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Association between dietary factors and malocclusion

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ASSOCIATION BETWEEN DIETARY FACTORS AND MALOCCLUSION

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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To my wife, Genevieve, for her dedication and example of perseverance.

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CHAPTER I

INTRODUCTION

In 1900, Angle classified malocclusions of the permanent dentition based on the first molar and canine relationships. (Angle, 1900) Since that time, the study and treatment of malocclusions has expanded dramatically. The American Association of Orthodontists (AAO) estimates that more than 3 million people in the United States wear braces every year. In addition, dental malocclusion affects roughly two-thirds of the population of the United States. (Proffit et.al., 1998)

Although orthodontic treatment is a good solution for correcting malocclusion, there is a significant disparity in treatment associated with household income of the family. (Whitesides et.al., 2008) In contrast, there is no difference in malocclusion prevalence based on socio-economic status. (Proffit et.al., 1998) According to Proffit et.al. (1998), treatment occurs more frequently in upper income groups (25-30%), with approximately 5% of those in the lowest income group and 10% to 15% of those in intermediate income groups reporting being treated.

In spite of the discomfort and cosmetic concerns associated with treatment, orthodontic care fills a need that exists based on prevalence in society, as well as an impact on function. It has been noted (Warren et.al., 2003) that the prevalence of malocclusions has increased in the past century. It is unclear why the prevalence has increased, but malocclusion is considered a disease of westernization (Corruccini et.al., 1983). The etiology of most malocclusions is not clear.

The etiology of malocclusions has been attributed to genetic and environmental factors affecting each individual (Proffit et.al., 2000). There are some tendencies for certain orofacial structures such as jaw size and tooth size to be hereditary. Environmental factors such as the lack of use or over-use of masticatory muscles and the presence of oral habits also affect the jaws and teeth. The interactions between genetic and environmental components contribute to the balance of the tooth/jaw complex to determine the equilibrium and occlusion for each individual. An imbalance can, but does not necessarily, lead to malocclusion. More needs to be understood about both the genetic and environmental variables that can affect the occlusion. Among the possible environmental contributions to occlusion, there are many factors, of which the diet appears to be one. However, the role of the diet and its effect on malocclusion is not well defined. (Proffit et.al., 1998)

This study will investigate dietary factors and how they are associated, if at all, with specific forms of malocclusion. Certain eating habits (Luz et.al., 2006) and non-nutritive habits have been associated with malocclusions. (Warren et.al., 2005) Other abnormalities in nutrition have also been linked to bone malformation, as well as cartilage disturbances. Some previous studies have hinted that dietary factors may affect jaw development, tooth size, as well as bone formation. (Lombardi, 1982) This study will examine dietary factors and their associations with malocclusions such as crowding.

In summary, dental malocclusion is a problem that affects nearly two-thirds of the population of the United States. There are some solutions to correcting the problem such as orthodontic treatment. The etiology of malocclusion is not well understood, but they are thought to stem from genetic and environmental effects. If the etiology were better understood, then it may be possible to reduce part of the burden of treatment and shift toward the prevention of the disorder. More needs to be understood about what contributes to the environmental effects on malocclusion. This study will address one potentially important environmental influence, dietary factors.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter will develop the background and significance of the studies that have led to the current investigation about the effect of diet on dental crowding and malocclusion. The current literature on the etiology of malocclusions will be summarized, as will be the prevalence of and different types of malocclusions. The effects of dietary factors on malocclusions will be discussed, as presented by the current and past scientific literature. Finally, a summary and research question will be presented.

Malocclusions Defined

The term malocclusion refers to the misalignment of teeth and/or an incorrect relation between the teeth of the maxilla and mandible. (Proffit et.al., 2000) In the 1890s, Edward H. Angle, who is considered the father of modern orthodontics, was the first to classify malocclusions based on the first permanent molar relationship. (Angle, 1900) According to Angle, normal occlusion involved the alignment of the maxillary and mandibular first molars in such a way that the mesiobuccal cusp of the maxillary first molar aligned with the mesiobuccal groove of the mandibular first molar. Any variation from this resulted in different types of classes of malocclusion. (Proffit et.al., 2000)

Severely misaligned, irregular, and maloccluding teeth may cause various problems for people. They can cause difficulties with oral function (e.g., swallowing, chewing, speech) (Subtelny et.al., 1973), less esthetic facial appearances, and increased risk for oral disease, such as trauma (Shulman et.al., 2004), tooth decay (Helm et.al., 1989), and periodontal disease (van Gastel et.al., 2007). Although some minor malocclusions might be an esthetic concern, this may have a strong psychosocial effect on the individual, including altered self-esteem, social and interaction responses, and increased awareness of people’s perceptions. (Helm et.al., 1985) Oral function can be affected by malocclusions including, but not limited to, the temporomandibular joint complex, adaptive functions of swallowing, speech modifications, mastication inefficiency, and muscle fatigue. Although the lips, tongue, and masticatory complex are adaptive in nature, severe malocclusions can present extreme circumstances where these structures cannot be compensated. Lastly, malocclusions can increase the individual’s risk for disease. Protrusion of the maxilla and retrusion of the mandible can increase the risk for trauma to the maxillary incisors. (Shulman et.al., 2004) Oral hygiene and plaque removal can be altered due to misalignment and crowding of the dentition, which can increase the risk for periodontal disease and caries. (Helm et.al., 1989)

Epidemiology of Malocclusion in the United States

Occlusal discrepancies and malocclusions are one of the most commonly reported problems among children and adolescents. At the simplest level, crowding is caused by a combination of factors that lead to insufficient space. As part of a national survey of healthcare problems and needs in the United States, estimates of orthodontic needs and malocclusions were included in the National Health and Nutrition Examination Survey (NHANES) during the years 1989-1994 (NHANES III). For the population age 8-17, the percentages of the U.S. population with an anteroposterior malocclusion as defined by Angle’s classification were: Class I Malocclusion (50%), Class II Malocclusion (19%), and Class III Malocclusion (1%), with the remaining 30% normal. (Proffit et.al., 1998) Within these groups of malocclusions were other types of misalignment of teeth. Just over half (53%) of U.S. children age 8-11 had well-aligned incisors, while the rest of the children

(47%) had varying degrees of misalignment ranging from 2-15 mm of crowding. As age increased, the percentage of adolescents and adults with well-aligned incisors decreased to 42% for ages 12-17 and 37% for ages 18-50. (Proffit et.al, 1998)

Posterior crossbite is a deviation from normal occlusion in the transverse plane. The percentage of posterior crossbite is about nine percent at all age groups. (Proffit et.al, 1998) Other deviations from normal are present in 59% of the population, with most of the malocclusion being mild. (Proffit et.al, 1998)

Overjet is defined as the horizontal overlap of the incisors in the antero-posterior plane. About 40% of the population has a normal overjet (0-3 mm), while approximately 40% has an overjet that is slightly increased (3-4mm). (Proffit et.al., 1998) The remaining population either has a negative overjet or a large overjet that is usually accompanied by a Class II malocclusion. (Proffit et.al, 1998)

Overbite is the vertical overlap of the incisors and open bite is the lack of overlap of these same teeth. Zero to two mm of overlap is considered normal for overbite. Nearly 48% of the population has normal overbite, with 3% having some form of open bite where the anterior teeth do not vertically overlap. (Proffit et.al., 1998) Although these are estimated national percentages, there is a wide range of variation in the malocclusions present in the United States. (Proffit et.al., 1998)

Etiology of Malocclusions

Many causes of malocclusions have been identified. Some of these include disturbances in embryologic development (Johnson, 1995), skeletal growth disturbances, muscle dysfunction (Ferguson, 1993), acromegaly (Lamberts et.al., 1997), disturbances in dental development (Becker et.al., 1997), genetic influences (Chung et.al., 1971), environmental influences (Corruccini et.al., 1990), changes in the soft tissue equilibrium, early loss of primary teeth, masticatory function (Kiliaridis, 1995), digit or pacifier sucking (Larsson et.al., 1985), tongue habits (Proffit, 1972), and soft diets (Ciochon et.al., 1997). The exploration of the etiology of all types of malocclusion is beyond the scope of this project. However, the etiology of significant crowding will be explored.

Although the prevalence of malocclusions has been widely reported, less has been reported concerning the factors associated with malocclusions. While many malocclusions are believed to be associated with genetic or inherited factors, there also are indications for environmental considerations. (Warren, 2005) Some environmental factors that have been associated with malocclusions include diet, mastication forces, extra-oral habits, non-nutritive sucking, habitual mouth breathing, and early loss of primary teeth. (Corruccini et.al., 1990)

Genetic considerations in orthodontics, and dentistry in general, are becoming more widely investigated. However, little is known about the specific genetic factors from parents and offspring that may cause an increase in malocclusion prevalence. Some have speculated and studied the similarities and differences between jaw size, tooth size and total arch size among father, mother and child. (Hu et.al., 1991)

Others researchers have postulated that the increased malocclusion from westernization comes from increased mixing of genetic information as different populations interact. (Brown et.al., 1987) As different groups of people intermix, the expression of different dental, orofacial and skeletal features can create imbalances in the maxillofacial complex leading to dental and skeletal malocclusions.

Environmental factors have been explored sporadically throughout the previous century. Non-nutritive sucking is perhaps the most widely accepted factor associated with anterior open bite and decreased maxillary arch width (DaCosta et.al., 2002). Another contributing factor to the narrowing of the maxillary arch is mouth breathing. The extra inward stress on the maxillo-mandibular complex placed by the cheek, buccinator and obicularis oris during mouth breathing has been associated with narrow maxillary arch. (Gois et.al., 2008)

Human development of the jaws occurs early in life. Inter-canine width is established by the eruption of the primary canines around age 2. This dimension is stable through the eruption of the permanent canines and decreases slightly after eruption of these teeth. Genetic factors play a role in determining inter-canine width as do environmental ones, which includes the diet. It is unclear, however, the contribution and relationship these factors have on crowding and malocclusion. (Bishara et.al., 1997)

It is generally accepted that the prevalence of malocclusion has increased in modern times. The reasons for this are unclear, but a prominent theory holds that changes in diet may explain some of the increased prevalence of malocclusion. The remainder of this review of literature will focus on studies that have investigated the relationship between diet and malocclusion. (Corruccini et al, 1990)

Literature Search

In order to better understand dietary effects on malocclusions, a review of the literature was conducted. Key words such as dental crowding, malocclusion, tooth size/arch length discrepancy (TSALD), diet, soft foods, mixed dentition, and Angle classifications were used. A PubMed search was initially used to search for articles. The search was limited to articles in English. A total of 36 articles about crowding, diet and/or malocclusion were found, of which seven articles were highly relevant to the topic at hand. A review of those articles is found in the next section. They were divided into the following sections:

1. Anthropologic Studies of Occlusion
2. Crowding
3. Dietary Components and Dental Considerations
   a. Diet consistency
   b. Fluoride and Dental Morphology
   c. Mastication Forces

<u>Anthropologic Studies of Occlusion</u>

Much information has been garnered by comparing the contemporary anatomy of the dentition and jaw to those of previous populations. As outlined by Lindsten and colleagues (2002), there has been a general increase in the size of human teeth in the past century. There has also been shown to be a reduction in the length of the lower jaw in modern human skulls when compared to primitive human populations. (Nicholoson et.al., 2006) This combination of tooth size increase and jaw size decrease has coincided with an increase in dental crowding and with the westernization and industrialization of the world. Along with cardiovascular disease and diabetes, malocclusions have been labeled “diseases of westernization.” (Corruccini et.al., 1983)

The effects of malocclusion can be seen in as little as one generation from the time of westernization based on studies by Corruccini. (Corruccini et al, 1990) Corruccini and colleagues conducted a matched case control study based on the Australian aboriginal tribes from the Yuendumu area. It is known that before industrialization, nomadic tribes ate with no utensils and their diet was composed of foodstuffs rarely cooked or processed. As a result, eating required a vigorous masticatory effort, they had very low caries rates, and they had high attrition, both on the occlusal surfaces and interproximally, with nearly perfect (Class I) occlusion.

