Proximity of the Mental Foramen to the Tooth Apex

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THESIS

Submitted as partial fulfillment of the requirements
for the degree of Master of Science in Oral Sciences
in the Graduate College of the
University of Illinois at Chicago, 2013

Chicago, Illinois

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LIST OF ABBREVIATIONS

B/w	Between
CBCT	Cone-Beam Computed Tomography
CBVT	Cone-Beam Volumetric Tomography
D	Distal
IAN	Inferior Alveolar Nerve
IRB	Institutional Review Board
M	Mesial
MDCT	Multi-Detector Computed Tomography
Mo	Molar
PM	Premolar
SD	Standard Deviation
SPSS	Statistical Software Program (Chicago, IL)

SUMMARY

The inferior alveolar nerve bundle exits from the mandible at the mental foramen as the mental nerve, providing innervation and vascular supply to more anterior soft tissues and muscles of facial expression. Posterior mandibular endodontic surgery is commonly performed in the vicinity of the mental foramen (3). If the endodontic surgeon is not conscientious about the position of the mental foramen, iatrogenic neurological complications could potentially occur (4, 5). Previously, many studies have been performed examining both dry skulls and conventional dental radiographs to evaluate the position of the mental foramen. While CBVT has been utilized in previous studies to examine the position of the inferior alveolar nerve, no study has been published utilizing CBVT to examine the position of the mental foramen.

Fifty CBVT scans were previously taken at Cameo Endodontics (Berwyn, IL), a dental specialty practice limited to Endodontics and dental implants. These scans were taken for purposes not related to this study on a Kodak 9000 CBVT machine (Carestream Dental, Rochester, NY). The scans were interpreted using Kodak Carestream specialized software. The mental foramen was identified and measurements made from the superior aspect of the mental foramen to the radiographic apex of the mandibular first premolar, second premolar, and mesial root of the first molar.

It was observed that the mental foramen lies most commonly in between the mandibular first and second premolars and inferior to the apex of the mandibular second premolar. However, many exceptions were observed, and the location of the mental foramen could be described as variable. No significant differences were found based on age or gender regarding the location of the mental foramen.

Therefore, due to the variable nature of the location of the mental foramen as detected by CBVT measurement, reliance upon statistical averages for the mental foramen location may mislead the clinician, potentially leading to undesirable neurological complications. Therefore, the endodontic surgeon should consider obtaining a preoperative CBVT scan prior to a posterior mandibular surgical procedure.

I. INTRODUCTION

1.1 Background

Endodontics has been defined as the prevention and treatment of apical periodontitis (1). Non-surgical endodontics is generally viewed as more preferred and less invasive treatment modality; however, in certain clinical scenarios surgical endodontics is indicated when nonsurgical retreatment is “impractical or unlikely to improve on the previous result” (2).

While endodontic surgery on anterior teeth rarely encroaches upon vital anatomic structures, anatomical considerations are often viewed as “impediments to posterior endodontic surgery” (3). The surgeon must consider the locations of the inferior alveolar nerve as well as its branch, the mental nerve, in flap design, osteotomy, and other related surgical procedures.

With regards to the mental nerve, the surgeon must locate the nerve during surgery and then shield it with retractors to prevent inadvertent neurovascular injury (3). Failure to appreciate the position of the mental nerve could lead to neural injury in both surgical (4) and non-surgical (5) endodontics.

The mental foramen is the opening on the buccal surface of the mandible in which the mental nerve branch of the inferior alveolar nerve exits the mandibular canal and enters the fascia covering the mandible where it then provides innervation to the skin of the chin, the lower lip, and to the labial mucous membranes and gingiva. (6).

Numerous studies have been performed to gain information about the position of the mental foramen. Previous study modalities have involved examining dry skulls (7-14) and conventional (two-dimensional) dental radiographs (15-20).

Conventional dental radiographs (periapical and panoramic films) provide invaluable anatomical and dental information. Conventional dental radiographs are relatively easy to obtain, are inexpensive, and have excellent resolution (21). However, conventional dental radiographs have numerous shortcomings such as failing to provide three dimensional images, being susceptible to distortion, allowing overlap of anatomic structures (21), and variable interpretation associated with poor intra-examiner and inter-examiner agreement (22, 23). With regards to locating the mental foramen, conventional dental radiographs were found to be unreliable and inaccurate (24, 25).

Medical Computed Tomography (CT) was previously used by some dentists and dental specialists in order to obtain three dimensional imaging. However, the widespread adoption of Medical CT was restricted due to its high cost, limited availability, and high radiation exposure (26). Cone-Beam Volumetric Tomography (CBVT; also known as Cone-Beam Computed Tomography, or CBCT) was invented in 1996 and approved for use in the United States in 2001 (21). CBVT has several advantages over Medical CT, including being less expensive, having shorter scan and processing times, and exposing the patient to significantly less radiation (27). Additionally, CBVT has isotropic voxels which allows more accurate measurement compared to Medical CT, which has anisotropic voxels dictated by the machine's slice thickness (21). However, Medical CT provides better soft tissue imaging (28) and produces fewer artifacts (21).

Studies have previously been performed utilizing CBVT to analyze the position of the mandibular canal to the apices of mandibular posterior teeth (29, 30). Additionally, previous studies have utilized CBVT to discover additional/accessory mental foramina (31, 32) as well as the absence of a mental foramen (32, 33). However, a detailed literature search did not yield any articles in which CBVT was utilized to analyze the position of the mental foramen.

1.2 Significance of the Study

This study will be the first performed in which CBVT is utilized to detect the position of the mental foramen.

1.3 Specific Aims

The specific aims of this study include:

A. Determining the average distances from the superior aspect of the mental foramen to the radiographic apices of the mandibular first premolar, second premolar and mesial root of first molar.

B. Determining the average position of the mental foramen both horizontally and vertically with respect to the mandibular posterior tooth apices.

C. Assessing if subject gender and age have any significant relationship to the position of the mental foramen

1.4 Hypotheses

The hypotheses of this study are:

A. The mental foramen is most commonly located horizontally in-line with the long axis of the mandibular second premolar.

