Prediction of the Size of Unerupted Canines and Premolars in a Northern Manitoban Aboriginal Population

BY

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ABSTRACT

During the mixed dentition period, forecasting the size of the unerupted canines and premolars relative to the existing arch space available is an important diagnostic process. Typically, the mesiodistal dimensions of the unerupted canines and premolars have been extrapolated from measurements of the erupted permanent mandibular incisors using Moyers' prediction tables or calculated using Tanaka and Johnston's prediction equations. Both techniques were developed using a population of "probable" northern European ancestry. Evidence of racial tooth size variability, however, suggests that prediction techniques based on a single racial sample may not be considered universal. The purpose of this investigation was to determine whether a more accurate method could be obtained to predict the mesiodistal dimensions of unerupted canines and premolars in the northern Manitoban First Nations population. Using simple regression linear analyses, prediction equations for the combined mesiodistal dimensions of the of the maxillary and mandibular canine-premolar segments based on the combined mesiodistal dimension of the mandibular incisors were generated from 51 northern Manitoban First Nations subjects. The sample under study consisted of 24 males and 27 females ranging in age from 13.5 years to 17.25 years. Significant sexual dimorphism was not found for the combined diameters of the canine-premolar segments and lower incisors. Accordingly, the tooth dimensions evaluated in this study were group together regardless of sex. The results of this study rejected the hypothesis that Moyers' prediction tables were applicable to the northern Manitoban First Nations population and partially rejected the hypothesis of the applicability of Tanaka and Johnston's prediction equations. Of the analyses

compared, only the Tanaka and Johnston analysis was found to be in agreement with the actual size of the mandibular canines and premolars in the northern Manitoban First Nations population. To improve prediction accuracy, new analyses were formulated for a northern Manitoban First Nations population. Testing of the newly created NMFN prediction analyses revealed no statistical differences between the predicted and actual values of the canines and premolars. The newly derived prediction methods, could be clinically useful in a northern Manitoban First Nations population for tooth size predictions.

DEDICATION

For my wife, Selena. Where would I be without the sunshine?

To my parents. Determination and perseverance without limits.

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INTRODUCTION

1.0 General Overview

At approximately age six a child's transition from deciduous to permanent dentition begins with the eruption of the permanent incisors and the first permanent molars. This transition is known as the mixed dentition phase. The canines and premolars do not erupt until a number of years later. During this mixed dentition phase, forecasting the size of the unerupted canines and premolars relative to the existing arch space available is an important diagnostic process in orthodontics. Early detection of a deficiency in arch length is usually indicative of potential future dental crowding or malalignment.

Mixed dentition analysis involves a decision process whereby the space required for the dentition is subtracted from the space available within the arch. The space required is the sum of the total mesiodistal dimensions of the permanent canines and premolars on each side of the arch plus the width of the four permanent incisors. Such measurements usually involve one of two methods[1]. The first involves placing a brass wire through the contact points of each tooth, then measuring the length of the brass wire when straightened out (Fig 1). The second method requires use of a Boley gauge to measure the distance between the mesial surface of the first permanent molar to the distal surface of the permanent canine, followed by recording the distance from the distal of the permanent canine to the mesial surface of the permanent central incisor (Fig 2). Addition of these two measurements constitutes

Figure 1. Brass wire measurement of the dental arch

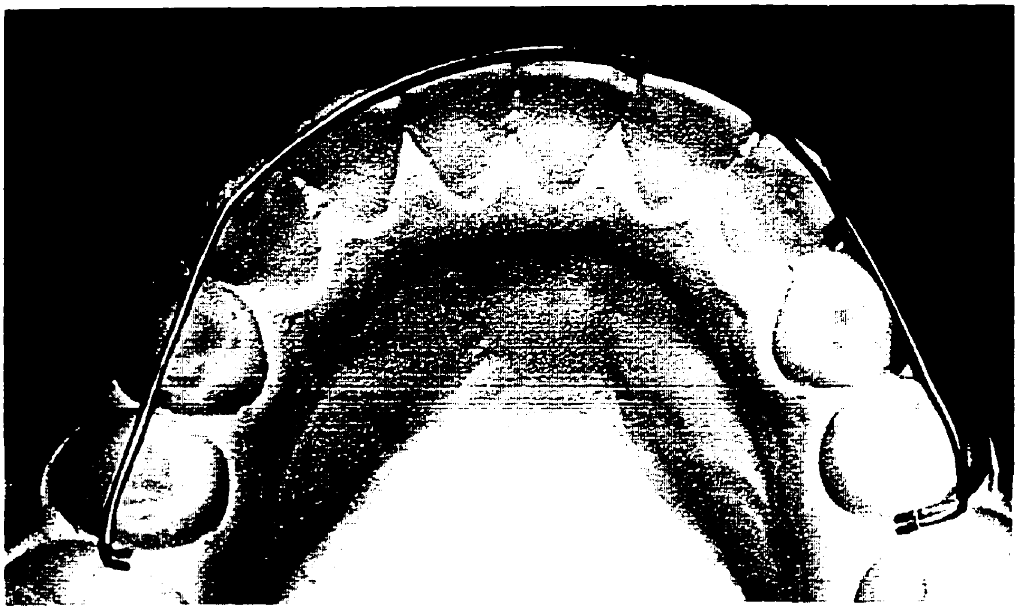
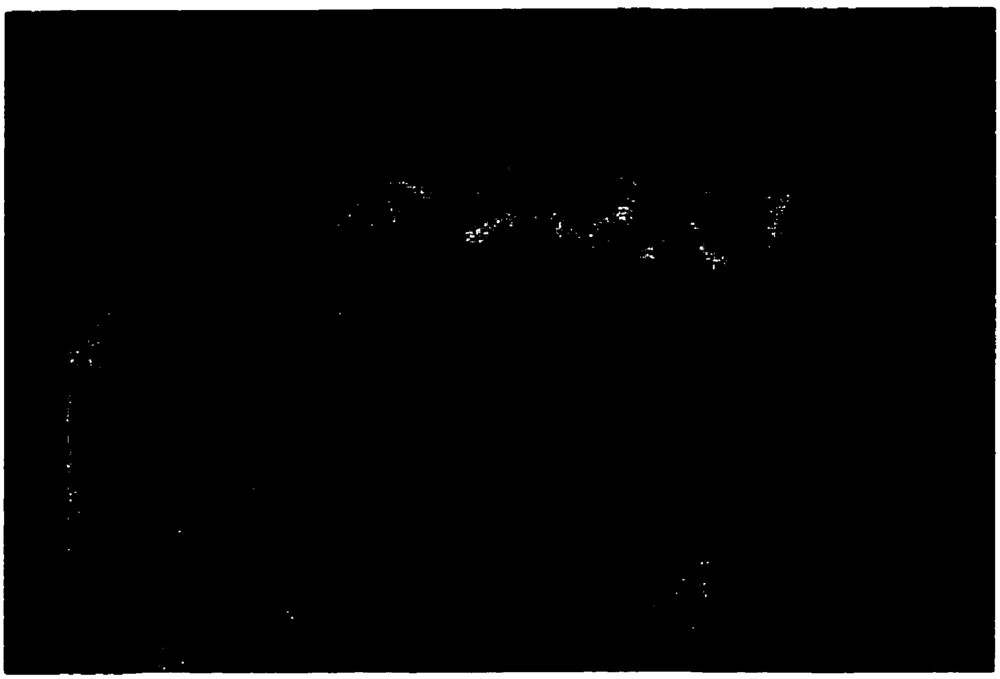


Figure 2. Boley gauge measurement of the dental arch



the total space available within each dental arch. If there is adequate or increased space for the eruption of the permanent dentition further treatment may not be necessary. However if inadequate space has been diagnosed, future treatment options may involve selective interproximal reduction of the dentition, arch expansion or extraction of selected permanent teeth.

The concept of dental space analysis is not a recent idea. Review of the literature indicates attempts to predict the width of the unerupted permanent canines and premolars were published in the early 1900's and can be categorized into three basic methods:

- measuring erupted teeth (Moyers[1], Tanaka and Johnston[2]);
- measuring teeth from radiographs (Nance[3], Huckaba[4]); and
- using a combination of the above two methods (Hixon and Oldfather[5], Staley and Kerber[6]).

1.1 The Nature of the Problem

Typically, the mesiodistal dimensions of unerupted canines and premolars have been extrapolated from measurements of the erupted permanent mandibular incisors using Moyers' probability tables[1] or calculated using the Tanaka and Johnston prediction equation[2]. Both prediction techniques were developed using a population of "probable" northern European ancestry. However neither study qualified the exact origins of the sampled studied. Unlike Moyers[1], Tanaka and Johnston[2] documented their sample size (506 subjects). In 1975, Bailit[7] discussed the variations in permanent tooth size that exist among different races. Comparisons of the mesiodistal dimensions of maxillary permanent teeth were conducted using a non-described sample of white Americans, Japanese, Australian Aborigines and Norwegian Lapps. From his data, Bailit concluded that permanent tooth size does vary among different races. Specifically, the mesiodistal dimension of the first molar in Australian Aborigines was almost 10% larger than that found in Norwegian Lapps. He also noted that there were racial differences in the relative size of specific teeth. For example, populations of Asian ancestry have large upper lateral incisors compared to their centrals. This trait is not demonstrated in the other racial groups listed. Evidence of racial tooth size variability suggests that prediction techniques based on a single racial sample may not be considered universal. Therefore, it is of the utmost importance that prediction techniques are interpreted relative to respective racial norms, since failure to consider tooth size, racial variations would render the interpretation of Moyers' probability tables[1] and Tanaka and Johnston prediction equations[2] as misleading and erroneous. To date, no data have been published regarding either the study of mixed dentition analyses or the study of mesiodistal tooth sizes in the First Nations population of Manitoba, Canada. The subset of Aboriginal children representing the northern Manitoban region is the focus of the current study.

1.2 Thesis Objectives

The objectives of this thesis are:

1. To determine if the analysis which uses measurements of the four permanent incisors can be used to reliably predict the mesiodistal dimension of the unerupted maxillary and mandibular premolars and canines

2. To evaluate the applicability of Moyers' Probability tables to the Manitoban First Nations population

3. To evaluate the applicability of Tanaka and Johnston prediction formula for the Manitoban First Nations population

4. To develop, if required, a new prediction formula to be used for the Manitoban First Nations population

5. To develop, if required, a new prediction table to be used for the Manitoban First Nations population.

6. To test the accuracy of the newly created prediction equations using a new Manitoba First Nations sample.

LITERATURE REVIEW

2.0 Development of the Mixed Dentition Analysis

The teeth are the building blocks from which the clinical orthodontist can modify the occlusal architecture. The clinical orthodontist must first understand the morphological parameters of the dentition before he or she may work towards occlusal harmony. The most fundamental aspect of tooth morphology in this regard is mesiodistal width.

Black[8] was the first to publish tables suggesting an average mesiodistal crown width in human teeth. Clinically, these average values were found unreliable because of the great variability in tooth size between subjects. Variability of permanent tooth size can be caused by variations in race[7,9], heredity[10], environment[11], secular changes[12], bilateral asymmetry[13,14] and gender[16].

The genetic basis for this variation is best explained by a polygenic model of inheritance. Lundstrom[15], in 1964, compared 97 pairs of like-sex monozygotic and dizygotic twins and found a stronger correlation in mesiodistal tooth size between monozygotic twins. He concluded that tooth size within a given population is determined to a large extent by genetic factors.

In many individuals the mixed dentition can be influenced by unfavorable factors such as ectopic eruption, congenitally missing permanent teeth, premature loss of deciduous teeth or unfavorable growth patterns. It is believed in orthodontic circles that a large number of cases of malocclusion become apparent during the mixed dentition stage which spans an interval from the sixth to the twelfth year of life[16]. Many of these developing malocclusions may be reduced in severity or even eliminated entirely by timely interceptive management[16]. Situations, in which there is an arch length deficiency, may warrant interceptive space maintenance, space recapturing, serial extraction or guidance of eruption to ensure a favorable outcome. An important aspect of early orthodontic treatment is the determination of the relationship of the unerupted permanent mesiodistal tooth size to the available arch length during this early phase of development.

The numerous methods developed to help quantify the possible disparity between tooth size and arch length can be divided into three categories. The methods include determining the unerupted mesiodistal widths of premolars and canines from (1) radiographs; (2) dental casts; and (3) a combination of dental cast and radiographic measurements.

Nance[17] was the first to quantify radiographically the space differential between deciduous canines and molars and their successive unerupted canines and premolars seen on radiographs. He noted a similarity between radiographic tooth size and white American mesiodistal tooth dimensions published in Black's Dental Anatomy[8]. Using a sample of 76 American born children of northwestern European descent, Hixon and Oldfather[5] predicted the widths of unerupted mandibular canines and premolars from the sum of the mesiodistal dimensions of the central and lateral incisors and the images of the first and second premolar from long cone radiographs[5]. According to their findings the correlation coefficient for this technique was r=0.87.

Due to the possibility of radiographic elongation or shortening, Huckaba recognized the need to compensate for radiographic distortion[4]. He developed the procedure on the basis that the degree of magnification on a given film is approximately the same for a primary tooth as for its permanent successor. Huckaba also determined that the mandibular permanent incisors were the most reliable indices of the size of the remaining permanent teeth of both arches.

After reviewing Morrees' Caucasian tooth size charts[18] Sim suggested a simpler radiographic mixed dentition analysis. Since the width of the first premolar is very nearly the average width of the canine and second premolar, he proposed simply to multiply the radiographic width of only the first premolar to obtain the segment's canine and premolars combined mesiodistal width[19]. Unfortunately the accuracy of Sim's technique has never been tested.

The accuracy with which the mesiodistal widths of unerupted teeth may be determined from a periapical radiograph depends in large part upon the technique with which the films were taken. Although the impact of these variables can be reduced by attention to the radiographic technique, presence of rotated teeth in their crypts will ultimately prevent a true measurement of mesiodistal width[20].

Compensating for possible measurement error is an exacting and time-consuming technique. These disadvantages may largely be overcome by a variety of regression schemes in which the tooth size is predicted from permanent teeth that are already present and easily measured[2].