The aims of the study were to explore the variations in dental occlusion related to industrialization and modernized dietary habits (Corruccini et.al., 1990). The study was conducted by collecting a convenience sample of dental casts from two different groups of individuals from years 1951 and 1971. The data collection included other demographic information about each individual. The cohort was divided based on birth year, with the older group being born before 1937 (48 individuals) and the younger group consisting of people born in 1937 or later (48 individuals). These two groups were matched to another group of 48 samples from pre-contact aboriginal crania from the South Australian Museum. Occlusal variables studied included overbite, overjet, posterior crossbite, buccal segment relationship, tooth rotation and displacement, and maxillary arch length and width.

Statistical analyses included Mann-Whitney U tests, chi-square tests, and F-tests. The results showed no statistically significant differences by gender, except for maxillary arch breadth and length, with males having wider and longer arches. The younger (industrialized) Yuendumu cohort had a statistically increased overbite, overjet, and more malocclusions of all classes, according to Angle's classification, as well as greater rotation, and displacement. There were no statistically significant differences among the cohorts for posterior crossbite or buccal segment relationship. The authors concluded that, overall, there was a shift or change in occlusal variables from occlusal harmony to a state of occlusal imbalance and attributed the majority of the assumed changes to dietary modification that occurred in the Yuendumu settlement during the years of the study. There were many limitations of the study. Although there was some increased gene mixing during this time, most of the Yuendumu tribe continued previous cultural trends of marrying within the tribe. Also, the diet shift from hunting and gathering to industrialized foodstuffs was not clear-cut and did not occur immediately. Rather, it was a gradual shift, so that occlusal changes may have been less than with an abrupt change.

Another study by Corruccini and colleagues examined a convenience sampling of casts from two cohorts of Pima American Indians (Corruccini et.al., 1983), the older group from 1949-1957 (67 individuals) and the younger group from 1963-1969 (274 individuals). The diets of these two cohorts were studied extensively at the group level cross-sectionally. The older cohort had a diet that consisted of primarily home-grown beans and stone-ground indigenous corn tortillas. The younger cohort's diet was different due to the opening of a commercial food processing facility on the reservation which provided commercially processed beans and pre-processed industrial cornmeal. These two staples of the diet were considerably more processed and required less vigorous mastication to ingest than traditional foods. Along with these staple foods, the diet was altered further by the availability of packaged foods for the younger generation. A stratified cross-sectional sample was selected for each of the two cohorts. The average ages of the cohorts were 14.7 for the younger and 27.7 for the older Pima Amerinds. Measured variables included Angle classification of occlusion, arch size, arch depth, overjet, overbite, crossbite, buccal segment relation (BSR), crowding, rotation and displacement (R/D), treatment priority index (TPI), and premature deciduous tooth loss (PDTL). Of these variables, there was a significant increase in the younger cohort as compared to the older cohort for overbite, BSR, class II malocclusions, R/D in the posterior teeth, arch depth, and a decrease in arch width. Overall, there was a statistically significant increase in crowding and malocclusion in the younger cohort.

Although these findings were statistically significant, the author recognized certain limitations that may have confounded the effects of the dietary factors. There could have been biased sampling in the older group, since the inclusion criteria required individuals to have nearly intact dentitions. In addition, only the younger generation received benefit from a post-WWII dental clinic that was opened on the reservation. Lastly, the dietary changes between groups cannot be identified as a complete shift from one to the other, since some individuals may have still obtained and prepared foods according to the traditional methods. However, the authors concluded that the change in masticatory function due to dietary changes was a likely factor in the increase in malocclusion measurements in the younger Pima Amerinds.

Another study conducted by Corruccini and Whitley (1981) examined occlusal variation in a rural Kentucky community. The study was a cross-sectional stratified sampling of 180 rural residents within a 20 mile radius of an isolated community. The area was selected based on relative isolation, no dental treatment beyond emergency extractions, and an acute change in diet 25 years before the sampling took place. The study consisted of bite impressions in thin wax for occlusal relationships, bigonial mandibular breadth, dietary information, age, and birthplace of participant and parents.

Occlusal characteristics were taken from the bite impressions and included overjet, anterior overbite, posterior crossbite, R/D, BSR, and posterior open bite. These were used to calculate the tooth priority index (TPI) (Kowalski et.al., 1976) for each subject. This index assigns weights to five variables that deal with occlusion (overbite/open bite, overjet, posterior crossbite, first molar buccal segment relation, and tooth displacement). Dietary information was used to categorize individuals into four categories: modern (entirely commercially purchased), semi-modern (beef is the basic meat, garden foods supplement purchased foods), semi-traditional (beef and cornmeal are commercially purchased, dried pork and garden foods supplement purchased foods), and traditional (dried salt-cured pork is the basic meat, hunting is practiced, cornmeal is stone-ground, wild and garden foods complement the diet).

The results of the study were that diet showed a stronger correlation with TPI than did age, and this association was still significant after adjusting for age. The author argued that occlusal transition could not have been due primarily to genetic variations, since this study constituted a single breeding population with little or no genetic influx. However, the authors recognized that genetic effects may have influenced predisposition to traits that affected malocclusion and that the environmental influences on the oral structures remained present.

Crowding

Over the years, specific protocols for measurement of the maxillary and mandibular arches have faded in and out of fashion. One that has remained vital to the orthodontic profession is Tooth Size/Arch Length Discrepancy (TSALD). TSALD is a well-established way to assess crowding of an individual. This measurement is based on the sum of arch length measurements and subtraction of the arch length sum from the sum of mesiodistal tooth sizes. (Warren et.al., 2003) By taking the sum of measurements around the dental arch, it is possible to come up with a total arch length for maxillary and mandibular arches. Then, by measuring the mesiodistal width for each individual tooth, a final measurement for tooth size is completed. TSALD is computed from these two numbers by subtracting the total tooth sizes from the total arch length in the maxillary and mandibular dentition. A negative number indicates that there is crowding (i.e., more tooth size than arch length) and a positive number indicates spacing. It has been reported that TSALD increases from primary to mixed dentition, as well as from mixed to permanent dentition. (Warren et.al., 2003)

A study by Warren and colleagues (2003) focusing on the topic of increased crowding in contemporary children reported that there had been an increase in crowding, which correlates to a decrease in TSALD, in the deciduous dentition of contemporary children compared with children from 50 years earlier. This was supported by the idea that arch lengths were significantly shorter in contemporary children. The study looked at secondary data from two cohort studies done in Iowa. The retrospective study looked at data from 199 contemporary children from the Iowa Fluoride Study (IFS) from 1996-1999. The older sample of children came from the Iowa Growth Study (IGS) data collected in the late 1940s and had records for 175 children. Each subject had casts and recorded data from exams performed at about 4 ½ -5 years of age. Measurements were made on all casts using digital calipers accurate to 0.05 mm (Mitutoyo Corp., Tokyo, Japan) and performed by a single examiner. Results from this study found that crowding of the deciduous dentition, as measured by TSALD, was statistically significantly greater in the contemporary sample population. This was true for both sexes, but particularly in girls. Limitations for this study include no a priori hypothesis and the study group was not heterogeneous. The authors stated that further research is needed to determine if this same association continues into the permanent dentition.

Dietary Components and Dental Considerations

Diet Consistency

Animal experiments done with induction of soft versus hard diets have shown mandibular and maxillary arch growth differences. A study by Ciochon and colleagues (1997) found that, when pigs were fed a soft diet, jaw development was less prominent compared to the normal diet pigs. This underdevelopment was seen both in arch width, as well as arch length. Arch width was measured as the distance in millimeters between the mesiobuccal cusps of the permanent first molars. Arch length was measured as the distance from the inter-incisal point to a horizontal line drawn between the distobuccal cusps of the permanent first molars. The study was conducted by raising eight Yucatan minipigs for eight months, four on hard diets and another four on equivalent softened diets. The hard diet consisted of commercially available pelleted chow. The soft diet consisted of the same pellets that were crushed and mixed with an equal volume of water. After the eight month period, the animals were sacrificed and occlusal/osteometric data were collected. After controlling for other possible etiologies of malocclusion (caries, periodontitis, attrition, genetic background, respiratory mode, and interproximal attrition), results supported the idea that dietary consistency is associated with dental malocclusion, specifically narrow maxilla.

Fluoride and Dental Morphology

Although the soft diet theory has been explored, the individual components of the diet can also play a role and may have a relationship to the malocclusion. One theory that has not been explored much is that systemic fluoride may have an effect on the development, morphology and size of the teeth. (Goose, 1979)

Goose and colleagues reported in a study from 1979 that systemic fluoride may be related to larger crown size. (Goose, 1979) This study was conducted in the United Kingdom on the island of Anglesey, where water fluoridation had been recently introduced. By sampling the parents (no systemic fluoride during tooth development) and children (fluoride during tooth development), they could control for most of the genetic variation in tooth size. Dental casts were gathered from 28 families and mesiodistal tooth dimensions were recorded and compared for the parent/sibling groups. They also used a mainland sample of 123 families as a control. The authors concluded that offspring tooth dimensions were significantly larger and they associated this with the change in water fluoridation. However, this study did not account for possible confounding factors or control for complete genetic variation in tooth size. Although the age range of the parents is not given in the methods, the parental group may have been affected by the World War II era including a change in supply of food and diet quality.

Mastication Forces

The force of mastication has been shown to affect the maxillo-mandibular complex and is a factor in determining occlusion. With the force of occlusion, four of the five muscles of mastication contribute to shaping the lower jaw, temporomadibular joint complex, ramus height, coronoid process, and maxillary width. Previous studies have shown the relationship among the maxillary width and mandibular length as the mastication force increases. (Katsaros, 2001) Conversely, results with animal models have shown that by induction of a soft diet, there occurs a narrowing of the maxillary arch (Yamamoto, 1996). Sixty inbred rats that were 14 days old were divided into two groups. One group was fed a solid diet in addition to milk, the other group received the same diet, but in liquid form. Vital staining was used to record bone apposition longitudinally. This consisted of injections of tetracycline HCL (20 mg/kg) and dotite calsein (8 mg/kg) after 48 and 55 days of life, respectively. All animals were sacrificed, processed and analyzed with anatomical measurements made by measuring the distance between the most external cervical points of the distobuccal cusps of the maxillary canines, as well as the most external cervical points of the distobuccal cusps of the maxillary first molars. The conclusions were that the difference in growth patterns induced by different food consistencies was caused by a difference in mechanical force of the masticatory muscles acting on the muscle insertion areas, as well as differences in growth patterns in the region of occlusal loading.

Another study by Larson and colleagues (Larson et.al., 2005) was done to investigate the idea that reduced maxillary arch width is associated with a decrease in function. However, the findings did not support the hypothesis that softer diets were associated with a decrease in arch width. Their samples size of 17 pigs (indoor group n=8, outdoor group n=9) were weaned at 5 weeks of age and divided into two cohorts: an indoor soft diet group and an outdoor hard diet group. The soft diet consisted of barley, oats, soya, and vitamin supplements mixed with water, with dry matter content around 25%. The hard diet group was fed solid foods. After 22 months of life, all animals were sacrificed, sectioned and measured in the transverse and sagittal dimensions. The authors found that the hard diet cohort had considerably more occlusal and interproximal attrition, resulting in shorter arch lengths, mesial migration of the posterior teeth, and a reduced tendency for crowding and rotating of the anterior teeth. They also found that the hard diet cohort had narrower arch widths and a higher prevalence of posterior crossbite. The soft diet group had a larger arch width, especially in the premolar region, and the authors mentioned that this may be due to an atypical tongue habit or swallowing mechanism. Although some of the findings in this study are supportive of other studies (increased attrition, both occlusal and interproximal), other findings are not. In particular, they found that the hard diet group had shorter arch lengths and narrower arch widths. This may be due to some of the underlying limitations in this study. There was no mention as to the genetic background of the subjects or how they were chosen. Also, the small sample size may have limited the ability to provide sufficient power.

Masticatory force has also been linked to tooth eruption and biting force. Decreases in masticatory force and duration can lead to supra-eruption, especially in the posterior teeth (Profitt et.al., 1993). This changes the oro-facial complex and increases lower facial height, which may be associated with malocclusion.