B. The mental foramen is most commonly located vertically inferior to the apices of the mandibular 2nd premolar.

C. Subject gender and age will have no significant relationship to the position of the mental foramen.

II. REVIEW OF THE LITERATURE

2.1 Review of Published Dry Skull and Radiographic Studies

Studies have been performed previously to assess the position of the mental foramen using dry skulls (7-14) and conventional dental radiographs (15-20, 34) to gather data. The results of these studies have been well summarized in previous articles by Moiseiwitsch (12) and Greinstein/Tarnow (35). Compiling the results of those summaries (12, 35) as well as some additional recently published literature (16, 17, 34), Table I summarizes the data of published studies utilizing dry skulls (7-9, 11-14), whereas Table II summarizes the data of the published studies utilizing conventional dental radiographs (15, 17-20). Table III summarizes the previous papers of Phillips and Weller (10, 16, 34) in which the authors studied the position of the mental foramen on 75 dry skulls by direct measurement (10), periapical radiographs (16), and panoramic radiographs (34). Importantly, Phillips and Weller noted that dry skull analysis and two-dimensional radiographic interpretation yield different spatial locations of the mental foramen. This suggests an inadequacy of utilizing conventional dental radiographs to identify the position of the mental foramen.

TABLE I

PUBLISHED STUDIES REPORTING THE HORIZONTAL POSITION OF THE MENTAL FORAMEN AS MEASURED ON DRY SKULLS (%)

Author	M to 1st PM	at 1st PM	B/w 1st PM & 2nd PM	at 2nd PM	B/w 2nd PM & 1st Mo	at 1st Mo
Matsuda (7)	0.0	3.0	16.0	69.0	6.0	6.0
Miller (8)	0.0	3.0	38.0	40.0	20.0	0.0
Mwaniki (9)	0.0	0.0	12.0	56.0	32.0	0.0
Tebo/Telford (11)	0.0	2.0	23.0	50.0	24.0	1.0
Moiseiwitsch (12)	1.0	5.0	41.0	18.0	31.0	4.0
Neiva (13)	0.0	0.0	58.0	42.0	0.0	0.0
Wang (14)	0.0	0.0	21.0	59.0	19.0	1.0
Average	0.1	1.9	29.9	47.7	18.9	1.7

TABLE II

PUBLISHED STUDIES REPORTING THE HORIZONTAL POSITION OF THE MENTAL FORAMEN AS MEASURED RADIOGRAPHICALLY (%)

Author	M to 1st PM	at 1st PM	B/w 1st PM & 2nd PM	at 2nd PM	B/w 2nd PM & 1st Mo	at 1st Mo
Sweet (15)	2.5	8.0	63.0	23.0	3.0	0.5
Haghanifar (17)	0.0	1.6	47.2	46.0	5.1	0.1
Fishel (18)	2.5	3.3	70.4	18.9	6.0	0.0
Ngeow (19)	0.0	3.4	6.6	69.0	20.0	1.0
Kekere-Ekun (20)	0.0	1.7	12.3	55.6	27.0	3.3
Average	1.0	3.6	39.9	42.5	12.2	1.0

Importantly, many of the previous studies collected data comparing both the left and right side mental foramina. For the purposes of this literature review, such data was compiled and only a single, average value was given. This study will not evaluate left versus right side mental foramina.

Three papers previously cited measured the vertical position of the mental foramen, and all have reported this measurement utilizing different parameters. Phillips and Weller (10) reported that the average vertical position of the mental foramen was 60% of the distance from the buccal cusp tip of the 2nd mandibular premolar to the inferior border of the mandible.

TABLE III

PHILLIPS AND WELLER PAPERS

Study	Methodology	% Mesial	Avg. Dist M (mm)	% At 2nd PM	% Distal	Avg Dist D (mm)
I (10)	Skull	18.0	1.9	63.0	19.0	2.2
II (16)	2D PA	70.6	3.8	10.6	18.6	2.7
III (34)	2D Pan	50.7	2.5	10.0	39.3	2.9

Neiva et al (13) found that the mental foramen was on average 15.52 mm from the most coronal aspect of mental foramen to most apical aspect of CEJ of tooth immediately superior to the mental foramen. Finally, Fishel et al (18) reported the vertical position of the mental foramen with respect to the apices of both the first and second premolar. This data is summarized in Table IV below.

TABLE IV

VERTICAL POSITION OF THE MENTAL FORAMEN – PERCENTAGES AS REPORTED BY FISHEL ET AL (18)

1st PM Apex			2nd PM Apex		
Inferior	At level	Superior	Inferior	At Level	Superior
38.6	15.4	46.0	24.5	13.9	61.6

Two studies reported data in which the gender of the subject was recorded. Both Moiseiweitch (12) and Haghanifar (17 found no significant difference in the position of the mental foramen with respect to gender. After performing a review of the literature, one paper was discovered that commented on changes in the vertical position of the mental foramen with age (36). According to Gershenson et al, with loss of teeth and bone resorptions (both of which are positively correlated with age), the mental foramen appears more superior and closer to the alveolar border.

2.2 Review of Published CBVT Studies

Bornstein et al (29) evaluated 38 CBVTs of mandibular molars. Bornstein found an average distance of 6.4 mm from the apices of the mandibular first molar to the inferior alveolar nerve utilizing CBVT sagittal images and 6.6 mm utilizing CBVT coronal images. Interestingly, on the same subjects Bornstein noted an average distance of 5.4 mm using periapical radiographs measuring the same distance, though the authors noted that in many subjects (64.7%) the IAN could not be clearly observed on the periapical radiograph. The authors also found that the average distance between the buccal cortical plate and the mandibular molar roots was 5.3 mm. The authors concluded that CBVT is “a valuable diagnostic method for the evaluation of anatomically demanding areas such as the posterior mandible before apical surgery.”