Realizing the limitations of radiographic tooth size prediction, Ballard and Wylie developed a prediction equation ($X=9.41+0.52Y$) based on a correlation relationship between the sum of the mesiodistal widths of the mandibular incisors and the sum of the mesiodistal widths of the permanent canine and premolars[20]. Description of the group under study is limited to the sample size. The sample is quantified as 441 individuals. Specifics as to gender, age, and ethnicity were not stated. In the equation, X is equal to the sum of the mesiodistal widths of the permanent canine and premolars, while Y is equal to the sum of the mesiodistal widths of the mandibular four incisors. Although the correlation coefficient is low, ($r=0.64$) Ballard and Wylie concluded that their method had only 2.6 percent error (0.6 mm) as compared to a 10.5 percent error (2.2 mm) when using only radiographs.

In 1960, Ono working in Japan, developed a regression equation to predict the mesiodistal width of unerupted permanent canine and premolars in the Japanese population[21]. He was the first researcher to present a tooth size prediction analysis based on a population other than Caucasian children. Similar correlation coefficient values, $r= 0.57$ were determined for Japanese permanent incisors and permanent canine and premolars in both arches as well as the mandibular permanent incisors and maxillary permanent canine and premolars.

Utilizing direct dental cast measurements from a Caucasian University of Michigan orthodontic patient population, Moyers[1] created a probability chart that would determine the mesiodistal width of the unerupted canine and premolars of both maxillary and mandibular arches based on the sum of the mesiodistal widths of the four mandibular incisors. Sample description including size, gender, and ages were not stated. Ethnicity of the sample was described as Caucasian Americans of northern European descent. The prediction tables were constructed such that predicted values could be assessed ranging from the fifth to the ninety-fifth percentiles. For clinical applications Moyers recommended values established for the seventy-fifth percentile. At this level 3 out of 4 predicted values would be equal to or smaller than the actual mesiodistal width. The table's format serves to protect the clinician from predicted values that may actually undervalue the actual mesiodistal width. Although never proven, Moyers states that no one figure represents the precise cuspid-premolar sum for all people, since there is a range of posterior tooth widths seen even when the incisors are identical[1].

The regression equation used to establish the probability tables as well as details regarding Moyers' sample have never been characterized in the literature. According to Proffit and Fields, the accuracy of Moyers' probability table is fairly good for northern Europeans white children on which the data was based, despite a tendency to overestimate the size of unerupted canines and premolars[22]. This method is therefore not valid across ethnic groups.

Tanaka and Johnston conducted a study that would repeat Moyers' observations on a new, larger sample that was drawn from a contemporary orthodontic population. Dental casts for 506 Caucasian patients of probable northern European descent were studied. Sample specifics such as gender and age were not stated. They utilized a simple linear regression equation to establish prediction tables. The prediction tables constructed by Tanaka and Johnston were practically identical to those published by Moyers. Tanaka and Johnston concluded that the size in millimeters of unerupted canines and premolars at the 75th percentile can be predicted by taking half the width of the mandibular incisors and adding 11.0 for the maxillary teeth and 10.5 for the mandibular teeth[2]. The aforementioned formulas can be used for both male and female patients.

2.01 Variations of Tooth Size Dimensions Among Various Races

Published articles in various physical anthropology and dental journals have determined the existence of tooth size variations among races. Bailit[7] states, "permanent tooth size does vary among different races. In fact, the comparison among groups with the largest and smallest teeth is rather dramatic. (Further), there are interesting racial differences in the relative size of specific teeth." Merz et al[23] measured the mesiodistal crown dimensions of 51 African Americans (35 female and 16 male) and 50 Caucasian Americans (34 female and 16 male). The combined mesiodistal dimension of the lower left quadrant was 1.92 mm greater in the African American group.

Similarly, in 1972, Lavelle[24] demonstrated tooth size variations in different racial groups. He found that the mandibular central and lateral incisors of the Mongoloid population were 0.17mm smaller than the same teeth of the Caucasoid population. In addition, the mandibular canine and first and second premolars of the Mongoloid population were 1.30mm larger compared to the Caucasoid population.

Similarity between the Mongoloid and the North American First Nations dentition has been supported by odontology research[25]. A previously published study examined the shape of fossil teeth in museum collections around the world and also contemporary teeth[26]. The study concluded that prehistoric and contemporary peoples of China, northeastern Asia generally, and the New World (North America) consistently demonstrated a similar Sinodont dental pattern rather than the Southeast Asian Sundadont or the European dental pattern. Dalhberg also suggests that shovel-shaped maxillary incisors are a part of a Mongoloid dental complex seen in North American First Nations populations[9]. In contrast, study of the North American Caucasoids indicates the absence of, or at most, a trace expression of shovel-shaped incisors[27]. These observations substantiate dental differences between the Caucasoid and Asian populations.

Therefore the link between Asian and First Nations populations is suggestive of dental differences between Caucasoids and First Nations populations.

2.02 Prediction Methods Applied to Other Racial Populations

As reviewed above, many methods have been created to predict the sizes of unerupted teeth. Of these methods, the Moyers probability tables and the Tanaka and Johnston prediction equations and tables are the most widely used today[28]. Both methods have been developed from a population of northern European descent; therefore the accuracy of these prediction methods could possibly be in question when applied to a population from a different ethnic origin. Proffit[22], referring to Moyers' and Hixon and Oldfather's analyses[5], states that "if a patient does not fit the population group, as a black or Oriental would not, direct measurement from the radiograph is the best approach". Hakanson applied Moyers' probability chart for a sample of White, Black and Asian children[29]. Results of the study indicated that the probability charts underestimated the size of the permanent canines and premolars in the maxilla and mandible and suggested that an adjustment be made for Asia and Black children.

Recently investigators have tested the applicability of Moyers' probability tables and Tanaka and Johnston prediction equations on various other ethnic populations. In 1993, Al-Khadra applied both methods of prediction on a limited sample of patients in Saudi Arabia. He concluded that the Moyers charts at the 75th percentile confidence level and the Tanaka and Johnston equations did not accurately predict tooth size in the Saudi sample. Both analyses overestimated the size of the buccal segments[28]. The smaller the mesiodistal dimension of the mandibular permanent incisors, the greater the error. Zilberman et al.[30] also found similar results when applying the Moyers' method to a Jewish Israeli population.

Schirmer and Wiltshire compared Moyers' probability tables to a Black South African population. The sample included 50 male and 50 female subjects between 13 and 20 years of age. They concluded that for Black subjects of South African descent, the Moyers' regression equations are statistically significantly different from those derived from data produced for Black South Africans, except for the prediction of maxillary canines and premolars for females at the 85% and 95% level of probability[31].

Lee-Chan, Jacobson, Jacobson, and Chwa compared the degree of accuracy the Tanaka and Johnston prediction equation would demonstrate when an Asian-American population was studied[16]. When the actual measurements were compared with the predicted values derived from the Tanaka and Johnston equations, significant differences (maxillary; $p>0.001$ and mandibular; $p>0.003$) were found. The study revealed that when the mesiodistal width of the canine and premolar was below 22 mm, the Tanaka and Johnston equation overestimated the actual size of the canine and premolars. However, when the mesiodistal width of the canine and premolars was above 24 mm, the Tanaka and Johnston equation underestimated the actual size of the canine and premolars. Applying the principals of the Tanaka and Johnston prediction equation, the authors were able to develop different regression equations appropriate for the Asian-American population. However reliability of these regression equations has never been tested

Chaiwat, Dechkunakorn, and Sawaengkit studied the accuracy of Moyers prediction charts in a Thai population[32]. They reported that 56% of the sample showed an underestimation by more than 2 mm and 36% of the sample showed an overestimation by more than 2 mm. Only 8% of the Thai sample were accurately predicted within +/- 2 mm.

The literature review indicates that many investigators found differences in tooth size between various ethnic groups and, as a result, a number of ethnic diagnostic standards must be developed. Specifically, ethnic tooth size prediction equations and tables should be created and applied to each ethnic population. Currently there is neither information regarding the study of mixed dentition analyses nor the study of mesiodistal tooth size in the First Nations population in Manitoba, many of whom frequently seek orthodontic treatment.

2.1 Origins of the Canadian Aboriginal Population

It is a consistent belief amongst archeologists that people have lived in the "New World" for at least 12,000 years. The conventional theory is that the first people came to North America from what is now Siberia via either a frozen water surface across the Bering Strait or a land bridge known as Beringia that existed intermittently from 70,000 to 12,000 B.C.[33]. Once in North America the descendants eventually migrated down the Pacific coast and then into the continent's interior. Most of what is now Canada was either abandoned when the arctic glaciers migrated southwards or was not settled at all until they melted. At that point ancestors of the people now known as Kutenai and Salish could move into the British Columbian interior from the west coast, the Algonquins and then the Siouans and the Iroquians into the central and eastern Canada from the south, and the Athapaskans into the interior northwest from the coast. Still later, a second wave of Asian migration involved the Inuit who moved across the Arctic in a series of west-to- east migrations.

North American Indians share similar phenotypical characteristics that link them together and separate them from Caucasoids. Aboriginal people tend to have straight black hair, a lack of male-pattern baldness, and little facial or body hair; they have a darker complexion and have skin that tans easily, rarely have blue eyes, and may have epicanthic eye folds[33]. They also exhibit a convex profile associated with bimaxillary dentoalveolar protrusion[25].

2.2 Defining the Canadian Aboriginal Population

The following definitions are intended to provide a general understanding of the current terminologies used by the Canadian federal government when describing or classifying the Canadian Aboriginal population[34].

1. **Aboriginal people**: The descendants of the original inhabitants of North America. The Canadian Constitution recognizes three groups of Aboriginal people - Indian, Métis and Inuit. These are three separate peoples with unique heritages, languages, cultural practices and spiritual beliefs.

2. **First Nation(s)**: A term that came into common usage in the 1970s to replace the word "Indian," which many people found offensive. Although the term First Nation is widely used, no legal definition of it exists. Among its uses, the term "First Nations peoples" refers to the Indian people of Canada, both Status and Non-Status. Many Indian people have adopted the term "First Nation" to replace the word "band" in the name of their community.

2. **Métis**: People of mixed First Nation and European ancestry who identify themselves as Métis people, as distinct from First Nations people, Inuit or non-Aboriginal people. The Métis have a unique culture that draws on their diverse ancestral origins, such as Scottish, French, Ojibway and Cree.

4. **Inuit**: An Aboriginal people in northern Canada, who live above the tree line in Nunavut, western Arctic, Northern Quebec and Labrador.

5. ***Indian Act***: This is the Canadian federal legislation, first passed in 1876, that sets out certain federal government obligations, and regulates the management of Indian reserve lands. The act has been amended several times, most

recently in 1985. Among its many provisions, the act requires the Minister of Indian Affairs and Northern Development to manage certain moneys belonging to First Nations and Indian lands, and to approve or disallow First Nation by-laws

6. **Status Indian**: An Indian person who is registered under the *Indian Act* (1876). The act sets out the requirements for determining who is a Status Indian.
7. **Non-Status Indian**: An Indian person who is not registered as an Indian under the Indian Act. This may be because his or her ancestors were never registered, or because he or she lost Indian status under former provisions of the Indian Act.
8. **Treaty Indian**: A Status Indian who belongs to a First Nation that signed a treaty with the Government of Canada.

2.3 The Manitoba First Nations People

The province of Manitoba, in central Canada, is inhabited by three major First Nations tribes the Algonquin, the Ojibway and the Sioux (Fig 3). Historically the delineation between these groups has been drawn on the basis of linguistic differences[35]. The Cree, the largest subset of the Algonquin tribe, constitute the largest First Nations group in Manitoba. According to data released by Statistics Canada, of the 76,475 Cree speaking Canadians, approximately 23,560 persons, or 31% of the Cree population resides in Manitoba[36]. The Cree's traditional habitat included Manitoba and Saskatchewan, between the Red and Saskatchewan

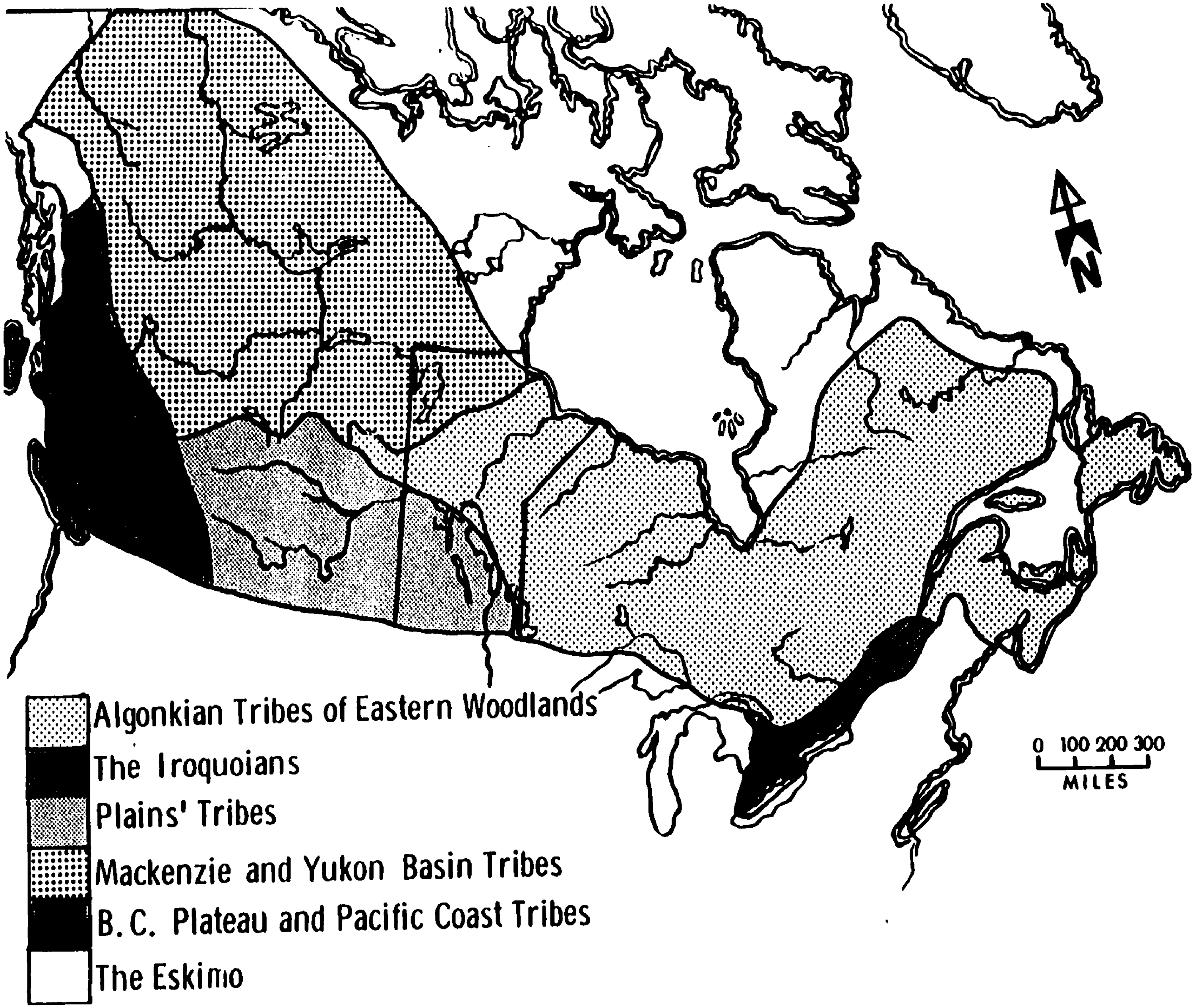


Figure 3. Major First Nations Tribes of Canada. (Adopted from Handbook of Indians in Canada 1973).

