not specific change in the parameters of the dentition under scrutiny. Each of the records was evaluated individually, measured, and compared for changes that occurred during the aging process.

Figure 2 illustrates the age range of each of the patients in the study. The endpoint on each of the lines designates age at Time 1, while the arrowhead at the other end of the line designates the patient's age at Time 2. It is important to point out that some of the patients could still have a potential for growth at the Time 1 record (age 17-20), especially the males. It is generally accepted that the adolescent growth spurt

occurs bewteen the ages of 10 and 12 years in the female and between 12 and 14 years in the male. In the female, the termination of active growth generally takes place in a plateauing of size change at approximately 14 years, with some minimal growth potential on to 18 years of age. Males, on the other hand, can be observed to continue actively in growth increments into the eighteenth and nineteenth years (Behrents 1985). This potential for growth must be considered in the final analysis of the data.

The categorical variables measured in the study (sex, Angle classification, and third molar presence) were designated in the following manner:

Table 2.--Designation of categorical variables

Sex	1= male 2= female
Angle Class	1= Class I Molar Relationship 2= Class II Molar Relationship 3= Class III Molar Relationship

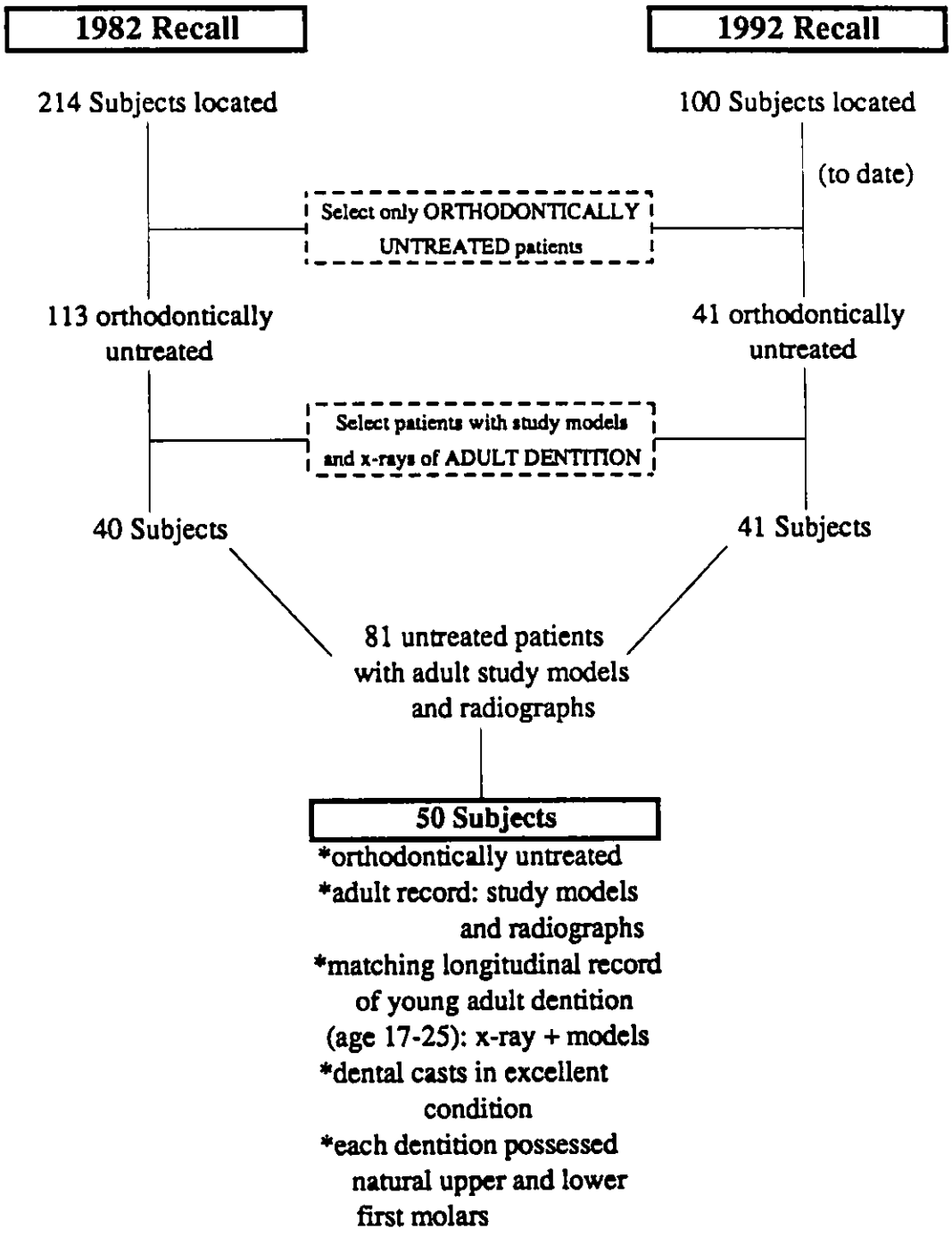


Figure 1. Flow Chart Summarizing Population Selection

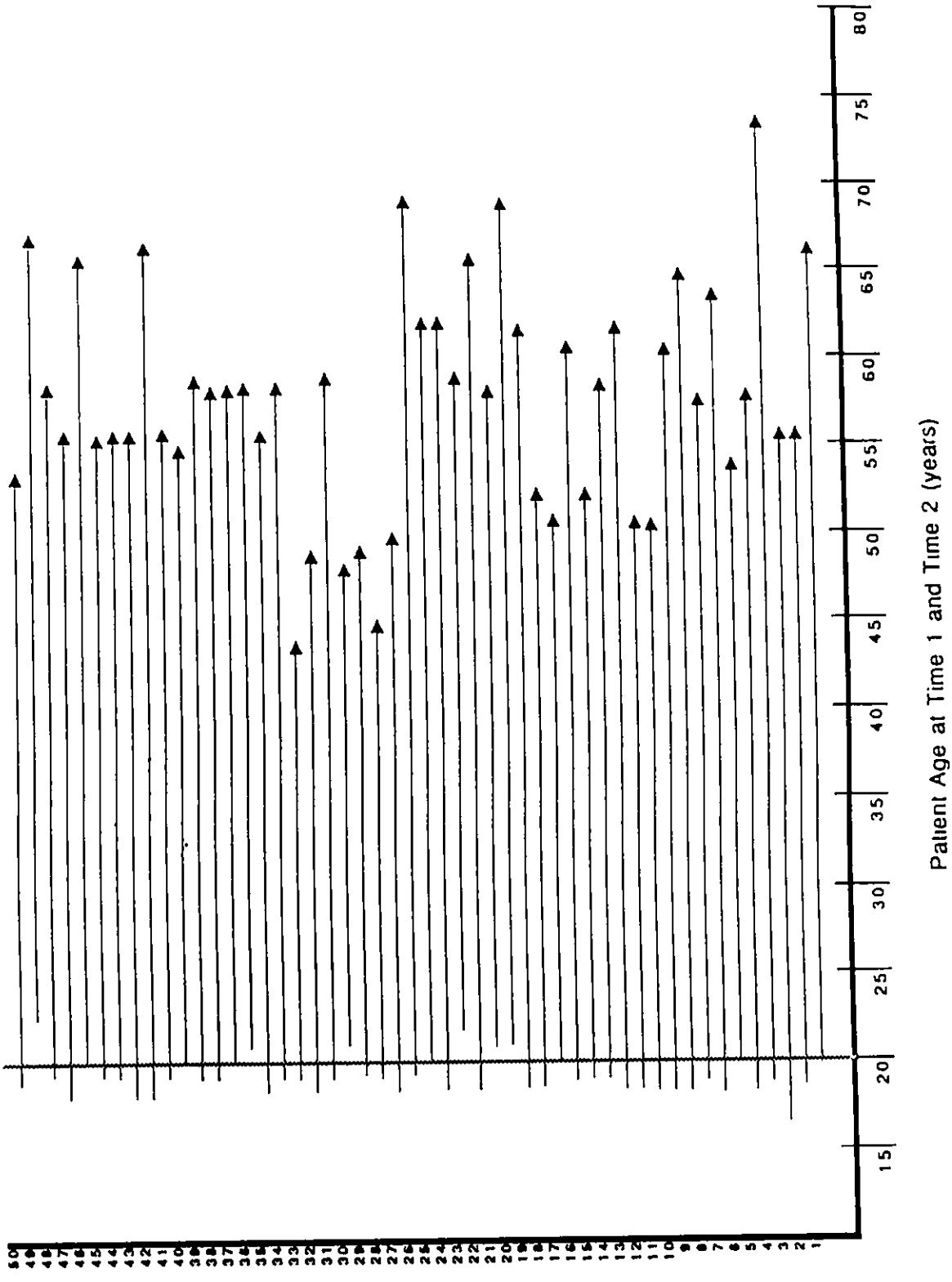


Figure 2. Description of the Sample
[— = Time 1 ▸ = Time 2]

Data Collection:

As mentioned previously, all of the [Time 1] data came from the original Bolton Study which included a thorough, yearly, oral dental examination to check for decayed, missing, and filled teeth; dental study models; and cephalometric x-rays (frontal and lateral). Casts had been made annually, up until approximately the eighteenth or nineteenth year, on the subjects. The impression technique in the 1930's and 1940's, was substantially different than it is today, however. At that time, maxillary and mandibular impressions and bite registrations were made at the same time in dental compound material. The casts were indexed by means of "dove-tailing" into the plaster in the posterior, and bite relationships were registered at maximum intercuspation. In the 1980 and 1992 recall, the method was different. Alginate impressions, which are generally considered to be very accurate, were taken of each arch, placed in a humidor, and poured in dental plaster within one hour to minimize shrinkage potential. In order to achieve accurate bite registrations, a warm wax bite was made with the teeth in centric occlusion.

Lateral and frontal radiographs, at all time ranges, (i.e. first examination and all subsequent recalls) were taken by the Western-Reserve Broadbent-Bolton Cephalometer using the method described by Dr. Broadbent (1931). As mentioned earlier, the radiographs, in combination with the dental records of each patient, were used to verify any and all missing and filled teeth.

All linear measurements of the dental study casts were read to the nearest tenth of a millimeter using digital read-out calipers (Mitutoyo Digimatic Calipers Series 500, Mitutoyo Corporation, Tokyo, Japan). Dental deflection was recorded using the digital calipers according to the method devised by Little (1975) and expanded by Behrents

(1993), and was accurate to 0.1mm. Overbite and overjet, was measured utilizing a standard, metal dental ruler in millimeter increments, accurate to the nearest 0.5mm (Proffit 1986). Arch perimeter, intercanine distance, and angle molar deflection was measured using the Mitutoyo calipers to a tenth of a millimeter accuracy.

Statistical Method

Observations were statistically analyzed using an SPSS (Statistical Package for the Social Sciences) program. All data entries were coded into a Macintosh personal computer (PC) utilizing a commercial spreadsheet program (Microsoft Excel 4.0, Microsoft Corp., California) and a graphical display program (Cricket Graph 1.3, Cricket Software Malvern, PA). The sample presented differences in starting ages, final ages, and Time 1-Time 2 intervals. To preserve the individuality of change, inferential testing was limited. The following analyses were utilized in this study:

1.] "Descriptive" Analyses: compilation of raw data expressed as a positive (increase at Time 2) or negative value (decrease at Time 2) of change for each variable measured. Means and standard deviations were not calculated in this study due to the varying Time 1-to-Time 2 intervals among subjects.

2.] The Wilcoxon Matched-Pairs Signed-Rank Test for Location: is a non-parametric analysis used to test a null hypothesis about a sample mean when the sample is not normally distributed. It is an analog of the paired-t test. This test is used to determine the *magnitude* of the differences between measurements and the *direction* of the

differences. It is a more powerful test than the Sign Test which only records the direction of the differences. The null hypothesis (Ho) of the Wilcoxon Signed Rank Test is that the median difference among the entire population is zero; or if Ho is true and there is no difference between groups, the sum of the positive ranks would be approximately equal to the sum of the negative ranks. To determine whether there is significance between the groups, the sum of either the positive or negative ranks (whichever is smallest) is compared to a table of critical values. N is the number of pairs of parameters being compared. A sum of signed ranks less than or equal to n-2 indicates a statistically significant difference at the α=.05 level. In this study, n=10 pairs and a sum of signed ranks $\leq$8 would indicate a significant difference at the α=.05 level.

3.] Correlation Coefficient: is a measure of the magnitude or strength of the relationship between variables. It measures the linear relationship between two continuous variables (those that are measured). The correlation coefficient *r* is an index number whose value ranges from -1 to +1. A correlation of zero would indicate that no linear relationship between the variables exists. A correlation of -1 or +1 , on the other hand, indicates either a perfect negative linear relationship or a perfect positive linear relationship. Correlations lie within the range of -1 to +1.

4.] t-Test for Paired Samples: was used to estimate the reliability of measures taken on each of the variables. In order to assess the level of measurement accuracy, 20 casts from the sample were selected randomly and remeasured. The null hypothesis is that the population means of the two groups are equal (μ1-μ2=0). When pairs are used, this hypothesis is equivalent to saying that the mean of the

population of *differences* is equal to zero, or Ho: D=0. The alternative to be tested in this case is D≠0 (two-tailed). If the values of the test statistic falls in the rejection region, it may be concluded that there is a statistically significant difference in the means of the two groups (reject Ho) at the α level of significance. If it does not, then it may be concluded that there is not a statistically significant difference in the means (or measurements) of the two groups (accept Ho) at the α level of significance.

Parameters

Only one parameter of the dentition was evaluated in Group One patients (N=50), the Decayed, Missing and Filled teeth index. It was abbreviated DMFT in all charts, tables and references.

The parameters of the mature dentition that were measured in Group Two patients (N=42), and their abbreviations include:

1.] Overbite [OB]
2.] Overjet [OJ]
3.] Arch Perimeter: Maxillary and Mandibular [PU and PL]
4.] Intercanine Distance: Maxillary and Mandibular [3|3 U and 3|3 L]
5.] Dental Deflection [DD]
6.] Angle Classification [Angle]
7.] Angle Deflection of Molars: Right and Left [ADeflMR and ADeflML]
8.] Third molars [3M] [Data and results in Appendix 1]

Parameters defined:

Decayed, Missing, and Filled Teeth [DMFT]: This parameter was defined as the number of teeth that were missing and/or filled, where "filled" was taken to mean any tooth that contained radiopaque restorative material. Traditionally, caries or tooth decay is measured by the DMF index, i.e. the number of teeth per person that are Decayed, Missing because of caries, or have been Filled. The index is simple to use and can be assessed quickly by clinical examination (Burt 1992). The simplicity of the this index has led to its wide utilization. However, there are some disadvantages to the DMFT index. For example, it is not known with certainty that all filled teeth were in fact carious, and subjective judgements are often required to determine why teeth were extracted or lost. The dental study casts were the primary means by which the DMFT score was derived. Generally, impressions of tooth and supporting structures are accurate enough to determine the number and type of restorations present in an arch. Full mouth dental radiographs were not included as part of the original Bolton-Brush examinations. In addition, they were not available for patients in the 1982 Recall by Behrents, or the Update 2000 project (summer 1992). Therefore, the combination of the accurate charts, records, and study casts collected by the Bolton Study and subsequent recalls; and the lateral and frontal cephalometric x-rays provided the enough information to verify the total number of teeth missing and filled. Dental decay was more difficult to estimate. However, the population under study was in relatively good dental health, was known to have had regular dental check-ups, and had reasonably good access to dental care. The presence of obvious carious lesions (i.e. holes in teeth) could be seen on the dental casts. None of the subjects in the study presented with frank decay on the study models. Missing teeth were defined as any tooth missing

from the arch (included those teeth replaced with a bridge etc.) with the exception of third molars. Filled teeth were defined as any tooth having a restoration whether it be an amalgam, composite, or casting. The table abbreviation for this parameter is **DMFT1** and **DMFT2**, with 1 and 2 relating to the time the record was taken. Time 1 was the time of the first examination (1934-1952) and Time 2 was the time of the second examination (1982-1992). Data in Appendix 2 shows the specific teeth missing and filled for each time period by using the universal tooth number system from 1 to 32 (with third molars 1, 16, 17, 32 excluded). The index results in a single score from the above "raw" data. The single score for all data is found in Appendix 2.

Overbite (OB): This parameter is defined as the distance, in millimeters, between the incisal edge of the mandibular central incisor and the incisal edge of the maxillary central incisor measured perpendicular to the functional occlusal plane (Carmen 1978, Proffit 1986). This measurement records the vertical overlap or open bite of the anterior teeth. Overbite is recorded relative to the coverage of the mandibular incisors or the degree of open bite. The recording zone will include those incisors most labial in position. The tooth with the greatest overlap is recorded. Measurement was made to the nearest tenth of a millimeter. Table abbreviations are **OB1** and **OB2**, with 1 and 2 relating to the age range of the patient, or time the record was taken.

Overjet (OJ): This parameter is defined as the distance, in millimeters, between the labial surface of the mandibular, most anterior central incisor to the labial surface of the incisal edge of the maxillary, most anterior central incisor (Proffit 1986). Positive overjet as well as teeth that were in crossbite were recorded. The recording zone included left to right lateral incisors. The most prominent aspect of any one incisor was

the one measured. When recording the overjet, the ruler must be held parallel to the occlusal plane and radial to the line of the arch (i.e. in line with the long axis occlusally). Table abbreviations were **OJ1** and **OJ2**, again with 1 and 2 relating to the age range of the patient.

Arch Perimeter (PU and PL): This is the distance measured in tenths of a millimeter from the mesial contact point of the first permanent molar to the mesial contact point on the contralateral side in both maxillary and mandibular arches (Vego 1962, Proffit 1986). The distances were taken as four linear segments of the arch, and were added together to find the total perimeter. A measure from mesial of the first molar to the distal contact of the cuspid, from the distal contact of the cuspid to the midline contact point, from the midline contact to the distal contact of the other cuspid, and from the distal contact point of the cuspid to the mesial contact point of the other first molar. Diastemas were included in the measurement. Measurement was performed to the nearest tenth of a millimeter using Mituoyo digital calipers. The table abbreviations are **PU1** or **2** and **PL1** or **2,** with U and L relating to either maxillary or mandibular arch, and 1 or 2 relating to the age range of the patient.

Intercanine Distance (3|3 Dist): This distance is defined as the measure, in millimeters, between the cusp tips of the maxillary and mandibular cuspids left to right (Carmen 1978, Proffit 1986). The "cusp tip" was taken to be the point through which the center axis (or axis of rotation) of the tooth was found. This aided in the measurement of cuspids that exhibited a flat wear facet. Measurement was made to the nearest tenth of a millimeter using digital readout calipers. The table abbreviation is **3|3 U** or **L**, time **1** or **2.**

Dental Deflection (DD): This parameter is defined as the sum total of the distances, in millimeters, between individual anatomical contact points of the ***mandibular incisors***, and one posterior adjacent tooth (premolar). There are 7 distances involved: left premolar to left cuspid, left cuspid to left lateral, left lateral to left central, left central to right central, right central to right lateral, right lateral to right cuspid, and right cuspid to right premolar. This measure is defined by Little (1975) to include only the mandibular incisors. It was suggested by Behrents (personal communication, March 1992) to add the additional tooth as an indication of irregularity around the curve of the arch as the anterior segment blends into the posterior segment. The total distances between the individual contact points of the teeth were performed using a digital readout caliper calibrated to the nearest 0.1 mm. Each of the seven measurements was obtained directly from the mandibular cast. Proper positioning of the caliper was essential for consistent accuracy. The mandibular cast was viewed from above, sighting down onto the incisal edges of the anterior teeth. The caliper *must* be held parallel to the occlusal plane while the beaks are lined up with the contact points to be measured. Each of the seven measurements represents a horizontal linear distance between the vertical projection of the anatomic contact points of adjacent teeth. Although contact points of anterior teeth can vary in the vertical plane, correction of vertical displacement will not appreciably affect anterior arch length; therefore all vertical discrepancies of contact points were disregarded (Little 1975). Properly placed and consistently parallel calipers will ensure the recording of only horizontal displacement and lead to an accuracy of 0.1mm. The table abbreviation is **DD1** or **2** depending on the date of examination.

Angle Classification (Angle): This parameter recorded any changes seen in the cuspid and molar relationship over time. The cuspid and molar was classified according to the Angle description of Class I, II, or III, over both time periods. The table abbreviation is **Angle**, time **1** or **2**.