Kovisto et al (30) evaluated 139 CBVT scans and found that the apices of the mandibular second molar were closest to the inferior alveolar nerve compared to other posterior teeth. Also, Kovisto noted that the distance between the mesial root of the mandibular second molar was closer to the inferior alveolar nerve in female subjects. Finally, Kovisto found that teeth apices were generally closer to the inferior alveolar nerve in younger patients (<18 years old) than older patients. The authors concluded that “CBCT is an accurate, noninvasive method to evaluate the proximity of the apices of teeth to the inferior alveolar canal.”

Simonton et al (37) evaluated 200 CBVT images and measured the distances between the inferior alveolar nerve and the mandibular molars. The authors found that females had significantly shorter distances between the inferior alveolar nerve and the mandibular molars as well as a thinner layer of mandibular bone at the level of the apices of the mandibular molars. Finally, the authors noted that the overall width of the mandibular bone decreased in both genders between the 3^{rd}-6^{th} decades of life.

In a similar study, Angel et al (38) analyzed 165 CBCT scans and using computer software measured the location of the inferior alveolar nerve in both axial and coronal views as well as the position of the mental foramen in the coronal view. The authors found no significant differences based on gender and age.

A recent study (39) by Haktanir et al. utilized Multi-Detector CT (MDCT, technology comparable to Medical CT) to evaluate the position of the mental foramen in living humans. To the best of the authors' knowledge, this was the first study to utilize MDCT to study the position of the mental foramen *in vivo.* The authors obtained MDCT scans of 100 subjects (47 male, 53 female) and utilizing computer software measured the distances from the midline and the superior border of the alveolar ridge to the mental foramen. On average, the mental foramen was located 24.9 mm from the midline (range: 19.6-29.8 mm) and 14.2 mm inferior to the alveolar ridge (range: 10.7-20.5 mm). No significant relationships were observed between left vs. right side foramina or age. While there was no difference with respect to gender for the vertical position of the mental foramen, the authors did find a significantly greater distance from the midline to the mental foramen in men compared to women.

Finally, recent studies have been performed to utilize CBVT to detect either accessory mental foramina (31, 32) or the absence of a mental foramen (32, 33). Naitoh et al (31) utilized CBVT on 157 patients and noted an accessory mental foramen in 7% of patients. Oliveria-Santos et al (32) in a similar study evaluated CBVT scans from 285 patients and noted a 9.4% prevalence of accessory mental foramina as well as 2 cases in which there was a unilateral absence of a mental foramen. Paes da Silva Ramos Fernandes et al (33) also presented a case report in which a Brazilian 63 year-old mother and her 27 year-old daughter had hypoplastic and absent mental foramina, respectively.

2.3 Summary of Important Points from Published Literature

To summarize the major points of the published literature utilizing dry skulls and conventional dental radiographs, the mental foramen has been reported to be in a variable location. Horizontally, the mental foramen appears to be most commonly in between the mandibular premolars or in-line with the long axis of the mandibular 2^{nd} premolar. However, it is not uncommon to find the mental foramen elsewhere, especially distal to the 2^{nd} premolar. Interestingly, the papers of Phillips and Weller (10, 16, 34) demonstrate how direct anatomical measurement and radiographic measurement of the location of the mental foramen on the same specimens can have distinctly different results. While papers have reported on the vertical location of the mental foramen (10, 13, 18), the parameters for reporting data have not been standardized, whereby some (10, 13) have reported the location with respect to the superior border of the mandible, and Fishel et al (18) reported the location with respect to the apices of both the mandibular premolars. No such comparisons can be made between the papers due to the differential reporting methodologies. After reviewing limited data from previous papers (12, 17), it appears that gender does not affect the position of the mental foramen. Gershenson et al (36) reported that with tooth loss and alveolar bone resorptions the mental foramen is more coronal in the mandible; however, this research will be evaluating the position of the mental foramen in dentate individuals, and therefore Gershenson's conclusions may be irrelevant to this study.

To summarize the major points from CBVT articles, there have been several papers published recently in which CBVT was successfully utilized to make measurements from tooth apices to the inferior alveolar nerve (29, 30, 37). Authors compared subjects based on gender and age, with two papers finding a smaller distance between teeth apices and the inferior alveolar nerve (30, 37), and another paper finding no such difference (38). The literature has also been controversial with regards to the effect of age on the position of the inferior alveolar nerve; Kovisto et al (30) found a greater distance from teeth apices to the inferior alveolar nerve with increasing age, whereas Angel et al (38) found no such association. CBVT has also been successfully used to document atypical anatomy such as accessory mental foramina (32, 33) or the absence of a mental foramen (33, 34). Finally a search of the literature identified one published study in which CT was used to document the position of the mental foramen (39). Haktanir et al utilized MDCT to examine the position of the mental foramen, documenting the average location with respect to the midline of the mandible horizontally and the superior border of the alveolar ridge superiorly. Haktanir et al also evaluated the data with regards to age and gender, only finding a significantly greater difference in the distance from the mandibular midline to the mental foramen horizontally in men compared to women.

2.4 Citations of Papers Reviewing CBVT Imaging Aquisition

In this study, the Kodak 9000 CBVT machine was utilized. For reviews of the history and technical details of image acquisition of CBVT, the reader is encouraged to reference reviews by White and Pharoah (26) as well as Scarfe et al (21).

III. METHODOLOGY

3.1 Introduction

Cameo Endodontics, LLC is a dental specialty private practice limited to endodontics and implant placement in Berwyn, IL. Cameo Endodontics has a Kodak 9000 Limited Field CBCT machine; the partner dentists gave permission to the principal investigator to perform all data collection at their private practice on a single, desktop computer.

University of Illinois Institution Review Board (IRB) Approval was obtained in November, 2012 under "Expedited Review". The IRB approved protocol number was #2012-0998. See Appendix C for further documentation of IRB Expedited Review Approval.

3.2 Sample Selection

Fifty patients of record were randomly selected from the practice's database of pre-existing CBVT scans. These pre-existing CBVT scans were exposed with a limited field of view (4 cm x 4 cm) using a voxel size of 76 microns. CBVT scans were utilized by the dental specialists for the purposes of diagnosis, treatment planning, treatment, and evaluation of treatment outcomes unrelated to this study.