Westernized Diet

Modern industrialized Western society is characterized by dental occlusion that has greater variability than in the past. Many times this variation exceeds the normal limits and results in malocclusion. About 50% of adolescents in the United States show a need for orthodontic treatment, with a treatment need rating at mandatory or desirable. (Kelley and Harvey, 1977) Many studies pin the cause of malocclusion on genetic factors that would make it difficult to prevent. However, there is evidence from Corruccini et.al. (1983) that westernization of the diet is associated with an increase in frequency of all classes of malocclusions. Similar to heart disease and diabetes, malocclusions seem to be “diseases of westernization” and have a higher prevalence in urban society. For the most part, the United States represents a country in which almost all parts of society have made a complete shift to industrialization.

A westernized diet is considered to be high in refined carbohydrates and processed foods, and relatively low in unrefined grains, such as coarse cornmeal, rice and other unprocessed fibrous foods. Although there may be sufficient fiber and protein in westernized diets, the type of fiber is so processed that sometimes it takes the form of a powder that is soluble in liquid. In summary, the degree of processing before consumption determines the level of westernization of the diet. As the diet becomes more “westernized”, the prevalence of malocclusions has been shown to increase. (Corruccini et.al., 1983)

Iowa Fluoride Study

The Iowa Fluoride Study (IFS) is a longitudinal cohort study conducted in eastern and central Iowa. The IFS recruited a convenience sample of 1,882 mothers with newborns from eight Iowa hospitals over a 36-month period from March 1992 to February 1995. (Levy et.al., 1998) The primary aim of the study was to assess fluoride intake and exposure prospectively and assess relationships with oral health, specifically dental fluorosis and dental caries. (Levy et.al., 1998; Levy et.al., 2005) Multiple fluoride sources were assessed, with food and beverage intake records collected periodically from birth. Many articles describing the relationships between fluoride exposures and dental fluorosis and dental caries have been published. (Levy et.al., 2002) In general, the analyses have found that reduced caries experience in the primary dentition was related to greater fluoridated water consumption (Levy et.al., 2003).

Other analyses have used the IFS data to examine factors related to occlusion and non-nutritive sucking. Warren and colleagues (2001) examined the association of oral habits and their duration on dental characteristics in the primary dentition. The prospective, longitudinal study included data on non-nutritive sucking and dental arch characteristics for

372 children around age 5 who were part of the IFS. Parameters were measured on study models with calipers and included arch depth (anterior and posterior), arch width (intermolar and intercanine), arch length (anterior and posterior), palatal depth, overjet, and overbite. Results showed that non-nutritive sucking was ubiquitous, with 97.8% of all subjects engaging in a habit at some point. Habits of 48 months or longer produced the greatest changes in occlusal and dental arch characteristics. Habits of shorter duration (24 to 47 months) had detectable differences from those with habits of minimal duration (<12 months).

This study used data from the IFS to assess the relationship between occlusal discrepancies/crowding and dietary factors among subjects. The cohort subset for these analyses consists of approximately 300 subjects who have dental cast information, as well as dietary information from birth.

Summary and Research Question

In summary, limited evidence suggests that diet may contribute to the etiology of malocclusion. Specifically, soft diets and resulting reduced mastication effects are thought to contribute to crowding; however, studies suggesting these relationships had significant limitations, including rather crude measures of diet and crowding. Thus, further research is needed. The research question for this study, therefore, was:

Is there an association between dietary factors and malocclusion, specifically crowding? More specifically, do fiber, solid energy and vitamin intakes have an association with increased crowding, as assessed using TSALD?

CHAPTER III

MATERIALS AND METHODS

Introduction

The aim of this study was to evaluate the dietary effects on occlusal characteristics among a subset of children enrolled in the Iowa Fluoride Study (IFS). Existing longitudinal data from the IFS were used for the purposes of addressing the aims of this study; thus is considered secondary data analysis of previously gathered data from the IFS. The methods will be outlined in general, followed by the specific methods used for this study, including the hypotheses and operational definitions. The approval process for conducting this research will also be discussed. The chapter will conclude by giving information on statistical methods, as well as data management for the study.

Institutional Review Board (IRB)

Approval from the University of Iowa Human Subjects Review Committee was obtained through an expedited process due to the nature of the data used for the project. Since prior IRB approval had been obtained for the Iowa Fluoride Study, the secondary data analysis for this project did not require separate, specific IRB approval. All regulations and rules of confidentiality were followed according to the University of Iowa IRB's protocols.

Iowa Fluoride Study (IFS) Main Study

Study Population and Recruitment

The primary IFS started in 1992 and enrolled 1,882 newborn participants and their mothers. There were 1,534 mothers who declined to participate in the study. There were 1,375 that participated after recruitment, and although there was some attrition that continued throughout the study, it remained very low. Informed consent was obtained from participants at the time of recruitment following approval of the study by the University of Iowa Human Subject's Review Committee (Levy et.al., 1997; Levy et.al., 2002). The recruitment and sampling of participants in the IFS was a convenience sample, not a random sample. The aims of the IFS were to study the children's fluoride exposures, biological and behavioral factors, and oral health (Levy et. al., 1998).

<u>Target Data Collection</u>

At the time of recruitment, detailed information was gathered regarding age, education and income of parents, other family demographics, and dietary information. This information was gathered by means of questionnaires developed and pilot tested on a separate sample of participants in a prior study. Additional questionnaires including 3-day food and beverage diaries were sent to participants when the children reached the ages of 6 weeks, and 3, 6, 9, 12, 16, 20, 24, 28, 32, and 36 months; and semi-annually after that (Hamasha et. al., 2006). Each questionnaire included questions concerning fluoride exposure, non-nutritive sucking and dietary intake during the previous time period for the child. Follow-up mailings were sent to non-respondents after 3 weeks and again after 6 weeks.

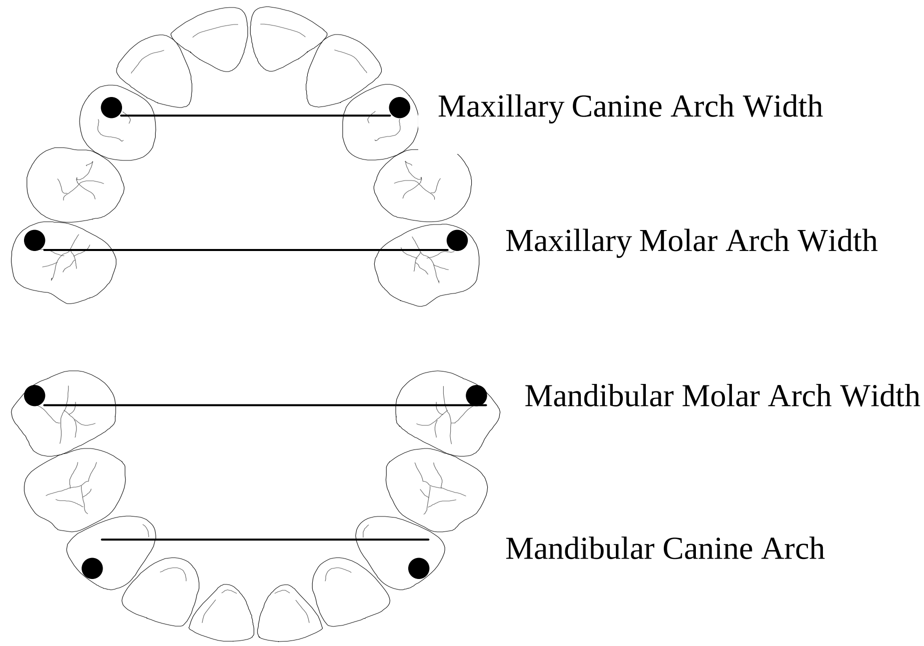
<u>Clinical Examination and Patient Record Collection</u>

As part of the IFS, subjects were examined at about 5 years of age, about 9 years of age, about 13 years of age, and currently about 17 years of age. The clinical exams were performed by a calibrated examiner using a portable chair, exam light, explorer, and DenLite® illuminated mirror system. (Warren et.al., 2003) For the examination, the primary aims were to record caries by surface, assess fluorosis levels (if any), and record the occlusion.

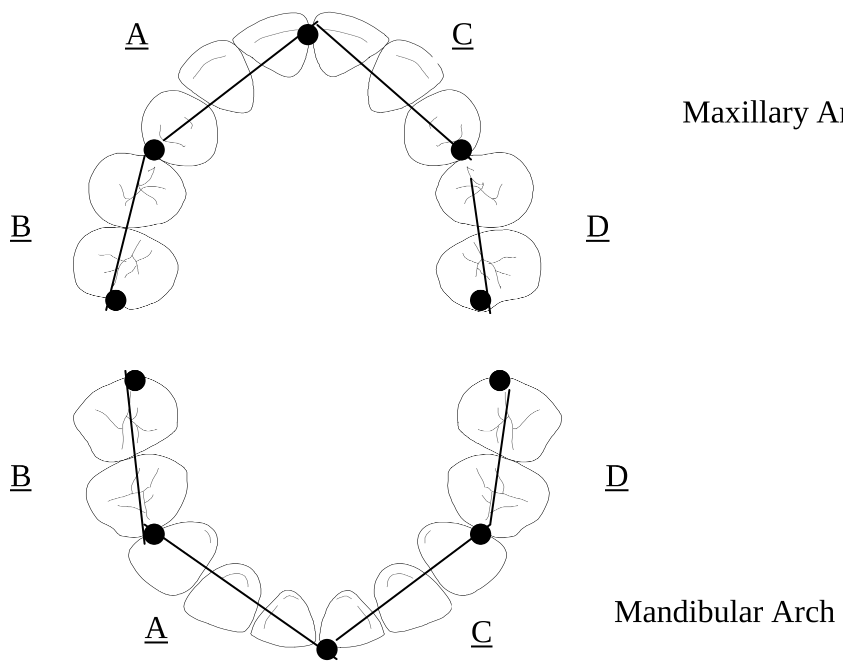
At the time of these exams, alginate impressions of the maxillary and mandibular arches were made on children who assented and were able to complete the procedure. Those who gagged excessively, had special needs, and /or were unable to cooperate were excluded. In addition to the impressions, wax bite registrations were made to record centric occlusion for each patient. This was done by placing a wax bite wafer on the maxillary teeth and assisting the child to bite in centric occlusion. (Warren et.al., 2001) After the impressions were made, the models were poured in yellow dental stone, labeled, and trimmed to centric occlusion using the wax bite registration. (Warren et.al., 2003) The models were hand articulated using the wax bite registration for analysis of occlusal characteristics.

Occlusal characteristics were assessed from the articulated casts and recorded for each subject and included the Angle classification of canine and molar relationship, presence of anterior or posterior crossbite, presence of open bite and presence of overjet of 4mm or greater. (Warren et.al., 2003) Other factors that were measured included amount of overbite, and overjet, , arch width, arch length (summation of anterior and posterior arch segments), arch depth and tooth size (mesio-distal width) . (Warren et.al., 2003) Measurements were made directly on the dental casts by one examiner (Dr. T. Yonezu -TY) using calipers accurate to 0.05 mm (Mitutoyo Corp., Tokyo, Japan). (Warren et.al., 2003) Canine arch width was measured (TY) between the tips of the canines in the maxillary and mandibular arches, for both the age 5 and age 9 exams. Molar arch widths were measured between the tips of the mesiobuccal cusps of the left and right most posterior molar (primary second molar for age 5, permanent first molar for age 9). Arch length was measured (TY) by dividing the arch into anterior and posterior segments as shown in Figure 1. (Warren et.al., 2003) The posterior segment was calculated by measuring from the distance from the most distal point of the canine to the most distal point of the most posterior tooth (primary second molar for age 5, permanent first molar for age 9). This was done for both the right and left sides and the sum comprised the total for the posterior segment in both the maxilla and mandible. The anterior segment was measured by summing the length of the most mesial point of the central incisor to the most distal point of the canine for both right and left sides. The maxillary anterior and posterior segments were totaled for a maxillary arch length. Similarly, this was done for the mandible.