Angle Molar Deflection (ADeflM): In order to further define any changes seen in the molar relationship over time, a measure of the deviation from the ideal Class I molar relationship was taken. Ideal Class I molar relation is defined as the mesiobuccal cusp tip of the maxillary permanent first molar interdigitating with the mesiobuccal groove of the opposing mandibular permanent first molar. The method used to record the distance from the apex of the mesiobuccal cusp of the maxillary molar to the buccal groove of the mandibular molar, was to place the casts in occlusion and record the measurement parasagitally and parallel with the occlusal plane. Digital readout calipers were used and were calibrated to an accuracy of 0.1 mm. Both right and left sides were recorded. Any deviation in an anterior-posterior direction from the ideal Class I relationship (i.e. Class II or Class III tendency) was recorded. When a case demonstrated a mandibular molar *distal* to the maxillary molar (i.e. Class II) a *negative* value was assigned. Cases that demonstrated a mandibular molar mesial to the maxillary molar (Class III) received a *positive* value (Harris and Behrents 1988). The table abbreviation for this parameter is **ADeflM,** either **R** (right) or **L**(left), and time **1** or **2**. For example, if ADeflMR-1 is 0, the angle deflection of the molar relationship on the right side at time one is zero, or ideal Class I. If the value is +3, the molar relationship deviates in a Class III direction by 3 millimeters. If the value is -2, the molar relationship deviates in a Class II direction by 2 millimeters.

Third Molars (3M): This parameter indicates the presence or absence of third molars. The data in Appendix 1 shows M=missing third molars, I=impacted third molars, and O=third molars in occlusion. In that there is no clear cut answer as to the influence of third molars on arch perimeter and mandibular incisor crowding, the data obtained on third molar presence will be noted in the appendix only. The sample size of this research project is too small and contains too much individual variation in patient care to gain meaningful trends or relationships between third molar location and changes in the dentition.

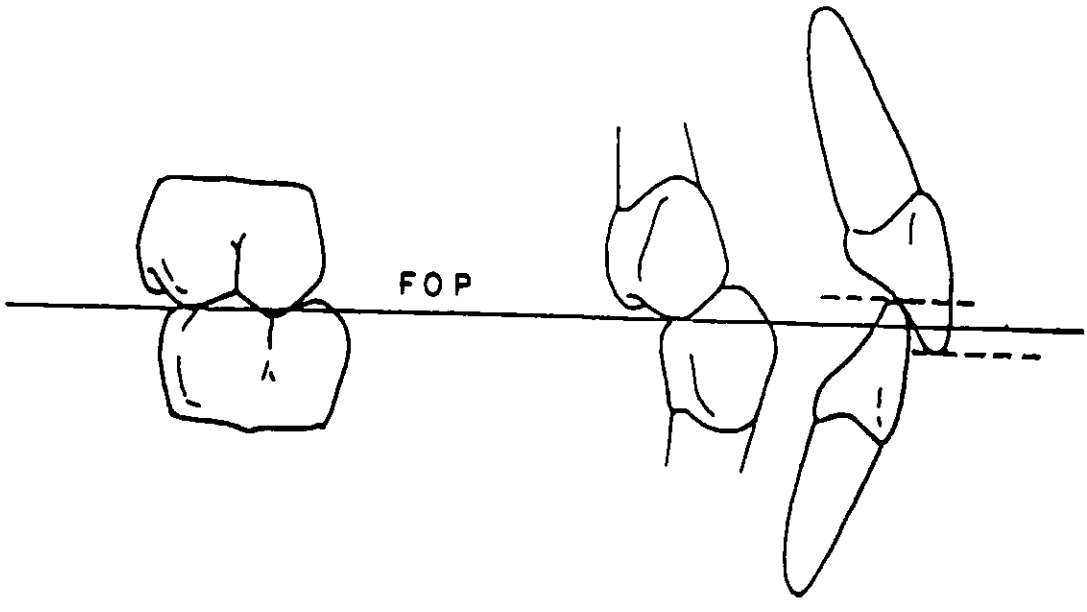


Figure 3. Diagram of Overbite Measurement

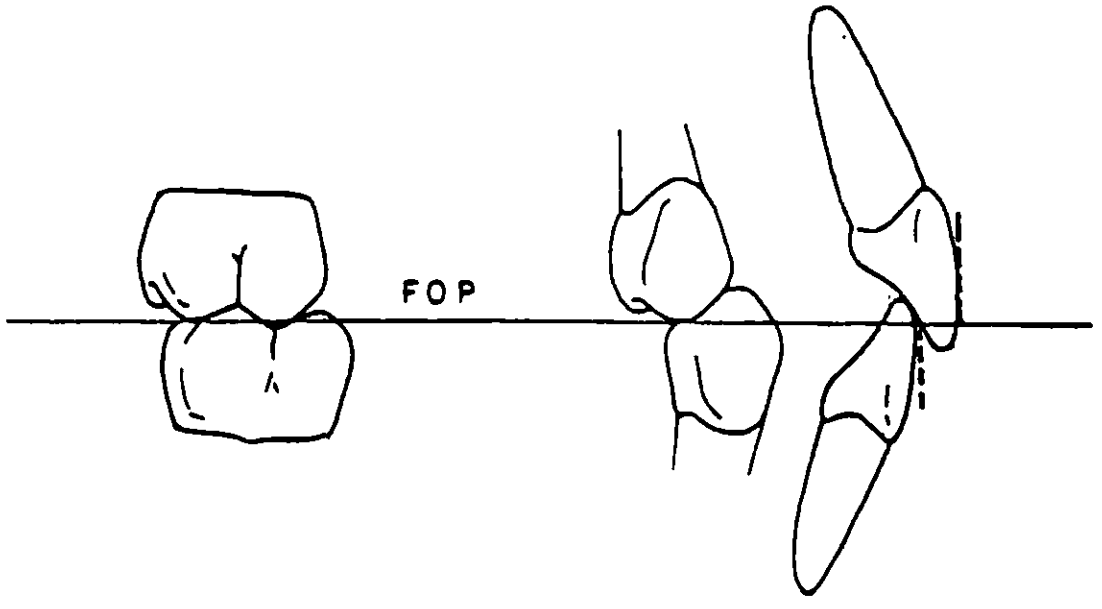


Figure 4. Diagram of Overjet Measurement

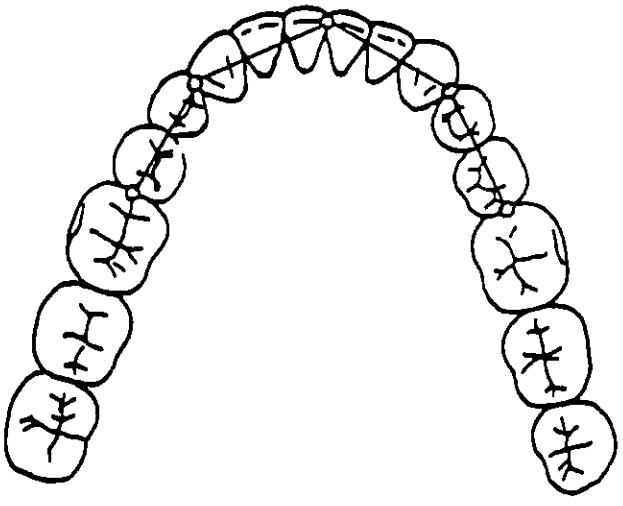


Figure 5. Diagram of Arch Perimeter Measurement

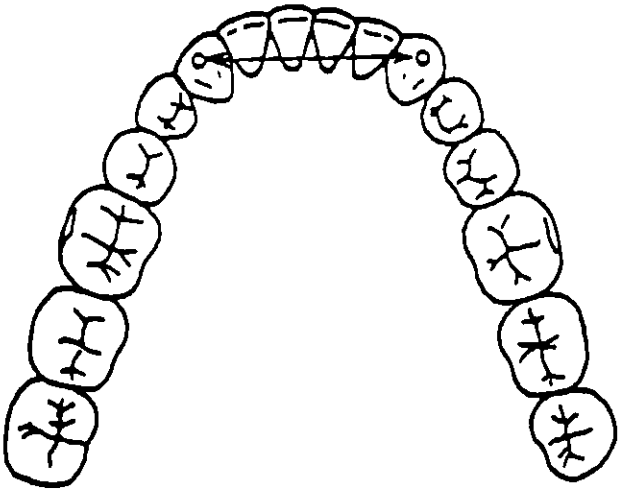


Figure 6. Diagram of Intercanine Distance Measurement

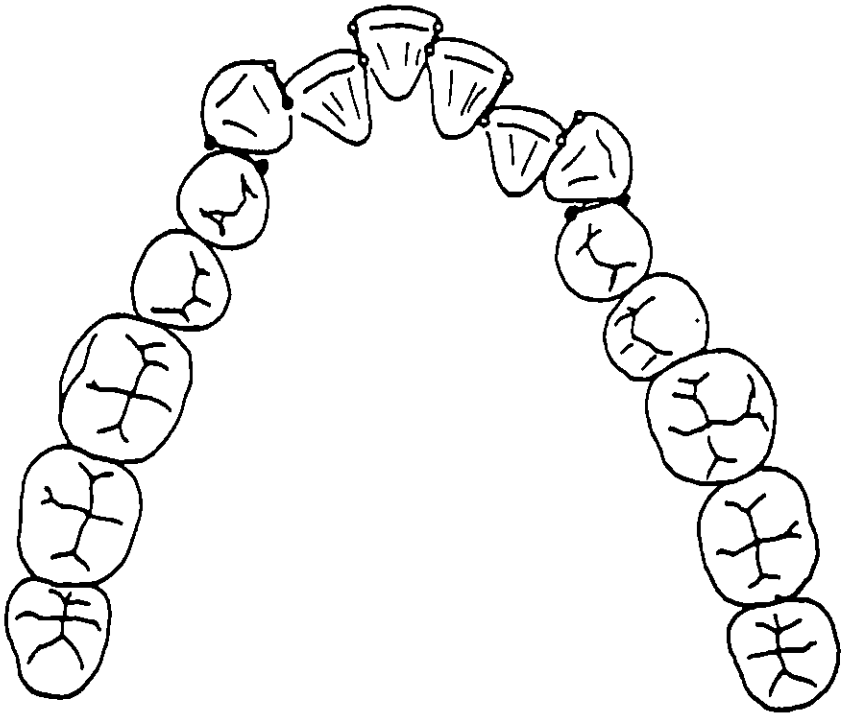


Figure 7. Diagram of Dental Deflection Measurement

RESULTS

The total change that occurred in each of the variables measured was tabulated and assigned a positive or negative value according to the direction of the change observed. Population distributions of the categorical variables were recorded for each age group, as were population distributions for DMFT. The maximum and minimum values for each variable at Time 1, 2, and T2-T1 (Δ) is presented. Scatter plots depicting the magnitude and direction of *change* for each of the parameters are shown in Figures 8 through 17. Each plot delineates male and female differences and the overall time interval between the visits (T1 and T2). The positive, negative, and tied ranks for males and females are presented utilizing the Wilcoxon Matched-Pairs Signed Ranks Test (Table 8). The categorical variables (sex, and Angle Classification) for **Group 1** are presented in Table 3. Note that the population is split approximately 60:40, males to females. There are more Class I type occlusions (54%) than Class II occlusions (44%); and the Class III type of occlusion is represented by one individual, or 2% of the population.

Table 3. Population Distribution of Categorical Variables Group 1 (Large Group N=50)

	Frequency	% of Population
Sex		
Male	31	62
Female	19	38
Angle Class		
Class I	27	54
Class II	22	44
Class III	1	2

The population distribution of *missing* teeth for the fifty patients of Group 1 is listed in Table 4. The majority of subjects had little to no tooth loss at Time 1. At Time 2, the majority of tooth loss ranged between 1 and 3 teeth for both males and females. Table 5 depicts the distribution of *filled* teeth for Group 1. The majority of patients, both males and females, had between 0 and 10 teeth filled at the Time 1 record. At Time 2, the number of teeth having restorations increased into the 11-20 range. Table 6 depicts the distribution of ***change*** in DMFT for Group 1. Figures 8-10 are a graphic representation of Tables 4-6. Male and female contribution to the number of missing and/or filled teeth is indicated at the top of each column. The majority of tooth loss and/or restoration seemed to fall within the range of 6 to 15 teeth for this particular sample. Figure 7 illustrates the overall change seen in DMFT for Group 1.

Table 4. Population Distribution of Missing Teeth for Group 1 (N=50)

# of Teeth Missing	# of Males		# of Females	
	Time 1	Time 2	Time 1	Time 2
0	29	22	16	9
1-3.	2	8	3	8
4-6.	0	0	0	2
7+	0	1	0	0

Table 5. Population Distribution of Filled Teeth for Group 1 (N=50)

# of Teeth Filled	# of Males		# of Females	
	Time 1	Time 2	Time 1	Time 2
0	7	0	4	0
1-5.	13	2	6	0
6-10.	8	7	7	0
11-15.	2	10	1	11
16-20	1	12	1	8

Table 6. Distribution of ***change*** in DMFT for Group 1 (N=50)

CHANGE in number of teeth missing or filled	# of Males	# of Females
0	1	0
1-5.	6	2
6-10.	12	6
11-15.	8	8
16-20	4	3

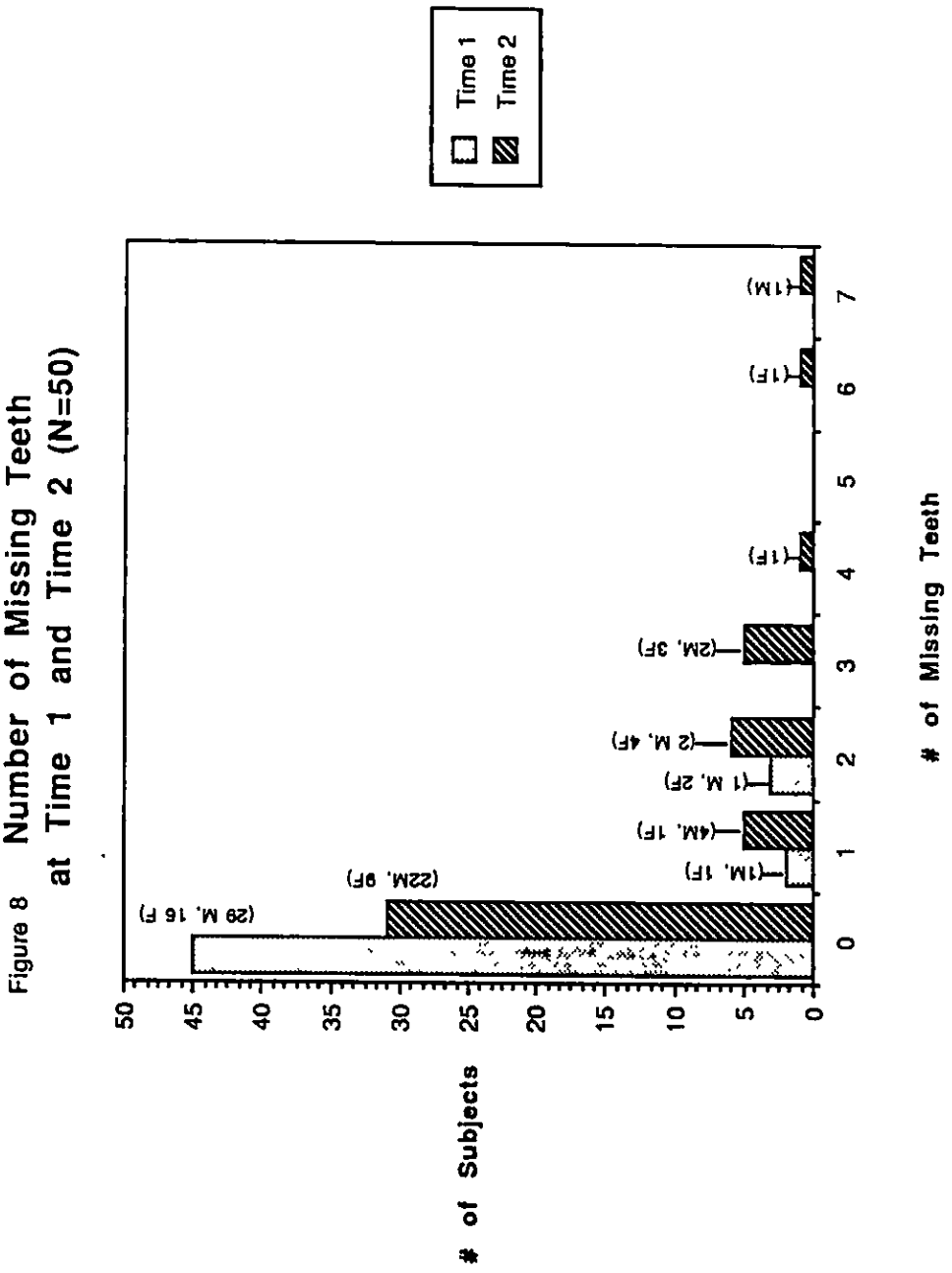

Figure 8 Number of Missing Teeth
at Time 1 and Time 2 (N=50)
Time 1
Time 2
# of Subjects
# of Missing Teeth
(29 M, 16 F)
(22M, 9F)
(1M, 1F)
(4M, 1F)
(1 M, 2F)
(2 M, 4F)
(2M, 3F)
(1F)
(1F)
(1M)

Figure 8.

Figure 9. **Number of Filled Teeth at Time 1 and Time 2 (N=50)**

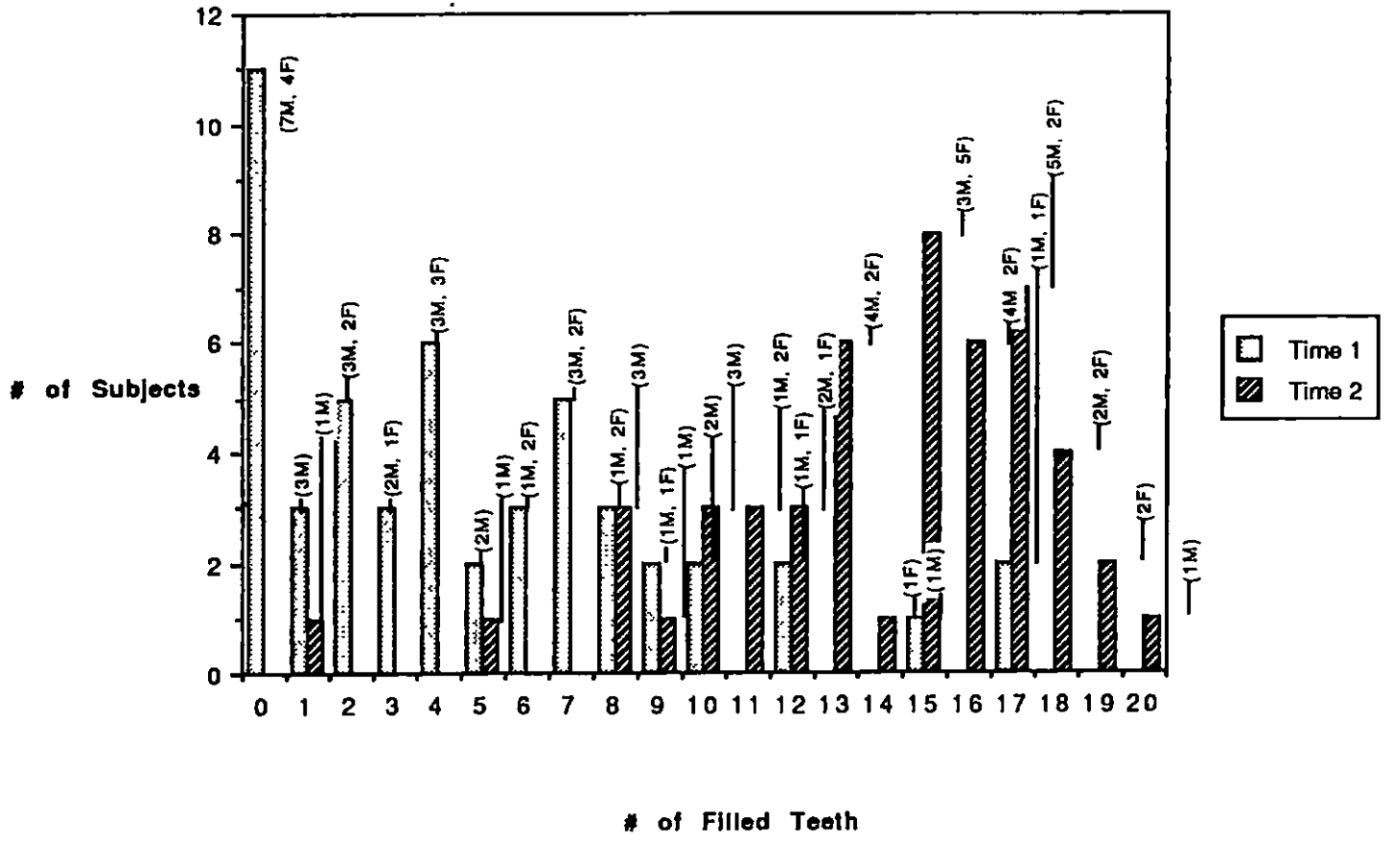


Figure 9.