Inclusion criteria:

1. Scan must clearly demonstrate the presence of the inferior alveolar nerve, mental foramen, first and second mandibular premolars, and first permanent molar teeth.
2. Scan obtained between January 2010 and December 2012.
3. Subjects over 18 years old.
4. Subject gender and age were recorded in the practice patient database.
5. Presence of a single mental foramen clearly visible on CBVT.

Any CBVT scans not conforming to the inclusion criteria were excluded.

In order to protect subject anonymity, an Excel spreadsheet was created in which subject names were recorded and were then assigned a random 6-digit number. This spreadsheet was saved only on a single desktop computer at Cameo Endodontics in Berwyn, and was never transferred anywhere else. Data collection was performed over three days (January 14-16, 2013). Following the conclusion of data collection on January 16, 2013, the spreadsheet file containing patient names and corresponding randomized numbers was permanently erased. All further data analysis was performed anonymously using randomized 6 digit numbers to identify subjects.

Due to the retrospective nature of this study, it was not possible to determine subject race.

3.3 CBVT Analysis

Kodak 9000 Carestream computer software was utilized for CBVT analysis. Each of the 50 CBVT scans were systematically analyzed using the following steps:

1. CBVT scan document was opened and all inclusion criteria were met.
2. Subject age and gender and random number were recorded.
3. “Curved” Slicing was selected as the modality of interpretation.

Figure 1. Arrow pointing to Curved Slicing interpretation.

4. An arch was traced utilizing the arch creation software. “Bullet points” were manually and sequentially placed in the middle of each tooth at the level of the CEJ and an arch was created.

Figure 2. Arrow pointing to Arch Creation tool. Arch Creation tool is selected, and then bullet points are placed in the center of each tooth in the lower left axial view.

Figure 3. Arch Created. Modified Sagittal (top) and Modified Coronal (lower right) views created. Modified Sagittal is the view perpendicular to the created arch. Modified Coronal is the view parallel to the created arch.

5. The Curved Slicing software then transforms this data so that the created arch becomes a plane of reference for measurement, also known as “multi-planar reconstruction”.

6. Following creation of the arch, three views of the subject are available: axial (upper left corner), simulated sagittal (view perpendicular to the created arch, in the upper right corner), and simulated coronal (view parallel to the created arch, in the lower right corner). Additionally, a three-dimensional reconstruction is performed by the software and is present in the lower left corner.

Figure 4. Image manipulated so that mental foramen identified. (See arrow)

7. Having identified the exit of the mental foramen, the image was then modified to have the radiographic apex of the mandibular first premolar, second premolar, and mesial root of first molar in the simulated sagittal view. Utilizing the linear measurement tooth in Carestream software, a single mouse click was made at the radiographic apex of the mandibular first premolar. Then, utilizing the middle “scroll” button on the mouse, the image was manipulated so that the simulated sagittal view moved buccally and was focused on the exit of the mental foramen. A second mouse click was made at the superior aspect of the mental foramen. A linear distance was then displayed, which signified the linear distance in the modified sagittal view between the radiographic apex of the mandibular first premolar and the superior aspect of the mental foramen. This particular measurement was selected as it is clinically relevant in endodontic surgery; the surgeon is interested in the distance between the root apex and the mental foramen in the plane of the curving mandibular buccal cortex, as this helps the surgeon to carefully direct the osteotomy following identification and protection of the mental foramen.

Figure 5: Arrow pointing to distance measurement tool. Note that Modified Sagittal view has been manipulated so that the mental foramen is clearly identified on the buccal cortical plate of the mandible.

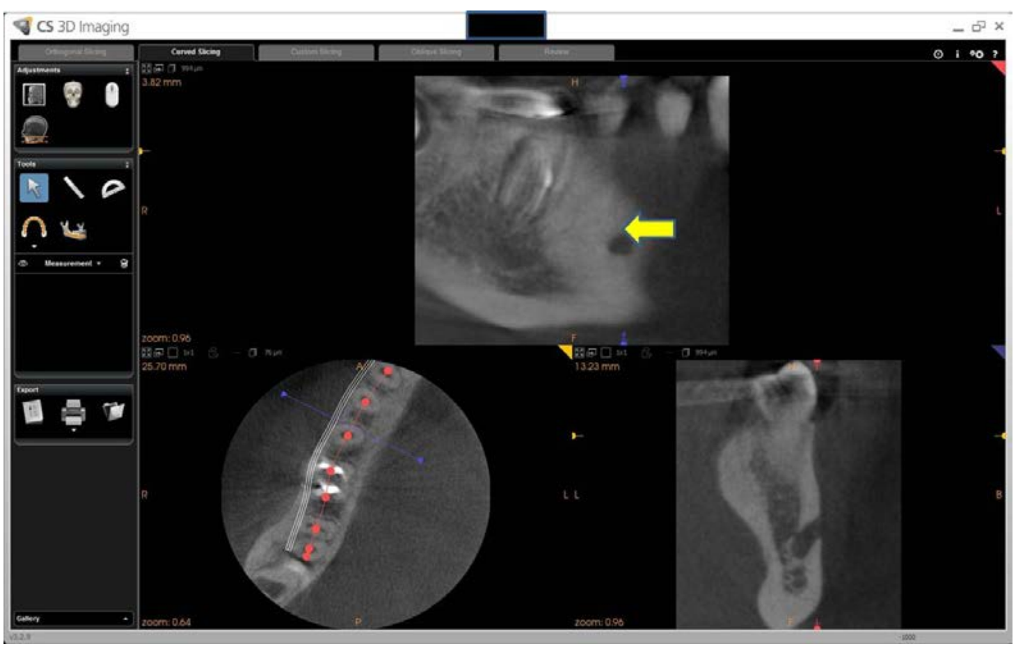

Figure 6: Arrow pointing to superior aspect of mental foramen in Modified Sagittal view. This is where the mouse is initially clicked after selecting the distance measurement tool.