TSALD is comprised of two components, a summation of each tooth size in the arch and the total arch length as described above. Tooth size was measured (TY) from most mesial to most distal point of each tooth in the arch. These tooth dimensions were then totaled to comprise the tooth size total of each arch for each individual. This number when subtracted from the arch length produces the tooth size/arch length discrepancy (TSALD). A positive number indicates spacing in the arch. A negative number indicates crowding in the arch.



Arch Lengths (Warren, et. al., 2003)



Arch Widths (Warren, et. al., 2003)
Total arch length = A + B + C + D

Figure 1 Arch Lengths and Widths

Dietary Information

Parents were mailed three-day food and beverage diaries when their children were 6 weeks of age; 3, 6, 9, and 12 months of age; every 4 months through 3 years of age; and every six months thereafter until the child was 9 years of age. Parents were asked each time to record the kinds, types, and quantities of all foods and beverages consumed by their children for two weekdays and one weekend day. Parents were given written instructions on how to record information in the diary and what information to include. A sample instruction sheet and diary are included in Appendix A. All diaries, once received, were reviewed for completeness, coded, entered, and verified for accuracy following data imputation by registered dietitians employed by the IFS. Weighted weekly averages were then calculated based on weekday and weekend consumption patterns for each individual. These data were then used to create a food and beverage intake table. (Marshall et.al., 2005)

Dietary intakes were determined at the age of the child for each diary response, which varied from a few days to a few months after the initial mailing. Yearly summaries of dietary intakes for each subject were computed by averaging the daily values each year. A nutrient table was created by the IFS staff from nutrient information obtained from the U.S. Department of Agriculture Research Service (USDA Nutrient Database for Standard Reference, Release 12), the Minnesota Food and Nutrient Database (Nutrition Coordinating Center NDS-R, Version 4.01; University of Minnesota, Minneapolis) and data from food and beverage manufacturers. Microsoft Access (Version SR-1, Microsoft, Redmond, Washington) was used to link the food and beverage intake table and the nutrient table to calculate individual fiber and nutrient intakes. Specifically, data regarding solid energy, protein and fiber, as well as vitamin A and vitamin D, were obtained using this nutrient table. (Marshall et.al., 2005; Marshall et.al., 2003)

IFS Data Entry

All dietary data were double-entered and verified by IFS staff into a relational database and imported into SAS. (v8.0 for Microsoft Windows; Cary, NC: SAS Institute Inc., 1999) Data from study models were entered directly by IFS staff into the SPSS statistical software package (v.11.1, Chicago, IL; SPSS Inc., 2001), (Warren et.al., 2003)

Methods for this Thesis

The IFS study started with 1,882 participants, of whom 1,375 provided at least one response to the periodic mailings during the first years of the study. At the time of the age 5 examinations, approximately 800 subjects were considered to be 'active' in the study, and of these 698 had a clinical exam around age 5. Of these 698 who participated, 547 subjects consented to have impressions made at the 5 year exam, and from these subjects, 526 useable study models were obtained, with 21 models having defects sufficient to make them unusable (Bishara et.al., 2006). The sample of study participants was limited further by those who had enough dietary data from 3-day dietary diaries. Of those IFS participants who had maxillary and mandibular study models at age 5, 168 participants had enough dietary data to be considered for this study. Of those IFS participants who had maxillary and mandibular study models at age 9, 125 participants had sufficient dietary data to be included in this study.

Dietary Data

Dietary information was further broken down into the following time periods: 24-60 months, 60-102 months, and 24-102 months so as to relate to the age 5 and age 9 cast data. Data from each time period, calculated as an area-under-the-curve (AUC) value as explained in the next section, was related to findings from dental casts at the different age periods. The age 5 dental casts were associated with the 24-60 month dietary information. The age 9 dental casts were associated with the 60-102 month and with the 24-102 month dietary information. These time periods were used for several reasons. First, the lower limit of 24 months was used since the diet changes considerably in the first two years of life and this is a time when children are typically transitioned to table foods. The upper limit of 60 months was chosen since that is when the 5-year dental exam occurred for most of the sample. The second time period was chosen with similar guidelines, including an endpoint of 102 months, as that correlates closely with the 9-year dental exam. Since the dietary influence on the development of the dentition and craniofacial complex starts at an early age, the beginning time periods of 24 and 60 months, respectively, were chosen to correlate with the age 9 cast data. An example of this is shown in Table 1.

Table 1 Cast and Dietary Data Groups

Sample Size	*Dental Cast Data*	*Dietary Time Periods*
168	5-year exam	24-60 months
125	9-year exam	60-102 months
125	9-year exam	24-102 months

Dietary Variables

Dietary information from the main IFS study was used for this study. However, due to the focus on dietary coarseness, the data were used exclusive of all liquids. No beverage or other liquid foodstuff was used in this study's dietary data. In addition, six key dietary variables were targeted due to their effect on growth and development. They included solid energy (kcal), fiber (g), protein (g), vitamin D (µg), vitamin A (µg), and a new variable created for this study in an attempt to quantify the vigor of chewing and coarseness of the diet, called chewing factor, which is described in the next section.

For dietary information, AUC estimates were used since not every subject had information at every time point. For each subject, area-under-the-curve (AUC) was computed by a member of the IFS staff by calculating the area of the trapezoid for each segment (between responses). Trapezoidal area was calculated by multiplying the mean intake by the width of the interval. Then the trapezoidal areas were summed and divided by the total age span. These were calculated using the trapezoidal method as described by Hanley and McNeil. (Hanley et.al., 1982) The AUC estimates required values at each endpoint, as well as a minimum amount of values in between the endpoints, for a total number of responses ranging from 4 to 8 (4 for 24-60 month AUC, 4 for 60-102 month AUC and 8 for 24-102 month AUC). AUC estimates reflect overall daily intakes for solid energy (kcal), fiber (g), protein (g), Vitamin D (µg), and Vitamin A (µg). Chewing factor AUC estimates reflect an overall average for all foodstuffs consumed in a day.

<u>Chewing Factor</u>

As previous literature has described, (Corruccini et.al., 1983) chewing cycles or masticatory effort are thought to play a role in the development of the orofacial complex. As a result, a variable was created in an attempt to correlate the vigor of chewing of each subject's diet with the dental cast information.

As part of the dietary classification for the IFS, foods and beverages were classified into different types based on composition. Each food type was then assigned a chewing factor number, which ranged in value on a scale from one to five with the lower number signifying less chewing and the higher number signifying more chewing necessary to create a swallowable bolus. The chewing factor was developed by the primary investigator and a dietitian (TM) as an estimate of the vigor necessary to change a foodstuff from its original form into a swallowable bolus. Its purpose was to quantify the effort needed to produce a swallowable bolus as a part of the dietary factors that may lead to a change in the developing dentition. Table 2 outlines some of the foods and where they were categorized in the Chewing Factor scale from 1 to 5.

Table 2 Chewing Factor Scale

Chewing Factor Scale	
Unit	Examples
1	Semi-solid foods
	Infant foods
2	Mashed Potatoes
	Processed foods- white bread/ sweet rolls/ desserts
	Most soups
	Cheeses
3	Canned fruits/vegetables
	Ground meats
	Pastas and rice
	French breads, bagels, whole grain breads and cereals
4	Cooked vegetables/fruits
	Pizza
	Chewy candies
	Softer raw fruits/vegetables (cantaloupe, tomatoes)
5	Nuts
	Raw and dried fruits/vegetables
	Meats

After all the foodstuffs were assigned values, each chewing factor effect was calculated by multiplying the chewing factor by the weight (or mass) of foodstuff ingested, as recorded in the diet diaries. Then, daily average values for each subject were calculated from an average of the values over each year.

Measures of Malocclusion

Crowding was specifically targeted as the key subset of malocclusion. The variables used to quantify malocclusion included TSALD and canine arch width (CAW). CAW was used due the ability of the canine dimension to set the width dimension of the individual.

TSALD not only captures anterior crowding but also captures posterior crowding, crowding due to mesial drift, or crowding due to an imbalance in the tooth size and jaw structure of the individual.

TSALD Extreme Data

Given that crowding is a significant contributor to the need for orthodontic treatment, groups were created from the TSALD data to facilitate analyses of cases with significant crowding (i.e., very low TSALD values). Thus, the distribution of TSALD values were roughly divided into thirds, with the highest and lowest thirds included to create a new variable called TSALD Extreme; while the middle third was excluded. As shown in Table 3, the maxillary and mandibular TSALD values that were at the lowest (most crowded) or highest (most spacing) were used in order to compare median dietary variables between these extreme groups to help identify whether dietary variables were associated with extreme crowding or spacing.

Table 3 TSALD Extreme Criteria

		TSALD Extreme	Values	
		Low (mm)	High (mm)	N
Age 5	Maxillary TSALD	<0	>3	96
	Mandibular TSALD	<-2.5	>0.2	100
Age 9	Maxillary TSALD	<0	>3	74
	Mandibular TSALD	<-2.5	>0.2	72

Non-nutritive Sucking

As part of the IFS questionnaires, data relating to digit and pacifier habits were obtained by asking parents to report whether the child regularly sucked any object and, if so, they were asked to choose from a list of objects that included thumb, finger, and pacifier. If non-nutritive sucking continued beyond 36 months of life, these individuals were excluded from the analysis for this study only, not for the IFS. Non-nutritive sucking habits that extend past 36 months may affect the orofacial complex irreversibly without orthodontic treatment. (Warren et.al., 2001)

Inclusion and Exclusion Criteria for this Study

Participants in the IFS have been followed over time with multiple clinical exams, numerous 3-day diet diaries, and many follow-up questionnaires. Since not every participant has all data for every exam, survey, and diet diary; several criteria were used to include and/or exclude IFS participants for the purposes of this study.

Inclusion criteria used were the following:

1. Participants must have had a clinical exam at about age 5 and 9 with useable study models made during one or both of the time periods. As part of this criterion, they must have had all primary dentition with no permanent dentition for the age 5 exam. For the age 9 exam, participants must have had all primary canines, four permanent first molars present, and eight permanent incisors.
2. Participants must have had a minimum of 4 recorded 3-day diet diaries for the 24 month to 60 month periods. For the 60 to 102 month period, participants must have had at least 4 recorded diaries as well. For the 24 to 102 month period, participants must have had at least 8 diaries to be included.

Exclusion criteria used were the following:

1. Any report of orthodontic treatment prior to the age 9 exam (interceptive or full bands).
2. Any non-nutritive sucking habit that was present beyond 36 months.

Operational Definitions

Dependent Variables

The primary dependent variables examined in this study were as follows:

Maxillary TSALD: tooth size/arch length discrepancy of the maxilla, measured in millimeters (two decimal places) by taking the sum of left and right anterior and posterior segments; subtracted from the sum of the mesiodistal widths of each individual tooth in the arch.

Mandibular TSALD: tooth size/arch length discrepancy of the mandible, measured in millimeters (two decimal places) by taking the sum of left and right anterior and posterior segments; subtracted from the sum of the mesiodistal widths of each individual tooth in the arch.

CAW: canine arch width, measured in millimeters (two decimal places) from cusp tip to cusp tip of the right and left canine for maxillary and mandibular arch.

Low TSALD Extreme: TSALD of roughly the lower one-third of the distribution of individuals in either the maxilla (TSALD<0 mm) or mandible (TSALD <-2.5 mm).

High TSALD Extreme: TSALD of roughly the higher one-third of the distribution of individuals in either the maxilla (TSALD<3 mm) or mandible (TSALD <0.2 mm).

Independent Variables

The independent variables in this study were as follows:

AUC solid energy: Daily average value of solid energy intake as abstracted from 3-day diet records and quantified in kilocalories (one decimal place) across specific time periods using an area-under-the-curve-calculation.

AUC fiber: Daily average value of fiber intake as abstracted from 3-day diet records and quantified in grams (one decimal place) across specific time periods using an area-under-the-curve-calculation.

AUC protein: Daily average value of protein intake as abstracted from 3-day diet records and quantified in grams (one decimal place) across specific time periods using an area-under-the-curve-calculation.

AUC VIT D: Daily average value of vitamin D intake as abstracted from 3-day diet records and quantified in micrograms (one decimal place) across specific time periods using an area-under-the-curve-calculation.