Figure 10. **Change in # of Teeth Missing and Filled between Time 1 and Time 2**

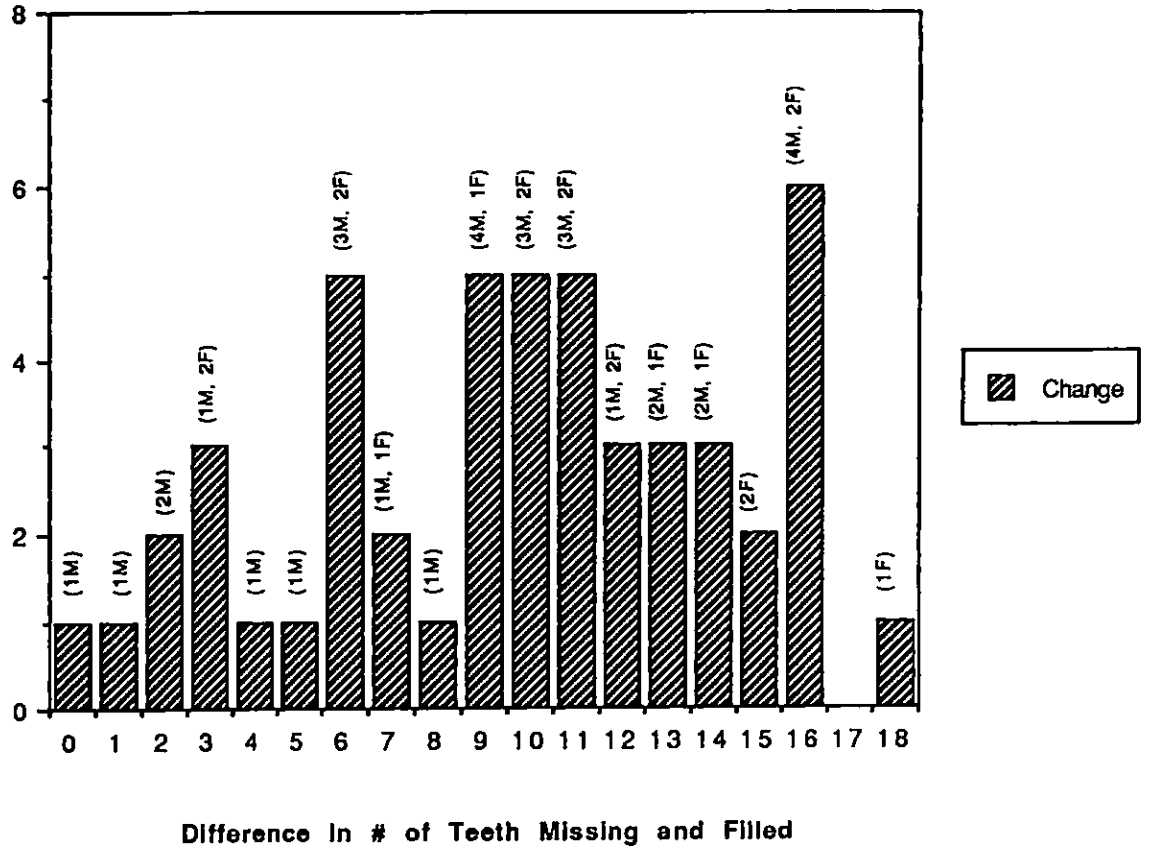


Figure 10.

The categorical variables for Group 2 is presented in Table 7. In this population, the split between males and females is 2:1. There are more Class I type occlusions (57.1%) than Class II (40.5%); and the Class III type occlusion is represented by one individual, or 2.4% of the population.

Table 7. Population Distribution of Categorical Variables Group 2 (N=42)

	Frequency	% of Population
Sex		
Male	28	66.7
Female	14	33.3
Angle Class		
Class I	24	57.1
Class II	17	40.5
Class III	1	2.4

Figures 11 through 17 illustrate each of the measured parameters of the mature human dentition. The changes in *overbite* seen in Figure 9 point to an overall decrease in overbite in most patients. The sex of the subject doesn't seem to influence this phenomenon in any way.

Overjet is illustrated in Figure 10 and shows fairly even distribution of change over time. It appears that the same number of individuals increase as decrease and a fair number of individuals maintain the same overjet over time.

Maxillary arch *perimeter* is depicted in Figure 11. This graph shows a significant number of individuals with a decreased arch perimeter over time. Sex distribution is relatively even. Mandibular arch perimeter, shown in Figure 12, illustrates much the same effect over time. Arch perimeter decreased over time and sex distribution remained relatively even.

Intercanine distances are shown in figures 13 and 14. The maxillary intercanine distances seemed to remain evenly distributed over time, while the mandibular intercanine distance decreased. Males and females were maintained an even distribution.

The *change in dental deflection* over time was significant (Figure 15). Almost all of the subjects experienced some increase in the degree of mandibular arch crowding. Males and females were evenly distributed. Only one individual showed no appreciable change in mandibular arch crowding.

The Angle Classification of *molar deflection* seems to remain a fairly constant variable. Figures 16 and 17 depict a large concentration of individuals along the zero line. This indicates no change in the deflection of the molar relationship. It is interesting however, that some individuals exhibit change in the molar relationship. Again, sex distribution was uniform.

In summary, the majority of tooth loss seems to fall within a range of 6 to 15 teeth for this particular population, and the parameters of the dentition that *change significantly* over time include: overbite, maxillary and mandibular arch perimeter, mandibular intercanine distance, and dental deflection. The parameters of overjet, maxillary intercanine distance, and molar deflection from Angle classification show change over time, but this change was not statistically significant.

The maximum and minimum values for each of the measured variables, according to time period and the change over the time period (T2-T1), is given in Table 8. Original measurements for each patient are presented in Appendix 2. The number of positive, negative, and tied ranks for each variable, is separated according to sex and is given in Table 9 under the Wilcoxon Matched-Pairs Signed Ranks Test. Table 10 depicts the correlation coefficients for each of the measured variables.

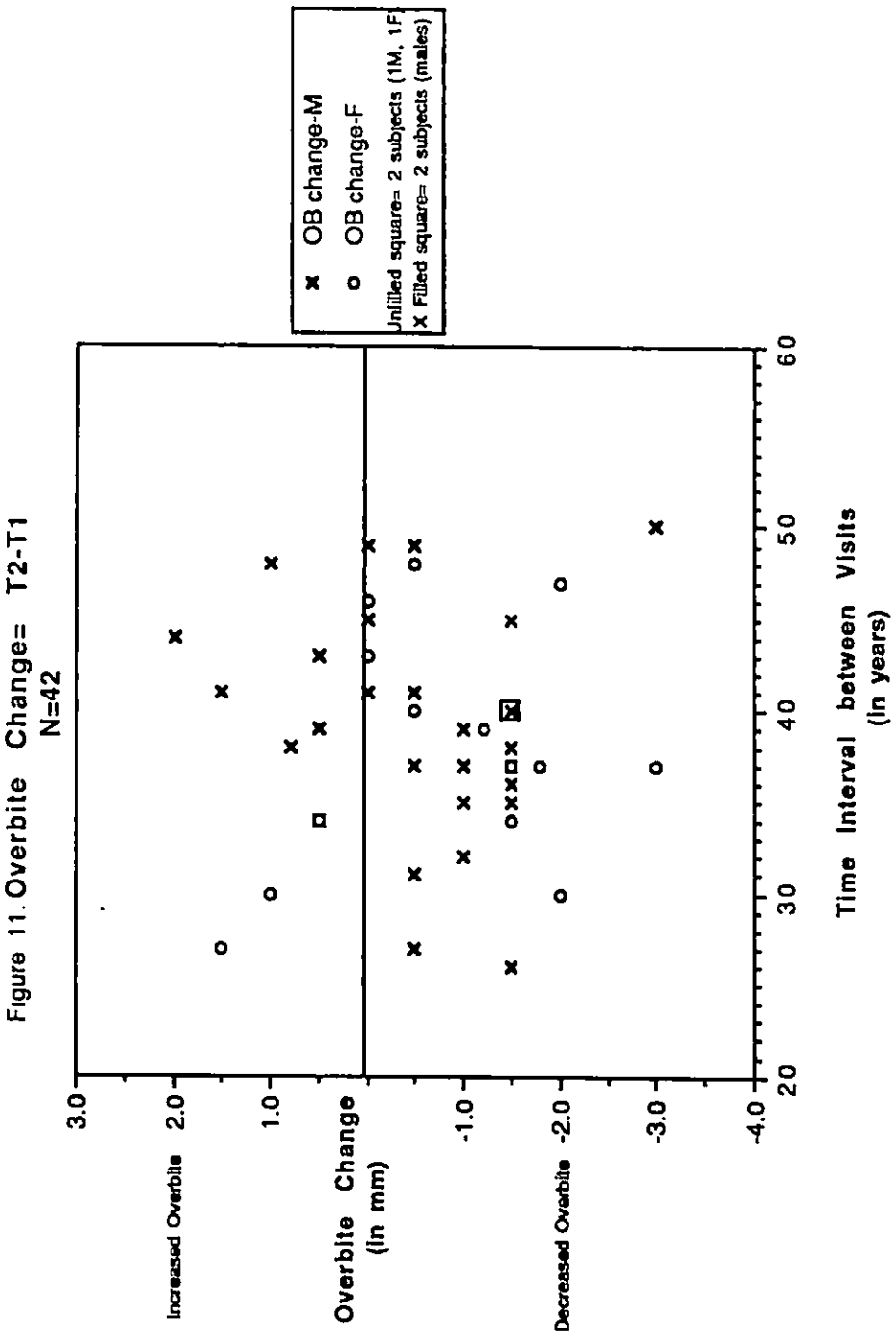

Figure 11. Overbite Change= T2-T1
N=42
OB change-M
OB change-F
Unfilled square= 2 subjects (1M, 1F)
Filled square= 2 subjects (males)
Increased Overbite
Decreased Overbite
Overbite Change
(in mm)
3.0
2.0
1.0
-1.0
-2.0
-3.0
-4.0
20
30
40
50
60
Time Interval between Visits
(in years)

Figure 11.

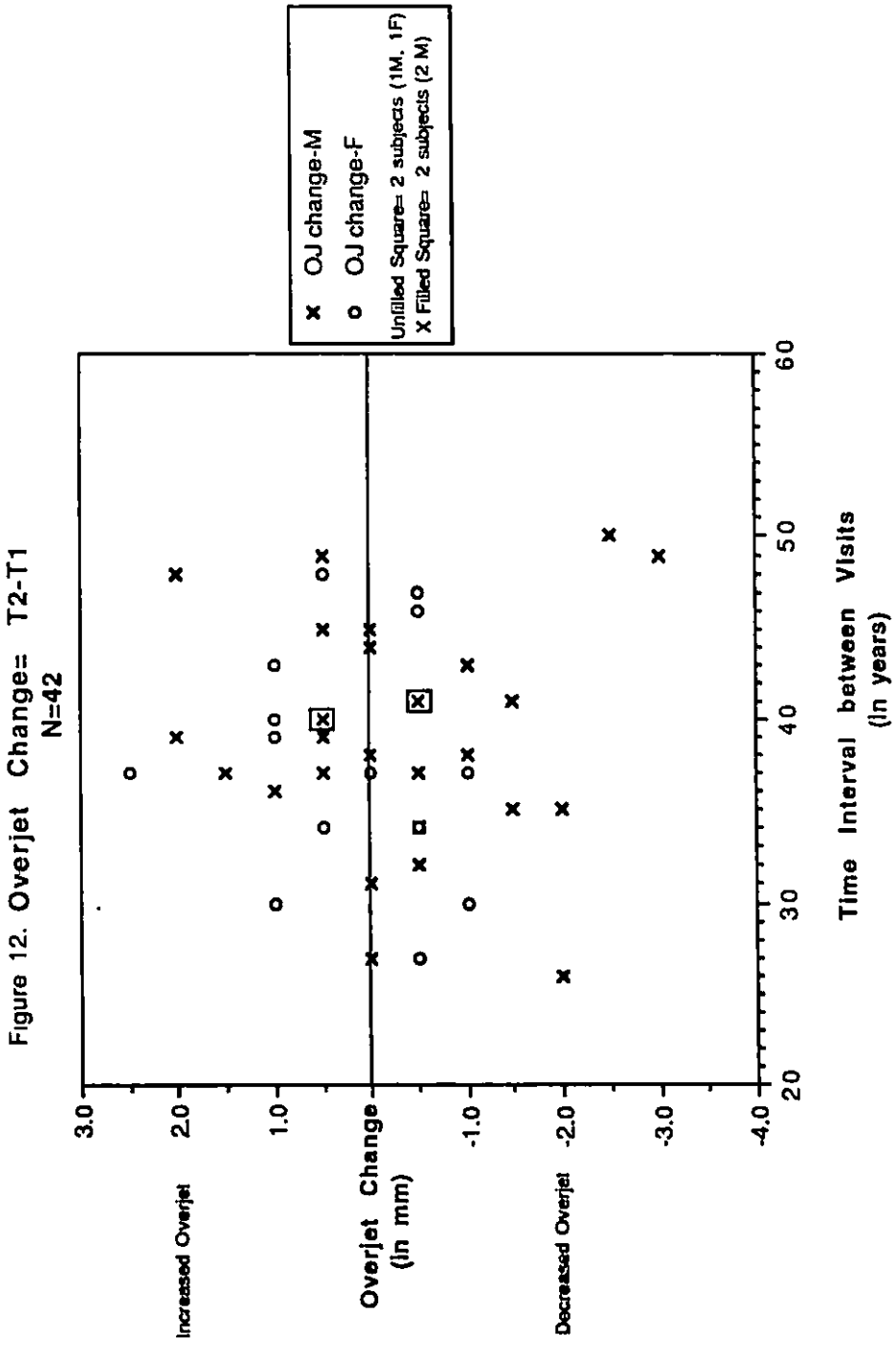

Figure 12. Overjet Change= T2-T1
N=42
OJ change-M
OJ change-F
Unfilled Square= 2 subjects (1M, 1F)
X Filled Square= 2 subjects (2 M)
Overjet Change
(in mm)
Increased Overjet
Decreased Overjet
3.0
2.0
1.0
-1.0
-2.0
-3.0
-4.0
20
30
40
50
60
Time Interval between Visits
(in years)

Figure 12.

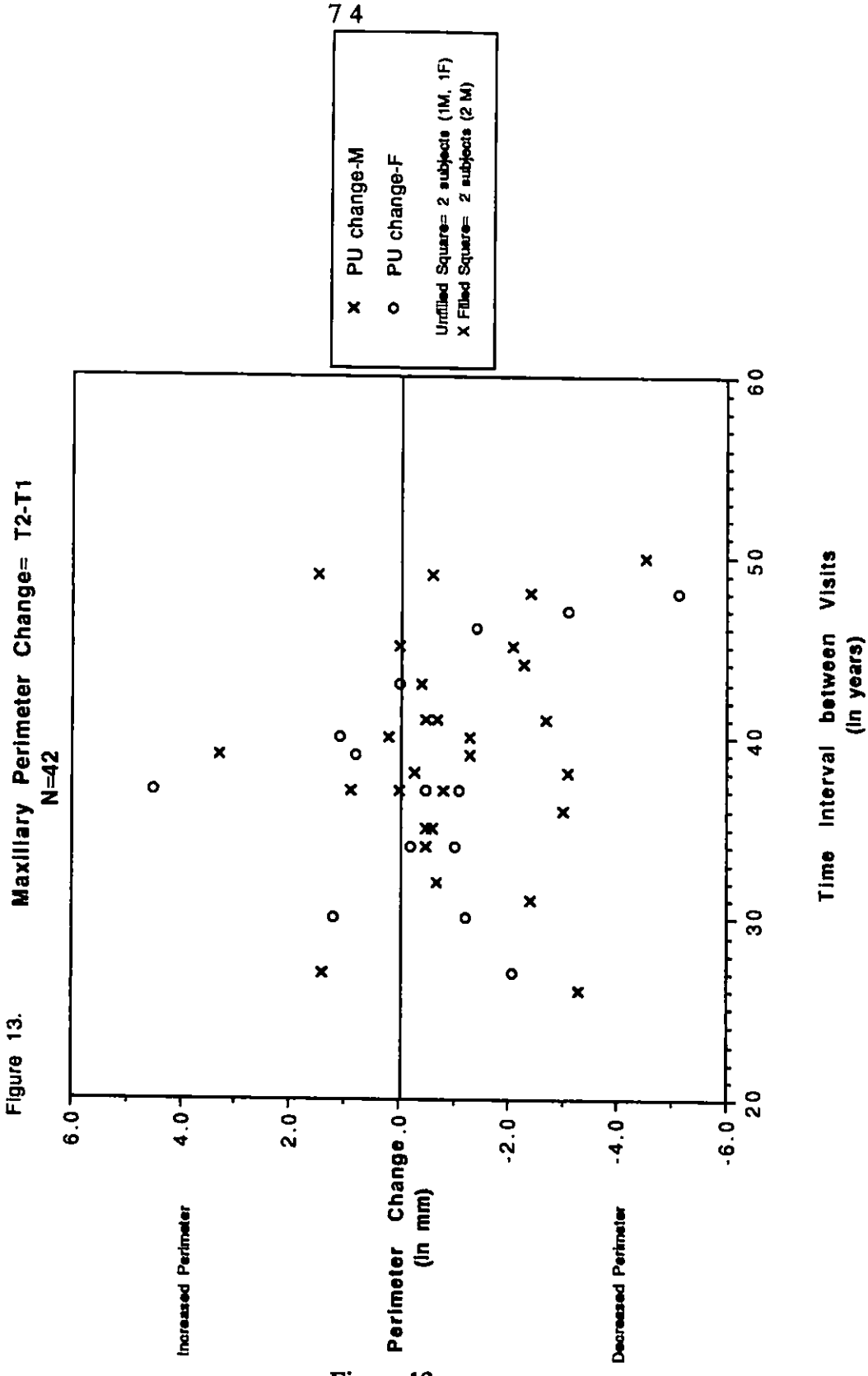

Figure 13.
Maxillary Perimeter Change= T2-T1
N=42
PU change-M
PU change-F
Unfilled Square= 2 subjects (1M, 1F)
X Filled Square= 2 subjects (2 M)
6.0
4.0
2.0
.0
-2.0
-4.0
-6.0
Increased Perimeter
Decreased Perimeter
Perimeter Change
(in mm)
20
30
40
50
60
Time Interval between Visits
(in years)

Figure 13.