Figure 7. Generation of measurements. After initial mouse click at superior aspect of mental foramen, the scroll button on the mouse is manipulated to move the Modified Sagittal view into the plane of the radiographic apex of the mandibular first premolar. A second mouse click is then performed at the radiographic apex of the mandibular first premolar, giving the distance from the superior aspect of the mental foramen to the radiographic apex of the mandibular first premolar in the plane of the Modified Sagittal view.

8. Step 7 was repeated for the mandibular second premolar and again for the mandibular first molar.

3.4 <u>Recorded Data</u>

Data recorded included:

1. Subject random number
2. Subject age
3. Subject gender

4. Distance between the radiographic apex of the mandibular 1st premolar and the superior aspect of the mental foramen in the plane of the arch curvature
5. Distance between the radiographic apex of the mandibular 2nd premolar and the superior aspect of the mental foramen in the plane of the arch curvature
6. Distance between the radiographic apex of the mesial root of the mandibular 1st molar and the superior aspect of the mental foramen in the plane of the arch curvature
7. Whether the horizontal position of the mental foramen was at the long axis of the first premolar, in between the first and second premolar, at the long axis of the second premolar, in between the second premolar and the mesial root of the mandibular first molar, or at the long axis of the mesial root of the first mandibular molar.
8. Whether the mental foramen in a particular subject was superior or inferior to the radiographic apex of the second premolar.

3.5 **Statistical Analysis**

Mean value, standard deviation, and ranges were calculated for the distances between the radiographic apices of the various tooth roots and the superior aspect of the mental foramen in the plane of the arch curvature.

SPSS statistical software version 12.0 (Chicago, IL) was used to assess for statistical significance among gender and age utilizing Pearson correlation calculations.

IV. RESULTS

4.1 Number of Subjects, Gender, Age

Fifty CBVT scans were initially reviewed. One subject was found to have a bifid mental foramen. As this would make distance measurements ambiguous, this subject was excluded and one additional CBVT was randomly selected from the private practice database. Therefore, a total of 51 CBVT scans were initially reviewed, but only 50 were considered for further analysis.

Thirty-one subjects were female, with nineteen being male. Subjects aged from 23-74 years old, with the mean age being 47.4.

4.2 Distance between Teeth Apices and the Mental Foramen in the Modified Sagittal Plane

TABLE V

AVERAGE/MINIMUM/MAXIMUM DISTANCES FROM THE SUPERIOR ASPECT OF THE MENTAL FORAMEN TO THE RADIOGRAPHIC APICES

Tooth	Avg Distance in mm, (SD)	Min	Max
1st PM	6.8, (3.1)	0.5	14.7
2nd PM	3.9, (2.1)	0.4	8.9
Molar	9.9, (3.0)	2.5	17.1

4.3 Horizontal and Vertical Position of the Mental Foramen

TABLE VI

HORIZONTAL POSITION OF THE MENTAL FORAMEN

Location	M to 1st PM	at 1st PM	B/w 1st PM & 2nd PM	at 2nd PM	B/w 2nd PM & 1st Mo	at 1st Mo
N	0	1	33	8	6	2
Percentage	0	2	66	16	12	4

TABLE VII

VERTICAL POSITION OF THE MENTAL FORAMEN, RELATIVE TO THE RADIOGRAPHIC APEX OF THE SECOND PREMOLAR

Location	Inferior	Superior
N	36	14
Percentage	72	28

4.4 Statistical Analysis: Effects of Age and Gender

SPSS was used to calculate correlation between age/gender with distance to 1st PM, 2nd PM, and 1st Mo as well as horizontal and vertical position. There were no statistically significant correlations found between age and gender and any of the measurements taken ($p>0.05$ for all calculations). A trend was noted between increasing age and greater proximity of the mental foramen to the radiographic apex of the mandibular first premolar. This will be discussed further in section V.

For the SPSS table output and Pearson Correlation statistics, see Appendix B.

V. DISCUSSION

5.1 Study Findings

Fifty CBVT scans from the Kodak 9000 CBVT machine were reviewed in this study. The subjects varied in age from 23-74, with a mean age of 47.4. The subject pool was predominantly female (62%), which was unintentional as the CBVT scans were randomly selected from a private practice's existing scan database. Perhaps the endodontic specialty practice in which research was conducted (Cameo Endodontics LLC, Berwyn, IL) treats a predominantly female patient population.

Measurements were obtained from the superior aspect of the mental foramen to the radiographic apex of the mandibular first premolar, mandibular second premolar, and the mesial root of the mandibular first molar. On average, the mental foramen was closest to the mandibular second premolar (average distance of 3.9 mm), followed by the mandibular first premolar (6.8 mm), and was furthest away from the mesial root of the mandibular first molar (9.9 mm). However, as will be later discussed in at the end of the next section (5.2), these measurements may not necessarily be clinically relevant and critical interpretation is needed.

Considering only the mean distances between the foramen and the tooth apices may be misleading; the ranges of values for each distance are perhaps more clinically relevant. The range of distances measured between the mental foramen and the radiographic apex of the mandibular first premolar was a minimum of 0.5 mm and a maximum of 14.7 mm. Similarly large ranges were observed for the mandibular second premolar (0.4 mm min, 8.9 mm max) and the mesial root of the mandibular first molar (2.5 mm min, 17.1 mm max). The mental foramen was closest to the mandibular first premolar in 16% of the subjects, closest to the mandibular 2nd premolar in 80% of the subjects, and the mesial root of the mandibular first molar in the remaining 4%. The broad ranges for each distance measurement as well as the fact that in 20% of the cases, the mental foramen was closer to a tooth other than the mandibular second premolar, suggest there is great anatomical variation in the position of the mental foramen as visualized by CBVT. This can have significant clinical implications if not preoperatively understood (4, 5).