AUC VIT A: Daily average value of vitamin A intake as abstracted from 3-day diet records and quantified in micrograms (one decimal place) across specific time periods using an area-under-the-curve-calculation.

AUC CHEW FACT: Daily average value of chewing factor (units) on a scale from 1 to 5 and applied to the sum of scores from all foodstuff intakes as abstracted from 3-day diet records across specific time periods using an area-under-the-curve calculation.

List of Hypotheses

1. Higher average energy intake is associated with higher mean TSALD.
    a. Higher average daily energy intake is associated with higher maxillary TSALD at age 5.
    b. Higher average daily energy intake is associated with higher mandibular TSALD at age 5.
    c. Higher average daily energy intake is associated with higher maxillary TSALD at age 9.

   d. Higher average daily energy intake is associated with higher mandibular TSALD at age 9.

2. Higher average fiber intake is associated with higher mean TSALD.
   a. Higher average daily fiber intake is associated with higher maxillary TSALD at age 5.
   b. Higher average daily fiber intake is associated with higher mandibular TSALD at age 5.
   c. Higher average daily fiber intake is associated with higher maxillary TSALD at age 9.
   d. Higher average daily fiber intake is associated with higher mandibular TSALD at age 9.
3. Higher average protein intake is associated with higher mean TSALD.
   a. Higher average daily protein intake is associated with higher maxillary TSALD at age 5.
   b. Higher average daily protein intake is associated with higher mandibular TSALD at age 5.
   c. Higher average daily protein intake is associated with higher maxillary TSALD at age 9.
   d. Higher average daily protein intake is associated with higher mandibular TSALD at age 9.
4. Higher average vitamin D intake is associated with higher mean TSALD.
   a. Higher average daily vitamin D intake is associated with higher maxillary TSALD at age 5.
   b. Higher average daily vitamin D intake is associated with higher mandibular TSALD at age 5.
   c. Higher average daily vitamin D intake is associated with higher maxillary TSALD at age 9.
   d. Higher average daily vitamin D intake is associated with higher mandibular TSALD at age 9.
5. Higher average vitamin A intake is associated with higher mean TSALD.
   a. Higher average daily vitamin A intake is associated with higher maxillary TSALD at age 5.
   b. Higher average daily vitamin A intake is associated with higher mandibular TSALD at age 5.
   c. Higher average daily vitamin A intake is associated with higher maxillary TSALD at age 9.
   d. Higher average daily vitamin A intake is associated with higher mandibular TSALD at age 9.
6. Higher average chewing factor is associated with higher mean TSALD.
   a. Higher average daily chewing factor is associated with higher maxillary TSALD at age 5.
   b. Higher average daily chewing factor is associated with higher mandibular TSALD at age 5.
   c. Higher average daily chewing factor is associated with higher maxillary TSALD at age 9.

    d. Higher average daily chewing factor is associated with higher mandibular TSALD at age 9.
7. Higher average energy intake is associated with higher median TSALD EXTREME.
    a. Higher median daily energy intake is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher median daily energy intake is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher median daily energy intake is associated with higher maxillary TSALD EXTREME at age 9.
    d. Higher median daily energy intake is associated with higher mandibular TSALD EXTREME at age 9.
8. Higher average fiber intake is associated with higher mean TSALD EXTREME.
    a. Higher average daily fiber intake is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher average daily fiber intake is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher average daily fiber intake is associated with higher maxillary TSALD EXTREME at age 9.
    d. Higher average daily fiber intake is associated with higher mandibular TSALD EXTREME at age 9.
9. Higher average protein intake is associated with higher mean TSALD EXTREME.
    a. Higher average daily protein intake is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher average daily protein intake is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher average daily protein intake is associated with higher maxillary TSALD EXTREME at age 9.
    d. Higher average daily protein intake is associated with higher mandibular TSALD EXTREME at age 9.
10. Higher average vitamin D intake is associated with higher mean TSALD EXTREME.
    a. Higher average daily vitamin D intake is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher average daily vitamin D intake is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher average daily vitamin D intake is associated with higher maxillary TSALD EXTREME at age 9.
    d. Higher average daily vitamin D intake is associated with higher mandibular TSALD EXTREME at age 9.
11. Higher average vitamin A intake is associated with higher mean TSALD EXTREME.
    a. Higher average daily vitamin A intake is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher average daily vitamin A intake is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher average daily vitamin A intake is associated with higher maxillary TSALD EXTREME at age 9.

    d. Higher average daily vitamin A intake is associated with higher mandibular TSALD EXTREME at age 9.

12. Higher average chewing factor is associated with higher mean TSALD EXTREME.
    a. Higher average daily chewing factor is associated with higher maxillary TSALD EXTREME at age 5.
    b. Higher average daily chewing factor is associated with higher mandibular TSALD EXTREME at age 5.
    c. Higher average daily chewing factor is associated with higher maxillary TSALD EXTREME at age 9.
    d. Higher average daily chewing factor is associated with higher mandibular TSALD EXTREME at age 9.
13. Higher average energy intake is associated with higher mean CAW.
    a. Higher average daily energy intake is associated with higher maxillary CAW at age 5.
    b. Higher average daily energy intake is associated with higher mandibular CAW at age 5.
    c. Higher average daily energy intake is associated with higher maxillary CAW at age 9.
    d. Higher average daily energy intake is associated with higher mandibular CAW at age 9.
14. Higher average fiber intake is associated with higher mean CAW.
    a. Higher average daily fiber intake is associated with higher maxillary CAW at age 5.
    b. Higher average daily fiber intake is associated with higher mandibular CAW at age 5.
    c. Higher average daily fiber intake is associated with higher maxillary CAW at age 9.
    d. Higher average daily fiber intake is associated with higher mandibular CAW at age 9.
15. Higher average protein intake is associated with higher mean CAW.
    a. Higher average daily protein intake is associated with higher maxillary CAW at age 5.
    b. Higher average daily protein intake is associated with higher mandibular CAW at age 5.
    c. Higher average daily protein intake is associated with higher maxillary CAW at age 9.
    d. Higher average daily protein intake is associated with higher mandibular CAW at age 9.
16. Higher average vitamin D intake is associated with higher mean CAW.
    a. Higher average daily vitamin D intake is associated with higher maxillary CAW at age 5.
    b. Higher average daily vitamin D intake is associated with higher mandibular CAW at age 5.
    c. Higher average daily vitamin D intake is associated with higher maxillary CAW at age 9.

    d. Higher average daily vitamin D intake is associated with higher mandibular CAW at age 9.
17. Higher average vitamin A intake is associated with higher mean CAW.
    a. Higher average daily vitamin A intake is associated with higher maxillary CAW at age 5.
    b. Higher average daily vitamin A intake is associated with higher mandibular CAW at age 5.
    c. Higher average daily vitamin A intake is associated with higher maxillary CAW at age 9.
    d. Higher average daily vitamin A intake is associated with higher mandibular CAW at age 9.
18. Higher average chewing factor is associated with higher mean CAW.
    a. Higher average daily chewing factor is associated with higher maxillary CAW at age 5.
    b. Higher average daily chewing factor is associated with higher mandibular CAW at age 5.
    c. Higher average daily chewing factor is associated with higher maxillary CAW at age 9.
    d. Higher average daily chewing factor is associated with higher mandibular CAW at age 9.

Data Entry and Analysis

IFS dietary data entry was described previously. All data were subsequently merged into SPSS for analyses by the author (AB) and IFS staff. A significance level of $p<0.05$ was considered statistically significant.

Descriptive statistics were generated for each variable. Pearson correlations were performed comparing the six dietary variables to TSALD and CAW in both the maxilla and mandible from the age 5 cast data as well as the age 9 cast data. Bivariate analyses were conducted for each time period separately (24-60 months, 24-102 months, 60-102 months). Mann-Whitney U tests were also performed to compare median dietary values of the six dietary variables between the low and high TSALD extreme groups of both the maxilla and mandible age 5 cast data, as well as age 9 cast data.

Body mass index (BMI) is a mathematical ratio that quantifies the weight to height relationship. It is computed by the following formula: BMI= Weight in kilograms/(Height in meters)^2. BMI was correlated with the maxillary TSALD age 5 cast data to determine that there was no association. This was done using Pearson correlation analyses.

A post-hoc power calculation was performed to determine what sample size would be necessary for a significant outcome. The post-hoc power calculation is an estimate of what sample size may yield a statistically significant result. (Levin, 1975) This was calculated using the standard deviation, alpha of 0.05, and the mean difference for the variables selected. The post-hoc power calculation was performed using a statistical calculator (Lenth, 2009) after inputting the necessary values.

CHAPTER IV

RESULTS

Introduction

The findings from this study are presented in three sections. The first section gives a description of the data and the variables examined. The second section describes the bivariate relationships between the dependent and independent variables, including comparisons and median tests. The last section describes further the dietary factors that may affect malocclusion, including a post-hoc power calculation.

Descriptive Statistics

Out of all IFS study participants, 168 subjects met the inclusion criteria for the age 5 period and 125 met the inclusion criteria for the age 9 time period. These subjects made up the sample population for this study.

Orthodontic Variables

Among the orthodontic variables, tooth size/arch length discrepancy (TSALD) and canine arch width (CAW) were of major importance. As shown in Table 4, the mean TSALD in millimeters for the maxilla at age 5 period was 1.74, with the median at 1.62. The age 5 TSALD mandibular mean in millimeters was -0.92, with a median of - 1.15. As shown in Table 5, the age 9 maxillary TSALD mean was 1.84 millimeters, with a median of 1.83. The age 9 mandibular TSALD mean was -0.86, with a median of -0.96.

The age 5 CAW maxillary mean was 28.42 millimeters with a median of 28.36. The age 5 CAW mandibular mean was 22.62 millimeters with a median of 22.53. (Table 4) The age 9 CAW maxillary mean was 28.38 millimeters with a median of 28.47. The age 9 CAW mandibular mean was 22.62 millimeters with a median of 22.56. (Table 5)

Table 4 Age 5 Orthodontic Descriptive Statistics

n=168	Mean	Median	Standard Deviation
Maxillary TSALD (mm)	1.74	1.62	2.93
Mandibular TSALD (mm)	-0.92	-1.15	2.76
Maxillary CAW (mm)	28.42	28.36	1.75
Mandibular CAW (mm)	22.62	22.53	1.40

Table 5 Age 9 Orthodontic Descriptive Statistics

n=125	Mean	Median	Standard Deviation
Maxillary TSALD (mm)	1.84	1.83	2.99
Mandibular TSALD (mm)	-0.86	-0.96	2.72
Maxillary CAW (mm)	28.38	28.47	1.61
Mandibular CAW (mm)	22.62	22.56	1.38

Dietary Variables

Dietary variables were taken from 3-day diet diaries at the various points during the study. Area-under-the-curve (AUC) values were performed for the variables solid energy, fiber, protein, vitamin D, vitamin A, and chewing factor. The age 5 cast data were correlated with the 24-60 month AUC dietary information. The age 9 cast data were correlated with the 24-102 month AUC dietary information and the 60-102 month AUC periods. Tables 6-8 detail the AUC descriptive statistical values and maximum values for each of these dietary variables for the different age periods in the study.

As shown in Table 6, the daily median (25^{th} %, 75^{th} %) intake from 24 to 60 months was 1049.1 (919.4, 1160.2) kilocalories, 7.8 (6.4, 9.3) grams of fiber, 32.9 (28.6, 37.7) grams of protein, 1.4 (1.1, 1.7) micrograms of vitamin D, 398.6 (315.9, 530.3) micrograms of vitamin A, and a chewing factor of 1437.3 (1191.6, 1707.5) units. As shown in Table 7, the daily median (25^{th} %, 75^{th} %) intake from 24-102 months was 1186.9 (1068.7, 1284.0) kilocalories, 8.6 (7.5, 9.9) grams of fiber, 36.6 (32.1, 41.3) grams of protein, 1.6 (1.2, 1.9) micrograms of vitamin D, 430.9 (363.4, 573.3) micrograms of vitamin A, and a chewing factor of 1597.0 (1330.4, 1855.4) units (Table 8). Table 8 shows the daily median (25^{th} %, 75^{th} %) intake from 60 to 102 months with caloric intake at 1289.8 (1144.0, 1416.8) kilocalories, 9.1 (7.8, 10.7) grams of fiber, 40.5 (35.1, 46.2) grams of protein, 1.6 (1.3, 2.1) micrograms of vitamin D, 475.5 (363.9, 599.4) micrograms of vitamin A, and a chewing factor of 1682.4 (1428.6, 2016.5) units.