Rivers. They ranged northeastward down the Nelson River, to the vicinity of Hudson Bay, and northwestward almost to Lake Athabaska. Based on slight linguistic variations the Cree can be further subdivided into three major divisions, the southern and eastern Swampy Cree, northern central Rocky Cree and the western Strongwoods Cree. The Swampy Cree reside in the region from James Bay, westward to Cumberland House, Saskatchewan; the Rocky Cree are in and west of the Nelson River drainage in northwestern Manitoba and Saskatchewan; the Strongwoods Cree are north of the Saskatchewan River in Saskatchewan and Alberta.

Similar to the Cree, the Ojibway are descendants of the larger Algonquin tribe. The Ojibway population represents the second largest Manitoban First Nations group. The Canadian Ojibway population totaling 22,625 is primarily divided between the provinces of Ontario and Manitoba whose populations equal 10,545 and 9,680 respectively[36]. Variants of Chippewa, Saulteaux, Plains-Ojibway and Northern Ojibway have often been used to refer to the Ojibway people. The Ojibway territory ranged from the shores of Lake Superior in Michigan and Ontario westward to the southern shores of Lake Winnipeg[37].

Southwestern Manitoba is the most northern extension of the expansive Sioux plains tribe. They are the second most populous North American linguistic family next to the Algonquian north of Mexico[38]. The limited Manitoban Sioux population, also known as the Dakota and Assiniboin, total approximately 715 individuals[36]. Before confinement by the European settlers, the Sioux territory ranged northward from Arkansas and westward from the Mississippi river extending nearly to the Rocky Mountains. Within Manitoba the Sioux's traditional northern migration was limited geographically by the southern shores of Lake Winnipeg.

2.4 Provision of Orthodontic Therapy for the Canadian Aboriginal Population

Under the *Indian Act* of 1876, the federal government of Canada has assumed jurisdiction over the health of Native Canadians. While the *Indian Act* itself says little about the specifics, there remains a commitment to the prevention of the spread of infectious diseases as well as the costs associated with its implementation. Health and Welfare Canada operate a number of broad programs that provide health care to Native people throughout Canada. The first major program is Community Health Services, which focuses on communicable disease control, health education, mental health, nursing, and the provision of medical advice and assistance. The second is the non-insured health benefits program (NIHB). Through this program, Native people are provided general health care through access to the provincial medicare systems and supplemental programs. The program includes dental services including orthodontic treatment[39].

According to figures released by the national Medical Services Board[40], during the period between 1996-1999, 1,496 Manitoban First Nations individuals have or currently are receiving orthodontic treatment. This value represents 2.4% of the total Manitoban First Nations population. The province of Manitoba comprises 11.8% of the national total of 12,699 individuals. The overall national NIHB expenditure for orthodontic treatment during the period between 1994-1999 totaled $10,308,056. This value represents 10% of the total national dental expenditure ($104,302,000).

Within Manitoba the typical delivery of orthodontic treatment to the First Nations population involves patients seeking the services of private practice orthodontists primarily based in the capital Winnipeg. Currently the northern and central remote areas of Manitoba are serviced by local general dentists and by Winnipeg based orthodontists who maintain satellite orthodontic offices located in The Pas, Thompson and Gillam. The western Manitoban First Nations are serviced by local general dentists and orthodontists based in Brandon.

2.5 Statistics

In order to better understand the results of this study and previously published studies, the following brief introduction to statistics is included[41].

1) Mean (x): The arithmetic average of a distribution

2) Standard Deviation (SD): an indication of how spread out the values is around the mean. 67% of the sample population falls within ±1 SD of the mean. 95% of the population within ±2 SD of the mean.

3) Standard Error of the Mean: a measure of the average deviation of any sample from the true mean.

4) Regression Analysis: an equation in the form y=a+bx (or y=mx+b) that can be used to predict or estimate the value of one variable given the value of the other variable.

y: dependent variable, or the variable that is predicted

b: slope of the regression line

x: independent variable, or the variable that has been calculated

a: y-intercept point on the regression line

5) r-value: Correlation coefficient. A measure of the degree or strength of association between two variables. A r-value that equals 1.0 represents a perfect correlation between two variables. A r-value that equals 0.0 represents no correlation between two variables.

6) Standard Error of the estimate: the standard deviation associated with the regression line.

7) p-value: The chance of something more unusual happening, when expressed as a proportion of one. Typical p-value, quoted in the research literature, written as $p<0.05$, that is, 5% or 5 in 100 individuals would have a more unusual result.

8) Two-tailed t-test: Establishing if there is a difference between two groups being aware to the possibility of differences in either direction. For example, testing of two groups, A and B, could demonstrate that group A is larger than group B, or group B is larger than group A.

Materials and Methods

3.0 Sample

The sample population used in this study consisted of fifty-four northern Manitoban First Nations (NMFN) subjects. The sample was randomly collected from two orthodontic offices in north-central Manitoba, The Pas and Thompson. The sample consisted of 24 males and 28 females ranging in age from 13.5 years to 17.25 years. Identification of linguistic origins of the selected sample was not known, however it is believed that First Nations people residing in the isolated areas of north-central Manitoba are primarily, but not exclusively, of Cree ancestry. Therefore it is not assumed that the selected sample is truly representative of a particular tribe in Manitoba.

Criteria for sample selection were based on complete fulfillment of the following criteria:

1. All subjects were Status Indians and demonstrated North American Indian phenotypical characteristics. Indian descriptive traits, as described by Grant[42], include:

   i Medium to Dark brown color of the skin
   ii Hair of the head is straight and black
   iii Relative absence of hair on the upper lip, chin and cheek
   iv Eye color ranges from dark brown to black

2. A maximum of 18 years of age was used to preclude any discrepancies based on significant proximal wear.
3. All permanent teeth (except second and third molars) were present and fully erupted in both the maxillary and mandibular arches.

3. The teeth measured were free of interproximal restorations, fractures, as determined by the dental casts.
4. Study models were pre-orthodontic to ensure against any interproximal reduction.
5. Cases with only minor malocclusions were included, e.g. minor crowding, rotations, or diastemas.

3.1 Tooth Selection

The teeth measured included the mandibular permanent central and lateral incisors, the maxillary and mandibular permanent canines, and the maxillary and mandibular first and second premolars.

3.2 Measuring Device

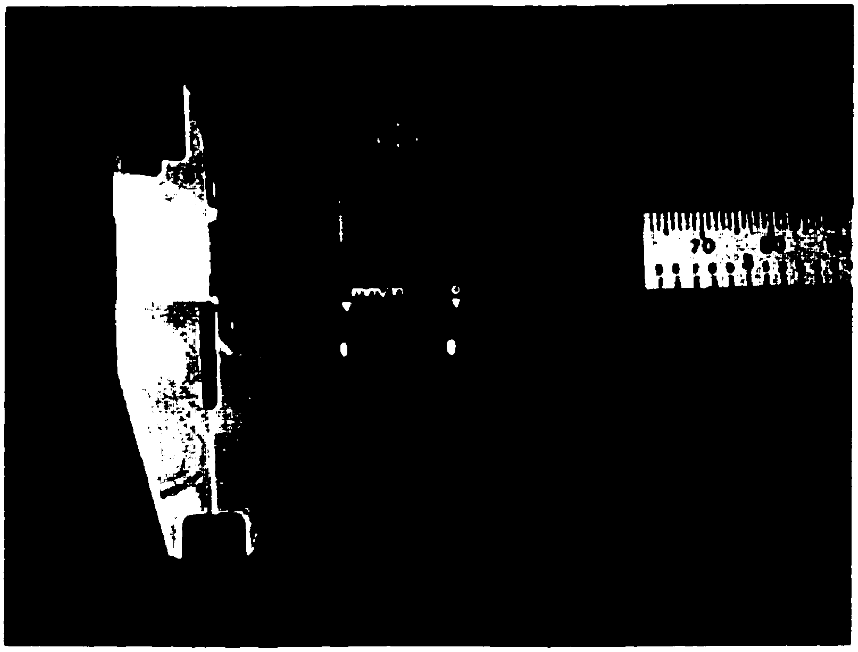
A Mitutoyo digital calipers (Fig 4) with a calibrated digital micrometer, read to the nearest 0.1 mm was used to record all mesiodistal dimensions. To improve accessibility into the interproximal region, Huckaba[4] recommends reduction of the gauge tips to fine points.

3.3 Measuring Technique

Two investigators measured teeth manually and independently. All measurements were taken directly from the unsoaped plaster study models. The mesiodistal dimensions of the teeth were determined by measuring the maximum distance between approximate surfaces of the teeth as described by Hunter and

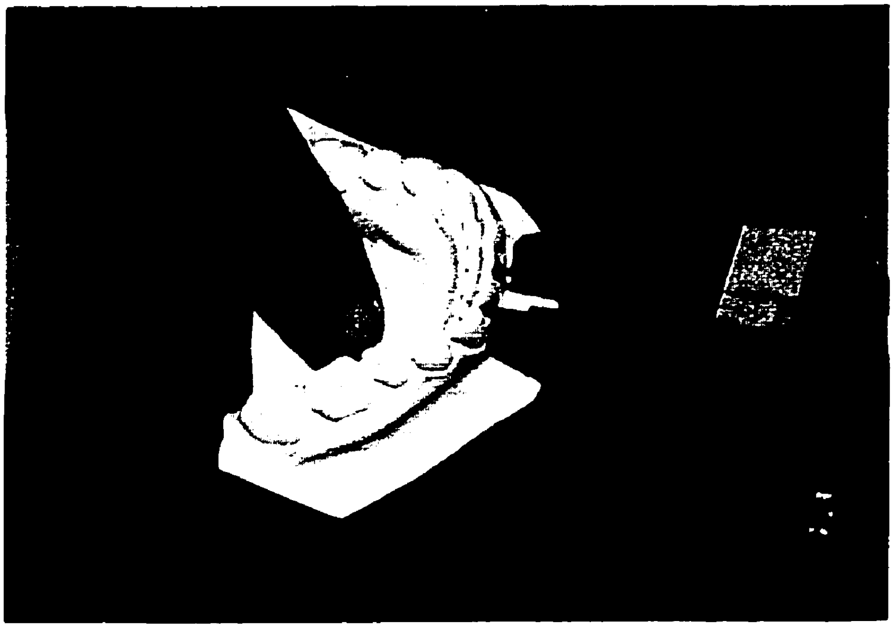
Priest[43]. All measurements were taken perpendicular to the long axis of the tooth, with digital calipers entering the interproximal area from either the buccal or the occlusal (Fig 5). The preferred method was from the buccal unless the tooth appeared severely rotated.

Figure 4. Mitutoyo Digital Calipers



Two investigators measured the teeth manually and independently. Intra-examiner and inter-examiner reliability was determined. In another tooth measurement study, Bishara recommended measurements varied by 0.2mm or less be averaged[44,45]. In accordance with this methodology, measurements that varied by more than 0.2mm were re-measured and the three measurements were averaged.

Figure 5. Measurements taken perpendicular to the long axis of the tooth, with digital calipers.



3.4 Data Analysis

Data analysis consists of three parts: 1) intra-examiner reliability; 2) inter-examiner reliability; 3) sample comparison.

1) Intra-examiner Reliability

Intra-examiner reliability was determined with measurements taken with the digital calipers from the plaster study models. The greatest mesiodistal dimension of the permanent incisors, canines, and premolars of the entire sample was measured and recorded. One week later, the same models were randomly measured according to the previously prescribed protocol. In both situations all measurements were obtained with the digital calipers and recorded to 0.01 mm. Correlation of the first and second measurements was calculated to determine the measurement reliability. There was excellent reliability between the repeated measurements taken by the principal examiner. The correlation values (r) for mandibular and maxillary measurements were 0.97 and 0.94 respectively.

2) Inter-examiner Reliability

Inter-examiner reliability was determined with measurements taken with the digital calipers from the plaster study models. Both examiners were instructed to measure and record the greatest mesiodistal dimension of the permanent incisors, canines, and premolars of the entire sample. In both situations all measurements were obtained with the digital calipers and recorded to 0.01 mm. There was excellent reliability between the two examiners. Repeated measures ANOVA represented in Table 1 found excellent inter-examiner reliability for both maxillary and mandibular tooth size measurements.

Table 1. Descriptive Statistics: Repeated measures ANOVA comparing examiners

Parameter	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level
Maxillary teeth Examiner 1 vs 2	1	0.000129	0.000129	0.00	0.502460
Mandibular teeth Examiner 1 vs 2	1	0.031877	0.031877	2.79	0.101165

3) Sample Comparison

Initially, statistical techniques were applied to the tooth dimensions of samples from two orthodontic offices. When subjected to an analysis of variance (ANOVA), the results summarized in Table 2 indicated no statistically significant differences between the two samples. The two samples were therefore combined together to increase the total sample size.

Table 2. Descriptive Statistics: ANOVA comparison of the two samples.

Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level
Location	1	7.42871	7.42871	0.00	0.958046
Sex	1	2.75004	2.75004	1.03	0.322696

3.5 Statistical Analysis

The following statistical analyses were calculated on the northern Manitoban First Nations population:

1) Utilizing the data collected, a range, mean, and standard deviation of the tooth groups were determined. A regression equation of the form Y= A + B (X) was formulated to predict the tooth size of unerupted canine and premolars in the northern Manitoban Aboriginal population.

2) Actual tooth measurements obtained from the sample verses calculated values determined by the Tanaka and Johnston prediction formula. In the Tanaka and Johnston prediction formula, the sum of the mesiodistal widths of the four mandibular incisors are correlated with the sum of the mesiodistal diameters of the mandibular and maxillary canines and premolars for both the right and left sides in male and female subjects. The Tanaka and Johnston regression equation is as follows:

Y= A+B (X) (A, B, constants derived mathematically)
Y= 10.5 + 0.5 (X) (Mandibular canine-premolar segment)
Y= 11.0 + 0.5 (X) (Maxillary canine-premolar segment)

Y= the estimate of the sum of the mesiodistal widths of the unerupted canines and premolars on either the right or left side.
X=the sum of the mesiodistal widths of the four mandibular incisors.

The difference between the predicted widths of the canine and premolars and the observed widths of the canine and premolars were tested for significance using a paired t -test.

3) Actual tooth measurements obtained from the two samples versus predicted values established by the Moyers' table. Actual measurements were statistically compared to the predicted values obtained with the Moyers' probability tables at the 75th percentile confidence levels using a paired t-test.

4) The newly created NMFN prediction formulas were tested on previously unmeasured NMFN subjects using paired t-tests.

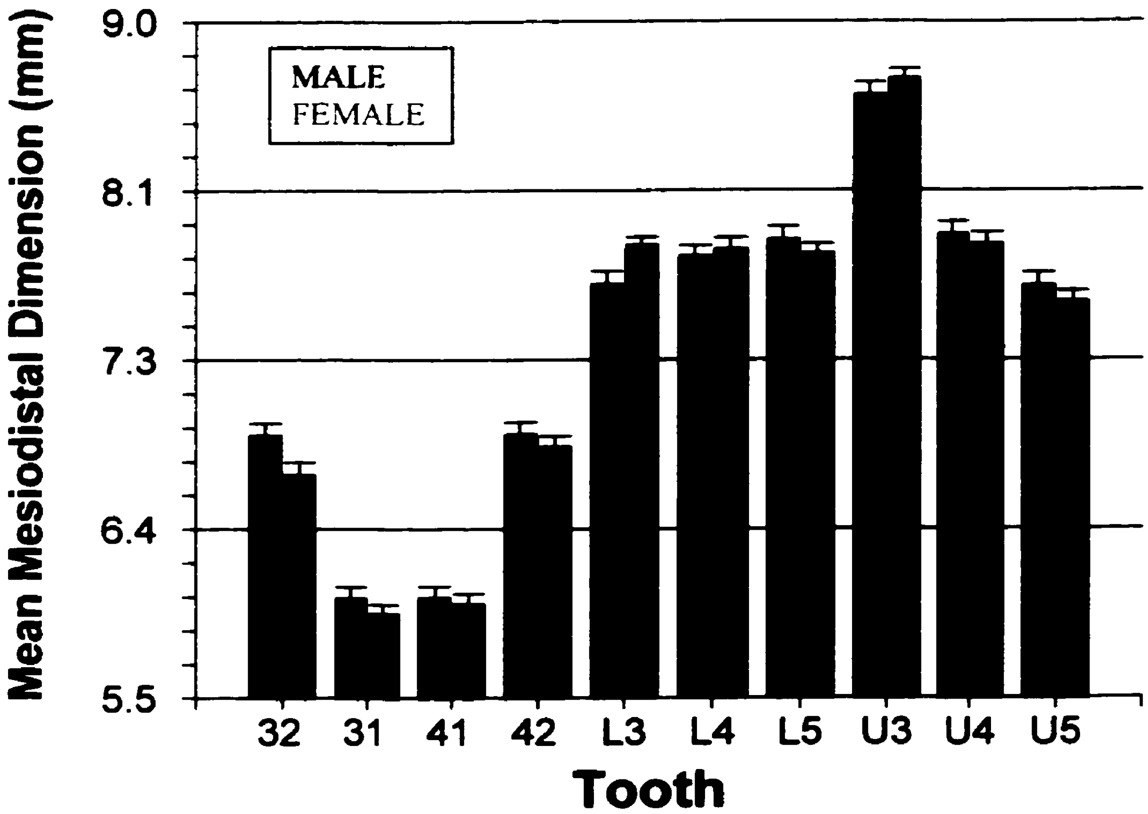
RESULTS

This section is divided into three parts. The first section describes the mesiodistal dimensions of the permanent mandibular incisors, canines and premolars measured from the northern Manitoban First Nations (NMFN) sample. This section includes descriptive statistical analyses of the collected tooth dimensions, whereas the second section examines the correlations between the combined mesiodistal dimension of the permanent mandibular incisors with the combined mesiodistal dimension of the maxillary and mandibular canine-premolar segments. Subsequently the final section compares Moyers' prediction tables[1] and Tanaka and Johnston's prediction equations[2] with the actual tooth sizes measured from the sample studied.

4.0 Mesiodistal Measurements

The mesiodistal dimensions of the mandibular incisors, maxillary and mandibular canines, and premolars are presented in Appendix 1 and 2. The mean mesiodistal dimensions and associated statistical data for the teeth included in this investigation are summarized in Table 3 (Appendix 3). These data are also summarized in graphical form in Fig 6, where the values computed separately for the male and female subjects permit the evaluation of sexual dimorphism. When all the dimensions were combined together, the teeth of the males were 0.02% greater than those of the females. However, since each dimension exhibited a range of 0.3% for the premolars to 3.2% for the canines, this sexual dimorphism proved insignificant statistically ($p > 0.2$). Although it is evident that gender differences were apparent in the sizes of the teeth, the combined dimensions between the sexes are essentially analogous.

Figure 6. Gender comparison of the mean mesiodistal crown dimensions of the NMFN subjects and their standard errors

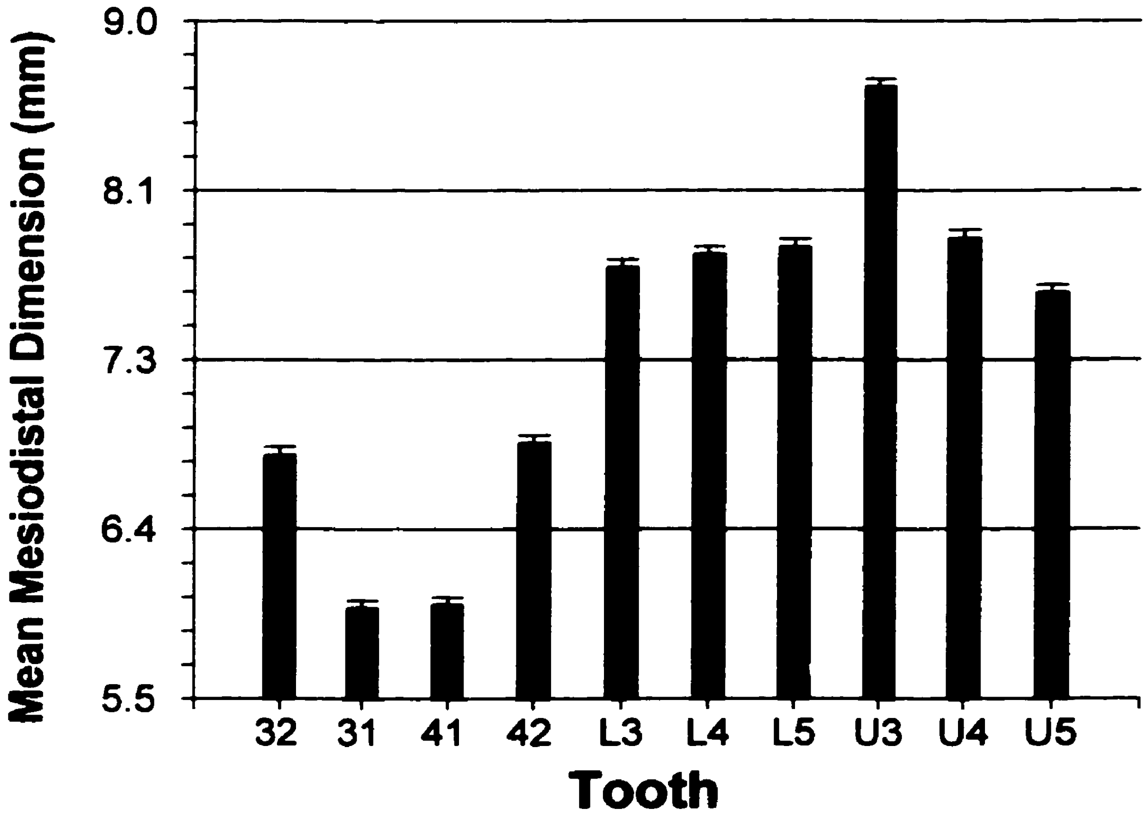


31 – mandibular left central incisor	41 – mandibular right central incisor
32 – mandibular left lateral incisor	42 – mandibular right lateral incisor
L3 - mandibular canine	U3 – maxillary canine
L4 – mandibular 1st premolar	U4 – maxillary 1st premolar
L5 – mandibular 2nd premolar	U5 – maxillary 2nd premolar

Accordingly, the tooth dimensions evaluated in this study were grouped together regardless of sex (Fig 7). These data showed that the mandibular central incisors are 11.6% smaller than the mandibular lateral incisors. Distal progression within the mandibular canine-premolar segment demonstrated a progressive increase in tooth size, whereas in the maxillary canine-premolar segment, tooth size decreased. The mandibular second premolar was 0.04% and 1.4% greater than the mandibular first premolar and mandibular canine respectively. In contrast, the maxillary canine was 9.0% and 12.3% greater than the maxillary first and second premolars respectively. The maxillary canine was the largest tooth (8.64 mm) and 32% greater than the smallest tooth, the mandibular central incisor (5.97 mm). The maxillary canine was 10.8% larger than the mandibular canine.

Descriptive analyses of the combined tooth measurements are reported in Table 3 and graphically displayed in Fig 7. Because the collected sample did not exhibit sexual dimorphism, the sample dimensions combined those for both males and females. The mean combined mesiodistal dimension of the permanent mandibular incisors was 25.5 mm, whereas these values for the maxillary and mandibular canine-premolar segments were 24.1 and 23.3 mm respectively. Combined measurements ranged from a low of 19.8 mm for the mandibular canine-premolar segment to a high of 26.4 mm for the maxillary canine-premolar segment, for an overall maxillary and mandibular discrepancy of 3.3%. The discrepancy between the two arches was attributed to the relatively larger maxillary canine, whose dimension was 0.93 mm or 11% greater than the mandibular canine.

Figure 7. Mean mesiodistal dimension of the NMFN subjects in millimeters



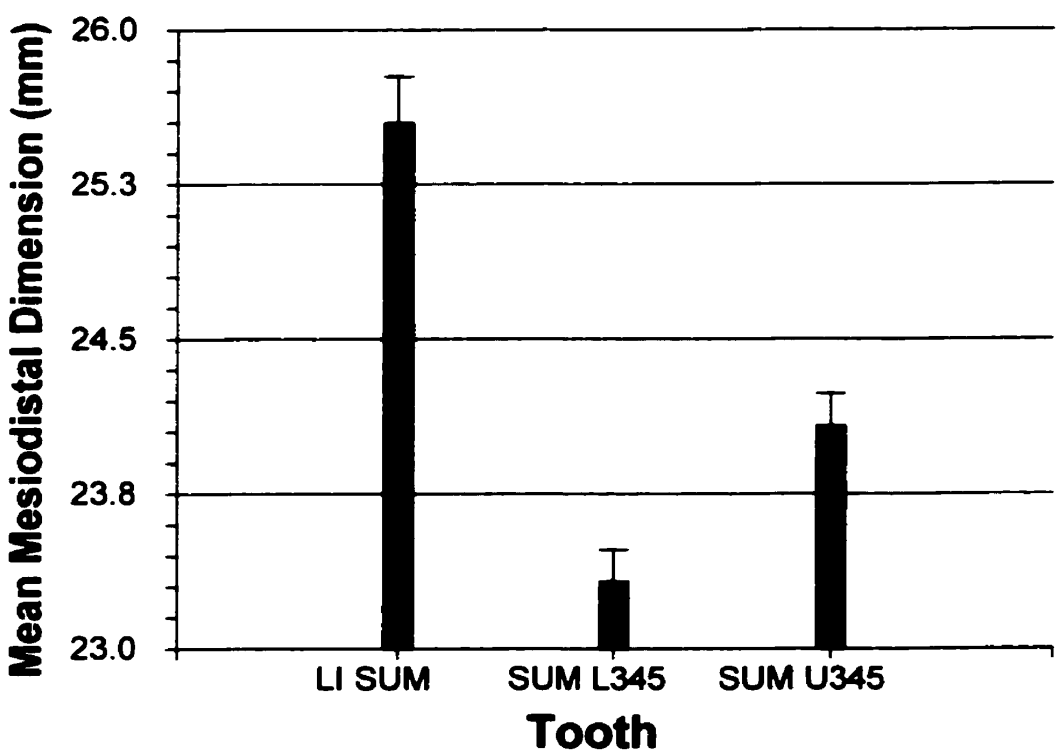
31 – mandibular left central incisor
32 – mandibular left lateral incisor
L3 - mandibular canine
L4 – mandibular 1st premolar
L5 – mandibular 2nd premolar

41 – mandibular right central incisor
42 – mandibular right lateral incisor
U3 – maxillary canine
U4 – maxillary 1st premolar
U5 – maxillary 2nd premolar

Table 3. Descriptive analysis combined mesiodistal tooth dimensions.