In this study, the mental foramen was located between the first and second mandibular premolars in 66% of the subjects; in 18% of the subjects, the mental foramen was horizontally in-line with the long axis of the mandibular second premolar. Therefore, the first hypothesis of this study ("the mental foramen is most commonly horizontally in-line with the mandibular second premolar") must be rejected as it does not account for the high frequency of mental foramina being located between the mandibular premolars. In considering the previously published studies in which dry skulls and conventional dental radiographs were used for measurement, the results of this study are similar to those of Sweet (15), Neiva (13), and Fishel (18). However, many other published studies found that the mental foramen is in line predominantly with the mandibular second premolar compared to the region in between the premolars (7, 9, 11, 14, 19, 20). Still, other studies have found that the mental foramen is located in between the premolars or at the level of the second premolar with essentially the same frequency (8, 17). Therefore, considering the results of this study in conjunction with those previously published, it appears that the mental foramen occurs horizontally most commonly either between the mandibular premolars or in-line with the second premolar.

The vertical location of the mandibular foramen was examined by assessing whether the foramen was inferior or superior to the apex of the mandibular second premolar. The mandibular second premolar was arbitrarily selected. In this sample it was observed that in 72% of the subjects, the mental foramen was inferior to the radiographic apex of the mandibular second premolar. Twenty-eight percent of the cases therefore were at the vertical level or superior to the radiographic apex of the mandibular second premolar. Therefore, the second hypothesis of this study is not rejected. These results contrast the findings of Fishel (18), in which in a majority of the subjects the mental foramen was found to be superior to the mandibular second premolar's radiographic apex. Phillips and Weller (10, 16, 34) measured the vertical location of the mental foramen with respect to the buccal cusp tip of the mandibular second premolar. Though interesting, this is not necessarily as clinically relevant to endodontic surgery as the buccal cusp tip could theoretically be modified by the presence of a dental restoration, cusp fracture, occlusal wear, etc. Haktanir et al (39) utilized MDCT to make measurements of the vertical location of the mental foramen with respect to the alveolar ridge. As Haktanir et al used the alveolar ridge as a landmark for measurement, the results of their study cannot be compared with this study.

Previous studies have documented the absence of a mental foramen or accessory mental foramina (31-33). Interestingly, out of the 51 total CBVT scans examined for this study, one subject was found to have a bifid mental foramen. Therefore, this anatomical variation must be considered in the preoperative planning stages of endodontic surgery. As previously discussed, this sample was excluded from all further assessment as having two mental foramina would lead to ambiguous measurement.

Statistical analysis was performed to assess if there was a statistically significant relationship between gender and age with regards to the position of the mental foramen. Following the calculation of Pearson correlation coefficients, there were no statistically significant findings. Therefore, based on this limited sample, there does not appear to be any age or gender related factors with regards to the position of the mental foramen, and the third hypothesis for this study is not rejected. This contrasts recent studies findings with regards to the position of the inferior alveolar nerve, where women and young subjects were found to have a shorter distance between teeth apices and the inferior alveolar nerve (30).

5.2 Clinical Relevance and Limitations

As previously stated, this was the first study known to have utilized CBVT to ascertain the location of the mental foramen. As CBVT is a relatively new technology, its accuracy for measurements may be called to question. A recent paper by Kim et al (40) found a that CBVT measurements are as accurate as anatomic dissection in the posterior mandible.

Clinicians should always be conscientious of minimizing radiation dosage to patients under the principle of ALARA (keeping radiation dosage “as low as reasonably achievable”). According to the joint position statement of the American Association of Oral and Maxillofacial Radiologists/American Association of Endodontists, “clinicians should use CBCT only when the need for imaging cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities (41)”. As can be discerned from the findings of Phillips and Weller (10, 16, 34), lower dose conventional dental radiography may not accurately identify the position of the mental foramen, whereas according to Kim et al (40) CBVT measurements are as accurate as anatomic dissection. Therefore, given the possibility of neurological complications if the location of the mental foramen is not understood (4) and the fact that lower dose conventional dental radiography does not accurately depict the location of the mental foramen, the clinician is justified under the principle of ALARA to prescribe a CBVT scan prior to posterior mandibular endodontic surgery.

Haktanir et al (39) utilized MDCT to make measurements with regards to the position of the mental foramen. The authors measured the mental foramen horizontally with respect to the midline of the mandible and vertically with respect to the alveolar ridge. While Haktanir et al (39) utilized a clinically relevant landmark for the vertical location of the mental foramen (the height of the alveolar ridge), their utilization of the midline of the mandible for a horizontal measurement starting point is not clinically useful in endodontic surgery. This study utilized the radiographic apices of the neighboring tooth roots as the landmarks for measurement, and provides information much more helpful to the endodontic surgeon. This study was also distinct in that it utilized CBVT, which has a smaller voxel size, has isotropic voxels, and has a lower radiation dose compared to MDCT (26).

In this study, the radiographic apex of the mandibular second premolar was arbitrarily selected as the "equator" for measuring whether the mental foramen was inferiorly or superiorly located. Fishel et al (18) previously measured the vertical position of the mental foramen with respect to the radiographic apex of both the mandibular first and second premolars. It would have perhaps been more thorough to include the vertical position of the mental foramen with respect to the radiographic apex of the mandibular first premolar as well in this study. However, the more significant point to discuss when comparing the results of this study with that of Fishel is that in Fishel's study, the mental foramen was more commonly superior to the tooth apices, whereas in this study the mental foramen was more commonly inferior to the radiographic apex of the mandibular 2^{nd} premolar 72% of the time. This is yet another demonstration of the variability of the location of the mental foramen, giving more evidence for the need of a preoperative CBVT scan prior to each endodontic posterior mandibular surgery.

One shortcoming of this study is that all measurements were obtained by the principal investigator through computer mouse "click and drag" movements; this could potentially incorporate human error if the principal investigator did not point exactly to the radiographic apex and/or the superior most aspect of the mental foramen. Perhaps the only way to prevent such errors in reliability of measurement would be a built-in computer software algorithm to compute the exact distance from the mental foramen to the teeth apices, which is not believed to be currently in existence. Until this point, whenever humans make measurements with any imaging modality (2D or 3D), there will always be the potential for human error. Theoretically, with a greater sample size, these errors due to human imperfection will be minimized.