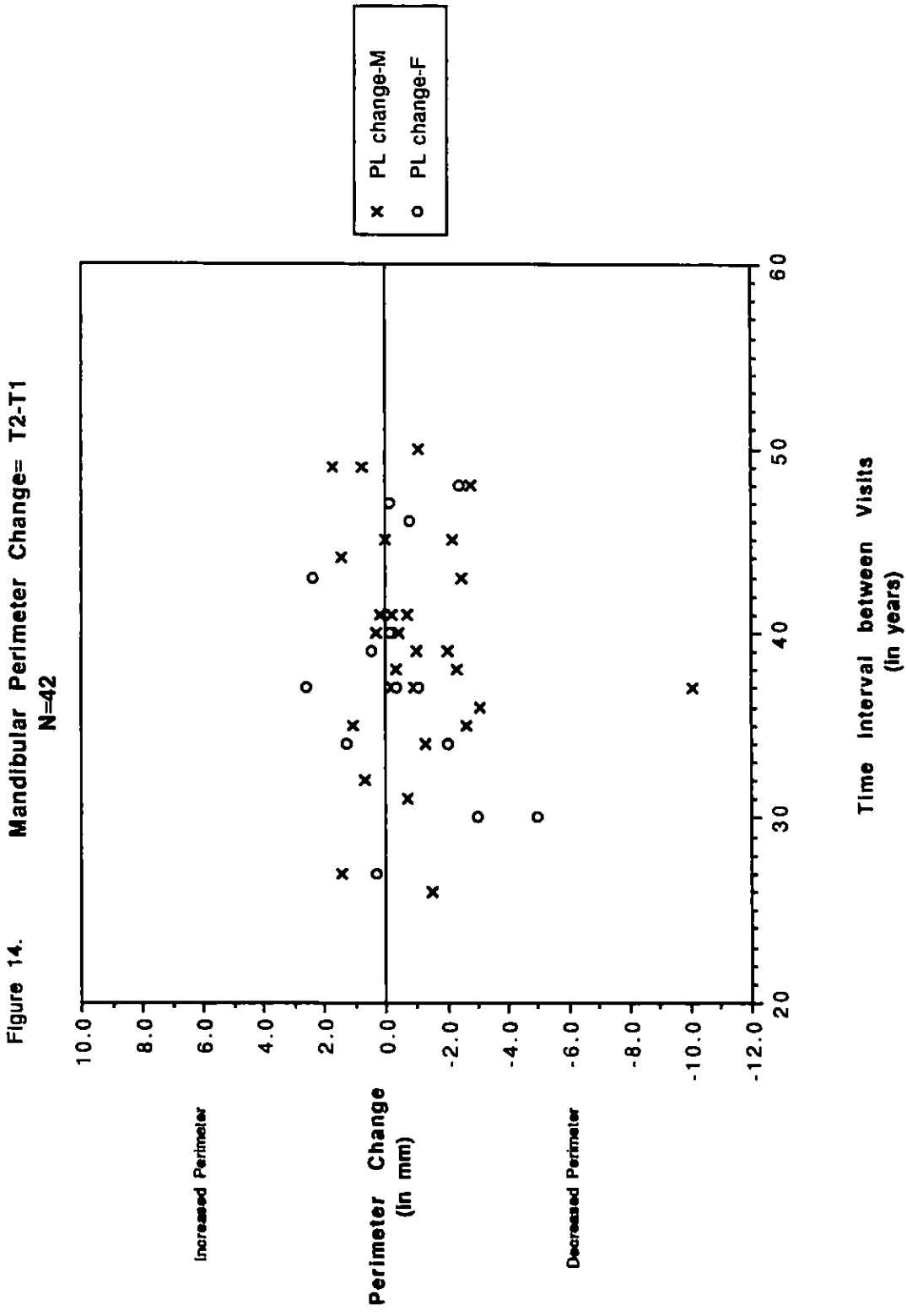

Figure 14. Mandibular Perimeter Change= T2-T1
N=42
PL change-M
PL change-F
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
Increased Perimeter
Perimeter Change (in mm)
Decreased Perimeter
20
30
40
50
60
Time Interval between Visits (in years)

Figure 14.

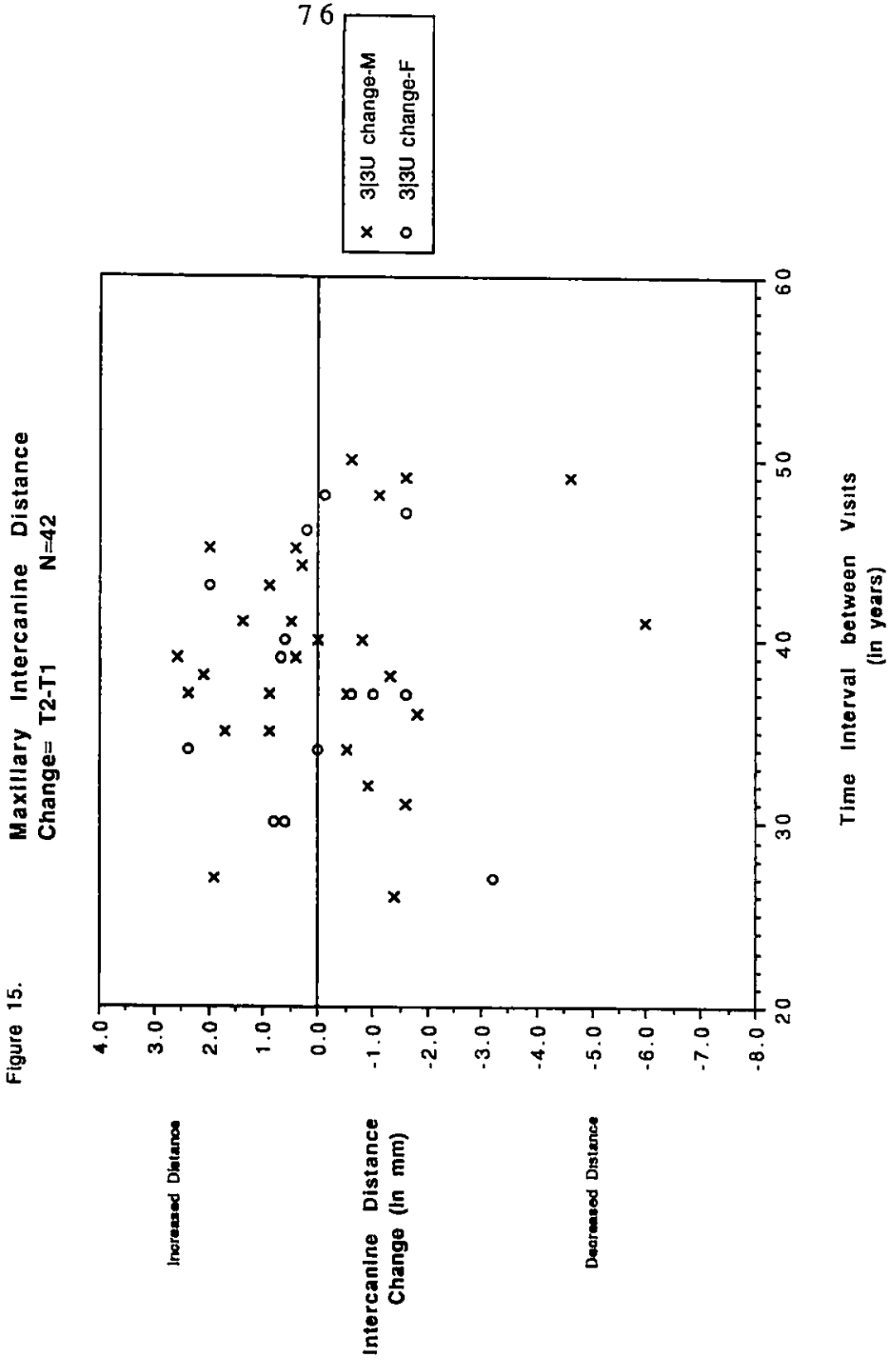

Maxillary Intercanine Distance
Change= T2-T1 N=42
3|3U change-M
3|3U change-F
Increased Distance
Decreased Distance
Intercanine Distance Change (in mm)
Time Interval between Visits (in years)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
20
30
40
50
60

Figure 15.

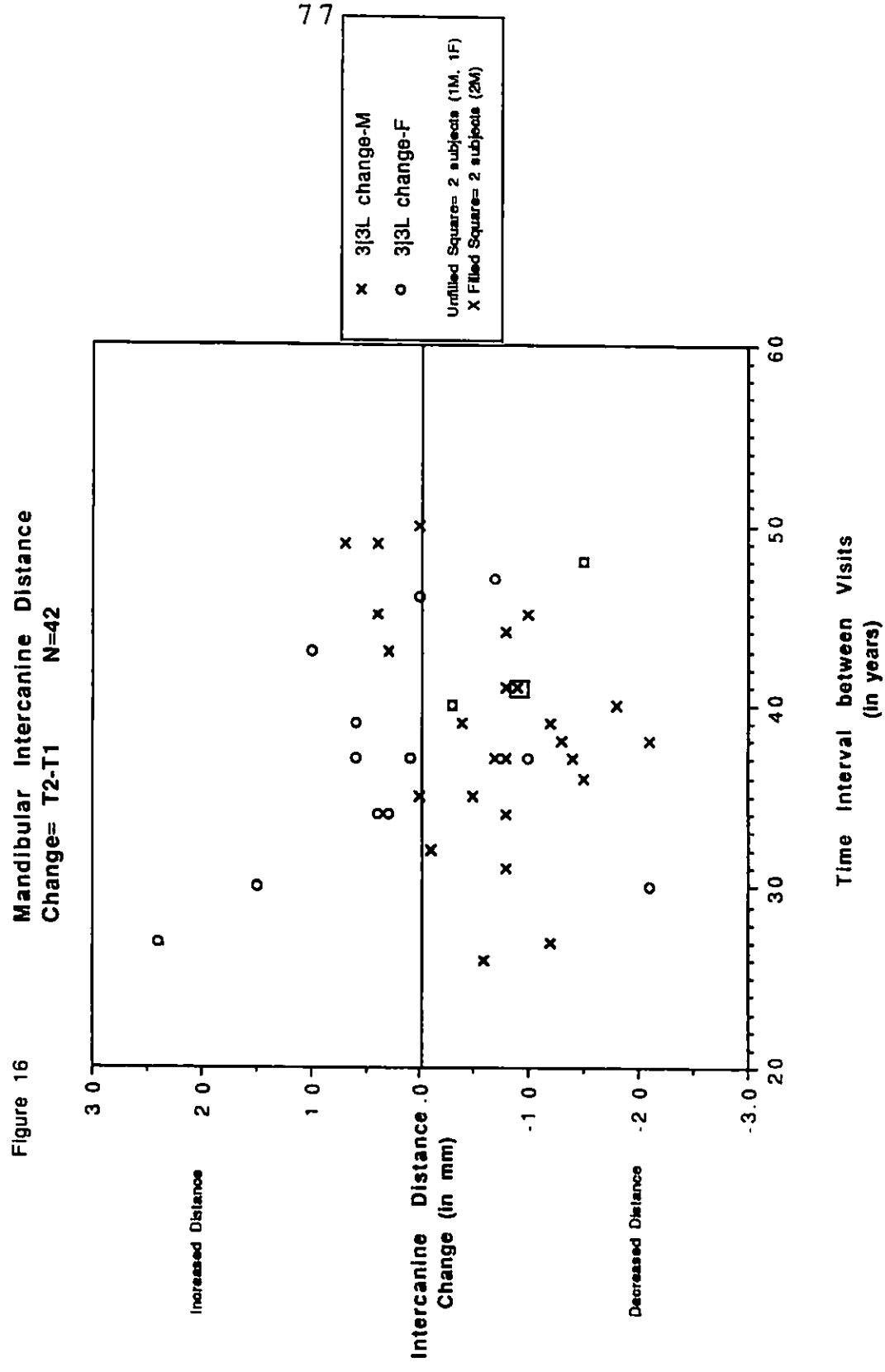

Figure 16
Mandibular Intercanine Distance
Change= T2-T1 N=42
3|3L change-M
3|3L change-F
Unfilled Square= 2 subjects (1M, 1F)
X Filled Square= 2 subjects (2M)
Intercanine Distance Change (in mm)
Increased Distance
Decreased Distance
30
20
10
.0
-10
-20
-3.0
20
30
40
50
60
Time Interval between Visits (in years)

Figure 16.

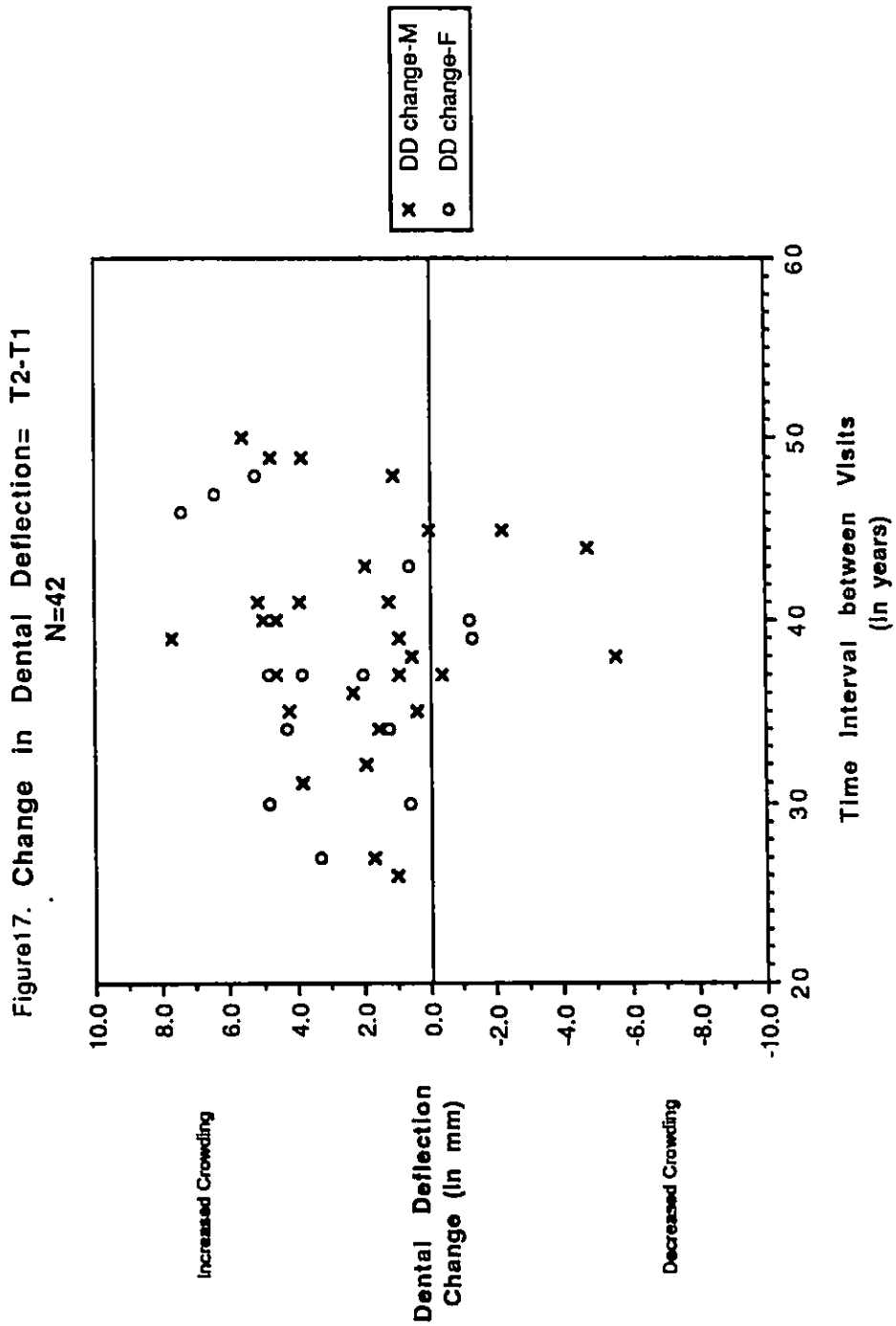

Figure17. Change in Dental Deflection= T2-T1
N=42
DD change-M
DD change-F
Dental Deflection Change (in mm)
Increased Crowding
Decreased Crowding
Time Interval between Visits (in years)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
20
30
40
50
60

Figure 17.

Table 8. Maximum and Minimum Values for each Variable

Variable	Time	Maximum	Minimum
Overbite (in mm)	1 2 * Δ	8.5 10 2	0 0 - 3
Overjet (in mm)	1 2 Δ	8 6 2.5	0 0 - 3
Max Perimeter (in mm)	1 2 Δ	80 79.2 4.5	65.1 63 -5.1
Mand Perimeter (in mm)	1 2 Δ	68.4 68.3 2.6	56.5 50.7 -10.1
Intercanine Distance Max (in mm)	1 2 Δ	39.9 24.5 2.6	27.7 39.4 - 6
Intercanine Distance Mand (in mm)	1 2 Δ	28.5 28.1 2.4	21 21.1 -2.1
Dental Deflection (in mm)	1 2 Δ	12.4 17 7.7	0 1.6 -5.6
Angle Deflection Right Molar (mm)	1 2 Δ	5.5 5.5 3	- 2 - 2 0
Angle Deflection Left Molar (in mm)	1 2 Δ	6 5.5 2	- 3 - 3 0

* where 'Δ' denotes "change from T1 to T2"

Table 9. Wilcoxon Matched-Pairs Signed Ranks Test Values for Group 2 (N=42)

Variable	# (+) Ranks	# (-) Ranks	# of Ties (no change)	2-Tailed P Value
Overbite	9 (7M, 3F)	28 (18M, 9F)	5 (3M, 2F)	.0007*
Overjet	17 (10M, 7F)	19 (13M, 6F)	6 (5M, 1F)	0.6887
Max. Perimeter	9 (5M, 4F)	30 (21M, 9F)	3 (2M, 1F)	.0091*
Mand. Perimeter	13 (8M, 5F)	28 (19M, 9F)	1 (1M)	.0165*
Intercanine Distance Maxillary	21 (14M, 7F)	19 (13M, 6F)	2 (1M, 1F)	0.9678
Intercanine Distance Mandibular	12 (4M, 8F)	27 (22M, 5F)	3 (2M, 1F)	.0032*
Dental Deflection	35 (23M, 12F)	6 (4M, 2F)	1 (1M)	.0002*
Angle Deflection Right Molar	13 (9M, 4F)	10 (6M, 4F)	19 (13M, 6F)	0.5841
Angle Deflection Left Molar	13 (8M, 5F)	14 (11M, 3F)	15 (9M, 6F)	0.8759

*Denotes significance at α=.05

Table 10. Correlation Coefficient for Group 2 (20 pairs) at α=.05

Variable	Mean	SD	95% C.I.	2-Tail Signif	Corr(r)
Overbite (T1)	0.03	0.103	-.018,.078	0.209	0.994
Overbite (T2)	0.045	0.128	-.015,.105	0.131	0.996
Overjet (T1)	-0.025	0.112	-.077,.027	0.33	0.992
Overjet (T2)	0	0.162	-.076,.076	1	0.99
Max. Perim (T1)	0.045	0.128	-.015,.105	0.131	0.998
Max. Perim (T2)	0	0.162	-.077,.027	0.33	0.996
Mand. Perim (T1)	0.02	0.07	-.013,.053	0.214	1
Mand. Perim (T2)	-0.01	0.102	-.058,.038	0.666	0.998
3|3 Max. (T1)	-0.025	0.085	-.065,.015	0.204	0.998
3|3 Max. (T2)	0.032	0.007	-.015,.015	1	1
3|3 Mand. (T1)	0.01	0.031	-.044,.024	0.163	1
3|3 Mand. (T2)	0.01	0.031	-.004,.024	0.163	1
Dental Deflection(T1)	0	0.032	-.015,.015	1	1
Dental Deflection(T2)	0	0.032	-.015,.015	1	1
ADeflM-Right (T1)	Standard	error of the	difference was 0		1
ADeflM-Right (T2)					1
ADeflM-Left (T1)	Standard	error of the	difference was 0		1
ADeflM-Left (T2)					1

The values obtained in this test allows one to conclude that there was no statistically significant difference in the measurements of the groups.