Combined Sum	**Mean (mm)**	Standard Deviation	Standard Error	Min	Max
LI	25.5	1.63	0.23	21.4	28.8
U345	24.1	1.13	0.16	21.9	26.4
L345	23.3	1.13	0.16	19.8	25.5

Figure 8. Mean combined mesiodistal tooth dimensions and their standard errors of the NMFN subjects



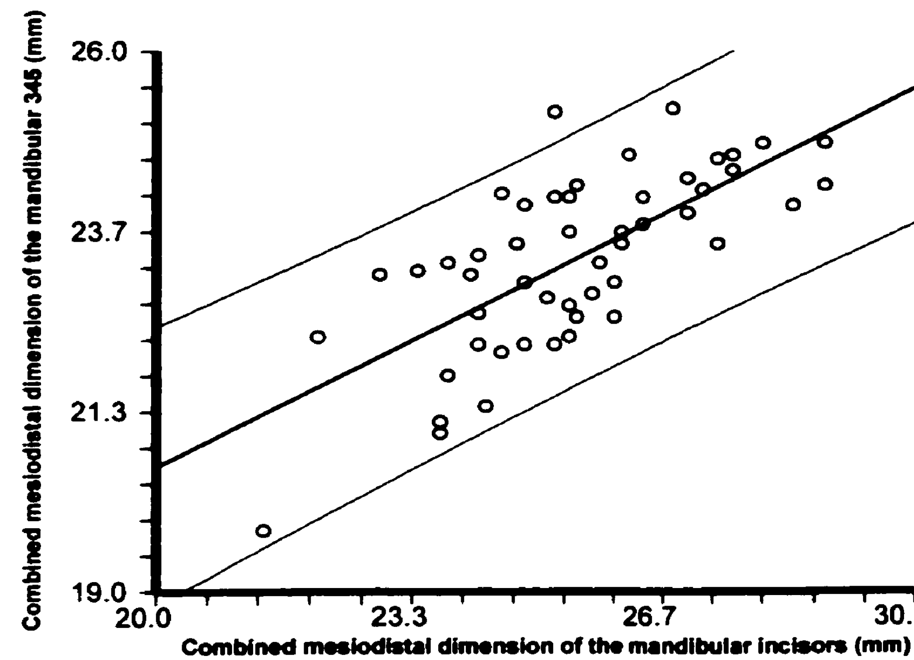
LI SUM - combined mesiodistal dimension of the permanent mandibular incisors
SUM L345 – combined mesiodistal dimension of the mandibular canine and premolars
SUM U345 – combined mesiodistal dimension of the maxillary canine and premolars

These dimensions were then subjected to regression analysis to evaluate the relationship between the combined mesiodistal dimension of the mandibular incisors and the canine-premolar segments.

4.1 Regression Analysis

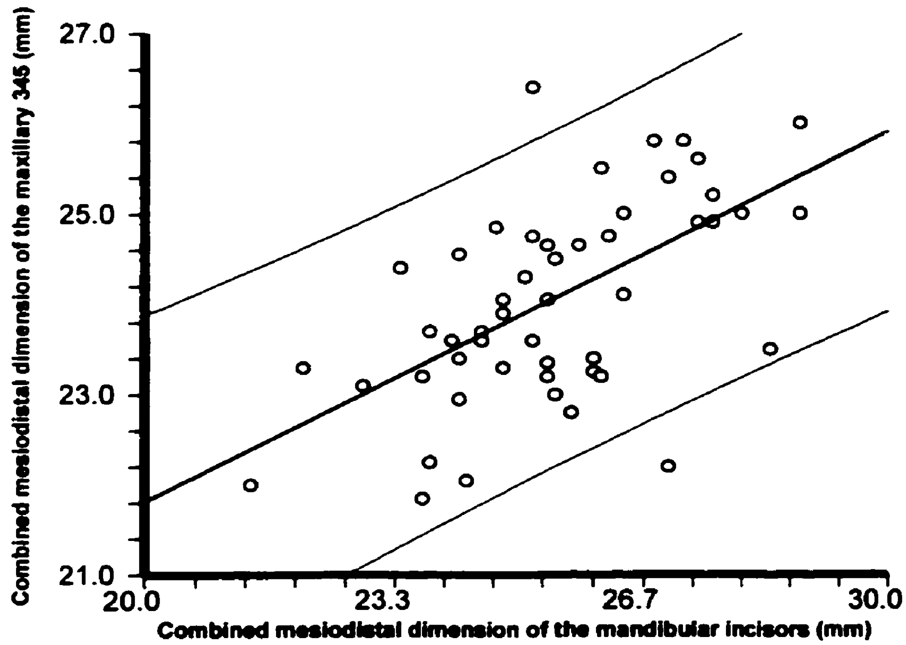
The regression relationship between the sum of the mesiodistal dimensions of the mandibular incisors and that of the mesiodistal dimensions of the canine and premolars were initially evaluated from scatter plots (Fig 9 and 10). Because the maxillary and mandibular arches were evaluated independently, their combined relationships were evaluated from two discrete scatter plots.

Figure 9. Regression of combined mesiodistal crown dimensions of mandibular canine and premolars (SUM L345) on combined mesiodistal crown dimensions of mandibular incisors (LI SUM).



This figure showed a linear relationship between the combined mesiodistal dimension of the mandibular incisors and the combined mesiodistal dimension of the mandibular canine-premolar segment, with one outer value that could not be explained despite repeat measurements.

Figure 10. Regression of combined mesiodistal crown dimensions of maxillary canine and premolars (SUM U345) on combined mesiodistal crown dimensions of mandibular incisors (LI SUM).



This figure showed a linear relationship between the combined mesiodistal dimension of the mandibular incisors and the combined mesiodistal dimension of the maxillary canine-premolar segment, with two outer values that could not be explained despite repeat measurements.

In both maxillary and mandibular scatter plots, points exist beyond the 95th confidence boundary. Repeated measurement of the outlying points did not result in plot changes, and may therefore represent the outer limits expected in a normal population.

A correlation between the two variables was suggested by the linear trend exhibited within each scatter plot. The correlation was represented by the regression equation derived from the equation of the slope, y=ax+b of each scatter plot.

Where, y = dependant variable (SUM U345 or SUM L345)
a = y –intercept
x = independent variable (LI SUM)
b = slope of the regression line

The regression equations were thus employed to determine the accuracy of predicting the mesiodistal diameter of the maxillary and mandibular canine and premolars, where the combined mesiodistal size of the lower incisors were used as predictors of the maxillary and mandibular canine and premolars. Table 4 represents two regression equations created to predict the total mesiodistal dimension of the maxillary and mandibular canine and first and second premolar combinations. Correlation of coefficient (r values) and standard errors of the estimate were also calculated for each equation.

Table 4. Regression analyses for canines and first and second premolars for NMFN subjects.

Dental Arch	**Regression Coefficients**		Standard Error of B coefficient	Coefficient of Correlation (R)	R^2
	A	B			
Maxillary	13.66	0.41	0.079	0.59	0.35
Mandibular	10.86	0.49	0.069	0.71	0.50

A correlation coefficient of 1.00 indicates a perfect relationship between independent and dependent variables, whereas values below 1.0 indicate an imperfect relationship. Such inaccuracies were expected from such a heterogeneous sample. The statistical evaluation of NMFN prediction equation accuracy is summarized in Table 5 and shows that an absolute mean error of 0.66 and 0.70 mm can be expected in the mandibular and maxillary segments respectively.

Table 5. Expected linear error derived from the newly created NMFN prediction equation in millimeters.

Arch	Absolute Mean Error	Standard Deviation	Standard Error	Min	Max
Maxillary	0.70	0.56	0.08	0.02	1.74
Mandibular	0.66	0.45	0.06	0.01	2.03

4.2 Comparison between Various Prediction Techniques

The average linear errors expected when using various prediction techniques are summarized in Table 6 and 7, where the mean error ranged between 0.66 and 0.79 mm. Of the techniques listed below, the NMFN technique demonstrated the least error for the maxillary canine-premolar segment (0.70 mm), whereas both the NMFN and Tanaka and Johnston techniques produce the least error for the mandibular canine-premolar segment (0.66 mm).

Table 6. Error comparisons between various maxillary prediction techniques in millimeters.

Maxillary Prediction	Mean Error	Standard Deviation	Standard Error	Min	Max	Significance
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Tanaka and Johnston	0.78	0.57	0.08	0.00	2.80	$p<0.05$*
Moyers	0.78	0.60	0.08	0.05	2.70	$p<0.05$*

* Denotes significance

Table 7. Error comparisons between various mandibular prediction techniques in millimeters.

Mandibular Prediction	Mean Error	Standard Deviation	Standard Error	Min	Max	Significance
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Tanaka and Johnston	0.66	0.45	0.06	0.00	2.10	
Moyers	0.79	0.45	0.06	0.05	1.80	p<0.01*

* Denotes significance

The actual widths of the maxillary canine-premolar segment showed a significant difference in size ($p<0.05$) from the widths predicted by the Tanaka and Johnston equation. However the Tanaka and Johnston equation was not statistically different from the actual mandibular canine-premolar segment. Significant differences ($p<0.05$) were found between the values of the NMFN subjects in this study and Moyers prediction values[1] (75^{th} percentile) for the maxillary ($p<0.05$) and mandibular segments ($p<0.01$) respectively.

Graphic comparison between the Tanaka and Johnston method of prediction[2] and Moyers prediction tables[1] (Figure 11 and 12) where the slopes of the Tanaka and Johnston equations[2] were positioned below the slopes established by the NMFN sample. The underestimation was more pronounced in the maxillary arch and became progressively greater as the combined mesiodistal dimension of the mandibular incisors decreased below 29.0 mm. Although the Tanaka and Johnston's mandibular equation[2] underestimated the size of the NMFN sample, the discrepancy, <0.2mm, was very small at its greatest point.

The slopes of Moyers' predicted values[1] were not representative of the slopes produced by the NMFN sample. As the combined mesiodistal dimension of the mandibular incisors increased, the degree of underestimation of the maxillary canine-premolar segment progressively decreased. However, at 26.3 mm a crossover occurred whereby Moyers' predicted values[1] progressively overestimated the actual NMFN tooth size. In contrast, Moyers' mandibular predicted values[1] tended to progressively overestimate the combined mesiodistal dimension of the mandibular incisors at dimensions greater than 21.9 mm. With dimensions less than 21.9mm Moyers' predicted values[1] slightly underestimated the actual NMFN mandibular canine-premolar segment.

The data from the present study therefore demonstrated the inadequacy of Moyers and Tanaka and Johnston prediction analyses, and the relative significance of these discrepancies are evaluated in the Discussion.

Figure 11. Comparison between Tanaka and Johnston's prediction equation, Moyers' prediction table values (75th percentile) and the actual mesiodistal dimension sum of the mandibular canine and premolars.

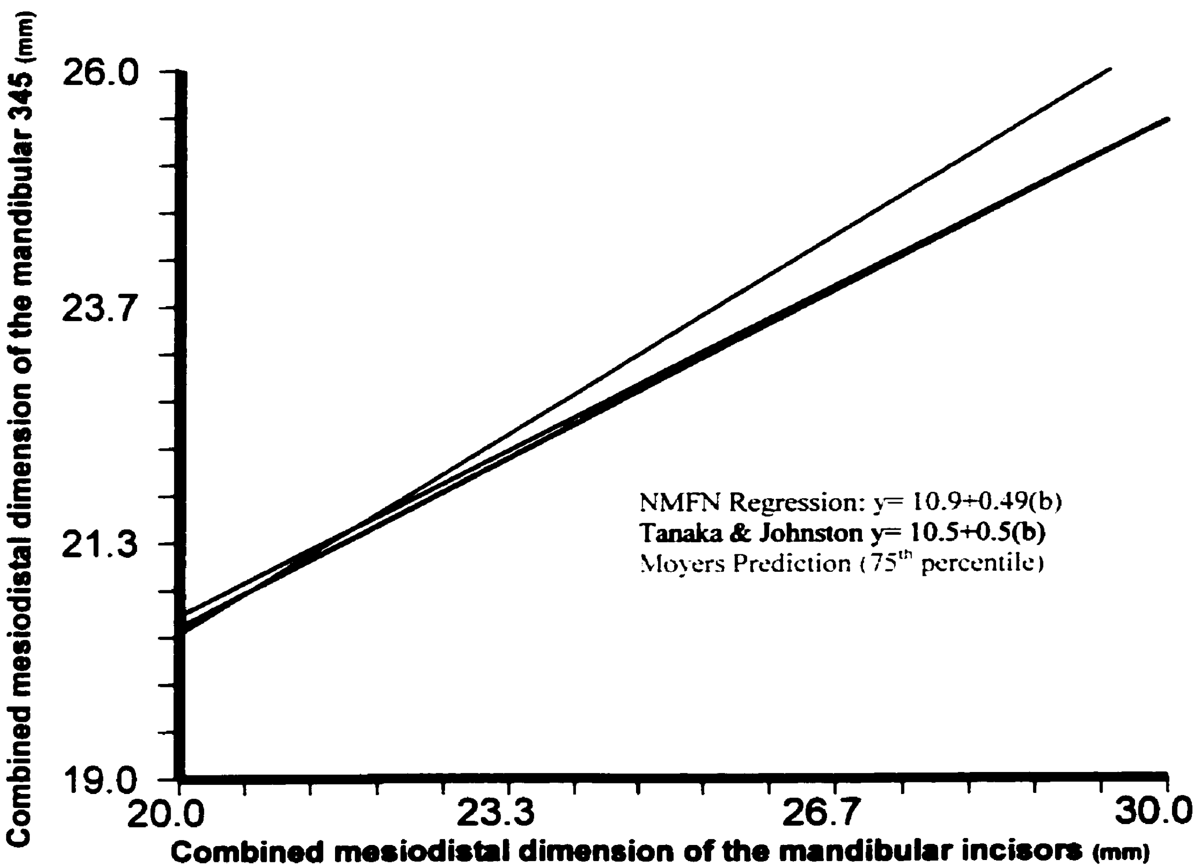
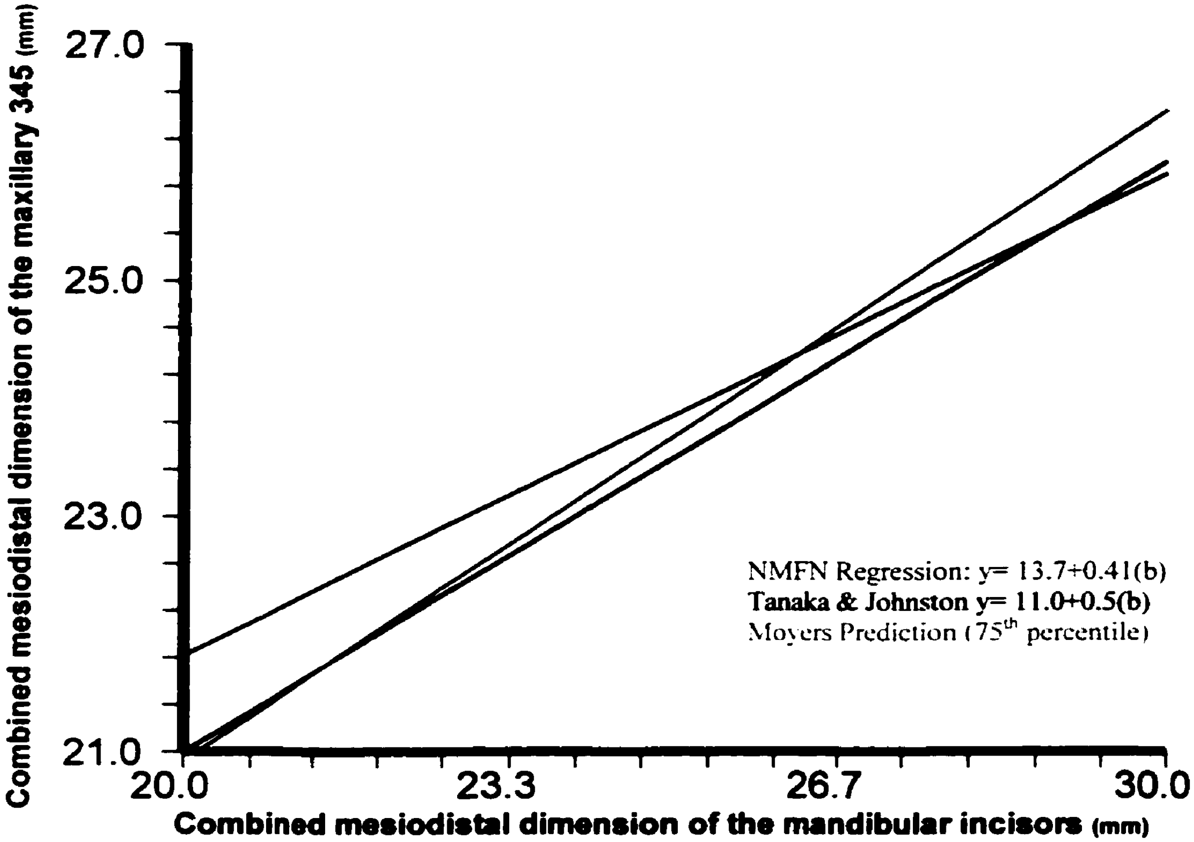