Table 6 Descriptive Statistics for Dietary Variables from 24-60 Month Dietary Data

n=168	Mean	Median	Standard Deviation	25th Percentile	75th Percentile
Solid energy (kcal)	1045.2	1049.1	177.6	919.4	1160.2
Fiber (g)	7.9	7.8	2.2	6.4	9.3
Protein (g)	33.1	32.9	7.0	28.6	37.7
Vitamin D (µg)	1.4	1.4	0.6	1.1	1.7
Vitamin A (µg)	427.9	398.6	157.6	315.9	530.3
Chewing Factor (units)	1466.2	1437.3	371.0	1191.6	1707.5

Table 7 Descriptive Statistics for Dietary Variables from 24-102 Month Dietary Data

n=125	Mean	Median	Standard Deviation	25th Percentile	75th Percentile
Solid energy (kcal)	1178.0	1186.9	175.6	1068.7	1284.0
Fiber (g)	8.8	8.6	2.1	7.5	9.9
Protein (g)	37.3	36.6	6.9	32.1	41.3
Vitamin D (µg)	1.6	1.6	0.5	1.2	1.9
Vitamin A (µg)	469.8	430.9	162.1	363.4	573.3
Chewing Factor (units)	1622.7	1597.0	371.4	1330.4	1855.4

Table 8 Descriptive Statistics for Dietary Variables from 60-102 Month Dietary Data

n=125	Mean	Median	Standard Deviation	25th Percentile	75th Percentile
Solid energy (kcal)	1290.9	1289.8	208.7	1144.0	1416.8
Fiber (g)	9.4	9.1	2.4	7.8	10.7
Protein (g)	41.0	40.5	8.1	35.1	46.2
Vitamin D (µg)	1.7	1.6	0.6	1.3	2.1
Vitamin A (µg)	503.9	475.5	195.8	363.9	599.4
Chewing Factor (units)	1737.4	1682.4	417.7	1428.6	2016.5

The median BMI for individuals at the age 5 time period was 15.61 and the median BMI for individuals at the age 9 time period was 15.50. (Table 9)

Table 9 Descriptive Statistics for BMI (kg/m^2)

	Mean	Median	Standard Deviation
Age 5 BMI	16.15	15.61	4.40
Age 9 BMI	16.19	15.50	5.06

Bivariate Analysis

The malocclusion of most interest was crowding, as measured by TSALD in millimeters. The correlation of TSALD and dietary factors was explored separately for the age 5 period and the age 9 period. The following tables show Pearson correlation coefficients relating TSALD and the dietary variables.

As shown in Table 10, results of the correlation of Age 5 TSALD values and 24-60 month AUC dietary data showed a weak but statistically significant correlation between maxillary TSALD and solid energy (p=0.031). This same correlation was not significant in the mandibular TSALD, however, it approached significance (p=0.072). No other correlations were statistically significant or approached significance.

Table 10 Correlation of Age 5 TSALD Variables and 24-60 month AUC Dietary Data

n=168		Maxillary TSALD	Mandibular TSALD
Solid energy (kcal)	Pearson Correlation	0.167*	0.139
	Sig. (2-tailed)	0.031	0.072
Fiber (g)	Pearson Correlation	0.096	0.071
	Sig. (2-tailed)	0.214	0.357
Protein (g)	Pearson Correlation	0.072	0.087
	Sig. (2-tailed)	0.351	0.260
Vitamin D (µg)	Pearson Correlation	0.086	0.064
	Sig. (2-tailed)	0.266	0.407
Vitamin A (µg)	Pearson Correlation	0.046	-0.027
	Sig. (2-tailed)	0.552	0.733
Chewing Factor (units)	Pearson Correlation	0.059	0.037
	Sig. (2-tailed)	0.451	0.632

* Correlation is significant at the 0.05 level.

Table 11 shows the correlation of age 9 TSALD values and 24-102 month AUC dietary data, where no correlations were found to be statistically significant. However, the correlations of maxillary and mandibular TSALD and solid energy did approach significance (p=0.078, p=0.083 respectively). Also, the correlation of mandibular TSALD and vitamin A approached significance with a p-value of p=0.107.

Table 11 Correlation of Age 9 TSALD Variables and 24-102 month AUC Dietary Data

n=125		Maxillary TSALD	Mandibular TSALD
Solid energy (kcal)	Pearson Correlation	0.158	0.156
	Sig. (2-tailed)	0.078	0.083
Fiber (g)	Pearson Correlation	0.058	0.034
	Sig. (2-tailed)	0.520	0.709
Protein (g)	Pearson Correlation	0.083	0.091
	Sig. (2-tailed)	0.359	0.310
Vitamin D (μg)	Pearson Correlation	0.049	0.030
	Sig. (2-tailed)	0.587	0.742
Vitamin A (μg)	Pearson Correlation	-0.076	-0.145
	Sig. (2-tailed)	0.400	0.107
Chewing Factor (units)	Pearson Correlation	0.043	0.037
	Sig. (2-tailed)	0.634	0.685

Table 12 Correlation of Age 9 TSALD Variables and 60-102 month AUC Dietary Data

n=125		Maxillary TSALD	Mandibular TSALD
Solid energy (kcal)	Pearson Correlation	0.125	0.110
	Sig. (2-tailed)	0.164	0.22
Fiber (g)	Pearson Correlation	0.014	-0.008
	Sig. (2-tailed)	0.873	0.929
Protein (g)	Pearson Correlation	0.063	0.059
	Sig. (2-tailed)	0.485	0.514
Vitamin D (µg)	Pearson Correlation	0.015	-0.014
	Sig. (2-tailed)	0.870	0.875
Vitamin A (µg)	Pearson Correlation	-0.131	-0.173
	Sig. (2-tailed)	0.145	0.054
Chewing Factor (units)	Pearson Correlation	0.041	0.040
	Sig. (2-tailed)	0.647	0.659

As shown in Table 12, the correlation of age 9 TSALD variables and 60-102 month dietary data showed no significant associations, but the negative association between vitamin A and mandibular TSALD did approach statistical significance (p=0.054).

As shown in the previous three tables, there was one statistically significant correlation and a few that approached significance. To be sure that the correlation between solid energy and TSALD was not due to a higher total consumption in individuals, the height and weight relationship (BMI) was explored. There was no significant correlation between

BMI and maxillary or mandibular TSALD at age 5 or age 9), suggesting no relationship. Therefore, further analyses did not adjust for BMI.

To explore the relationship between the more severely crowded subjects and the dietary factors, the extreme TSALD groups were compared using the Mann-Whitney U test. The extreme TSALD variables were those subjects with the most crowding and the subjects with the least crowding, as defined in the methods section.

Table 13 provides the results for the Mann-Whitney U test comparing the 24-60 month dietary AUC values for Age 5 maxillary TSALD extreme groups and shows age 5 TSALD (mm) measures. Solid energy was found to be positively and significantly associated with the TSALD extremes at age 5.

Table 13 Results of Mann-Whitney U Test comparing 24-60 month Dietary AUC variables for Age 5 Maxillary TSALD Extreme Groups

n=96	Sig.	Median Dietary Variables	
		Lower TSALD Group (n=44)	Higher TSALD Group (n=52)
Solid energy (kcal)	0.024	1002.97	1085.62
Fiber (g)	0.116	7.11	7.65
Protein (g)	0.374	31.43	33.52
Vitamin D (µg)	0.286	1.36	1.46
Vitamin A (µg)	0.860	366.86	382.84
Chewing Factor (units)	0.152	1277.53	1428.42

As shown in Table 14, the Mann-Whitney U test comparing 24-60 month dietary AUC values for age 5 mandibular TSALD extreme groups showed statistically significant results for solid energy, with those in the high TSALD group having higher energy intakes. AUC Fiber also approached significance (p=0.065). As shown in these tables, there were generally only small differences between group medians.

Table 14 Results of Mann-Whitney U Test comparing 24-60 month Dietary AUC values for Age 5 Mandibular TSALD Extreme Groups

n=100	Sig.	Median Dietary Values	
		Lower TSALD Group (n=50)	Higher TSALD Group (n=50)
Solid energy (kcal)	0.011	997.90	1080.28
Fiber (g)	0.069	7.14	7.91
Protein (g)	0.126	30.98	33.57
Vitamin D (µg)	0.327	1.36	1.40
Vitamin A (µg)	0.665	387.42	391.94
Chewing Factor (units)	0.180	1405.57	1414.56

As shown in Table 15, there were no statistically significant differences between age 9 TSALD extreme groups on any dietary values.

Table 15 Results of Mann-Whitney U Test comparing 24-102 month and 60-102 month Dietary AUC values for Age 9 Maxillary TSALD Extreme Groups

	n=74	Sig.	Median Dietary Values	
			Lower TSALD Group (n=32)	Higher TSALD Group (n=42)
24-102 months	Solid energy (kcal)	0.053	1084.03	1184.83
	Fiber (g)	0.556	8.14	8.48
	Protein (g)	0.295	34.15	36.98
	Vitamin D (µg)	0.814	1.43	1.53
	Vitamin A (µg)	0.241	386.46	451.45
	Chewing Factor (units)	0.583	1489.58	1531.07
60-102 months	Solid energy (kcal)	0.091	1164.14	1273.87
	Fiber (g)	0.711	8.70	9.06
	Protein (g)	0.305	37.59	41.11
	Vitamin D (µg)	0.655	1.51	1.59
	Vitamin A (µg)	0.072	395.31	495.50
	Chewing Factor (units)	0.670	1579.70	1632.52

As shown in Table 16, the results of the Mann-Whitney U tests for the age 9 mandibular TSALD extreme values and the median AUC dietary values were not significantly related for any dietary category.

Table 16 Results of Mann-Whitney U Test comparing 24-102 month and 60-102 month Dietary AUC values for Age 9 Mandibular TSALD Extreme Groups

	n=72	Sig.	Mean Dietary Values	
			Lower TSALD Group (n=35)	Higher TSALD Group (n=37)
24-102 months	Solid energy (kcal)	0.023	1148.04	1214.65
	Fiber (g)	0.494	8.16	8.69
	Protein (g)	0.113	34.90	37.75
	Vitamin D (μg)	0.336	1.42	1.60
	Vitamin A (μg)	0.336	410.32	430.54
	Chewing Factor (units)	0.404	1574.35	1611.62
60-102 months	Solid energy (kcal)	0.069	1275.93	1355.72
	Fiber (g)	0.694	8.04	9.23
	Protein (g)	0.297	39.07	40.51
	Vitamin D (μg)	0.297	1.51	1.63
	Vitamin A (μg)	0.896	429.52	490.63
	Chewing Factor (units)	0.392	1598.65	1638.17

As shown in Table 17, the correlations of the age 5 canine arch width and 24-60 month AUC dietary variables showed a statistically significant positive relationship between solid energy and maxillary CAW. There also was a significant positive relationship between vitamin A and maxillary CAW for the same dietary time period.

Table 17 Pearson Correlations of Age 5 Canine Arch Width (CAW) and 24-60 month AUC Dietary Variables

n=168		Maxillary CAW	Mandibular CAW
Solid energy (kcal)	Pearson Correlation	0.193*	0.105
	Sig. (2-tailed)	0.012	0.177
Fiber (g)	Pearson Correlation	0.097	0.054
	Sig. (2-tailed)	0.209	0.486
Protein (g)	Pearson Correlation	0.119	0.020
	Sig. (2-tailed)	0.124	0.798
Vitamin D (µg)	Pearson Correlation	0.108	-0.040
	Sig. (2-tailed)	0.164	0.606
Vitamin A (µg)	Pearson Correlation	0.193*	0.032
	Sig. (2-tailed)	0.012	0.678
Chewing Factor (units)	Pearson Correlation	0.077	-0.024
	Sig. (2-tailed)	0.324	0.756

*Correlation is significant at the 0.05 level (2-tailed).