DISCUSSION

Thorndike and Barnhardt (1972) describe aging as "a becoming old or older...the process of maturing. Stedman's Medical Dictionary (1982) states that the aging process is marked by a "failure of cells to replace themselves in sufficient number to maintain function; and a gradual deterioration of the mature organism due to time-dependent, irreversible changes in structure." Age has many meanings. For example, age is measured chronologically. Year after year we use the calendar as an index of time marking the days since our birth. Biological age represents where a person is relative to his or her maximum potential life span, and has many implications in the health-related aspects of function. Age has a social connotation. There are unwritten expectations of how individuals of a certain chronologic age should act. Age also has a psychological aspect. This refers to the ability a person has to adapt to the ever-changing environmental demands placed upon him. These abilities include memory, intelligence, motivation, feelings, and maintenance of self-esteem (Niessen 1991). Often, how an individual views this last aspect of age, is important to the long term health and happiness of that individual. As Rodin and Langer state (1980), "being considered 'old' by others can affect personal self-esteem and self image, as well as how that person is perceived by others." One general feature that seems to characterize *all individuals* is a progressive modified ability to adapt to changes in the surrounding environment (Adelman 1989). Through the years, science, medicine, and technology have made it possible for man to adapt to his surroundings in better ways. Today,

psychological aging is *not* necessarily an inevitable outcome of the aging process. Gilbert (1989) states that aging is no longer seen as a progressive deterioration until death. Rowe and Kahn (1987), in a study of the normal aging process, divided aging into two categories: the successful and the usual. Those persons aging in the *usual* manner exhibited normal declines in various physiologic parameters as they aged, and *successful* elders had no or minimal physiologic loss when compared with the average of their younger counterparts. Media and the health care profession have communicated to the world, that it is possible to live a long healthy life if the proper steps are followed. To be a part of today's society, one has to take care of himself and those around him. Exercise and healthy eating habits know no age limits. Whether you're nine or ninety-nine, it is important to stay fit and active. It was not too many years ago that it was considered "normal" for elderly people to lose all their natural teeth at an early age. It seemed that the aging process commenced as the dentition began its degeneration. The teeth are more than just part of the "chewing apparatus". As Melsen (1989) states, "psychologically, teeth have a much deeper meaning...preserving the natural dentition can greatly influence the quality of life and a person's self perception." Seide (1976) states, "certainly nothing will make a person feel older than losing some or all of their teeth." This is an important concept when one considers how quickly the aging population is growing.

In 1900, the number of individuals over age 65 was approximately 3.1 million, or 4.1% of the population. In 1978, the number jumped to 24.1 million, or 11 % (an eight-fold increase!). Since it is expected that the population of aging individuals in the United States will continue its growth as it has in the past; experts state that persons over the age of 65 will soon constitute over 20% of the population. A considerably larger percentage of the population will be in this age range by the year 2010 (U.S.

Bureau of the Census 1979, Burt 1989 and 1992). This has enormous implications for the practice of dentistry as a whole. With an increase in the population of aging adults, comes an increase in the number of people who want to maintain their teeth. Therefore there is an increased need for more information and more specialized knowlegde on how to best treat these aging adults. As Dr. Achenbaum (1989) states, "the inexorable aging of America's population will affect every institution in our society and the ways people live in the twenty-first century." The field of orthodontics has not been "skipped" in the treatment of the aging adult. Our knowledge of the modern day, aging dentition and its relationship to orthodontics is limited. Birte Melsen (1989) and Seide (1976) describe a few of the important considerations one has in the treatment of the degenerated dentition. It is important to expand the research into the adult population of today. At present, it is uncertain which parameters of the dentition/malocclusion remain stable over time. This research project was an initial attempt to examine some of the changes seen the aging dentition.

The first parameter examined in the study was the DMFT index and tooth loss. According to Burt (1992), 41.1% of the 65-and-over group in the United States were edentulous in 1985 to 1986. Of the dentate subjects remaining, he showed an average of 17.2 teeth remaining (or 10.8 teeth missing, exclusive of third molars). Of this group, 9.6 teeth remained sound (i.e. no history of decay or filling), 0.7 were diagnosed as actively carious, and 6.9 had previously been filled. Within this overview, there was considerable variation by age, gender, race, and socioeconomic status.

Although the present study did not take into account factors such as socioeconomic status, education, and household income, it would be fair to state that the research sample, on the average, exhibited a relatively low rate of tooth loss.

Tables 4 and 5 illustrate that despite the unequal distribution of males to females, the amount of missing and filled teeth was fairly similar. It is important to remember that the sample in this study is very small and any broad sweeping generalizations would be inappropriate. The amount of filled surfaces seen in each of the casts was moderately high as would be evidenced in Figure 9 and the DMFT score. One must remember that the "growing years" for these adults, did not include the early benefits of flouride, therefore one would expect to see a higher rate of filled surfaces. Future studies in this area might expect to see a greatly reduced DMFT score (Appendix 2). One of the greatest difficulties encountered in this study was locating patients that did not exhibit a tremendous amount of posterior restoration and/or tooth loss. In that the caries rate has so dramatically decreased over the years (Brunelle 1989, Graves et al., 1986.), it will be far easier to examine and quantify the various changes seen in the maturing dentition in the future. No relationships between DMFT and the other variables were found.

The next parameter of the maturing dentition examined was that of overbite change (Figure 11). Overbite decreased in most of the subjects over time. This decrease was statistically significant (refer to Table 9). The range for overbite change was approximately -2 to +2 mm. In only two instances a decrease in overbite exceeded -2mm. Patient number B3397 (male) presented at Time 1 with 3 mm of overbite, a Class I malocclusion, and some evidence of wear on the anterior teeth. At Time 2 the anterior relationship was edge-to-edge with 0 mm of overbite. Over the time interval between visits, the number of filled teeth increased from 7 at Time one to 18 at Time 2. He was missing no teeth at either visit. A similar finding occurred in patient B2537(female) whereby the malocclusion at Time 1 was Class I with 7.5 mm of overbite and a slight degree of incisal wear. At Time 2, the patient presented with 4.5 mm of overbite and more evidence of wear. As many previous authors have sited,

excessive wear reduces crown height and this in turn can influence the depth of overbite (Begg 1954, Beyron 1954). There was a moderately strong relationship between overbite measurements taken at Time 1 and Time 2. This would tend to indicate that decreases in overbite are related to the amount of incisal and posterior wear occurring over time. As a patient continues in their chewing or bruxing pattern, tooth material is lost and degree overbite decreases.

The Wilcoxon Matched-Pairs Signed Ranks Test value for change in overjet was not statistically significant (p value=.6887, refer to Table 9). Here approximately the same number of individuals increased or decreased overjet. The range was plus or minus 2.5 mm. The important result to note here is that a *change* occurred. Two individuals were slightly outside the cluster of points in Figure 12. Patient number B3132 presented with a Class I deep bite and 8 mm of overjet at Time 1. At Time 2, the overjet had reduced to 5 mm and there was significant evidence of occlusal wear in the canine and bicuspid region in all four quadrants. One could postulate that as the occlusal table and guiding inclines of the teeth were diminished, the arches were free to articulate a little further foreward. The patient may also have a history of posturing foreward to continue a possible bruxing habit. Patient Number B3397, who was mentioned earlier also showed a significant decrease in overjet. There was a moderately strong relationship between overjet measurements taken at Time 1 and 2.

Maxillary and mandibular arch perimeter changes were significant. For both parameters, almost all subjects *changed*. The majority of change occurred in the negative direction indicating a decrease in arch perimeter with increasing age. The range for this change was approximately plus or minus 3 mm for both arches. There were two outlying points in the maxillary perimeter scatter plot (Figure 13) and these were patients B3397 (again) and B2517. Recall that patient B3397 had some extensive

dental work in the posterior region between Time 1 and 2, this could have influenced the degree to which arch perimeter was lost. The pattern of his restorative work was not unique to the sample however. Many of the subjects underwent substantial dental work within the time interval studied. The fact that the patient had obvious signs of wear, one might assume that attrition was occurring interproximally as well. Interproximal wear is a difficult parameter to measure because the individual "losses" in each tooth are minute, yet when added together as a whole, can amount to a significant amount of tooth loss over time. There was also one outlying point in the figure of mandibular perimeter change (Figure 14). Patient B3159 at Time 1 presented with no teeth missing and a mandibular arch perimeter of 60.8 mm. At Time 2 however, a mandibular left bicuspid was missing. This loss of a dental unit would account for the -10mm value for change in mandibular arch perimeter. The measurements of perimeter at Time 1 and 2 had a strong relationship. A moderately strong relationship between maxillary and mandibular perimeter was found; and moderately strong relationships between perimeter and intercanine distance were found (refer to Table 9 and 10). These findings indicate that over time there is a trend for decrease in arch length on both maxillary and mandibular arches. The changes that are observed in the maxillary arch tend to correlate with the changes seen in the mandibular arch, and one area that the change is readily observed is in the intercanine area.

Intercanine distance was also evaluated in the mature dentition (Figure 15 and 16). Measurement of maxillary intercanine distance, although demonstrating change (+/- 3 mm), was not found to be significant. Of note are the two outlying points in the maxillary intercanine distance diagram (Figure 15). Patient B2581 showed a 4.6 mm loss in intercanine distance between Time 1 and 2. After examining her dental history it was found that she had a rather large composite restoration on her maxillary left lateral

incisor. The loss in perimeter was probably not completely due to the restoration, because she exhibited a mild amount of anterior crowding as well. The correlation of intercanine distances to the other variables in the study was mentioned above.

Another significant finding was the change observed in the amount of dental deflection (Figure 17). Nearly all patients examined showed an increase in deflection or crowding of the mandibular anterior segment. One could speculate that change was due in part, to late mandibular growth effects, periodontal attachment loss, or deepening of the bite due to attrition or occlusal wear. Dental deflection showed a moderately strong relationship between Time 1 and 2 measurements. This is one of the findings expected in the project. As mentioned earlier, late mandibular growth effects, especially in the male, was expected to influence the change in dentition. Periodontal attachment loss, especially in the older adults could also have a dramatic affect on the position and status of the mandibular anterior segment. One must remember that all of the patients involved in the study had relatively good dental health at the time the records were obtained. The changes observed in the periodontal tissues and the effects on the dentition were most likely the effects of age and not periodontal disease. Attrition and occlusal wear also contribute to the changes seen in dental deflection. As the surfaces wear over time, the subject may progressively be posturing foreward to continue function. This may lead to a greater tendency for anterior crowding.

The other parameters that were examined included Angle classification, deflection of the right and left molar from the Angle Classification, and shape. Of these, Angle classification and third molars showed no strong relationships to any of the other variables, according to the correlation coefficient test. The deflection of the molar from the Angle classification on both right and left sides exhibited a strong

relationship between the Time 1 and Time 2 measurements, but showed no other associations with the other variables.

There were no significant differences between males and females in any of the parameters examined. No specific conclusions were drawn as to the status and relationship that third molars have on the changing dentition. Reasons for this include very small sample size, and lack of information as to when third molars were removed (See Appendix 1 for data).

Limitations of the Study

As mentioned earlier, some of the problems that occurred in this study included lack of patients with little to no restoration. In that the study sample was small, any implications cannot be applied clinically without full realization of the limitations and scope of the study. Past studies indicate that there is an uneven distribution among socioeconomic strata, gender, race, education, and income in the area of tooth loss and decay. It was impossible to control for this fact given the unique character of the study population. The amount of longitudinal data available for the aging dentition is negligible. The Bolton Brush study was one of the first long-term, comprehensive growth studies in the world, therefore it is practically the only with any record of a mature dentition. Another factor concerning the Bolton records is the fact that at the time, compound impressions were taken of the teeth. While fairly accurate registrations can be achieved with compound, often the posterior region of the dentition was distorted, or the clinical margin of the gingiva was obliterated. It is because of these factors, that attrition could not be studied on the maturing dentition. Many of the

currently accepted indices for tooth wear and attrition utilize some type of landmark for where the clinical crown terminates. Some of the models in the original Bolton Study did not have an accurate registration of gingival level to gain any long term data.

In addition to the above limitations, it was difficult to describe the population statistically. In that the patients were not the same age at the starting point, descriptive statistics, in the way of means and standard deviations, would be misleading.

Other potential confounding factors that were not considered in this study include: specific health problems experienced by the patient (i.e. diabetes, arthritis, cardiovascular disease, and respiratory problems), xerostomia, and medications taken by the patient.

How the mature, aging dentition changes it experiences over time has not been studied extensively. National statistics are limited to reports of for tooth loss, decay, and periodontitis. This study was an initial attempt to examine some of the ***changes*** seen in the dentition. The possibility for future study is infinite. For example, as time goes on and more adults undergo orthodontic treatment for specific dental concerns including degenerating dentitions, the information gained will aid in developing better treatment plans and diagnoses. Additionally, as the number of aged individuals increases, there will be a greater source of information on changes in the adult.

SUMMARY AND CONCLUSION

The findings of this investigation would suggest that: 1.) the majority of tooth loss and/or restoration seemed to fall within a range of 6 to 15 teeth in this mature sample; 2.) the parameters of the dentition that *change significantly* over time include: overbite, maxillary and mandibular arch perimeter, mandibular intercanine distance, and dental deflection; and 3.) the parameters of overjet, maxillary intercanine distance, and molar deflection from Angle Classification show change over time, but this change seems to be evenly distributed and not statistically significant.

The overall clinical effect of the current findings suggest that as individuals age, their dentition tends to change in parameters that might affect dental restoration and orthodontic treatment planning. Dental function may be influenced by changes in tooth loss and overbite; and changes in arch perimeter may affect decisions regarding dental restoration including prosthetic replacement and long term retention of orthodontic treatment.

The mature adult dentition not a static entity. It exhibits gradual, yet significant change over time, and this change is highly individualized. As is often said, the only constant is change.

We grow neither better nor worse as we get old,
but more like ourselves -Mary Lamberton Becker

Aging...

No wise man ever wished to be younger. -Jonathan Swift

For the unlearned, old age is winter; for the learned,
it is the season of harvest -Hasidic saying

We grow neither better nor worse as we get old,
but more like ourselves -Mary Lamberton Becker

They tell you that you'll lose your mind when you grow older.
What they don't tell you is that you won't miss it very much -Malcolm Cowley

Part of the American dream is to live long and die young -Edgar Friedenberg

At age fifty, every man has the face he deserves -George Orwell

I am not young enough to know everything -Oscar Wilde

The hardest years in life are those between ten and seventy -Helen Hayes
(at age 83)

The secret to staying young is to live honestly, eat slowly,
and lie about your age -Lucille Ball

Life, we learn too late, is in the living, in the tissue of every
day and hour -Stephen Leacock

It is not the years in your life but the life in your years that counts.
-Adlai Stevenson

APPENDICES

Appendix 1. Data Collected on the Presence or Absence of Third Molars

Figure 18. Third Molars in Lower Arch (where Males=28 and Females=14)

	Missing		Impacted		Occlusion	
	Male	Female	Male	Female	Male	Female
Time 1	6	1	19	11	3	2
Time 2	16	9	3	5	9	0

Figure 19. Change in Molar Status from T1 to T2

T1 to T2	Males	Females
I to M	11	7
I to O	6	0
O to M	0	2
M to M	5	0
I to I	3	5
O to O	3	0

The questions raised concerning third molars include whether or not the subjects with larger decreases in perimeter had impacted third molars, missing third molars, or third molars in occlusion. In addition, there was the question of whether or not third molars influenced the tendency for greater crowding in the mandibular anterior segment. It would appear from the limited data available that there is no trend in third molar impact on these parameters of the dentition. A much larger study sample is necessary to verify any conclusions on third molar influence.

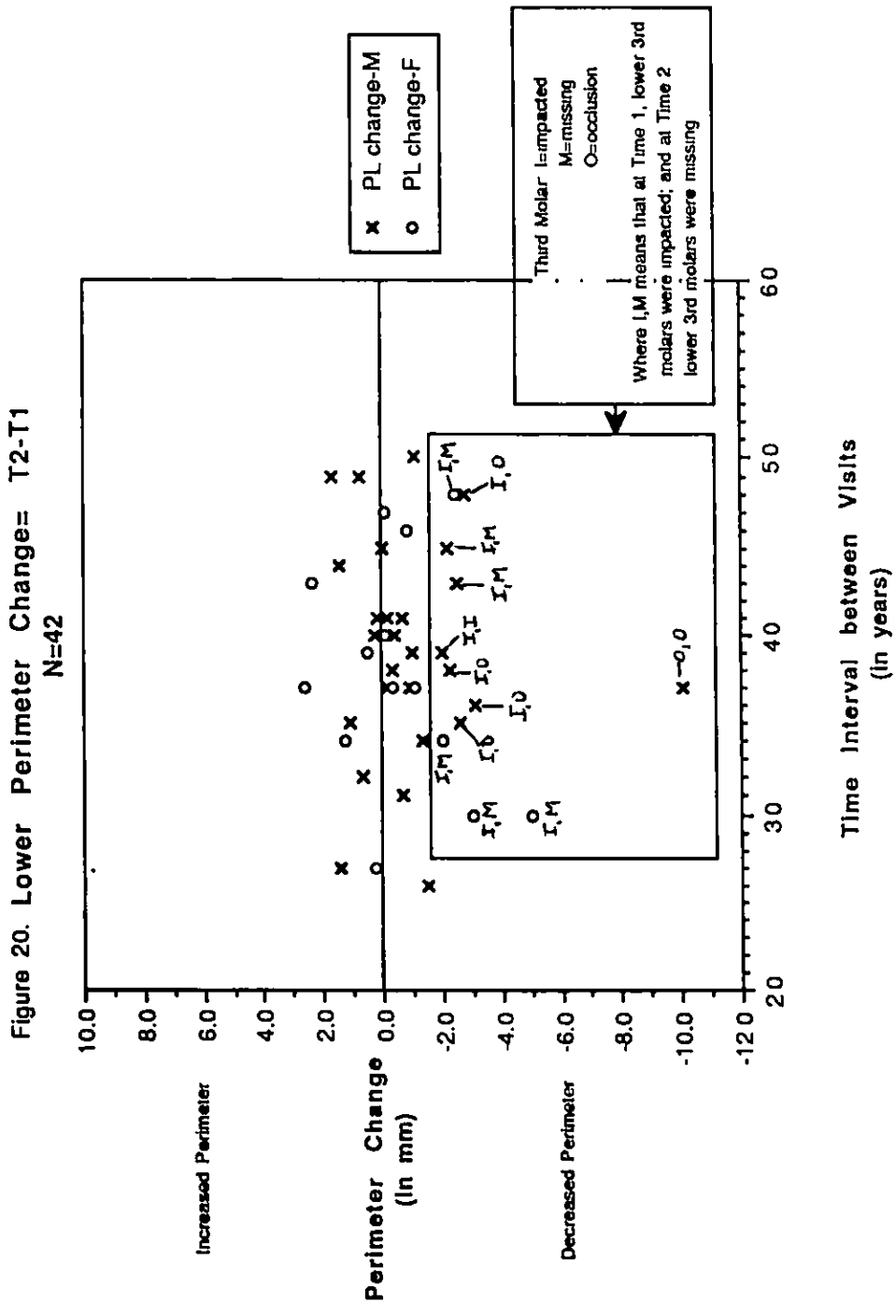

Figure 20. Lower Perimeter Change= T2-T1
N=42
PL change-M
PL change-F
Third Molar I=impacted
M=missing
O=occlusion
Where I,M means that at Time 1, lower 3rd molars were impacted; and at Time 2 lower 3rd molars were missing
Perimeter Change (In mm)
Increased Perimeter
Decreased Perimeter
Time Interval between Visits (in years)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
20
30
40
50
60

Figure 20.