Further discussing sample size, another shortcoming of this study was that only 50 CBVT scans were included. In the statistical analysis of this paper, it was found that there was no significant relationship between age and gender and any of the measured distances between the mental foramen and teeth apices as well as horizontal and vertical positioning of the mental foramen. However, upon review of the correlation output (see Appendix), the relationship between age and distance to both the second premolar and mesial root of the first molars were approaching significance (P=0.059, P=0.066 respectively). There was a positive Pearson correlation coefficient for both, suggesting a trend for increasing age and increasing distance to the root apices of the mandibular 2nd premolar and mesial root of the mandibular first molar. Perhaps with a larger sample size, a significant relationship would have been observed between increasing subject age and the distance to the mental foramen.

During the data analysis of this paper, the principal investigator noted a critical ambiguity in some of the measurements being compared that compromises a small subset of the results. More specifically, computer software was utilized to measure the distance between the superior aspect of the mental foramen and various teeth apices. These distances were recorded in scalar quantities, i.e. having no direction to them. However, in retrospect there should have been a modified Cartesian coordinate system used which would allow the mental foramen to be specified as superior or inferior (or anterior or posterior in the case of the horizontal axis) to a tooth apex. The problem with this ambiguity is illustrated in the following scenario: if in one subject the mental foramen is 3 mm superior to the radiographic apex of the second premolar, and in another subject the mental foramen is 3 mm inferior to the radiographic apex of the second premolar, the statistics used in this study would have considered the roots the same in proximity to the mental foramen, even though clinically the scenarios are completely different. Clearly, when the foramen is inferior to the apex, apicoectomy is possible; whereas when the foramen is superior to the apex, apicoectomy may be anatomically contraindicated and intentional replantation may be indicated.

This ambiguity makes the analysis comparing distances to the mental foramen from the various teeth apices of less clinical value. Therefore, the conclusions that can be drawn with more conviction from this study are those deduced from Tables VI and VII as well as simply noting the great variability in location of the mental foramen among individual subjects. The individual distance comparisons between the mental foramen and the various tooth apices, as well as the statistical analyses of the effects of age and gender on distance between the mental foramen and teeth apices are potentially not clinically relevant, which in retrospect is a major shortcoming.

5.3 Suggestions for Future Studies

For future investigations regarding the use of CBVT to investigate the location of the mental foramen, a larger sample size should be attained. In this study it was observed that there was a trend in which as subject age increased, the mental foramen appeared to be found closer to the first premolar and further from the second premolar and mandibular molars. A larger sample size would allow a more robust statistical analysis to discern whether the trend revealed in this study has statistical significance or is merely coincidence.

Also, as previously stated, future investigators should consider utilizing a modified Cartesian coordinate system to make distance measurements. A recommendation would be to have the (0,0) point at the superior aspect of the mental foramen, and then assigning coordinates (x,y) to the radiographic apices of the mandibular first premolar, second premolar, and mesial root of the mandibular molar. The coordinates would take on both positive and negative values as dictated by their spatial locations. This would perhaps be more clinically meaningful than the absolute value of the distance from a particular tooth apex to the mental foramen, which was reported in this study. In order to simplify measurement, it would be recommended to have the z-axis fixed to be coincidental with the arch curvature. Having a fixed z-axis would facilitate two-dimensional measurement.

VI. CONCLUSION

Fifty CBVT scans were reviewed and measurements were made using computer software to assess for the location of the mental foramen. The mental foramen was most commonly located inferior the radiographic apex of the mandibular second premolar and horizontally between the mandibular first and second premolar roots; however, great variability was observed. No significant differences were observed based on age or gender. Distances between the apices and the mental foramen were recorded, but these distances were discovered to be less clinically relevant. Reasons for these irrelevant measurements were detailed and solutions for future research were described. Due to the great variability observed in the location of the mental foramen, and due to the possibility of neurological complications if the location of the mental foramen is not identified preoperatively, the endodontic surgeon is encouraged to obtain a preoperative CBVT scan prior to every posterior mandibular endodontic surgery.

APPENDICES

APPENDIX A

Raw Data

Number	Age	Gender	Dist to 1st PM	Dist to 2nd PM	Dist to 1st Mol
1	47	Female	9.6	8.9	12.1
2	58	Female	2.1	7.4	12.9
3	39	Male	14.7	4.4	2.5
4	33	Male	4.2	7.9	13.3
5	28	Female	9.7	5.2	6.8
6	28	Female	6.1	4.6	10.8
7	59	Male	4.8	8	14.6
8	44	Male	4.3	6.2	11.9
9	48	Female	7.6	1.7	8.7
10	52	Female	6.7	5.4	10.9
11	43	Female	7	1.4	8.1
12	51	Male	10.9	4.6	7.8
13	71	Male	2.6	6.4	14.7
14	61	Female	0.5	5.7	14.5
15	35	Female	5.6	0.4	6.5
16	38	Female	6.3	4.8	13.9
17	74	Female	0.9	5.9	11.3
18	55	Female	5.4	5.1	10.1
19	51	Male	8.6	2.1	8.5
20	53	Male	6.5	4.1	11.9
21	40	Female	8.2	1	7.1
22	59	Female	7.5	1.6	8
23	49	Male	14.1	6.6	7.2
24	31	Female	9.9	4.2	10.8
25	38	Female	7.8	0.4	7.8
26	37	Male	8.8	0.4	4.4
27	36	Female	6	5.3	12.4
28	60	Male	8.2	8.5	17.1
29	40	Female	7.6	2.3	6.4
30	45	Female	12.3	2.4	7.7
31	63	Female	10.7	2.8	8.2
32	29	Male	4.6	3.3	11.6
33	55	Male	6	3.8	10.1
34	45	Female	4	3.6	11.7
35	60	Female	5.5	3.5	11.6
36	42	Male	5.4	4.3	11.4