As shown in Table 18, the correlations of the age 9 CAW and 24-102 month AUC dietary variables showed no significance between any dietary values and CAW.

Table 18 Pearson Correlations of Age 9 Canine Arch Widths and 24-102 month AUC Dietary Variables

n=125		Maxillary CAW	Mandibular CAW
Solid energy (kcal)	Pearson Correlation	0.128	0.087
	Sig. (2-tailed)	0.153	0.333
Fiber (g)	Pearson Correlation	0.057	-0.022
	Sig. (2-tailed)	0.525	0.806
Protein (g)	Pearson Correlation	0.058	-0.045
	Sig. (2-tailed)	0.520	0.620
Vitamin D (µg)	Pearson Correlation	0.063	-0.092
	Sig. (2-tailed)	0.482	0.310
Vitamin A (µg)	Pearson Correlation	0.094	-0.048
	Sig. (2-tailed)	0.299	0.598
Chewing Factor (units)	Pearson Correlation	0.059	-0.052
	Sig. (2-tailed)	0.510	0.561

As shown in Table 19, the correlations of the age 9 canine arch widths and 60-102 month AUC dietary variables showed no statistical significance between any dietary variables and CAW.

Table 19 Pearson Correlations of Age 9 Canine Arch Widths and 60-102 month AUC Dietary Variables

n=125		Maxillary CAW	Mandibular CAW
Solid energy (kcal)	Pearson Correlation	0.129	0.080
	Sig. (2-tailed)	0.150	0.372
Fiber (g)	Pearson Correlation	0.059	-0.082
	Sig. (2-tailed)	0.516	0.363
Protein (g)	Pearson Correlation	0.073	-0.039
	Sig. (2-tailed)	0.417	0.668
Vitamin D (µg)	Pearson Correlation	0.043	-0.052
	Sig. (2-tailed)	0.633	0.563
Vitamin A (µg)	Pearson Correlation	0.075	-0.028
	Sig. (2-tailed)	0.406	0.757
Chewing Factor (units)	Pearson Correlation	0.080	-0.043
	Sig. (2-tailed)	0.375	0.634

Post-hoc Power Calculations

Post-hoc power calculations were performed to assess the sample sizes that would have been needed to obtain statistically significant results, assuming the finding obtained in this study. Based on the sparse statistically significant findings, along with the suggestive relationship between dietary factors and crowding from the dental literature, there existed a need to determine what sample size may be needed to show a statistically significant relationship, if any, between dietary factors and crowding for future studies. Certain dietary factors were selected based on findings from this study that were significant or approached statistical significance. Fiber and Vitamin A were selected because they were statistically significant or approached significance. Chewing Factor was selected because it was unique to this study. It also is presumed to be the factor that would require the largest sample size to show a statistically significant relationship since its effects take a long time to manifest themselves in the orofacial complex, as suggested by previous studies. (Corruccini et.al., 1983) Results in Table 20 show that the projected total sample sizes to detect a statically significant result for the selected dietary factors were 450, 1808 and 322, for fiber, Vitamin A, and Chewing Factor, respectively.

Table 20 Post-hoc power calculations for T-test using Age 5 Maxillary TSALD with 24-60 Month Dietary Variables (Power=0.80, alpha=0.05)

Power= 0.80	Std. Dev. (σ)	Mean Diff.	Proposed Total Sample Size (subjects)
Chewing Factor	375	76	450
Vitamin A	150	20	1808
Fiber	2.2	0.7	322

Summary and Review of Hypotheses

The orofacial cast and dietary intake data from a subgroup of IFS participants who met inclusion criteria for this study (Age 5, n=168; Age 9, n=125) were analyzed. Results included descriptive statistics, bivariate analysis and post-hoc power calculations.

The following presents a re-statement of each hypothesis and the pertinent results that support or refute each of them.

1. AUC solid energy, as found in the first hypothesis, was found to have an association with the Age 5 maxillary TSALD. As solid energy consumption increased, maxillary TSALD decreased. Age 5 mandibular TSALD was not statistically significant but approached it. Overall, there was weak support for the hypothesis that there was a relationship between solid energy intake and TSALD.
2. AUC fiber, as found in the second hypothesis, was not found to have a statistically significant association with TSALD in the results of this study, and the hypothesis was not supported.
3. AUC protein, as found in the third hypothesis, was also not found to have an association with TSALD, and thus, the hypothesis was not supported.
4. AUC Vitamin D, as found in the fourth hypothesis, was not found to have a statistically significant association with TSALD in the results of this study, so that the hypothesis was not supported.
5. AUC Vitamin A, as found in the fifth hypothesis, was not found to have a statistically significant association with TSALD in the results of this study, so that the hypothesis was not supported.
6. AUC Chewing Factor, as found in the sixth hypothesis, was not found to have a statistically significant association with TSALD in the results of this study, and thus, the hypothesis is not supported.

7. AUC solid energy, as found in the seventh hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
8. AUC fiber, as found in the eighth hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
9. AUC protein, as found in the ninth hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
10. AUC Vitamin D, as found in the tenth hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
11. AUC Vitamin A, as found in the eleventh hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
12. AUC Chewing Factor, as found in the twelfth hypothesis, was not found to have a statistically significant association with TSALD Extreme in the results of this study, and thus the hypothesis is not supported.
13. AUC solid energy, as found in the thirteenth hypothesis, was found to have a statistically significant association with maxillary CAW for the age 5 period. However, further study is needed to explore that relationship.

14. AUC fiber, as found in the fourteenth hypothesis, was not found to have a statistically significant association with CAW in the results of this study, and thus the hypothesis is not supported.
15. AUC protein, as found in the fifteenth hypothesis, was not found to have a statistically significant association with CAW in the results of this study, and thus the hypothesis is not supported.
16. AUC Vitamin D, as found in the sixteenth hypothesis, was not found to have a statistically significant association with CAW in the results of this study, and thus the hypothesis is not supported.
17. AUC Vitamin A, as found in the seventeenth hypothesis, was found to have a statistically significant association with maxillary CAW for the Age 5 period. However, further study is needed to explore this relationship.
18. AUC Chewing Factor, as found in the eighteenth hypothesis, was not found to have a statistically significant association with CAW in the results of this study, and thus the hypothesis is not supported.

CHAPTER V

DISCUSSION

Introduction

This chapter first discusses the study findings in general, followed by general limitations of the study. Then the findings and the implications of the findings will be discussed. To complete the chapter, recommendations on future directions of research will be discussed.

The initial intent of this study was to assess associations between dietary factors and crowding, a significant component of malocclusion. A subset of study participants from the Iowa Fluoride Study (IFS) was used as a convenience sample because there were existing, extensive longitudinal dietary data available from this study. Data on crowding were taken from dental casts obtained from participants at about age 5 and at age 9. These were correlated with dietary information that was collected for the same subjects in the form of 3-day dietary diaries recorded over the life of the subject from 24 to 102 months.

Review of Significant Findings

This study should be considered mainly as a pilot study or a study of correlation and associations. There were a few statistically significant findings, however, some findings that were not significant may have had an association, but were not identified due to the limited sample size. Also, the findings that were significant may or may not have clinical significance.

Solid Energy and TSALD

Higher AUC solid energy was significantly associated with greater Age 5 Maxillary TSALD. The association approached significance with the Age 9 Maxillary TSALD. This pattern, even after controlling for body mass index (BMI), is the strongest trend from the data. It is possible that higher caloric intake could correspond to larger body size and, thus, more space in the dentition. Furthermore, genetic components were not controlled for and this drawback is a limitation of this study.

Due to the frequency of the significance of the association between solid energy and less crowding as measured by TSALD, it is possible that this is due to the intake patterns within subjects. Those with higher solid energy intakes could have had bigger jaw sizes so that there was less arch crowding. Another possibility is that there could be a tendency for those with larger mouths to consume larger portion sizes. However, each of these ideas seems unlikely and unsupported thus far in the literature.

Vitamin A and TSALD

Higher AUC Vitamin A was significantly associated with the high Age 9 TSALD Extreme group for the maxilla. Vitamin A is primarily found in preformed meat products, as beta carotene in fruits and vegetables, and as fortified milk. These foods, except for fortified milk, require vigorous mastication. Vigorous mastication could be involved in the interdental attrition, as well as the increase in muscle and bone development, adding to the body of the ramus of the mandible due to the increased use of the masseter muscle. Vitamin A is also an essential part of bone growth and development. Additional study would be required to truly ascertain the relationship between vitamin A and less crowding. There are no previous studies concerning vitamin A and crowding, and thus, no data available with which to compare findings.

Canine Arch Width and Dietary Factors

Canine arch width (CAW) is one of the orthodontic measures that contribute to arch dimension. It is one of the more static measures from early age (primary dentition) to adulthood. It does increase as the orofacial complex increases, but does so at the same relative rate as the orofacial complex. CAW was found to be statistically significantly associated with solid energy and vitamin A at the Age 5 casts data in the maxilla, but not in the mandible. This could be due to the constriction of the mandibular canines by the maxillary jaw effects.

A pattern noted in many of the correlations was a greater number of associations that were significant or approaching significance in the maxilla, as compared with the mandible. This could be due to the different growth characteristics of the maxilla and mandible at the different ages of 5 and 9. Mandibular growth occurs throughout early childhood and adolescence, but is greatest during adolescence (age 13-18). The growth of the maxilla occurs throughout childhood and adolescence, but is the greatest during the ages of 6-10 years. (Proffit et.al., 2000) Although a handful of findings were statistically significant, it is unclear if these associations have clinical significance.

One thought from the maxillary/mandibular pattern seen in the correlations is that, if there were cast data from the second or third decade of life, there would be more significant findings in the mandible at these ages. Another possibility is that the mandibular arch measures are not affected as much by the diet until later in adolescence. Lastly, it could be that the dietary factors in this study were not strong enough to show a significant relationship until later in life.

No statistically significant associations were found for fiber, protein, vitamin D, or chewing factor. Based on the previous literature, fiber and chewing factor were the variables that were expected to have the strongest associations. No statistically significant associations were found with these four variables, but they still could have clinical significance or relevance. When examining the data, there is a clear pattern of higher fiber and chewing factor scores being associated with higher TSALD, which can be seen throughout the results, including multiple findings that approached statistical significance. The fiber variable had multiple findings that approached statistical significance, including the maxillary and mandibular age 5 TSALD Extreme Groups. Similarly, chewing factor also approached statistical significance in the Mann-Whitney Test comparing 24-60 month dietary AUC values for the age 5 maxillary TSALD extreme groups.

Although fiber and chewing factor were not found to be statistically significant, it does not mean that coarse diet has no effect. Coarse diet could have an effect, but the study could have lacked sufficient power to detect this relationship, or it could be that the non-validated "chewing factor" measure was not an accurate measure of diet coarseness. Additional research is needed to better define these associations.

Limitations of the Study

The published literature on this topic is sparse. On the fringes of this topic, many studies of how dietary factors are associated with changes in the human body are found in other published literature. It is sufficient to say that there is still a paucity in the scientific literature, specifically the dental literature, on the associations of dietary factors and malocclusion.

This study examined multiple dietary and crowding variables that were unique; including TSALD Extreme and Chewing Factor. While these variables do not directly compare to those of other studies, corollary lines can be drawn to other studies cited in the literature. However, it is important to emphasize that the diets of the study participants, while varied in components, were not as extreme as those in the other anthropological studies. This limited the ability to study the outcome of chewing factor significantly. It also impaired the ability to assess the impact of coarse diets on occlusion, canine arch width, and crowding as measured by TSALD.