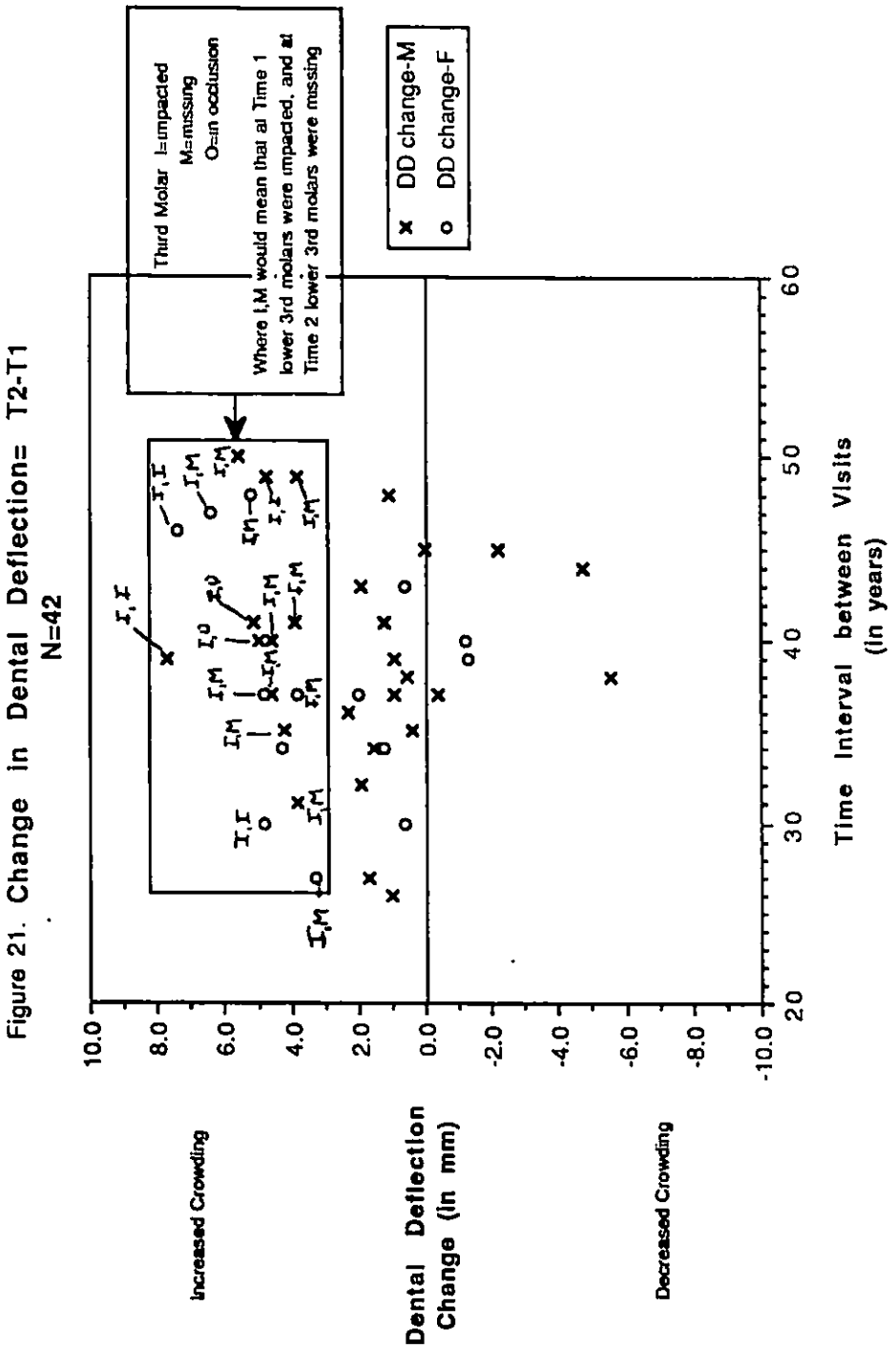

Figure 21. Change in Dental Deflection= T2-T1
N=42
Thurd Molar I=impacted
M=missing
O=in occlusion
Where I,M would mean that at Time 1 lower 3rd molars were impacted, and at Time 2 lower 3rd molars were missing
DD change-M
DD change-F
Dental Deflection Change (in mm)
Increased Crowding
Decreased Crowding
Time Interval between Visits (in years)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
20
30
40
50
60

Figure 21.

Appendix 2 DATA

#	B#	Pt Select	Universal Tooth #	(young=Time1)	Universal Tooth #	(young= Time1)
#	B#	PtSelect	Missing/Young	Total Missing/y	Filled/Young	Total Filled/Y
1	110	4	0	0	2,3,14,15,18,19,30,31	8
2	113	2	0	0	0	0
3	133	1	0	0	0	0
4	141	3	0	0	2,3 14,15	4
5	1051	1	0	0	3 14,19,30	4
6	1208	1	0	0	0	0
7	1257	2	0	0	2,3,14,15,18,19,29,30,31	9
8	1681	3	0	0	2,3,14,18,19,30,31	7
9	1836	2	24,25	2	3,14,18,19,30,31	6
10	1922	3	30	1	2,3 14,15,18,19 31	7
11	1932	3	30	1	3,13,14,19,31	5
12	1973	1	0	0	0	0
13	2013	2	0	0	0	0
14	2055	1	0	0	2	1
15	2131	1	0	0	30	1
16	2202	1	0	0	2,3,14	3
17	2210	1	0	0	2-5,12-15,18-20,28-31	15
18	2285	1	0	0	3,14,	2
19	2321	1	0	0	3,14	2
20	2517	2	0	0	2 7,9,12-15,18-20,29-31	17
21	2537	1	0	0	3,19,30,31	4
22	2581	1	0	0	2-5,7,12-15,18-20,27,28-31	17
23	2614	1	0	0	5,8,19,30	4
24	2652	4	0	0	2,3,4,8,12,14,15,18 20,30,31	12
25	2702	2	0	0	3,14,15,19,30,31	6

Appendix 2 DATA

#	B#	Pt Select	Universal Tooth #	(young=Time1)	Universal Tooth #	(young= Time1)
#	B#	PtSelect	Missing/Young	Total Missing/y	Filled/Young	Total Filled/Y
26	2747	4	0	0	2 3 14 15 18 19 30 31	8
27	2816	1	0	0	0	0
28	2891	2	7 10	2	20 29	2
29	3047	1	0	0	0	0
30	3057	1	0	0	0	0
31	3060	1	0	0	3,14,15,30	4
32	3061	1	0	0	2,3,4,12 14,15 18 19 30 31	10
33	3092	1	0	0	14 19,30	3
34	3098	2	0	0	2,3,13,14,15,18 20 30 31	10
35	3132	1	0	0	3 14 19,30	4
36	3159	2	0	0	3 14 15,18,31	5
37	3194	1	0	0	2,3,4,13,14 18 29 31	9
38	3195	2	0	0	14 19,30	3
39	3204	1	0	0	0	0
40	3345	1	0	0	0	0
41	3396	1	0	0	0	0
42	3397	1	0	0	2,5 14,19,20,29 30	7
43	3401	1	0	0	3,4,5,7,13-15,18 19,28 30	12
44	3433	1	0	0	19 30	2
45	3471	1	0	0	2,3,14,18 19,30,31	7
46	3481	1	0	0	3,14,15,18 19 30,31	7
47	3483	1	0	0	19	1
48	3517	3	24,25	2	12,14,15,18 30 31	6
49	3648	2	0	0	4,5	2
50	4665	1	0	0	4,5,12,13,14,15,19,30	8

Appendix 2. DATA

Universal Tooth# Missing/Old	(old= Time 2) Total Missing/O	Universal Tooth# Filled/Old	(old=Time 2) Total Filled/O	DMFT MF 1	DMFT MF-2	[MFchange=2 1]
5 9 23,24 25,28	6	2-4,6,8,12-15 18-21 22 27 28 31	19	8	24	16
24	1	15	1	0	2	2
0	0	2 3,4 12,13,14 15,16,19 20 28,29 30 31	12	0	12	12
11 14 30	3	2 6,9,10,12,13,15,16 21,28 29 31	16	4	19	15
0	0	3 7,14,15,16,19 30 31	8	4	8	4
0	0	2 5,10-15,19 21 28,29	15	0	15	15
2 13	2	3-5,12,14,15,18 20 28 31	13	9	15	6
18,30	2	2-5,12 15,19,20,29 31	12	7	14	7
24 25	2	2,3,14,15,18 19,30,31	8	8	10	2
4 20,30	3	2,3,5,8,12-15,18 21,28 29,31	15	8	18	10
2,4,30	3	3,5,8,9-14,18 21 28 31	17	6	20	14
0	0	2-5,4-7,16-21 28 31	16	0	16	16
5,6,7	3	2,3,12,13,15,18 20,30,31	10	0	13	13
0	0	2 5,6,10,12 15,18-20 28-31	17	1	17	16
0	0	2-5,8,12-15,18-21 28 31	17	1	17	16
0	0	2-7,10,12,13,18-20,25,28-31	16	3	16	13
0	0	2-5,12-15,18-21 28-31	18	15	16	1
0	0	3-5,13-15,18-20,28-31	13	2	13	11
0	0	3,12-15,18-20,28-31	11	2	11	9
13	1	2-5,9,12,14,15,18 21,28 31	19	17	20	3
0	0	2 5,12-15,18-20 28-31	14	4	14	10
0	0	2-5,7,12-15,18 20,27,28 31	17	17	17	0
0	0	2-5,7,8,12-15,18-20 28-31	17	4	17	13
7,8 9,10	4	2-5,6,11,12-15,18 21 28 31	18	16	22	6
20,28	2	2-5,6,7,12-15,18,19,28 30 31	15	6	17	11

Appendix 2 DATA

Universal Tooth# Missing/Old	(old= Time 2) Total Missing/O	Universal Tooth# Filled/Old	(old=Time 2) Total Filled/O	DMFT MF-1	DMFT MF-2	[MFchange=2-1]
4 5 14 18 19 30 31	7	2 3 6,12,13 18 20 21 28 29	10	8	17	9
0	0	2 6,14 18 19 30	6	0	8	8
7 10	2	2,4,5 12,13 18 20,29-31	11	4	13	9
0	0	2 5 7 8 9 10 12 15 18 20 29 31	18	0	18	18
0	0	3 18,20,29 30	5	0	5	5
0	0	2-6,12-15,18 20,30,31	13	4	13	9
0	0	2 5,7,8,10-15 18 21 28-31	20	10	20	10
0	0	4,5,6-11,14 15 18 20,30 31	13	3	13	10
8	1	2-5,7,9,13-15 18 20,29-31	15	10	16	6
0	0	2-8,12-15 18 20 30 31	16	4	16	12
12	1	3-5 11 13-15,18-20,27 31	15	5	16	11
0	0	2-4,6,7,13 15 18 20 31	12	9	12	3
2 15	2	3-5,11-14,18 21,28 31	15	3	17	14
0	0	2-5,14,15,18 19,30,31	10	0	10	10
0	0	2-5,12-15,18 21,28-31	16	0	16	16
0	0	2,3,5,14,15,18,19,30,31	9	0	9	9
0	0	2-6,11-15,18 21,28-31	18	7	18	11
0	0	2-5,8,9,12-15,18 21,28 31	18	12	18	6
0	0	2-6,12-14,19,20,29-31	13	2	13	11
0	0	2 5,14,15,18-20,29-31	13	7	13	6
0	0	2,3,12-15,18 19,29-31	11	7	11	3
0	0	2,4-8,10,12 15,18 21,30,31	15	1	15	14
18,19,26	3	2 7,11-15,20,21 28 31	17	8	20	12
9	1	2-6 8,110 15 18-20,29,31	17	2	18	16
0	0	2-5,12-15,18-21,29-31	15	8	15	7

Appendix 2. DATA

OB	OB		OJ	OJ		PU	PU		PL	PL	
OB-1	OB-2	[OBchange=2-1]	OJ-1	OJ-2	[OJchange=2-1	PU-1	PU-2	[PUchange=2 1]	PL-1	PL-2	[PLchange=2 1]
4	2	-2	2	1	-1	69 6	66.8	-2 8	59 1	55 5	-3 6
4 5	5 3	0.8	6	6	0	76 4	73 3	-3 1	63 3	61	-2 3
4	2 8	-1 2	2 5	3.5	1	67 1	67 9	0 8	56 5	57	0 5
3 5	4	0.5	3	2	-1	73 2	70 6	-2 6	59.7	56 9	-2 8
8.5	10	1.5	1 5	0	-1.5	69 7	67	-2 7	62 5	61 8	-0.7
2.5	3	0 5	2.5	3	0.5	76 5	76 3	-0 2	62.5	63.8	1 3
5.5	3 5	-2	2 5	2	-0.5	73.9	70 8	-3.1	59 7	59 6	-0 1
2.5	3 5	1	2.5	4	1 5	75 4	74 6	-0 8	65.6	63 9	-1 7
3.5	4.5	1	0	2	2	65.9	63.5	-2.4	60 1	57 3	-2.8
5	5 5	0 5	4	6	2	67 1	65.4	-1.7	56.1	56.6	0.5
3	3 5	0.5	3.5	4	0.5	70 1	71 5	1 4	63.3	65 5	2.2
3.5	2	-1.5	3.5	3	-0.5	73.8	72.8	-1	64 8	62.8	-2
0	0	0	0	0	0	73	73	0	67.4	67 4	0
4	2.5	-1 5	3.5	4	0.5	73.9	75.1	0 2	65.8	66.1	0 3
4	2.5	-1.5	4 5	2.5	-2	80	79.2	-0.6	68.4	65.8	-2 6
5.5	6	0.5	2.5	1.5	-1	72 1	71.7	-0.4	59.9	57.4	-2 5
4.5	3 5	-1	3 5	3	-0.5	72.6	71.9	-0.7	60.5	61.2	0.7
5	3.5	-1.5	4	5	1	80	77	-3	64.8	61.7	-3.1
4.5	3	-1.5	1.5	2	0.5	73 9	71 8	-2.1	62.7	60.5	-2 2
4 5	4	-0.5	2.5	3	0.5	75.2	72.2	-5.1	58.1	55.7	-2 4
7.5	4.5	-3	2.5	2.5	0	70	68 9	-1 1	58.5	61 1	2.6
5	5	0	3.5	4	0 5	70 4	71.9	1.5	63	64 7	1 7
5	3.5	-1.5	2.5	5	2 5	70.4	74.9	4.5	62 2	61 9	-0 3
1	1	0	2	3	1	66 8	68.3	1 5	57.6	58.8	1 2
3.5	3.5	0	2 5	3.5	1	74 3	74.3	0	63 7	66 1	2 4

Appendix 2. DATA

OB	OB		OJ	OJ		PU	PU		PL	PL	
OB-1	OB-2	[OBchange=2-1]	OJ-1	OJ-2	[OJchange=2-1	PU-1	PU-2	[PUchange=2-1]	PL-1	PL-2	[PLchange=2-1]
3	3	0	2	2.5	0.5	74 6	73.4	-1.2	65 3	65 3	0
5	5.5	0.5	2.5	2	-0.5	71 3	70 8	-0.5	64.1	62 8	-1 3
3 5	2	1.5	3	2.5	-0.5	65.1	63	-2.1	62.6	62 9	0 3
1 5	2.5	1	2	3	1	75 5	76.7	1 2	62.7	59 7	-3
2 5	2	-0.5	2	2	0	74 1	75.5	1.4	61.5	62.9	1.4
2	2	0	3	2.5	-0.5	79 2	78 5	-0.7	68.1	68.3	0 2
2	1.5	-0.5	2	2	0	70.1	67 7	-2.4	58.3	57 6	-0 7
5	3.5	-1.5	6	4	-2	76.3	73	-3.3	65.7	64.2	-1 5
5	3.5	-1.5	2	2.5	0.5	72.4	71.1	-1.3	62.3	61.9	-0.4
4	3.5	-0.5	8	5	-3	79 4	78.8	-0.6	66.8	67 6	0.8
5	3.5	-1.5	3	4.5	1.5	76.7	77.6	0 9	60.8	50.7	-10 1
5	3.5	-1.5	3.5	2.5	-1	70.8	70.5	-0.3	62.6	62 3	-0.3
5	4.5	-0.5	1.5	2.5	1	71.5	72.6	1.1	62.4	62 3	-0.1
3	2.5	-0.5	5.5	5	-0.5	75.1	74.6	-0.5	60.3	60.1	-0.2
5	4	-1	5.5	4	-1 5	77 2	76.7	-0.5	66.4	67.5	1.1
4	3.5	-0.5	3	3.5	0.5	71 9	71.1	-0.8	58.8	57.9	-0.9
3	0	-3	2.5	0	-2.5	74.5	70	-4.5	62.1	61	-1.1
5.5	6	0.5	2	4	2	74.8	78.1	3.3	66.1	65.1	-1
5	2.5	-1.8	3	2	-1	66.3	65.8	-0.5	60.6	59.5	-1.1
6.5	5.5	-1	1.5	1	-0.5	66.3	66.3	0	58.4	58.2	-0.2
3	3	0	3	2.5	-0.5	69.7	68.3	-1.4	62	61.2	-0.8
2.5	1.5	-1	4	4.5	0.5	72.3	71	-1.3	59.7	57.7	-2
6	6	0	2.5	3	0.5	68.1	68.8	0.7	55.6	52.8	-2.8
3.5	5.5	2	5	5	0	68 1	65.8	-2.3	56.8	58 2	1.4
4	2	-2	4	3	-1	72.4	71.2	-1.2	66.5	61.5	-5

Appendix 2. DATA

3|3U	3|3U		3|3L	3|3L		DD	DD		ANGLE	DEFL	DEFL	
3|3U-1	3|3U-2	[3|3change=2-1]	3|3L-1	3|3L-2	[3|3change=2-1]	DD-1	DD-2	[DDchange=2-1]	Angle	ADefMR-1	ADefMR-2	[Change=2-1]
35	34 4	-0 6	24.3	22.7	-1 6	4 2	1 5	-2 7	22	0	0	0
33	31 7	-1 3	23.2	21.1	-2 1	8 3	2 7	-5.6	21	3	3	0
31.8	32 5	0 7	22.8	23.4	0.6	7	5 7	-1 3	1	0	0	0
34.5	-99	-99	23.9	20.1	-3.8	5 9	9	3.1	1	-2	-2	0
33.3	33 8	0 5	26.5	25.6	-0.9	3 2	4 4	1 2	2	3	3 5	0 5
35	35	0	24.3	24.6	0.3	9 4	10 6	1.2	1	0	-0.5	0 5
34.6	33	-1 6	23.3	22.6	-0 7	3 6	10	6 4	1	0	0	0
33.3	33	-0 3	24.1	24.1	0	1 8	3 4	1.6	21	1.5	3	1 5
32	30 9	-1 1	23.4	21.9	-1.5	1 1	2 2	1 1	22	0	-1	1
29.1	28 5	-0.6	23.1	22.9	-0.2	8.4	7 7	-0.7	21	-99	5 5	-99
30.3	33.4	3 1	23.5	23 6	0.1	1 2	2 8	1.6	21	-99	6	-99
34	36.4	2.4	26.8	27.2	0.4	2 5	6 8	4.3	1	-0 5	-0 5	0
32.5	34.5	2	24.1	24.5	0 4	2	2	0	3	-1	-1	0
36.2	36.2	0	26.8	26.5	-0.3	2.6	7 2	4.6	22	0	0	0
34.9	36.6	1 7	26.5	26.5	0	2.2	6 4	4.2	1	0	0	0
30.5	31 4	0 9	21	21.3	0.3	4.1	6	1 9	1	-1	0	1
36.1	35.2	-0.9	24.2	24.1	-0.1	6 7	8.6	1.9	1	0	0	0
34.1	32.3	-1 8	24.2	22.7	-1.5	10.8	13.1	2.3	1	0	-0.5	0 5
34.3	34.7	0.4	26.5	25.5	-1	6	3.8	-2.2	1	-1	-2	1
36.3	36.2	-0.1	24.1	22.6	-1 5	11.8	17	5.2	1	-1	-0.5	0 5
31.7	31.1	-0.6	23.6	24.2	0 6	1 5	3 5	2	1	0	0	0
37.8	33 2	-4 6	25.9	26.6	0 7	2 8	7 5	4 7	21	4	4.5	0 5
38.3	36.7	-1 6	26.4	25.4	-1	6.2	10	3.8	2	2	2	0
31.7	31.3	-0 4	23.8	23.3	-0.5	2.8	4 6	1 8	1	0	0	0
34	36	2	26.2	27.2	1	3	3 6	0.6	1	0	1.5	1.5