Figure 12. Comparison between Tanaka and Johnston's prediction equation, Moyers' prediction table values (75th percentile) and the actual mesiodistal dimension sum of the maxillary canine and premolars.



DISCUSSION

5.0 Purpose

This study was designed to establish the validity of Tanaka and Johnston's prediction equations[2] and Moyers' prediction table[1] for a Northern Manitoba First Nations population (NMFN). The NMFN sample consisted of 52 subjects, 28 males and 24 females (aged 12 years, 6 months to 17 years, 2 months), from First Nations and Inuit communities within northern Manitoba. No attempt was made to evaluate their genetic homogeneity. Appropriate statistical tests revealed no statistical difference between the two samples, so that their tooth dimensions were combined to increase total sample size.

5.1 Gender

Male subjects, with the exception of the canines, demonstrated slightly larger tooth sizes (Table 3). However, unlike other ethnic tooth size studies[16,46], the difference ranged between 0.1 and 0.2 mm and was not statistically different. Although there are tooth size differences between the sexes, the combined tooth size revealed little difference, as the males exhibited only a 0.2% larger size. The surprisingly absence of statistically significant sexual dimorphism revealed in this study permitted grouping of the data regardless of sex.

The results of this study contrasted Caucasian American norms (Table 8), which have larger tooth size discrepancies between sexes[18]. Males combined tooth size is 1.9mm or 3% greater than females, with the greatest difference, 0.5mm, demonstrated between the canines.

Table 8. Mesiodistal Crown Dimension of Caucasian American Permanent Teeth

Tooth	Male Mean ± SD (mm)	Female Mean ± SD (mm)
31/41	5.4± 0.31	5.3± 0.36
32/42	6.0± 0.38	5.8± 0.38
33/43	7.0± 0.36	6.5± 0.32
34/44	7.1± 0.35	6.9± 0.38
35/45	7.3± 0.52	7.0± 0.40
13/23	8.0± 0.42	7.5± 0.37
14/24	7.1± 0.38	6.9± 0.42
15/25	6.8± 0.37	6.6± 0.43
Total	54.7	52.8

Adopted from: The Dentition of the Growing Child: A longitudinal study of dental development between 3 and 18 years of age. Moorrees CFA pg 99[18].

5.2 Regression Analyses

The slope of the simple linear regression served to indicate the strength of the relationship between the dependent and independent variables of the regression equation[43]. The regression coefficients calculated in the present study slightly differed from those published by Tanaka and Johnston[2]. The interpretation of the NMFN subjects relative to those of Tanaka and Johnston[2] indicated that the mandibular incisors demonstrated a slightly lower correlation, r=0.59 for the maxillary buccal segment (Tanaka and Johnston r=0.62), and a slightly higher coefficient, r=0.71 for the mandibular buccal segment (Tanaka and Johnston r=0.65). Although the respective coefficients differed, the variation was considered insignificant.

The NMFN mandibular coefficient value was among the higher published data whereas the maxillary coefficient ranked less favorably (Table 9). Moorrees and Reed reported figures of 0.51 (SUM U345: LI SUM) and 0.58 (SUM L345: LI SUM)[47]. Other Caucasian studies[2,5,20] reported higher values for both arches (r=0.63 to 0.69), similar to values demonstrated in Israeli children[30] . Coefficients were larger for American blacks than for Caucasians, but smaller than for Hong Kong Chinese, except for the coefficients between SUM L345 with SUM LI in males[46]. Comparison between Hong Kong and American Chinese demonstrate greater coefficient values in the Hong Kong Chinese sample. Differences in coefficient values between the various ethnic studies illustrate tooth size variability between different ethnic groups.

Table 9. Comparison of correlation coefficients for different ethnic groups.

Study	Ethnic Group	SUM U345: SUM LI		SUM L345: SUM LI	
		Male	Female	Male	Female
Ballard, Wylie[20]	Caucasian			0.64	
Hixon, Oldfather[5]	Caucasian			0.69	
Moorrees, Reed[47]	Caucasian	0.51		0.58	
Tanaka, Johnston[2]	Caucasian	0.62		0.64	
Ferguson et al.[48]	American Black	0.63		0.71	
Frankel, Benz[49]	American Black	0.72	0.61	0.79	0.66
Chan et al.[16]	American Chinese	0.64		0.66	
Yeun, Tang, So[46]	Hong Kong Chinese	0.79	0.65	0.77	0.69
Ziberman et al.[30]	Israeli	0.64		0.66	
Present Study	**NMFN**	**0.59**		**0.71**	

SUM LI: combined mesiodistal dimension of the mandibular incisors
SUM U345: combined mesiodistal dimension of the maxillary canine and premolars
SUM L345: combined mesiodistal dimension of the mandibular canine and premolars

The moderately high linear coefficients between the combined mesiodistal dimension of the lower incisors and the mesiodistal dimension of the canine-premolar segment permitted the prediction of the size of the premolar segment using the lower permanent incisors. This was a useful clinical predictor, since estimates of such dimensions served to predict the unerupted mesiodistal dimension of the maxillary and mandibular canine-premolar segments.

Applying the values of coefficients A and B listed in Table 4, two equations for the prediction of maxillary and mandibular combined mesiodistal dimension of the canine and premolars were derived as follows:

NMFN Mandibular: y= 10.9+0.49(b)

NMFN Maxillary: y= 13.7+0.41(b)

Where,

b = Mesiodistal dimension of the four permanent mandibular incisors in millimeters
y = Mesiodistal dimension of the canine and premolars in one quadrant in millimeters

Charts predicting the mesiodistal dimension of the canine/premolar segment for the NMFN population presented in Appendix 4 were similar to Moyers' prediction charts for Caucasians, containing percentile confidence intervals. The proposed new probability tables for NMFN subjects are, however, considered more accurate and relevant to this specific population. They may therefore be applied to determine the sum of the mesiodistal dimensions of unerupted permanent canines and premolars when the four mandibular permanent incisors are fully erupted. Although the predicted sum of the mesiodistal dimensions of unerupted canines and premolars can be read at any of the stated probability levels, Moyers[1] recommended the 75th percentile level. For instance using the 75th percentile level, the mesiodistal dimension of the canine/premolar segment will not be greater than the given width in 75% of the cases tried. Unlike other studies[31,46,49], separate gender prediction tables proved unnecessary for this population.

5.3 Error

The standard error of the estimate (SEE) expressed the error in the use of the prediction equations. The regression line provided a mean predicted size of canine-premolars for a given size of the combined mesiodistal dimension of the permanent mandibular incisors, where the SEE for NMFN ranged from 0.6 mm for the mandibular segment to 0.8 mm for the maxillary segment. These values were clinically acceptable, and comparable to the errors reported in the literature[2,5,16,20,46] (Table 10).

Table 10. Comparison of standard errors of estimate for various prediction methods in millimeters.

Study	Maxillary Arch	Mandibular Arch
Moyers[1]	1.00	1.10
Tanaka and Johnston[2]	0.86	0.85
Yuen, Tang, So[46]	0.82	0.61
Chan et al[16]	0.90	0.85
Hixon and Oldfather[5]		0.57
Ballard and Wylie[20]		0.60
Present Study	**0.80**	**0.60**

In the present study, the absolute mean error (mean error without regard to sign) of buccal segment prediction ranged from 0.66 to 0.70 mm. The error ranged from 1.76 to 2.04 mm for the maxillary and the mandibular arches respectively. The percentages of observations with absolute error greater than 1mm for maxillary and mandibular arches were 31% and 27% respectfully. Although prediction error exists, it is apparent that the amount is clinically insignificant.

5.4 Analysis Comparison

Data from the NMFN sample to predict the total widths of the mandibular and maxillary canines and premolars were than evaluated by reference to the Tanaka and Johnston[2] and Moyers[1] analyses. Comparisons with the actual tooth widths indicated that both analyses based on Caucasians of probable northern European descent produced significantly different values for all tests ($p < 0.05$) except for the Tanaka and Johnston mandibular equation[2]. Although relatively accurate, the Tanaka and Johnston mandibular prediction equation[2], however had some limitations, in that it tends to slightly underestimate the actual NMFN mandibular buccal segments. The underestimation, <0.2 mm at the greatest point was, however clinically insignificant and was more evident as the combined mesiodistal dimension of the mandibular permanent incisors decreased.

Although both analyses were based on a sample of Caucasian American children of probable northern European descent, the different prediction values may have reflected the slight ethnic variations within the sample. Details of the samples used in both studies were, however limited, and the criteria of sample selection were not disclosed. Sample selection based on probable northern European ancestry proved ambiguous and could have been derived from ethnic grouping. Such underlying racial diversity may have contributed to prediction errors when the data were applied to samples from Caucasian North American children. This study strived to maintain a relatively pure racial sample, however, by adhering to the criteria stated in the Method and Materials section. However without serological testing, purity of the sample could not be guaranteed.

Ethnic tooth studies, listed in Table 11, illustrate the various tooth size prediction formulas. The results of these studies are evidence of ethnic tooth size variation. The different results obtained in this study supported the hypothesis that racial differences necessitate separate ethnic tooth size prediction equations.

Table 11. Comparison of regression formulas in different ethnic groups.

Study	Ethnic Group	Mandibular	Maxillary
Ballard, Wylie[20]	Caucasian	Y= 5.52 + 0.53(b)	
Tanaka, Johnston[2]	Caucasian	Y= 10.5 + 0.5(b)	Y= 11.0 + 0.5(b)
Frankel, Benz[49]	American Black	Y= 8.3 + 0.64(b)	Y= 10.1 + 0.52(b)
Ziberman et al.[30]	Israeli	Y= 8.6 + 0.55(b)	Y= 7.2 + 0.63(b)
Yeun, Tang, So[46]	Hong Kong Chinese	Y= 8.2 + 0.58(b) (male) Y= 6.7 + 0.64(b) (female)	Y= 8.0 + 0.66(b) (male) Y= 8.3 + 0.61(b) (female)
Chan et al.[16]	American Chinese	Y= 7.5 + 0.6(b)	Y= 8.2 + 0.6(b)
Present study	**NMFN**	**Y= 13.7+0.41(b)**	**Y= 10.9+0.49(b)**

Where,

b = Mesiodistal dimension of the four permanent mandibular incisors in millimeters

Y = Mesiodistal dimension of the canine and premolars in one quadrant in millimeters

The results of this study indicated that the currently popular Moyers[1] analysis was not sufficiently accurate to predict the canine-premolar segment in northern Manitoban First Nations populations. This conclusion was consistent with other studies that compared Moyers' analysis to populations other than Caucasian American children[28,30,31]. Application of Moyers' prediction tables on Saudi[28] and Israeli[30] populations produced predicted tooth sizes greater than the actual tooth sizes that ranged between 0.5 and 1.0 mm per quadrant. Similarly, in this study Moyers' predicted values[1] also overestimated actual tooth size, however, overestimation was greater in the maxillary segment and occurred at LI SUM values greater than 26.3 mm. In both arches, overestimation progressively increased as the LI SUM increased. The largest recorded overestimation for the maxillary and mandibular segments were 0.6 mm and 0.5 mm respectively. In contrast, Schirmer and Wiltshire concluded that Moyers' prediction tables[1] underestimated Black South African tooth size[31]. According to their results, the posterior teeth would be underestimated by 0.22 mm per quadrant if Moyers' tables[1] were to be used for Black South African subjects. Similarly, this study also concluded that Moyers' predicted values[1] underestimated actual NMFN tooth measurements. However, underestimation of tooth size occurred at LI SUM values less than 26.3 mm and 21.9 mm in the maxillary and mandibular segments respectively. Underestimation of tooth size was more significant, 0.8 mm in the maxillary segment compared to 0.02 mm in the mandibular segment.