Limitations of the Sample

There are three main limitations of the sample. First, the sample size used in this thesis was limited by the total sample size of the Iowa Fluoride Study (IFS). The total number of subjects with sufficient data recorded for crowding at age 5 and dietary information from 24 to 60 months was 168. The total number of subjects included with sufficient data for crowding at age 9 and dietary information from 60 to 102 months was 125. The total number of subjects included with sufficient data for crowding at age 9 and dietary information from 24 to 102 months was 125. These sample sizes could have been greater had there been better cast data and better compliance with dietary diaries. With a greater sample size, there is greater statistical power to detect associations. Second, the sample was from a population that had a limited range of socioeconomic status, as well as limited racial and ethnic diversity, and in general was limited to eastern and central Iowa. Lastly, the sample for this thesis was limited by age attained by the participants of the IFS. The cohort, while still being followed, had not reached an age old enough to attain data on the full permanent dentition at the time of this study. With full permanent dentition data, it would be expected that even greater differences could be seen, including attrition(interproximal, occlusal, etc.). Also, the diet of the individual would have more time to impact the dentition, and have had a greater ability of detecting a statically significant and/or clinically relevant result.

An important topic is the generalization of these findings to the general population. The subset of subjects used in this research was a convenience sample taken from the Iowa Fluoride Study (IFS). It is assumed that the IFS subjects are a fairly representative sample of the population of Iowa. A bigger question exists: Is the population of Iowa, and the prevalence of malocclusions similar to that of the general population of the United States? The answer to this question is unknown, as there is no evidence that malocclusions of any type are more or less prevalent in the population of Iowa or among the subjects of the IFS. It is important to recognize that due to the many years of follow-up, the educational and economic levels of its participants were not static but dynamic with shifts in both income and educational levels.

Limitations of the Data

The data used were collected as part of a larger study; therefore, there was no *a priori* hypothesis related the topic of this thesis. The same limitations exist for this study as do for all secondary data analysis studies. These include no control over information collected or how it was collected, no ability to modify or change how variables were defined, and no chance to modify problems that may have arose during data collection. For example, if a certain survey had a very low response rate that subsequently limits total participation numbers for the overall study, there is no way to remedy or know the root cause. Another example is that a variable like age may have been collected in categories instead of a continuous variable. These examples illustrate the limitations of a study not being designed to captures the data specifically to answer the questions of this thesis. In addition, the dietary data were subject to recall bias. However, each participant was urged to record everything as soon as possible to prevent these errors.

The dietary information was collected over time, with not every subject completing every diet diary. If one or more dietary diaries were missing, then a previous diary was used to compensate for the missing data. If too many were missing, the subject was excluded altogether, as each subject in the analysis had to have at least four diaries completed. The dietary information was vulnerable to recall bias and recording errors; although the recording was crosschecked and parents were asked to record entries each day, this was still a potential source of error. As in all survey instruments there were likely errors in understanding and completion. Notwithstanding all these issues, the longitudinal dietary information collected in the IFS and how it was used for this study, was more extensive than what is available in most other scientific studies.

The dietary data used for this study were chosen based on various assumptions. For example, no dietary information was included prior to 24 months because the diet for the first 24 months of life is not representative of the diet after 24 months. The infant/toddler diet (age 24 months and younger) is typically softer in consistency and would not require great forces of mastication to create an ingestible bolus. While chewing some harder foods could have had some effect (as hypothesized for older ages) at these younger ages, a brief examination of the data suggested little variation among this subgroup prior to 24 months of age. Thus, no dietary data were used prior to 24 months.

Crowding and other orthodontic data were collected using casts from age 5 and 9 years of age. It would have been beneficial to have had had more data at a follow-up of age 13 and 17. This data would have given more insight into the growth and development of the adolescent years of participants and given more insight into the changes that occur later in life. Dietary effects are subtle and are seen over decades, not single years. Although orthodontic treatment is common in these age groups and would be an exclusion criterion, this information would shed more light on the idea of crowding in the permanent dentition, where smaller effects from factors such as diet would have time to manifest themselves.

Dietary and cast data were chosen not based on design, but convenience, due to it being part of a larger study, that of the Iowa Fluoride Study (IFS). Had the study been designed *a priori* to address each hypothesis, the study would likely have been designed differently. First, the sample size would have been larger. Second, information would have been gathered about the full permanent dentition. Third, a longer course of study would be indicated. Instead of stopping at 9 years of age, it would have been advantageous to lengthen data collection to two or three decades in order to highlight the dietary effects further. Another shortcoming was the dietary components of the sample. While varied in components, the diets consumed by the subjects were not nearly as extreme as those in previous anthropologic studies. (Corruccini et.al., 1983; Corruccini et.al., 1981) It is also important to consider that the collection of data did not include or consider other non-nutritive chewing factors, such as gum chewing or bruxism. Lastly, the study population was generally similar in social, racial, and ethnic makeup, such that one could say it was rather homogenous in nature. It would have been better to have more diversity in the study population to capture more diverse diets. However, the more diverse the study population, the more diverse the genetic factors of that population. If it is desired to control more for genetic factors, then a homogenous study population, such as in the present study, would be desirable.

The statistical analysis consisted of multiple correlations. As in any statistical findings, there is the risk of committing type I and type II errors. As the number of correlations increases, there is an increased risk committing a type I error, or finding a statistically significant result where there is not one. Since this study had many correlations, there is a risk of committing a type I error. This point is brought out to illustrate that this is inherent in the nature of this thesis. To avoid committing a type II error, it is necessary to set the acceptable p value to less than of 0.05. This was not done in this study due to the small number of statistically significant findings, as well as the relatively small sample sizes available.

Future Directions

In future studies, attention should be paid to the design of the study to ensure enough power to detect any significant relationships. This is especially true when data are divided into subgroups, especially those with extreme crowding or spacing. In order to obtain sufficient sample sizes, future research may require a large, multi-site study, or require a longitudinal study over a more focused and shorter time period. Also, future studies should not only focus on solid energy or vitamin A, but also include fiber and diet coarseness. Moreover, future studies should attempt to obtain more diverse samples with more diverse and extreme diets so as to better assess how coarser diets may affect crowding. As there seemed to be more association with the more extreme crowding, both in the total arch as well as the canine arch width, future studies may also want to focus more on these extreme cases.

Although this study did not involve any multivariable analysis, this would be something to pursue in future studies. No multivariable modeling was done because little value that would be gained by doing these analysis, considering the small number of statistically significant findings in the present study. Larger sample sizes and greater variance in dietary factors would allow for multivariable analyses.

Conclusions

Dietary factors and dentition measures from a subset of IFS study subjects were used to assess the relationships between diet and certain malocclusions, as examined in this study. This study found that solid energy and vitamin A had statistically significant relationships with the crowding variables. Several other factors were found to have associations that approached significance, but were not statistically significant. Thus, while the study found some dietary factors that were associated with malocclusion, further research is needed to better determine the nature of the relationships between dietary factors and malocclusion. Moreover, although some of the hypotheses were not supported by the findings, this does not rule out the possibility that there could still be associations between certain dietary factors and crowding. Additional research is needed to explore the multi-factorial nature of malocclusion, including dietary, environmental, and genetic contributions. The findings of this further research would potentially be used to help develop preventive interventions that could result in a decrease in the prevalence and/or severity of malocclusions and need for orthodontic treatment in the future.

APPENDIX

IOWA FLUORIDE STUDY
3-DAY FOOD DIARY

GENERAL DIRECTIONS:

-Please list **all** the foods, beverages and water that your baby eats and drinks during 3 days (72 hours)-including meal times and snacks.

If your baby does not attend child care include:

1 weekend day
2 week days

If your baby attends child care everyday Monday through Friday include:

1 weekend day
2 child care days

If your baby attends child care some days Monday through Friday include:

1 weekend day
1 child care day
1 week day

Be sure to write down every time your baby drinks water.

Try to write down what your baby eats or drinks immediately after they eat or drink it to be sure you remember everything that was eaten and how much.

If your baby will be at child care for part of the day, then be sure to ask the child care provider to record all foods, beverages and water and how much your baby eats and drinks.

We are most interested in the location that foods were prepared (water added, etc.). So if you prepare food or beverages with water and send them to child care, when the source of water should be listed as from home.

Be specific when writing down the type and/or preparation. For example, please write down that the formula or juice your baby drinks is ready-to-feed or from powder concentrate, liquid concentrate or frozen concentrate.

If you are breastfeeding, you do not need to estimate the amount of breast milk your baby received at your breast. Write down the number of ounces of breast milk your baby received **only** if you have pumped your breast milk.

Please feel free to write down any notes or explanations that you think are necessary for us to fully understand your answers.

If you have any questions, please call Ms. Mary Kiritsy at (319) 335-7182 or Dr. Steven Levy at (319) 335-7185. If you are calling long distance, please call collect and we will accept the charges.

DIRECTIONS FOR FILLING OUT THE DIARY: (also see sample diary)

1. At the top of the diary, list the day of the week and date, whether it was a day that your baby attended child care and whether your baby was ill.

2. In the first column, list the time of day the food was eaten.

3. **Using columns 2-5, name and describe each food your baby ate or drank.**

Examples:
Formula, Similac®, 32 oz can, liquid concentrate made with home tap water

Apple juice, Gerber®, 64 oz bottle, ready-to-feed

Kool-aid®, grape, powder concentrate made with Humbolt® Drinking (bottled) water

Think about:
What was the food your baby ate or drank?
What kind was it?
Does it have a brand name?
What type and size container did the beverage come in?
Did you prepare dry infant cereal with formula, juice or milk?

4. In column 6, remember to write down the amount <u>eaten</u> by your baby.

Examples:
Formula, Similac®, 32 oz can, liquid concentrate made w/ home tap water **8 oz**

Apple juice, Gerber®, 64 oz bottle, ready-to-feed **¼ cup**

Kool-aid®, grape, powder concentrate made with Humbolt® Drinking (bottled) water **4 oz**

Use: **Measuring cups or spoons,** which can be abbreviated as follows:

tablespoons or Tbsp or T	cup or c
teaspoons or tsp or t	slice or sl
ounce or oz	piece or pc

Please measure the size of the glasses and bowls that you usually use at home with a standard measuring cup of 8 ounces. Consider this standard sized cup of 8 ounces when reporting in cups.

or a Ruler

or the Amount from the package label

Remember to tell:

How many? What size?
Did your baby eat all, some or part of what was served?
Did you check to see if any food was spilled or dropped?
Was a second helping eaten?

3. For mixed dishes (such as casseroles, pizza, etc.), break the item down into its parts, and list each food separately. If the food item is not a standard recipe, please include a list of ingredients and their amounts. For example:

Grilled Cheese and Tomato Sandwich

Bread, white, Wonder®		2 sl
Cheese, American, Kraft® singles	1 sl	
Mayonnaise, Hellmans®		1 Tbsp
Margarine, soft tub, Promise®		2 tsp
Tomato, raw, sliced	2 sl	

<u>SUMMARY OF HOW TO RECORD PORTION SIZES:</u>

Record in cups or ounces: (1 cup = 8 ounces)

Beverages - including water, formula, milk, juice, juice drinks, pop, tea, etc.

Record in cups:

Potatoes, rice, pasta, etc.
Fruits, vegetables (cooked or canned)
Cereals, ready-to-feed baby foods
Soups, casserole dishes
Jello, pudding

Record in teaspoons or tablespoons: (3 teaspoons = 1 tablespoon)

Peanut butter, jelly, jam, sugar, syrup
Sauces, gravies, salad dressings
Dry baby cereal
Butter, margarine (one pat = 1 teaspoon)

Record by number, size or amount of package:

Bread, rolls, crackers
Raw fruits and vegetables

Meat, chicken, fish (3 oz portion = the size of a deck of playing cards)
Hot dogs
Snack items - nuts, candy, potato chips
Cookies

Record by servings: (use portion of whole item, i.e., 1/4 of 12" or medium pizza)

Pie
Cake, coffee cake
Pizza

Day:____________________ Date:_________/___________/_________

Was this a child care day? ___________Yes __________No

Was your child ill today? ___________Yes __________No

Please remember to write down everything that your child eats and drinks

Brand names are needed for all beverages. We will determine the fluoride content from the specific brand name listed

If you have any questions, please refer to the example pages or call us **collect** at 319-335-7026 or 319-335-7182.

am/pm	**Place:** H-Home C-Child care O-Out	**Food and Beverages**	**Type and/or Preparation:** (ready-to eat; frozen, liquid or powder concentrate)	**Water from:** H-Home tap C-Child care O-Out B-Bottled	**Amount Ate and Drank**	**DO NOT WRITE HERE**

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