Appendix 2 DATA

3|3U	3|3U		3|3L	3|3L		DD	DD		ANGLE	DEFL	DEFL	
3|3U-1	3|3U-2	[3|3change=2-1]	3|3L-1	3|3L-2	[3|3change=2-1]	DD-1	DD-2	[DDchange=2-1]	Angle	ADefIMR-1	ADefIMR-2	[Change=2-1]
34	34 1	0.1	25.8	23	-2 8	3 1	11 6	8.5	2	5	5 5	0 5
34	33 5	-0.5	25.7	24 9	-0 8	1 5	3	1 5	21	5 5	5 5	0
27 7	24 5	-3.2	25.1	27.5	2 4	7 1	5	3 3	2	5	4.5	0 5
34.7	35 5	0.8	24 9	26.4	1 5	1 2	1 8	0 6	1	-2	0	2
34.8	36 7	1 9	23.8	22 6	-1 2	6 8	8 5	1 7	1	-2	-2	0
38	39 4	1.4	28.5	27.6	-0.9	9 7	14 8	5.1	1	0	1	1
31.7	30 1	-1.6	23.1	22 3	-0 8	2	5 8	3.8	1	0	0	0
35.1	33 7	-1.4	27.2	26.6	-0.6	1	2	1	22	0	0	0
31.8	31	-0.8	24	22.2	-1.8	8 7	13 1	5	1	0	0	0
37	35.4	-1.6	27.7	28.1	0 4	5	8 8	3.8	2	2	2 5	0 5
36.7	39 1	2.4	23.5	22.8	-0 7	12 4	12	-0.4	1	0	-0.5	0.5
32.9	35	2.1	25.8	24.5	-1 3	2 3	2 8	0.5	2	2	2	0
31.7	32.3	0.6	22	21 7	-0 3	9.7	8.5	-1.2	1	0	2	2
39.9	33.9	-6	23.7	22.9	-0.8	6.3	10.2	3.9	1	0	-1	1
35.5	36.4	0.9	26.7	26 2	-0 5	7 3	7 7	0.4	2	3	1 5	1 5
34.2	35.1	0.9	24.5	23.1	-1.4	6	6 9	0.9	1	0	-2	2
34.6	34	-0.6	23.7	23 7	0	0 5	6.1	5.6	1	0	0	0
35.9	38.5	2.6	26.7	25.5	-1.2	2 5	1 6	0.9	1	0.5	0	0.5
32.6	31.6	-1	24.3	24.4	0.1	2.2	7	4.8	2	3	3	0
33.7	33 2	-0.5	25.4	24.6	-0.8	2	6 6	4.6	22	0	0	0
34.5	34.7	0 2	27	27	0	3.5	10 9	7.4	2	4.5	2.5	2
32.3	32.7	0 4	25.3	24.9	-0.4	4.8	12 5	7.7	1	-1	-2	1
29.8	30.9	1 1	21.1	20	-1 1	5	7 8	2 8	1	0	0	0
30.1	30 4	0 3	26.1	25.3	-0.8	12.4	7.7	-4.7	2	0	1.5	1 5
32	32.6	0 6	26.1	24	-2.1	0	4 8	4.8	2	3	0	3

Appendix 2. DATA

DEFL	DEFL		upper/lower	upper/lower	AGE-M	AGE-M		AGE-Y	AGE-Y	*	Birthdate
ADeflML 1	ADeflML-2	[Change=2-1]	3rd Molars/Yng	3rd Molars/Old	Age-1[mo]	Age-1[mo]	T2-T1	Age-1[yr]	Age-2[yr]	Sex	Birthdate
2	0	2	I/I	I/I	240	811	571	20	67 07	2	5/26/25
0.5	-1	0.5	I/I	M/M	217	678	461	18.01	56 06	1	6/15/26
0	0	0	I/I	M/M	204	675	471	17	56.03	2	11/16/27
0	0	0	O/I	M/M	223	889	666	18.07	74 01	2	10/7/17
4	4 5	0.5	M/M	M/M	206	698	492	17.02	58 02	1	2/22/25
0	-1	1	I/I	I/I	240	649	409	20	54 1	2	9/13/28
0	-0 5	0.5	I/I	M/M	204	769	565	17	64 01	2	6/19/28
1.5	3	1.5	I/I	M/M	217	698	481	18.01	58.02	1	4/20/25
4 5	5	0.5	I/I	O/O	205	785	580	17.01	65.05	1	4/19/27
0.5	0 5	0	I/I	M/M	204	733	529	17	61.02	2	7/25/31
0	0	0	I/I	M/M	209	613	404	17 05	51.1	1	7/29/31
0	0	0	I/I	M/M	210	618	408	17.06	51.06	2	8/20/31
-2.5	-2 5	0	I/M	O-I/M	204	747	543	17	62.03	1	6/13/30
3	3	0	I/I	M/M	217	697	480	18 01	58.01	1	1/10/25
0	0	0	I/I	M/M	217	641	424	18.01	53.05	1	8/7/29
-1	-3	2	I/I	O-M/O	218	733	515	18.02	61.01	1	3/5/22
0.5	0	0.5	M/M	M/M	249	629	380	20.09	52.05	1	9/10/30
0	-0.5	0.5	I/I	M/O	204	638	434	17	53.02	1	9/30/29
-1	-2	1	I/M	I/O	205	747	542	17.01	62.03	1	4/19/30
0	0	0	I/I	M/M	252	831	579	21	69.03	2	4/9/23
0	0	0	O/O	M/M	252	700	448	21	58.04	2	7/28/24
0	0	0	I/I	M/M	206	792	586	17.02	66	1	9/5/26
2.5	2	0.5	I/I	M/M	264	719	455	22	59.11	2	9/18/23
0	1	1	I/I	M/M	216	760	544	18	63.04	2	10/25/18
0	0	0	I/I	I/I	241	757	516	20.01	63.01	2	6/11/29

Appendix 2. DATA

DEFL	DEFL		upper/lower	upper/lower	AGE-M	AGE-M		AGE-Y	AGE-Y	*	Birthdate
ADeflML-1	ADeflML 2	[Change=2-1]	3rd Molars/Yng	3rd Molars/Old	Age-1[mo]	Age-1[mo]	T2-T1	Age-1[yr]	Age-2[yr]	Sex	Birthdate
1	2	1	I/I	M/M	228	831	603	19	69.03	1	5/1/23
0.5	2	1.5	I/I	O-M/M	204	601	397	17	50.01	1	1/28/33
6	5.5	0 5	I/I	O/M	217	549	332	18.01	45.09	2	8/29/33
-2	0	2	O/O	M/M	229	588	359	19.01	49	2	3/15/34
-2	-3	1	I/I	O/O	261	577	316	21.09	48.1	1	3/24/34
0	0 5	0.5	I/I	O/O	221	713	492	18.05	59.05	1	1/17/24
0	0	0	I/I	M/M	207	584	377	17.03	48.08	1	4/3/34
5	5 5	0.5	O-M/O-M	O-M/O-M	242	529	287	18	44.01	1	6/8/34
0	0	0	M/O	M/O	216	699	483	18	58 03	1	6/20/34
3	2 5	0 5	I/I	I/I	204	795	591	17	66.03	1	1/28/17
-1	-0.5	0.5	M/M-O	M/M-O	252	702	450	21	58.06	1	3/11/24
3	4 5	1 5	O/M	O/M	240	701	461	20	58 05	1	5/7/24
0	0	0	I/I	M/I	217	702	485	18.01	58.06	2	5/9/24
-3	-2.5	0 5	I/I	M/M	216	709	493	18	59.1	1	6/5/23
3	1 5	1 5	I/I	M/M	240	663	423	20	55.03	1	12/29/28
0	0	0	I/M	I/M	228	679	451	19	56.07	1	3/21/26
-1	0	1	M/I	M/M	206	808	602	17.02	67.04	1	4/7/25
0.5	1	0.5	M/I	M/M	204	679	475	17	56.07	1	4/15/26
1	0	1	I/M	I/I	228	677	449	19	56.05	2	5/24/26
4	4.5	0 5	M/I	O-M/I	228	673	445	19	56.01	1	10/8/26
0	1	1	M/I	M/I	240	793	553	20	66 1	2	10/23/25
0	0	0	M/I	M/I	204	673	469	17	56 01	1	11/2/26
0	-99	-99	I/I	M/M	230	696	466	19 02	58	2	3/18/25
2	2	0	I/I	M/M	281	810	529	23 05	67 06	1	9/1/15
2	2 5	0 5	I/I	M/M	217	578	361	18 1	48 02	2	10/15/35

BIBLIOGRAPHY

Achenbaum, WA. The aging society. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:1-15.

Adams, D. 1991. Age changes in oral structures. Dent Update. 18(1):14-17.

Adelman, RC. 1989. Myths and realities of biological aging. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:23-31.

Ades, AG., DR Joondeph, RM Little, and MK Chapko. 1990. A long-term study of the relationship of third molars to changes in the mandibular arch. Am J Orthod Dentofac Orthop 97(4):323-335.

Allen, EF. 1944. Statistical study of the primary cause of extractions. J Dent Res 23:453-458.

Andrews, LF. 1972. The six keys to normal occlusion. Am J. Orthod. 62(3):296-309.

Avci, M and H Iplikcioglu. 1992. An analysis of edentulous maxillary arch width and palatal height. Int J Prosthodont 5(1):73-77.

Axelsson, P, J Lindhe, and B Nyström. 1991. On the prevention of caries and periodontal disease: Results of a 15 year longitudinal study in adults. J Clin Periodontol 18:182-189.

Baer, PN. 1963. Alveolar bone loss and occlusal wear. Periodontics 1:45

Bailit, HL, R Braun, GA Maryniuk, and P Camp. 1987. Is periodontal disease the primary cause of tooth extraction in adults. JADA 114:40-45.

Barnhart, CL and RK Barnhart. 1972. The World Book Dictionary. Thorndike and Barnhart. Doubleday and Company. Chicago, Illinois.

Barrow, GV. and JR White. 1952. Developmental changes of the maxillary and mandibular dental arches. Angle Orthodontist 22:41-46.

Baum, BJ and L Bodner. 1983. Aging and oral motor function: Evidence for altered performance among older persons. J Dent Res 62(1):2-6.

Begg, PR. 1954. Stone Age man's dentition. Am J Orthod 40:298-312, 373-383, 462-475, 517-531.

Behrents, RG. 1988. The consequences of adult craniofacial growth. Orthodontics in an Aging Society Monograph 22 Craniofacial Growth Series Center for Human Growth and Development. The University of Michigan, Ann Arbor, Michigan pp:53-99.

Behrents, RG. 1986. Dr. Rolf Behrents on adult craniofacial growth. J Clin Orthod 20(12):842-847.

Behrents, RG. 1985. Growth in the aging craniofacial skeleton. Monograph 17 Craniofacial Growth Series Center for Human Growth and Development. The University of Michigan, Ann Arbor, Michigan.

Behrents, RG. 1984. In: In Search of Truth for the Greater Good of Man: A Chronological Account of the Bolton-Brush Growth Studies. Cleveland, Ohio Case Western Reserve University.

Behrents, RG. 1992. TMJ research: responsibility and risk. Am J Orthod Dentofac Orthop 101(1):1-3.

Bergsten, JW. 1960. Loss of teeth, United States July 1957-June 1958. U.S. Department of Health, Education, and Welfare, Public Health Service. Health Statistics from the U.S. National Health Survey. PHS Publication No. 584-B22. Washington D.C.: U.S Government Printing Office.

Bernick, S. 1967. Age changes in the blood supply to human teeth. J Dent Res 46(3):544-550.

Beyron, HL. 1954. Occlusal changes in adult dentition. J. Am Dent Assoc 48:674-686.

Bierman, EL. 1985. Ateriosclerosis and Aging. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company, New York. p:842-858.

Bishara, SE, LC Peterson, and EC Bishara. 1984. Changes in facial dimensions and relationships between the ages of 5 and 25 years. Am J. Orthod. 85(3):238-252.

Bishara, SE, JR Jackobsen, JE Treder, and MJ Stasi. 1989. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood. Am J Orthod Dentofac Orthop 95:46-59.

Bittner, C and H. Pancherz. 1990. Facial morphology and malocclusions. Am J Orthod Dentofac Orthop 97(4):308-315.

Bjertness, E. 1991. The importance of oral hygiene on variation in dental caries in adults. Acta Odontol Scand 49:97-102.

Björk, A and V Skieller. 1972. Facial development and tooth eruption: an implant study at the age of puberty. Am J Orthod 66:339-83.

Björk, A. 1951. A discussion on the significance of growth changes in facial pattern and their relationship to changes in occlusion. Dent Rec 71:197-208.

Björk, A, A Krebs, and B Solow. 1964. A method for epidemiological registration of malocclusion. Acta Odontol Scand 22:27-45.

Boersma, H. 1974. Alteration of skull dimensions in aged persons. J Dent Res 53(3):678-682.

Bouma, J, RMH Schaub, and F van de Poel. 1987. Relative importance of periodontal disease for full mouth extractions in the Netherlands. Community Dent Oral Epidemiol 15:41-45.

Boyd, RL, PJ Leggott, RS Quinn, WS Eakle, and D Chambers. 1989. Periodontal implications of orthodontic treatment in adults with reduced or normal periodontal tissues versus those of adolescents. Am J Orthod Dentofac Orthop 96:191-199.

Brace, CL. 1977. Occlusion to the anthropoligical eye. Monograph 7 Craniofacial Growth Series Center for Human Growth and Development. The University of Michigan, Ann Arbor, Michigan.

Brekhus, PJ. 1929. Dental diseases and its relation to the loss of human teeth. J Am Detn Assoc 16:2237-2247.

Brook, PH and WC Shaw. 1989. The development of an index of orthodontic treatment priority. Eur J Orthod 11:309-320.

Brown, LJ and LH Meskin. 1988. Socioeconomic differences in tooth loss patterns in U.S. employed adults and seniors, 1985-1986. Gerodontics 4:345-362.

Brunelle, JA. 1988. National Institute of Dental Research. Oral Health in United States Adults. Regional Findings. The National Survey of Oral Health in U.S. Employed Adults and Seniors:1985-1986. U.S. Department of Health and Human Services. NIH Publication No. 88-2869.

Brunelle, JA. 1989. National Institute of Dental Research. Oral Health in United States Children. National Findings. The National Survey of Dental Caries in U.S. school children: 1986-1987. U.S. Department of Health and Human Services. NIH Publication No.89-2247.

Burgersdijk, RCW, GJ Truin, FWA Frankenmolen, H Kalsbeek, MA van't Hof, and J Mulder. 1991. Malocclusion and orthodontic treatment need of 15-74 year old Dutch adults. Community Dent Oral Epidemiol 19:64-7.

Burnham, CE. 1974. Edentulous persons: United States-1971. National Center for Health Statistics. Vital and Health Statistics, Series 10-#89. DHEW Publication No. (HRA)74-1516. Health Resources Adminstration, Rockville MD U.S. Government Printing Office.

Burt, BA. 1989. Dental practice in the aging society. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:17-21.

Burt, BA. 1992. Epidemiology of dental diseases in the elderly. Clin Geriatr Med 8(3):447-459.

Campbell, MJ, AJ McComas, and F Petito. 1973. Physiological changes in aging muscle. J Neurol Neurosurg Psychiatr 36:174-182.

Carlos, JP. 1970. Evaluation of indices of malocclusion. Int Dent J 20(4):606-617.

Carmen, RB. 1978. A study of mandibular anterior crowding in untreated cases and its predictability. Master's Thesis. Case Western Reserve University, Cleveland, Ohio.

Cohen, JT. 1940. Growth and development of the dental arches in children. J Am Dent Assoc 27:1250-1260.

Crothers, AJR. 1992. Tooth wear and facial morphology. J Dent. 20(6):333-341.

Dahl, B, O Gudbrand, A Andersen, and O Bruaset. 1989. The suitability of a new index for the evaluation of dental wear. Acta Odontol Scand 47:205-210.

DeKock, W. 1972. Dental arch depth and width studied longitudinally from 12 years of age to adulthood. Am J Orthod 62(1):56-66.

Dockrell, RB. 1952. Classifying the aetiology of malocclusion. Dent Rec 72:25-31.

Doris, JM, BW Bernard, and MM Kuftinec. 1981. A biometric study of tooth size and dental crowding. Am J Orthod79(3):326-336.

Draker, H. 1960. Handicapping labio-lingual deviations: a proposed index for Public Health purposes. Am J Orthod 46:295-305.

Dyer, GS, EF Harris, and JL Vaden. 1991. Age effects on orthodontic treatment: adolescents contrasted with adults. Am J Orthod Dentofac Orthop 100(6):523-530.

Ekfeldt, A, A Hugoson, T Bergendal, and M Helkimo. An individual tooth wear index and an analysis of factors to incisal and occlusal wear in an adult Swedish population. Acta Odontol Scand 48:343-349.

Enlow, DH. 1989. "Growth" and aging in the adult craniofacial skeleton. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:101-103.

Enlow, DH. 1990. Handbook of facial growth. Philadelphia, W.B. Saunders Co.

Epker, BN and HM Frost. 1966. Periosteal appositional bone growth from age two to age seventy in man. Anat Rec 154:573-578.

Ferguson, DB. 1987. An overview of physiological changes in the aging mouth. Front Oral Physiol. 6:1-6.

Finch, CE. and EL Schneider. 1985. Handbook of the Biology of Aging. Second edition. New York, Van Nostrand Reinhold Company.

Fisk, RO. 1966. Normal mandibular arch changes between ages 9-16. J Can Dent Assoc 32(11):652-658.

Forsberg, CM, S Eliasson, and H Westergren. 1991. Face height and tooth eruption in adults--a 20-year follow-up study. Eur J Orthod. 13(4):249-254.

Forsberg, CM. 1979. Facial morphology and ageing: a longitudinal cephalometric investigation of young adults. Eur J Orthod. 1(1):15-23.

Forsberg, CM. 1988. Tooth size, spacing, and crowding in relation to eruption or impaction of third molars. Am J Orthod Dentofac Orthop 94(1):57-62.

Foster, TD, MC Grundy, and CLB Lavelle. 1977. A longitudinal study of dental arch growth. Am J Orthod 72(3):309-314.

Fröhlich, FJ. 1962. Changes in untreated Class II type malocclusions. Angle Orthod. 32(3): 167-179.

Garn, SM. 1989. Directions of aging. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:1-15.

Ghafari, J, SA Locke, and JM Bentley. 1989. Longitudinal evaluation of the treatment priority index. Am J Orthod Dentofac Orthop. 96(5):382-389.

Gilbert, GH. 1989. 'Ageism' in dental care delivery. JADA 118:545-548.

Gitlin, LN, MP Lawton, LA Windsor-Landsberg, MH Kleban, and J Posner. 1992. In search of psychological benefits: exercise in healthy older adults. J Aging and Health 4(2):174-192.

Goldenberg, BS, JK Hart, and JS Sakumura. ---. The loss of occlusion and its effect on mandibular immediate sideshift. J Prosthet Dent --(2):163-166.

Goldenstein, MS and FL Stanton. 1937. Facial growth in relation to dental occlusion. Int J Orthod Oral Surg 23(9):859-892.

Grant, D and S Bernick. 1970. Arteriosclerosis in periodontal vessels of aging humans. J Periodontol 41:170.

Graves, RC and JW Stamm. 1985. Oral health status in the United States: prevalence of dental caries. J Dent Educ 49:341-52.

Graves, RC, HM Bohannan, JA Disney, JW Stamm, JD Bader. and JR Abernathy. 1986. Recent dental caries and treatment patterns in US children. J Public Health Dent 46(1):23-29.

Grewe, JM and DV Hagan. 1972. Malocclusion Indices: a comparative evaluation. Am J Orthod 61(3):286-294.

Halter, JB. 1989. Clinical implications of the aging process. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:41-52.

Hand, JS, Hunt RJ, and Kohout FJ. 1991. Five year incidence of tooth loss in Iowans aged 65 and older. Community Dent Oral Epidemiol 19:48-51.

Harman, SM and GB Talbert. 1985. Reproductive aging. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company, New York. p:457-510.

Harris, EF, GS Dyer, and JL Vaden. 1991. Age effects on orthodontic treatment: skeletodental assessments from the Johnston analysis. Am J Orthod Dentofac Orthop 100(6):531-536.

Harris, EF and MG Johnson. 1991. Heritability of craniometric and occlusal variables: A longitudinal sib analysis. Am J Orthod Dentofac Orthop 99(3):258-268.

Harris, EF and RG Behrents. 1988. The intrinsic stability of Class I molar relationship: A longitudinal study of untreated cases. Am J Orthod Dentofac Orthop 94(1):63-67.

Harris, EF, K Aksharanugraha, and RG Behrents. 1992. Metacarpophalangeal length changes in humans during adulthood: a longitudinal study. Am J Phys Anthrop 87:263-275.

Harris, EF and RJ Smith. 1982. Occlusion and arch size in families: a principal component analysis. Angle Orthod 52(2):135-143.

Harvey, C and JE Kelly. 1981. Decayed, missing, and filled teeth among persons 1-74 years, United States. National Center for Health Statistics. Vital and Health Statistics, Seried 11-No.223. DHHS Publication No. (PHS)81-1673. Washington, D.C.: U.S. Government Printing Office.

Hasund, AP. 1965. Attrition and dental arch space. Trans Eur Orthod Soc p:121-131.

Hasund, AP and R Sivertsen. 1971. Dental arch space and facial type. Angle Orthod 41(2):140-145.

Hausman, PB and ME Weksler. 1985. Changes in the immune response with age. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company, New York. p:414-431.

Heft, MW, and GH Gilbert. 1991. Tooth loss and caries prevalence in older Floridians attending senior activity centers. Community Dent Oral Epidemiol 19:228-232.