5.5 NMFN Prediction Equations Testing

Testing of the prediction equations derived from the current study served to substantiate the reliability of the analysis. The precision of the NMFN prediction equations was tested on 15 previously unmeasured NMFN subjects. Because the test sample was derived from a different geographic location within northern Manitoban, a t-test comparison was necessary to determine if the collected test sample differed from the research sample. The results indicated no statistical difference between the two samples. According to values stated in Table 12, the mean absolute error for the maxillary and mandibular arches ranged between 0.69 mm (SD 0.51) and 0.86 mm (SD 0.54) respectively.

Table 12. Comparison between values predicted by the NMFN formulas and actual NMFN tooth measurements.

Arch	Absolute Mean Error (mm)	Standard Deviation	Standard Error	Min	Max
Maxillary	0.86	0.51	0.14	0.01	1.80
Mandibular	0.69	0.54	0.14	0.01	1.84

Although a small degree of error existed, the amount could be considered clinically acceptable, i.e. both mean error values were below 1 mm. It was therefore concluded that the newly created NMFN prediction equations could be successfully used to predict the unerupted mesiodistal dimension of the canine-premolar segments and that the minimal error associated with the prediction is clinically acceptable.

5.6 Clinical Importance of Tooth Size Prediction

The following discussion serves to illustrate the clinical importance of tooth size prediction.

The primary second mandibular molars are typically 2 mm larger than the second premolar, while in the maxillary arch, the primary second molars are 1.5 mm larger. The primary first molar is only slightly larger than the first premolar, but does contribute an extra 0.5 mm in the mandible. The difference in relative tooth size in each quadrant creates space, known as the leeway space, that range between 1.7 and 2.5 mm and 0.9 and 1.5 mm per quadrant in the mandibular and maxillary arches respectively[3,22].

Typically the leeway space is consumed by mesial migration of the permanent first molars, however, because the mandibular leeway space is larger than its maxillary counterpart, greater mandibular mesial movement occurs. This differential molar movement contributes to the normal transition from a flush terminal plane relationship in the mixed dentition to a Class I molar relationship in the permanent dentition. The balance of mandibular molar mesial movement is the result of differential mandibular growth[22].

Prediction of the size of the canine-premolar segment prior to exfoliation of the deciduous posterior teeth would enable the clinician to predict the leeway space. If sufficient leeway space exists, slightly crowded mixed dentitions could be aligned using this transient space. Unfortunately anterior alignment is not a spontaneous event, since even in the presence of incisor crowding, the leeway space is typically consumed by mesial molar migration[22]. Therefore interceptive anterior alignment involving extraction or interproximal reduction of deciduous teeth must occur prior to exfoliation of the deciduous second molars. Management of the leeway space to correct crowding may prevent future orthodontic treatment or reduce its complexity. The amount of leeway space however, is dictated by the size of the unerupted canine and premolars. Therefore prediction of the canine-premolar segment dimension is a critical step in orthodontic treatment planning. By way of example, it is generally accepted that a Class II molar relationship could be corrected by inhibiting mesial maxillary molar movement via a Nance appliance or extra-oral retraction, while allowing spontaneous mesial mandibular movement into the leeway space. Similarly leeway space management is important in the correction of minor Class III molar relationships. In these situations, the malocclusion could be improved with minor dental movements if it is predicted that the unerupted maxillary canine-premolar segment is larger than the unerupted mandibular canine-premolar segment. Restraining mesial mandibular molar movement with a holding arch while promoting mesial migration of the maxillary molar via distal interproximal reduction of the deciduous second molars would result in greater maxillary differential movement. In both clinical situations, leeway space management is dictated by the relative size of the unerupted canine-premolar segment.

In contrast, individuals who demonstrate significant mixed dentition crowding and deficient leeway space, as determined by canine-premolar size prediction, could forgo unnecessary space maintenance or recapturing therapy. Failure to recognize and quantify future permanent dentition crowding during the mixed dentition may result in unnecessary interproximal enamel reduction or placement of space maintenance appliances. The unnecessary interceptive treatment would burden the patient financially and could result in unnecessary iatrogenic effects such as enamel decalcification. Similarly, clinicians that forgo evaluation of the canine-premolar segment size may mistakenly insert a functional appliance in a patient who demonstrates a mixed dentition Class II molar relationship, well-aligned incisors and minimal overjet. Although the molars demonstrate a Class II relationship, the normal overjet is suggestive of a Class I relationship. Although the clinician perceives a successful orthopedic change, correction of the Class II molar has been the result of differential molar movement into the leeway spaces. Unnecessary functional appliance use in this clinical situation may result in an iatrogenic transition to a Class III malocclusion. Attention to the relative tooth size of the permanent teeth would prevent inappropriate treatment.

Leeway space management is crucial to early interceptive orthodontic treatment. Inaccurate tooth size prediction affects the leeway space prediction and would ultimately result in selection of inappropriate treatment modalities. Therefore accurate tooth size prediction is a fundamental step in a mixed dentition analysis. In an effort to minimize tooth size prediction errors, this study demonstrates the importance of using ethnic specific prediction analyses.

SUMMARY and CONCLUSION

The purpose of this study was to evaluate the accuracy of Moyers'[1] and Tanaka and Johnston's[2] prediction methods on a northern Manitoban First Nations population, and, if necessary, to create new analyses to precisely predict tooth size in studied population.

Mesiodistal tooth dimensions were measured from study models representing 28 male and 24 female (aged 12 years, 6 months to 17 years, 2 months) northern Manitoban First Nations Treaty and Inuit subjects. Regression equations used to predict the total diameters of mandibular and maxillary canines and premolars were then calculated from the combined mesiodistal dimension of the mandibular permanent incisors and were compared to Tanaka and Johnston regression equations[2] and Moyers' (75^{th} percentile) prediction values[1].

The following conclusions were apparent:

1) The studied northern Manitoban First Nations sample did not demonstrate statistically significant sexual dimorphism in tooth size. Separate gender analyses were therefore unnecessary.
2) The results of this study rejected the hypothesis that Moyers' prediction tables[1] were applicable to the northern Manitoban First Nations population and partially rejected the hypothesis of the applicability of Tanaka and Johnston's prediction equations[2]. Of the analyses compared, only the Tanaka and Johnston analysis[2]

was found to be in agreement with the actual size of the mandibular canines and premolars in the northern Manitoban First Nations population. Although the predicted values were not statistically different from the actual measurements, the values predicted were less than the actual measurements. Because of this discrepancy, use of the newly formulated NMFN mandibular equation would be advised to improve prediction accuracy. The difference between the two analyses, however, would be clinically insignificant (0.2mm per quadrant) and therefore use of Tanaka and Johnston's mandibular prediction equation[2] would be clinically acceptable.

3) New analyses, based on the four permanent mandibular incisors, were formulated which predict the combined mesiodistal dimensions of the canines and premolars in the northern Manitoban First Nations population.

   a) NMFN Prediction Equations:

   NMFN Mandibular: y= 10.9+0.49(b)
   NMFN Maxillary: y= 13.7+0.41(b)

   b) Prediction Tables: presented in Appendix 4.

   Testing of the newly created NMFN prediction equations revealed that the absolute mean error for the mandibular and maxillary arches ranged between 0.69 and 0.86 mm per quadrant respectively. Statistical analyses revealed no significant differences between the predicted and actual values of the canines and premolars. The newly derived prediction methods, therefore, could be clinically useful in a northern Manitoban First Nations population for tooth size predictions.

The applicability of the newly created NMFN equations and prediction tables to other Canadian First Nations populations is yet to be determined. Although anthropological evidence suggests a common ancestry among Canadian First Nations populations[38], tooth size variability can occur within an ethnic population, and therefore homogeneity of the various Canadian First Nations populations cannot be assured. Variability is a human trait; therefore it would be premature and erroneous to assume that the newly created NMFN prediction analyses can be universally applied to all North America First Nations populations. Before the newly created NMFN prediction analyses can be applied to other First Nations populations, future research must establish statistically similar tooth sizes within this population.

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Appendix 1 The average of the antimeres (Ave.) and the sum of the mesiodistal dimension of the mandibular canine and premolars (L345) are included. Measurements are recorded in millimeters.

32	31	41	42	LI SUM	33	43	L3 Ave.	34	44	L4 Ave.	35	45	L5 Ave.	L345 SUM
6.7	5.7	5.7	6.7	**24.80**	7.5	7.5	**7.50**	8	8	**7.70**	7.8	7.8	**7.80**	**23.00**
6.4	5.9	5.9	6.6	**24.80**	8	8	**8.00**	8	8	**8.30**	7.8	7.6	**7.70**	**24.00**
7.1	6.5	6.5	7.3	**27.40**	8.3	8.3	**8.30**	8	8	**8.15**	8.1	8.2	**8.15**	**24.60**
6.3	5.9	6.3	7.5	**26.00**	7.5	7.5	**7.50**	8	8	**7.50**	8	8	**8.00**	**23.00**
6.4	6.1	6.1	6.8	**25.40**	8	8	**8.00**	8	8	**8.10**	8	8	**8.00**	**24.10**
7.3	6.3	6.3	7.3	**27.20**	8	8	**8.00**	8	8	**8.20**	8	8	**8.00**	**24.20**
7	6.5	6.5	7	**27.00**	7.9	7.9	**7.90**	8	8	**7.90**	8.1	8.1	**8.10**	**23.90**
7.4	6.3	6.3	7.4	**27.40**	7.9	7.9	**7.90**	8	8	**7.80**	7.8	7.8	**7.80**	**23.50**
6.2	5.9	5.9	6.2	**24.20**	7.8	7.8	**7.80**	8	8	**7.90**	7.9	7.4	**7.65**	**23.35**
6.8	6.4	6.4	6.8	**26.40**	7.8	7.8	**7.80**	8	8	**7.95**	8	8	**8.00**	**23.75**
5.8	5.1	5.4	5.8	**22.10**	7.5	7.5	**7.50**	8	8	**7.50**	7.3	7.3	**7.30**	**22.30**
6.9	6	6	6.9	**25.80**	7.5	7.5	**7.50**	8	8	**7.80**	8	7.9	**7.95**	**23.25**
6.3	5.8	5.8	6.3	**24.20**	7.2	7.2	**7.20**	8	8	**7.50**	7.5	7.5	**7.50**	**22.20**
7.8	6.4	6.9	7.3	**28.40**	8	8	**8.00**	8	8	**8.00**	8	8	**8.00**	**24.00**
7.5	6	6	7.3	**26.80**	8.2	8.4	**8.30**	8	8	**8.15**	8.9	8.7	**8.80**	**25.25**
7.2	6.3	6.3	7.2	**27.00**	8.1	8.2	**8.15**	8	8	**8.00**	8.2	8.2	**8.20**	**24.35**
7	6.2	6.2	7	**26.40**	8.2	8.2	**8.20**	8	8	**7.80**	8.1	8.1	**8.10**	**24.10**
7.3	6.3	6.3	7.3	**27.20**	8	8	**8.00**	8	8	**8.20**	8	8	**8.00**	**24.20**
7.3	6.5	6.5	7.3	**27.60**	8.3	8.3	**8.30**	8	8	**8.00**	8.3	8	**8.15**	**24.45**
7.5	6.9	6.9	7.5	**28.80**	8.3	8.3	**8.30**	8	8	**8.30**	8.2	8.2	**8.20**	**24.80**
7.4	6.3	6.3	7.4	**27.40**	7.9	7.9	**7.90**	8	8	**7.80**	7.8	7.8	**7.80**	**23.50**
6.6	6.4	6.4	6.7	**26.10**	7.8	7.8	**7.80**	8	8	**7.70**	8	8	**8.00**	**23.50**
6.9	6	6	7.1	**26.00**	7.8	7.7	**7.75**	7	7	**7.40**	7.3	7.5	**7.40**	**22.55**
6.7	5.5	5.5	6.8	**24.50**	7	6.8	**6.90**	7	7	**7.40**	7.8	7.8	**7.80**	**22.10**
6.8	5.8	5.8	6.8	**25.20**	6.9	6.9	**6.90**	8	8	**7.50**	7.8	7.8	**7.80**	**22.20**
6.6	5.9	5.8	6.9	**25.20**	8.1	8.3	**8.20**	9	9	**8.55**	8.4	8.5	**8.45**	**25.20**
6.1	6.1	6.1	6.4	**24.70**	7.9	7.9	**7.90**	8	8	**7.70**	7.9	7.9	**7.90**	**23.50**
6.9	6.1	6.1	7	**26.10**	7.6	7.5	**7.55**	8	8	**7.85**	8.4	8.1	**8.25**	**23.65**
7.4	6.3	6.5	7.4	**27.60**	8.4	8.5	**8.45**	8	8	**8.30**	7.9	7.9	**7.90**	**24.65**
6.7	6	6.2	6.6	**25.50**	7.2	7.2	**7.20**	9	9	**8.55**	8.5	8.5	**8.50**	**24.25**
6.5	6	6.1	6.6	**25.20**	8.2	8	**8.10**	8	8	**8.25**	7.8	7.7	**7.75**	**24.10**
6.7	6	5.8	7	**25.50**	7.7	7.6	**7.65**	8	8	**7.50**	7.4	7.4	**7.40**	**22.55**
6.7	6.4	6.4	6.7	**26.20**	7.9	8.2	**8.05**	8	8	**8.10**	8.5	8.5	**8.50**	**24.65**
7.5	6.4	6.4	7.7	**28.00**	8.1	8.1	**8.10**	9	9	**8.70**	8	8	**8.00**	**24.80**
6.2	5.7	5.4	6.8	**24.10**	7.8	7.8	**7.80**	8	8	**7.70**	7.6	7.6	**7.60**	**23.10**
6.2	5.7	5.7	6.2	**23.80**	7.5	7.5	**7.50**	8	8	**7.65**	8.1	8.1	**8.10**	**23.25**
6.4	5.7	5.8	6.4	**24.30**	7.3	7.3	**7.30**	7	7	**7.20**	7	6.8	**6.90**	**21.40**
6.3	5.7	5.9	6.6	**24.50**	7.9	7.8	**7.85**	8	8	**8.05**	8.5	8	**8.25**	**24.15**
5.8	4.9	5	5.7	**21.40**	6.6	6.6	**6.60**	7	7	**6.80**	6.4	6.4	**6.40**	**19.80**
6.4	5	5	6.5	**22.90**	8.1	8.1	**8.10**	8	8	**7.60**	7.4	7.4	**7.40**	**23.10**
7.1	5.9	5.9	6.8	**25.70**	7.5	7.5	**7.50**	8	8	**7.90**	7.3	7.6	**7.45**	**22.85**
6.9	5.8	5.8	6.9	**25.40**	7.9	7.9	**7.90**	8	8	**7.80**	8.1	7.8	**7.95**	**23.65**
5.9	5.5	5.5	6.9	**23.80**	7.1	7	**7.05**	7	7	**7.30**	7.4	7.5	**7.45**	**21.80**