37	57	Female	5	3.5	9.1
38	43	Female	6	2.8	8.8
39	51	Male	4.7	3.9	10.1
40	45	Female	5.7	3.8	11.1
41	49	Female	8.4	3.6	6.7
42	43	Female	5	4.4	10.9
43	65	Female	5.7	2.3	11.7
44	41	Male	4.8	3.5	11.7
45	47	Female	5.8	2.7	10.5
46	54	Male	14.1	4.9	2.6
47	59	Male	4.4	3.2	11.6
48	41	Female	9.2	2.1	6.2
49	55	Female	5.5	1.7	8.9
50	23	Male	5	0.7	10.7

APPENDIX B

Statistical Output with SPSS

		Distance to 1st PM	Distance to 2nd PM	Distance to 1st M	Horiz: At 1st PM	Horiz: B/w 1st PM and 2nd PM	Horiz: At 2nd PM	Horiz: B/w 2nd PM and 1st M	Horiz: At 1st PM	Vertical: Inferior	Vertical: Superior
Age	**Pearson Correlation**	-.232	.269	.262	.172	.085	-.059	-.122	-.016	.085	-.085
	Sig. (2-tailed)	.105	.059	.066	.231	.555	.684	.397	.911	.556	.556
Gender	**Pearson Correlation**	-.102	-.230	-.073	.112	-.040	.229	-.091	-.261	-.121	.121
	Sig. (2-tailed)	.482	.108	.615	.439	.783	.109	.528	.067	.402	.402

APPENDIX C

IRB Documentation

Approval Notice

Initial Review – Expedited Review

November 26, 2012

Michael Munaretto, DDS

Endodontics

801 Paulina #304D (ENDO)

M/C 642

Chicago, IL 60612

Phone: (708) 308-9828 / Fax: (312) 996-3375

RE: Protocol # 2012-0998

"Proximity of the Mental Foramen to the Tooth Apex"

Dear Dr. Munaretto:

Members of Institutional Review Board (IRB) #3 reviewed and approved your research protocol under expedited review procedures [45 CFR 46.110(b)(1)] on November 21, 2012. You may now begin your research.

Please note the following information about your approved research protocol:

Protocol Approval Period: November 21, 2012 - November 21, 2013

Approved Subject Enrollment #: 50 Total

Additional Determinations for Research Involving Minors: These determinations have not been made for this study since it has not been approved for enrollment of minors.

Performance Sites: UIC, Cameo Endodontics, LLC

Sponsor: None

Research Protocol(s):

a. Proximity of the Mental Foramen to the Tooth Apex, Version 1.0, August 9, 2012

Informed Consent(s):

a. Waiver of Informed Consent granted under [45 CFR 46.116(d)]

HIPAA Authorization(s):

a. Waiver of Authorization granted under [45 CFR 164.512(i)]

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific category:

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

Please note the Review History of this submission:

Receipt Date	Submission Type	Review Process	Review Date	Review Action
11/13/2012	Initial Review	Expedited	11/21/2012	Approved

Please remember to:

→ **Use only the IRB-approved and stamped consent document(s) enclosed with this letter when enrolling new subjects.**

→ Use your **research protocol number** (2012-0998) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements of the,

"**UIC Investigator Responsibilities, Protection of Human Research Subjects**"

Please note that the UIC IRB has the right to ask further questions, seek additional information, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS office at (312) 996-1711 or me at (312) 355-1404. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Sheilah R. Graham, BS

IRB Coordinator, IRB # 3

Office for the Protection of Research Subjects

Enclosure(s):

1. **UIC Investigator Responsibilities, Protection of Human Research Subjects**
2. **HIPAA Authorization(s):**
    a. Certification of Waiver of Authorization
3. Data Security Enclosure

cc: Mohamed I. Fayad, Faculty Sponsor, Endodontics, M/C 642, Christopher Wenckus, Endodontics, M/C 642, Privacy Office, Health Information Management Department, M/C 772

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VITA

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D.D.S., Doctor of Dental Surgery, University of Illinois at Chicago, Chicago, IL, 2011

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HONORS

May 4, 2011

Dr. James R. Havera Award for top-ranking student in graduating class

Dr. William McElroy Award from UIC Dept of Endodontics for outstanding achievement in Endodontics

Dr. Gerald Wine Scholarship Award from UIC Academic Affairs for outstanding interaction with faculty, patients, and staff

Sullivan-Schein Predoctoral Student Achievement Award from UIC Dept of Oral Surgery for excellence in implant dentistry.

Delta Sigma Delta Award for most outstanding academic achievement in graduating class

Delta Dental of Illinois Dental Student Award for excellence in comprehensive care

Elected to Omicron Kappa Upsilon Dental Honors Society as an Alumni member of the Sigma Chapter (UIC)

May 5, 2010

Dr. William Starek Award from UIC Dept of Endodontics for outstanding achievement in Endodontics

Dr. Marshall W. Milnarik Award from UIC Academic Affairs for outstanding academic and clinical performance during the D2 year.

February 5, 2010	*Henry J. Bosworth CaseCAT Award* at UIC Clinic and Research Day for best CaseCAT presentation.
January 30, 2010	*Delta Sigma Delta Table Clinics Honorable Mention Award*. Received at Annual Regional Meeting in Milwaukee, WI.
December 2009	*Arcolian Italian Dental Arts Society Scholarship Award*
2003-2007	Dean’s List, University of Illinois at Urbana-Champaign James Scholar Honors, University of Illinois at Urbana-Champaign
September 2007	*Pi Kappa Phi Health Professions Scholarship Award* from the Pi Kappa Phi Foundation.
May 2007	UIUC *Bronze Tablet Award* given for being in top 3% of graduating class
May 2006	*Pi Kapp Scholar Scholarship Award* from the Pi Kappa Phi Foundation.
April 2005	*GE Scholar Award* from UIUC General Engineering Department

PROFESSIONAL MEMBERSHIP: American Association of Endodontists, Chicago Dental Society, American Dental Association, Illinois State Dental Society, Edgar D. Coolidge Endodontic Study Club, Seattle Study Club - Windy City Seminars, Omicron Kappa Upsilon, Pi Beta Phi