Helm, Sand PE Petersen. 1989. Individual changes in malocclusion from adolescence to 35 years of age. Acta Odontol Scand 47:211-216.

Hinton, RJ and JA McNamara. 1984. Effect of age on the adaptive response of the adult temporomandibular joint: a study of induced protrusion in Macaca mulatta. Angle Orthod 54(2):154-162.

Houston, F, H Hanamura, GE Carlsson, T Haraldson, and H Rylander. 1987. Mandibular dysfunction and periodontitis: a comparative study of patients with periodontal disease and occlusal parafunctions. Acta Odontol Scand 45:239-246.

Houston, WJB and WAB Brown. 1980. Family likeness as a basis for facial growth. Eur J Orthod. 2(1):13-18.

Howe, RP, JA McNamara, and K O'Conner. 1983. An examination of dental crowding and its relationship to tooth size and arch dimension. Am J Orthod Dentofac Orthoped 83(5):363-373.

Humphrey, GM. 1858. A Treatise on the human skeleton. Cambridge, Macmillan and Company.

Hunt, RJ, SM Levy, and JD Beck. 1990. The prevalence of periodontal attachment loss in an Iowa population aged 70 and older. J Public Health Dent 50(4):251-256.

Israel, H. 1973. Age factors and the pattern of change in craniofacial structures. Am J Phys Anthrop 39:111-128.

Israel, H. 1977. The dichotomous pattern of craniofacial expansion during aging. Am J Phys Anthrop 47:47-52.

Israel, H. 1973. The failure of aging or loss of teeth to drastically alter mandibular angle morphology. J Dent Res 52(1):83-90.

Israel, H. 1973. Recent knowledge concerning craniofacial aging. Angle orthod 43(2):176-184.

Ive, JC, PA Shapiro, and JL Ivey. 1980. Age-related changes in the periodontium of pigtail monkeys. J Periodont Res 15:420-427.

Jensen, WO. 1990. Effects of comparative jaw size on mandibular movement and occlusion. J Prosthet Dent 64(2):174-179.

Johnson ES, JE Kelly, and LE VanKirk. 1965. Selected dental findings in adults, by age, race, and sex: United States-1960-1962. U.S. Department of Health, Education, and Welfare, Public Health Service. PHS Publication No.1000 Series 11 No.7. Washington D.C: U.S. Government Printing Office.

Johnson, MA, MA Brown, LW Poon, P Martin, and GM Clayton. 1992. Nutritional patterns of centenarians. Int J Aging and Human Dev 34(1):57-76.

Jowsey, J. 1960. Age changes in human bone. Clin Orthop 17:210-217.

Kalsbeek, H , GJ Truin, RCW Burgersdijk, and MA Van't Hof. 1991. Tooth loss and dental caries in Dutch adults. Community Dent Oral Epidemiol 19:201-204.

Kaplan, RG 1974. Mandibular third molars and postretention crowding. Am J Orthod 66(4):411-430.

Karlsson, S and GE Carlsson. 1990. Characteristics of mandibular masticatory movement in young and elderly dentate subjects. J Dent Res 69(2):473-476.

Karlsson, S, M Persson, and GE Carlsson. 1991. Mandibular movement and velocity in relation to state of dentition and age. J Oral Rehabil.18(1):1-8.

Kelly, JE, and and CR Harvey. 1979. Basic data on dental examination findings of persons 1-74 years: United States, 1971-1974. Vital Health and Statistics, Series No. 214. DHEW Publication No. (PHS)79-1662. Washington D.C.: U.S. Government Printing Office.

Kerley, ER. 1965. The microscopic determination of age in human bone. Am J Phys Anthropol 23:149-164.

Kligman, AM, GL Grove, and AK Balin. 1985. Aging of human skin. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company, New York. p:820-841.

Knott, VB. 1972. Longitudinal study of dental arch widths at four stages of dentition. Angle Orthod 42(4):387-94.

Knott, VB. 1961. Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence. Am J Phys Anthropol 19:263-284.

Könönen, M, J Wolf, E Kilpinen, and E Melartin. 1991. Radiographic signs in the temporomandibular and hand joints in patients with psoriatic arthritis. Acta Odontol Scand 49:191-196.

Krogstad, O and BL Dahl. 1985. Dento-facial morphology in patients with advanced attrition. Eur J Orthod 7:57-62.

Lavelle, CLB. 1968. The effect of age on the proliferative activity of the periodontal membrane of the rat incisor. J Periodont Res 3:48.

Leake, JL. 1990. An index of chewing ability. J Public Health Dent. 50(4):262-267.

Leighton, BC and WS Hunter. 1982. Relationship between lower arch crowding and facial height and depth. Am J Orthod 82(5):418-425.

Lewis, KJ and BGN Smith. 1973. The relationship of erosion and attrition in extensive tooth tissue loss: case report. Brit Dent J 135:400-404.

Lindqvist, B and B Thilander. 1982. Extraction of third molars in cases of anticipated crowding in the lower jaw. Am J Orthod 81(2):130-139.

Little, RM, R.A. Riedel, and J. Artun. 1988. An evaluation of changes in mandibular anterior alignment from 10-20 years postretention. Am J Orthod Dentofac Orthop 93(5):423-428.

Little, RM. 1975. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 68(5):554-563.

Little, RM., R Riedel, and A Stein. 1990. Mandibular arch length increase during the mixed dentition: Postretention evaluation of stability. Am J Orthod Dentofac Orthop 97:393-404.

Little, RM, and R Riedel. 1989. Postretention evaluation of stablity and relapse–mandibular arches with generalized spacing. Am J Orthod Dentofac Orthop 95(1):37-41.

Lombardi, AV. 1982. The adaptive value of dental crowding: a consideration of the biologic basis of malocclusion. Am J Orthod 81(1):38-42.

Lundström, A. 1969. Changes in crowding and spacing of the teeth with age. Dent Practit. 19(6):218-224.

Lundström, A. 1977. Need for treatment in cases of malocclusion. Trans Eur Orthod Soc 53:111-123.

Mair, LH. 1992. Wear in dentistry-current terminology. J Dent 20(3):140-144.

Manson, JD and RB Lucas. 1962. A microradiographic study of age changes in the human mandible. Arch Oral Biol. 7:761-769.

Mappes, MS, EF Harris, and RG Behrents. 1992. An example of regional variation in the tempos of tooth mineralization and hand-wrist ossification. Am J Orthod Dentofac Orthop 101(2):145-151.

McMillan, DR, G Tryde, K Stoltze, T Maeda, and N Brill. 1978. Age changes in the perception of comfortable mandibular occlusal positions. J Oral Rehabil. 5:365-369.

Melsen, B. 1989. Orthodontic treatment of the degenerated dentition. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:105-136.

Merz, ML, RJ Isaacson, N Germane, and LK Rubenstein. 1991. Tooth diameters and arch perimeters in a black and a white population. Am J Orthod Dentofac Orthop 100(1):53-58.

Miethke, RR and A Behm-Menthel. 1988. Correlations between lower incisor crowding and lower incisor position and lateral craniofacial morphology. Am J Orthod Dentofac Orthop 94(3):231-239.

Miller, AJ, JA Brunelle, JP Carlos, LJ Brown, and H Löe. 1987. National Institute of Dental Research. Oral Health in United States Adults. National Findings. The National Survey of Oral Health in U.S. Employed Adults and Seniors: 1985-1986. U.s. Department of Health and Human Services. NIH Publication No 87-2868.

Mixson, JM, HC Eplee, PH Fell, JJ Jones, and M Rico. 1990. Oral health status of a federal prison population. J Public Health Dent. 50(4):257-261.

Miyazaki, H, T Pilot, MH Leclerq, and DE Barmes. 1991. Profiles of periodontal conditions in adults measured by CPITN. Int Dent J. 41:74-80.

Molnar, S, JK McKee, and I Molnar. 1983. Measurements of tooth wear among Australian Aborigines: I. Serial loss of the enamel crown. Am J Phys Anthrop. 61:51-65.

Moorrees, CF and B Reed. 1954. Biometrics of crowding and spacing of the teeth of the mandible. Am J Phys Anthropol 12:77-88.

Moorrees, CF, LML Lebret, and RL Kent. 1979. Changes in the natural dentition after second molar emergence (13-18 years). Int Assoc Dent Res: Abst 737,276.

Moorrees, CF, AM Gron, L Lebret, P Yen, and F Frohlich. 1969. Growth studies of the dentition: A review. Am J Orthod 55:600-616.

Moyers, RE. and CJ Summers. 1970. Application of the epidemiologic method to the study of occlusal disorders. Int Dent J 20(4):575-592.

Murphy, TR. 1959. Compensatory mechanisms in facial height adjustment to functional tooth attrition. Aust Dent J 4:312-323.

Murphy, TR. 1964. Reduction of the dental arch by approximal attrition. Br Dent J 116:483-510.

Naeim, F and RL Walford. 1985. Aging and cell membrane complexes: the lipid bilayer, integral proteins, and cytoskeleton. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company , New York. p:272-289.

Nakasima, HJR and Y Takahama. 1991. Heritability of dental arch dimensions in humans. J Craniofac Gen Dev Biol 11:165-169.

Nance, H. 1947. The limitations of orthodontic treatment. Am J Orthod Oral Surg 33:253-301.

Nanda, RS and SK Nanda. 1992. Considerations of dentofacial growth in long-term retention and stability: Is active retention needed? Am J Orthod Dentofac Orthop 101(4):297-302.

Newton, JP, RW Abel, EM Robertson, and R Yemm. 1987. Changes in human masseter and medial pterygoids with age: a study by computed tomography. Gerodontics 3:151-154.

Niessen, LC and RJ Weyant. 1989. Causes of tooth loss in a veteran population. J Public Health Dent 49(1):19-23.

Niessen, LC and JA Jones. 1991. Facing the challenge: the graying of America. In: Geriatric Dentistry: Aging and Oral Health. Mosby Year-Book Inc., St. Louis.

Oilo, G, BL Dahl, G Hatle and AL Gad. 1987. An index for evaluating wear of teeth.Acta Odontol Scand 45:361-365.

O'Reilly, TX. 1951. Deciduous dental arch widths and widths of the face in early childhood. Am J Orthod 37(9):698-705.

Osborn, JW and LJ Francis. 1989. The position of the dentition in the mandible and its possible relation to orthodontic abnormalities. Am J Orthod Dentofac Orthop 96(4):327-332.

Oyen, O and TP Tsay. 1991. A biomechanical analysis of craniofacial form and bite force. Am J Orthod Dentofac Orthop 99(4):298-309.

Page, RC. 1984. Periodontal diseases in the elderly: a critical evaluation of current information. Gerodontol 3:63.

Palmqvist, S, B Soderfeldt, and D Arnbjerg. 1991. Dental conditions in a swedish population aged 45-69 years: A questionnaire study. Acta Odontol Scand 49:377-384.

Pelton, WJ, EH Pennell, and A Druzina. 1954. Tooth morbidity experience in adults. J Am Dent Assoc 49:439-445.

Peterson, LJ. 1992. Rationale for removing impacted teeth: when to extract or not to extract. J Am Dent Assoc 123:198-204.

Pöllmann, L, F Berger and B Pöllmann. 1987. Age and dental abrasion. Gerodontics 3:94-96.

Popovich, F, and GW Thompson. 1971. A longitudinal comparison of the orthodontic treatment priority index and the subjective appraisal of the orthodontist. J Public Health Dent 31(1):2-8.

Popovich, F. 1991. A review of studies from the Burlington Growth Centre, 1956-1989. Monograph 24 Craniofacial Growth Series Center for Human Growth and Development The University of Michigan, Ann Arbor, Michigan. p.313-343.

Poulton, DR and SA Aaronson. 1961. The relationship between occlusion and periodontal status. Am J Orthod 47(9):690-699.

Proffit, WR. 1989. Orthodontics in an aging society: an overview. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:159-166.

Proffit, WR. 1986. Contemporary Orthodontics. St. Louis, C.V. Mosby Company.

Proffit, WR and J Ackerman. 1973. Rating the characteristics of malocclusion: a systematic approach for planning treatment. Am J Orthod 64:258-269.

Radnzic, D. 1988. Dental crowding and its relation to mesiodistal crown diameters and arch dimensions. Am J Orthod Dentofac Orthop 94(1):50-56.

Reff, ME. 1985. RNA and protein metabolism. In: Handbook of the Biology of Aging. Second edition. Van Nostrand Reinhold Company, New York. p:225-254.

Reinhardt, GA. 1983. Attrition and the edge-to-edge bite: an anthropological study. Angle Orthod 53(2):157-164.

Richards, LC and T Brown. 1981. Dental attrition and degenerative arthritis of the temporomandibular joint. J Oral Rehabil 8:293-307.

Richardson, ME. 1979. Late lower arch crowding: facial growth or foreward drift? Eur J Orthod 1:219-225.

Richardson, ME. 1986. Late lower arch crowding: the role of facial morphology. Angle Orthod 56(3):244-254.

Richardson, ME. 1992. Lower arch crowding in the young adult. Am J Orthod Dentofac Orthop101(2):132-137.

Richardson, ME. 1989. The role of the third molar in the cause of late lower arch crowding: a review. Am J Orthod Dentofac Orthop 95(1):79-83.

Richmond, S, WC Shaw, KD O'Brien, IB Buchanan, R Jones, CD Stephens, CT Roberts, and M Andrews. 1992. The development of the PAR index (peer assessment rating): reliability and validity. Eur J Orthod 14:125-139.

Richmond, S, WC Shaw, CT Roberts, and M Andrews. 1992. The PAR index(peer assessment rating):methods to determine outcome of orthodontic treatment in terms of improvement and standards. Eur J Orthod 14:180-187.

Ricketts, RM. 1960. The influence of orthodontic treatment on facial growth and development. Angle Orthod 30(3):103-133.

Rodin, J and E Langer. 1980. Aging labels:the decline of control and the fall of self-esteem. J Social Issues 36:12-29.

Rowe, DJ. 1983. Bone loss in the elderly. J Prosthet Dent 50:607-610.

Rowe, JW and RL Kahn. 1987. Human aging: usual and successful. Science 237:143-149.

Salzmann, JA. 1968. Handicapping malocclusion assessment to establish treatment priority. Am J Orthod 54(10):749-765.

Salzmann, JA. 1970 Treatment priority index of malocclusion. Int Dent J 20(4):618-632.

Sarnäs, KV and B Solow. 1980. Early adult changes in the skeletal and soft-tissue profile. Eur J Orthod. 2(1):1-12.

Saunders, SR, F Popovich, and GW Thompson. 1980. A family study of craniofacial dimensions in the Burlington Growth Centre sample. Am J Orthod 78(4):394-403.

Seide, LJ. 1976. Adult orthodontics. J Prosthet Dent 24:83-93.

Seligman, DA, AG Pullinger, and WK Solberg. 1988. The prevalence of dental attrition and its association with factors of age, gender, occlusion, and TMJ symptomatology. J Dent Res 67(10):1323-1333.

Shikata H, N Utsumi, and D Fujimoto. 1987. Collagen in aging bone of the jaw. In: The Aging Mouth. Ferguson DB, ed. Basel Karger. pp.85-95.

Ship, JA. 1992. Oral sequelae of common geriatric diseases, disorders, and impairments. Clin Geriatr Med 8(3):483-497.

Sillman, JH. 1964. Dimensional changes of the dental arches: Longitudinal study form birth to 25 years. Am J Orthod 50(11):824-842.

Sinclair, PM and RM Little. 1985. Dentofacial maturation of untreated normals. Am J. Orthod 88(2):146-156.

Siriwat, PP and JR Jarabak. 1985. Malocclusion and facial morphology: is there a relationship? An epidemiologic study. Angle Orthod 55(2):127-138.

Smith, BGN and JK Knight. 1984. A comparison of patterns of tooth wear with aetiological factors. Br Dent J 157:1619.

Smith, BGN and JK Knight. 1984. An index for measuring the wear of teeth. Br Dent J 156:435-438.

Smith, JR and DW Lincoln. 1984. Aging of cells in culture, Int Rev Cytol 89:151.

Southard, TE, KA Southard, and EA Tolley. 1992. Periodontal force: a potential cause of relapse. Am J Orthod Dentofac Orthop 101(3):221-227.

Southard, TE , RG Behrents, and EA Tolley. 1989. The anterior component of occlusal force. Part 1. Measurement and distribution. Am J Orthod Dentofac Orthop 96(6):493-500.

Southard, TE, RG Behrents, and EA Tolley. 1990. The anterior component of occlusal force. Part 2. Relationship with dental malalignment. Am J Orthod Dentofac Orthop 97(1):41-44.

Southard, TE, KA Southard, and LW Weeda. 1991. Mesial force from unerupted third molars. Am J Orthod Dentofac Orthop 99(3):220-225.

Southard, TE. 1992. Third molars and incisor crowding: when removal is unwarranted. J Am Dent Assoc 123:75-79.

Speck, TN. 1950. A longitudinal study of developmental changes in human lower dental arches. Angle Orthod 20(4):215-228.

Staley, RN., WR Stuntz, and LC Peterson. 1985. A comparison of arch widths in adults with normal occlusion and adults with Class II, division 1 malocclusion. Am J Orthod 88(2):163-169.

Stedman, TL. 1982. Stedman's Medical Dictionary. Twenty-fourth edition. Williams and Wilkins, Baltimore, Maryland.

Stern, JA, PJ Oster, and K Newport. Reaction time measures, hemispheric specialization and age. Aging in the 1980's. LW Poon (Ed.). American Psychological Association, Washington D.C.

Stutzmann, JJ and AG Petrovic. 1989. Responsiveness of alveolar bone to orthodontic treatment in adult patients. Monograph 22 Craniofacial Growth Series. Center for Human Growth and Development. University of Michigan, Ann Arbor, Michigan. p:181-199.

Sullivan, B, TJ Freer, D Vautin, and KE Basford. 1991. Occlusal contacts: comparison of orthodontic patients, posttreatment patients, and untreated controls. J Prosthet Dent 65(3)232-237.

Suzuki, A and Y Takahama. 1991. Parental data used to predict growth of craniofacial form. Am J Orthod Dentofac Orthop 99(2):107-119.

Tallgren, A and B Solow. 1991. Age differences in adlut dentoalveolar heights. Eur J Orthod. 13(2):149-156.

Tallgren, A. 1957. Changes in adult face height due to aging, wear, and loss of teeth and prosthetic treatment. Acta Odontol Scand (suppl 24):7-122.

Tice RR, and RB Setlow. 1985. DNA repair and replication in aging organisms and cells. In: Handbook of the Biology of Aging. Second edition. New York, Van Nostrand Reinhold Company. p:173-224.

Tonna, EA. 1960. Osteoclasts and the aging skeleton: a cytological, cytochemical and autoradiographic study. Anat Rec 137:251-260.

Van der Linden, FP. 1991. The role of the occlusion in the development of the dentition and facial growth, in orthodontic diagnosis and treatment, and in retention. Monograph 24. Craniofacial Growth Series, Center for Human Growth and Development , The University of Michigan, Ann Arbor, Michigan. 123-143.

VanKirk, L and EH Pennell. 1959. Assessment of malocclusion in population groups. Am J Public Health 49(9):1157-1163.

Vego, L. 1962. A longitudinal study of mandibular arch perimeter. Angle Orthod 32(3):187-192.

Weintraub, JA and BA Burt. 1985. Oral health status in the United States: tooth loss and edentulism. J Dent Educ 49(6):368-76.

Whittaker, DK, T Molleson, AT Daniel, JT Williams, P Rose and R Resteghini. 1985. Quantitative assessment of tooth wear, alveolar-crest height and continuing eruption in a Romano-British population. Arch Oral Biol 30(6):493-501.

Witter, DJ, P van Elteren, and AF Käyser. 1987. Migration of teeth in shortened dental arches. J Oral Rehabil. 14:321-329.

Wolkenstein, AS. and DJ Butler. 1992. Quality of life among the elderly: self-perspectives of some healthy elderly. Gerontology & Geriatrics Education 12(4):59-68.

Woods, GA. 1950. Changes in width dimensions between certain teeth and facial points during human growth. Am J Orthod 36(9):676-700.

Xhonga, FA. 1977. Bruxism and its effect on the teeth. J Oral Rehabil 4:65-76.

Yaffe, A, N Hochman, and J Erlich. 1992. A functional aspect of anterior attrition or flaring and mode of treatment. Int J Prosthodont 5(3):284-289.