32	31	41	42	LI SUM	33	43	L3 Ave.	34	44	L4 Ave.	35	45	L5 Ave.	L345 SUM
6.5	5.8	5.4	6.5	**24.20**	7.2	7	**7.10**	8	8	**7.65**	7.9	7.8	**7.85**	**22.60**
5.8	5.8	5.9	6.2	**23.70**	7.3	7.4	**7.35**	7	7	**6.65**	6.8	7.3	**7.05**	**21.05**
6.7	5.7	5.7	6.7	**24.80**	7.4	7.4	**7.40**	7	7	**7.30**	7.4	7.6	**7.50**	**22.20**
6.6	6	6	6.5	**25.10**	7.7	7.7	**7.70**	8	8	**7.60**	7.5	7.5	**7.50**	**22.80**
6.8	5.7	5.9	7	**25.40**	7.8	7.7	**7.75**	8	8	**7.60**	7.4	7.3	**7.35**	**22.70**
6.2	5.4	5.6	6.2	**23.40**	7.6	7.7	**7.65**	8	8	**7.80**	7.7	7.7	**7.70**	**23.15**
6.8	5.9	5.9	6.8	**25.40**	7.3	7.3	**7.30**	7	7	**7.20**	7.8	7.8	**7.80**	**22.30**
6.6	5.4	5.4	6.3	**23.70**	6.8	6.6	**6.70**	7	7	**7.30**	7.2	7.2	**7.20**	**21.20**
7.6	6.8	6.8	7.6	**28.80**	8	8	**8.00**	8	8	**8.00**	8.3	8.2	**8.25**	**24.25**

Appendix 2 Mesiodistal widths of the mandibular incisors, maxillary canines,1[st] and 2[nd] premolars. The average of the antimeres (Ave.) and the sum of the mesiodistal dimensions of the maxillary canine and premolars (U345) are included. Measurements are recorded in millimeters.

32	31	41	42	LI SUM	13	23	U3 Ave.	14	24	U4 Ave.	15	25	U5 Ave.	U345 SUM
6.7	5.7	5.7	6.7	**24.80**	8.3	8.3	**8.30**	8	8	**7.50**	7.5	7.5	**7.50**	**23.30**
6.4	5.9	5.9	6.6	**24.80**	9	8.9	**8.95**	8	8	**7.50**	7.5	7.4	**7.45**	**23.90**
7.1	6.5	6.5	7.3	**27.40**	9.5	9.5	**9.50**	8	8	**8.10**	8	8	**8.00**	**25.60**
6.3	5.9	6.3	7.5	**26.00**	8.4	8.4	**8.40**	7	7	**7.35**	7.5	7.5	**7.50**	**23.25**
6.4	6.1	6.1	6.8	**25.40**	8.7	8.8	**8.75**	8	8	**7.90**	7.4	7.4	**7.40**	**24.05**
7.3	6.3	6.3	7.3	**27.20**	8.7	8.7	**8.70**	9	9	**8.90**	8.2	8.2	**8.20**	**25.80**
7	6.5	6.5	7	**27.00**	9	9	**9.00**	7	7	**6.90**	6.3	6.3	**6.30**	**22.20**
7.4	6.3	6.3	7.4	**27.40**	9	9	**9.00**	8	8	**8.00**	7.9	7.9	**7.90**	**24.90**
6.2	5.9	5.9	6.2	**24.20**	9.1	9	**9.05**	8	8	**7.90**	7.8	7.4	**7.60**	**24.55**
6.8	6.4	6.4	6.8	**26.40**	8.8	8.8	**8.80**	8	8	**8.00**	7.3	7.3	**7.30**	**24.10**
5.8	5.1	5.4	5.8	**22.10**	8.4	8.4	**8.40**	7	7	**7.40**	7.5	7.5	**7.50**	**23.30**
6.9	6	6	6.9	**25.80**	8.9	9	**8.95**	8	8	**8.35**	7.5	7.2	**7.35**	**24.65**
6.3	5.8	5.8	6.3	**24.20**	8.4	8.4	**8.40**	8	8	**7.50**	7.5	7.5	**7.50**	**23.40**
7.8	6.4	6.9	7.3	**28.40**	8.5	8.5	**8.50**	8	8	**7.50**	7.5	7.5	**7.50**	**23.50**
7.5	6	6	7.3	**26.80**	9.2	9.2	**9.20**	9	8	**8.35**	8.2	8.3	**8.25**	**25.80**
7.2	6.3	6.3	7.2	**27.00**	9.2	9.2	**9.20**	8	8	**8.30**	7.9	7.9	**7.90**	**25.40**
7	6.2	6.2	7	**26.40**	8.8	8.8	**8.80**	8	8	**8.20**	8	8	**8.00**	**25.00**
7.3	6.3	6.3	7.3	**27.20**	8.7	8.7	**8.70**	9	9	**8.90**	8.2	8.2	**8.20**	**25.80**
7.3	6.5	6.5	7.3	**27.60**	9.1	9.1	**9.10**	8	8	**8.00**	7.8	7.8	**7.80**	**24.90**
7.5	6.9	6.9	7.5	**28.80**	9.1	9.1	**9.10**	8	8	**8.10**	7.8	7.8	**7.80**	**25.00**
7.4	6.3	6.3	7.4	**27.40**	9	9	**9.00**	8	8	**8.00**	7.9	7.9	**7.90**	**24.90**
6.6	6.4	6.4	6.7	**26.10**	8.4	8.4	**8.40**	7	7	**7.40**	7.4	7.4	**7.40**	**23.20**
6.9	6	6	7.1	**26.00**	8.3	8.3	**8.30**	8	8	**7.80**	7.3	7.3	**7.30**	**23.40**
6.7	5.5	5.5	6.8	**24.50**	7.9	7.9	**7.90**	8	8	**7.95**	7.7	8	**7.85**	**23.70**
6.8	5.8	5.8	6.8	**25.20**	8.5	8.4	**8.45**	8	8	**7.80**	7.3	7.4	**7.35**	**23.60**
6.6	5.9	5.8	6.9	**25.20**	9.4	9.4	**9.40**	9	9	**8.70**	8.3	8.3	**8.30**	**26.40**
6.1	6.1	6.1	6.4	**24.70**	8.5	8.3	**8.40**	8	8	**7.95**	8.5	8.5	**8.50**	**24.85**
6.9	6.1	6.1	7	**26.10**	8.8	8.8	**8.80**	8	8	**8.30**	8.2	8.6	**8.40**	**25.50**
7.4	6.3	6.5	7.4	**27.60**	9	8.7	**8.85**	9	9	**8.65**	7.7	7.7	**7.70**	**25.20**
6.7	6	6.2	6.6	**25.50**	7.7	7.7	**7.70**	8	8	**8.30**	8.5	8.5	**8.50**	**24.50**
6.5	6	6.1	6.6	**25.20**	9	8.9	**8.95**	8	8	**8.10**	8	7.4	**7.70**	**24.75**
6.7	6	5.8	7	**25.50**	8.4	8.4	**8.40**	8	8	**7.50**	7.1	7.1	**7.10**	**23.00**

32	31	41	42	LI SUM	13	23	U3 Ave.	14	24	U4 Ave.	15	25	U5 Ave.	U345 SUM
6.7	6.4	6.4	6.7	**26.20**	9.1	9.1	**9.10**	8	8	**8.10**	7.7	7.4	**7.55**	**24.75**
7.5	6.4	6.4	7.7	**28.00**	8.5	8.5	**8.50**	9	9	**8.50**	8	8	**8.00**	**25.00**
6.2	5.7	5.4	6.8	**24.10**	8.4	8.4	**8.40**	8	8	**8.00**	7.2	7.2	**7.20**	**23.60**
6.2	5.7	5.7	6.2	**23.80**	8.7	8.7	**8.70**	8	8	**7.70**	7.3	7.3	**7.30**	**23.70**
6.4	5.7	5.8	6.4	**24.30**	8	8.2	**8.10**	7	7	**7.15**	6.9	6.7	**6.80**	**22.05**
6.3	5.7	5.9	6.6	**24.50**	8.3	8.3	**8.30**	8	8	**7.80**	7.5	7.5	**7.50**	**23.60**
5.8	4.9	5	5.7	**21.40**	7.7	7.7	**7.70**	7	7	**7.30**	7	7	**7.00**	**22.00**
6.4	5	5	6.5	**22.90**	8.7	8.7	**8.70**	7	7	**7.40**	7	7	**7.00**	**23.10**
7.1	5.9	5.9	6.8	**25.70**	8.4	8.4	**8.40**	7	7	**7.40**	7	7	**7.00**	**22.80**
6.9	5.8	5.8	6.9	**25.40**	9.1	9	**9.05**	8	8	**8.10**	7.5	7.5	**7.50**	**24.65**
5.9	5.5	5.5	6.9	**23.80**	7.6	8.2	**7.90**	7	7	**7.25**	7.1	7.1	**7.10**	**22.25**
6.5	5.8	5.4	6.5	**24.20**	8.2	8.7	**8.45**	7	7	**7.10**	7.4	7.4	**7.40**	**22.95**
5.8	5.8	5.9	6.2	**23.70**	8.1	8.6	**8.35**	8	8	**7.50**	7	7.7	**7.35**	**23.20**
6.7	5.7	5.7	6.7	**24.80**	8.6	8.4	**8.50**	8	8	**7.90**	7.6	7.7	**7.65**	**24.05**
6.6	6	6	6.5	**25.10**	8.9	9.3	**9.10**	8	8	**7.60**	7.6	7.6	**7.60**	**24.30**
6.8	5.7	5.9	7	**25.40**	8.6	8.6	**8.60**	7	7	**7.40**	7.2	7.2	**7.20**	**23.20**
6.2	5.4	5.6	6.2	**23.40**	8.6	8.6	**8.60**	8	8	**8.10**	7.7	7.7	**7.70**	**24.40**
6.8	5.9	5.9	6.8	**25.40**	8.3	8.8	**8.55**	7	7	**7.30**	7.5	7.5	**7.50**	**23.35**
6.6	5.4	5.4	6.3	**23.70**	7.7	7.8	**7.75**	7	7	**7.40**	6.7	6.7	**6.70**	**21.85**
7.6	6.8	6.8	7.6	**28.80**	9.4	9.4	**9.40**	9	9	**8.60**	8	8	**8.00**	**26.00**

Appendix 3

Table 3. Descriptive statistics of the mesiodistal dimension of the mandibular incisors, maxillary and mandibular canine, 1st and 2nd premolars measured from a northern Manitoban First Nations population in millimeters.

Tooth	Male Mean ± SD	Female Mean ± SD
31	6.0± 0.48	5.9± 0.33
41	6.0± 0.46	6.0± 0.39
32	6.8± 0.52	6.6± 0.47
42	6.9± 0.51	6.8± 0.38
33	7.6± 0.48	7.8± 0.29
43	7.6± 0.53	7.9± 0.31
34	7.8± 0.43	7.8± 0.45
44	7.8± 0.40	7.8± 0.39
35	7.9± 0.50	7.8± 0.41
45	7.8± 0.48	7.8± 0.36
13	8.6± 0.48	8.7± 0.35
23	8.6± 0.53	8.7± 0.36
14	7.9± 0.49	7.8± 0.46
24	7.9± 0.53	7.9± 0.44
15	7.6± 0.54	7.5± 0.41
25	7.6± 0.49	7.6± 0.39

Appendix 4: NMFN Probability Tables

Probability Chart for Predicting the Sum of the Widths of L345 from ΣLI

ΣLI mm	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0
95%	22.8	22.9	23.2	23.5	23.7	23.9	24.2	24.4	24.6	24.9	25.1	25.4
85%	22.2	22.5	22.7	23.0	23.2	23.4	23.7	23.9	24.1	24.4	24.6	24.9
75%	21.9	22.2	22.4	22.6	22.9	23.1	23.4	23.6	23.9	24.1	24.3	24.6
65%	21.7	21.9	22.2	22.4	22.6	22.9	23.1	23.4	23.6	23.9	24.1	24.3
50%	21.3	21.6	21.8	22.1	22.3	22.6	22.8	23.1	23.3	23.5	23.8	24.0
35%	21.0	21.3	21.5	21.8	22.0	22.3	22.5	22.7	23.0	23.2	23.5	23.7
25%	20.8	21.0	21.3	21.5	21.8	22.0	22.3	22.5	22.8	23.0	23.2	23.5
15%	20.5	20.7	21.0	21.2	21.5	21.7	22.0	22.2	22.5	22.7	22.9	23.2
5%	19.9	20.2	20.5	20.7	21.0	21.2	21.5	21.7	22.0	22.2	22.4	22.7

Probability Chart for Predicting the Sum of the Widths of U345 from ΣLI

ΣLI mm	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0
95%	24.0	24.2	24.4	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.0	26.2
85%	23.5	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0	25.2	25.4	25.6
75%	23.1	23.3	23.5	23.7	23.9	24.1	24.3	24.5	24.7	24.9	25.1	25.3
65%	22.8	23.0	23.2	23.4	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0
50%	22.4	22.6	22.8	23.0	23.2	23.4	23.7	23.9	24.1	24.3	24.5	24.7
35%	22.1	22.3	22.5	22.8	22.9	23.1	23.3	23.5	23.7	23.9	24.1	24.3
25%	21.8	22.0	22.1	22.4	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0
15%	21.4	21.6	21.8	22.1	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.7
5%	20.8	21.0	21.3	21.5	21.7	21.9	22.1	22.3	22.5	22.7	22.9	23.1