ARAŞTIRMA / ORIGINAL ARTICLE

Gülhane Tıp Dergisi 2010; 52: 69-75

Retrospective radiographic evaluation of the interforaminal region with spiral computerized tomography: adequacy for dental implant placement related to age and dental status

Sermet Şahin (*), Yavuz Kaya (*), Metin Şençimen (**), Işıl Saygun (*), Hasan Ayberk Altuğ (***)

SUMMARY

The aim of this study was to evaluate the variation of the anatomical landmarks at interforaminal region with age and dental status by examining spiral computed tomographies. Fifty young (≤40) and 50 older (>40) patients' interforaminal regions were evaluated with spiral computed tomographic images. In both age groups, 25 of the patients were fully dentate up to mandibular bicuspids contralaterally and the rest were completely edentate at interforaminal region including mandibular bicuspids. The distances between mental foramen to alveolar crest (MF-AC), mental foramen to lower cortex (MF-LC), mental foramen to lingual external border (MF-LEB), mental foramen to contralateral mental foramen (MF-MF), and the height (HMF) and width of MF (WMF) and anterior loop of mental foramen (ML) were measured by an experienced calibrated clinician. In spiral computed tomographic images, MF-AC and MF-LC were significantly lower in edentate subjects being independent of age ($p<0.001$). WMF and HMF were found significantly smaller in both older and edentate subject groups ($p<0.01$), MF-MF was significantly longer ($p<0.001$) in both edentate and older patients, and MF-LEB was not affected by age or dental status ($p>0.05$). The anatomical landmarks at interforaminal region more likely depend on dental status rather than the age. Safety zone should be 3 mm far from MF for dental implant placement in interforaminal region as the anterior loop of mental foramen was measured as approximately 3 mm.

Key words: *Dental implants, interforaminal region, mental nerve, spiral computed tomography*

ÖZET

İnterforaminal bölgenin retrospektif olarak spiral bilgisayarlı tomografi ile radyolojik değerlendirilmesi: dental implant uygulaması için uygunluğun yaş ve dişsel durumlar ile ilişkisi

Bu çalışmanın amacı, interforaminal bölgedeki anatomik noktaların, yaş ve dişsel durumları ile ilişkilerinin spiral bilgisayarlı tomografi ile değerlendirilmesidir. Kırk yaş altı ve 40 yaş üstü ellişer hastanın interforaminal bölgeleri spiral bilgisayarlı tomografi ile değerlendirildi. Her iki yaş grubunda da 25'er hasta mandibular azı dişlerine kadar kontralateral olarak tam dişli idi ve geri kalan 25'er hasta ise mandibular azı dişleri de dahil olmak üzere interforaminal bölgede total dişsizdi. Mental foramen-alveolar krest arası mesafe (MF-AC), mental foramen-alt korteks arası mesafe (MF-LC), mental foramen-lingual eksternal yüzey arası mesafe (MF-LEB), mental foramenler arası mesafe (MF-MF), mental foramenin dikey yüksekliği (HMF) ve yatay genişliği (WMF) ve mental foramenin öne doğru kıvrımı (ML), deneyimli bir klinisyen tarafından ölçüldü. Spiral bilgisayarlı tomografik incelememelerde MF-AC ve MF-LC, dişi olan hastalarda yaştan bağımsız olarak daha düşük değerlerde saptandı ($p<0.001$). WMF ve HMF hem yaşlı, hem de dişi olan gruplarda daha düşük olarak, MF-MF daha uzun olarak tespit edildi ve MF-LEB'nin yaş ve dişsel durumdan etkilenmediği saptandı ($p>0.05$). İnterforaminal bölgedeki anatomik oluşumlar yaştan daha çok dişsel duruma bağlıdır. Mental foramenin öne doğru kıvrımının, ortalama 3 mm olarak ölçülmesinden dolayı, bu bölgedeki implant uygulamalarının MF'den 3 mm uzakta yapılması daha güvenli olacaktır.

Anahtar kelimeler: *Dental implant, interforaminal bölge, mental sinir, spiral bilgisayarlı tomografi*

* Department of Periodontology, Dental Sciences Center, Gulhane Military Medical Academy
** Department of Oral and Maxillofacial Surgery, Dental Sciences Center, Gulhane Military Medical Academy
***Dental Service, Turkish Military Academy

Reprint request: Dr. Hasan Ayberk Altuğ, Dental Service, Turkish Military Academy, Dikmen-06540, Ankara, Turkey
E-mail: aybork@yahoo.com

Date submitted: January 07, 2010 • **Date accepted:** February 22, 2010

Introduction

The anatomical position of the mental foramen (MF) is important in many processes of dentistry, including diagnosis, anesthesia, endodontics and surgery. Locating mental nerve, identifying its loop and measuring its length have great importance before replacement of missing teeth with endosseous implants at interforaminal region (1,2). Surgical traumas to mental nerve are possible during the implant therapy and cause altered sensation in lower lip and chin. The location of the MF and the anterior loop of mental neurovascular bundle determine the number and the location of dental implant at interforaminal area (1-3). As the age advances, the direction of aperture of the MF alters in direction from forwards to upwards and backwards (1,4). Besides, after losing lower bicuspids, MF approaches to the superior border of alveolar process owing to the alveolar atrophy, shortens the length of dental implant to be located or precludes implant therapy in this region (1-3). Some studies have shown that the distance between MF and lower cortex of mandible is also smaller in older patients owing to basal bone atrophy (1,4-6).

There are evident differences among studies in the location and available alveolar bone quantity around mental nerve (7-15). Reports have shown that the MF is not in a constant location, changing with age (4,13), gender (10,14,15), dental status (5,6,13,14), systemic conditions (10) and racial variety (1-3). In previous reports the localization and the measurements related with MF was determined by panoramic radiography (PR) (5,6,9,12-16), periapical radiography (8,12,17), direct measurement during the surgery (3) or dissection in anatomic cadavers (2,4,7,10,11).

PR is a commonly used diagnostic imaging technique, showing all oral anatomic landmarks in one radiographic image. Its accuracy is limited owing to difficulty in controlling the distortion and magnification; however, it has been commonly used before implant surgery to estimate the quality and quantity of the alveolar bone for appropriate implant length and wide to avoid damage to anatomic structures during the surgery (1,3,9,15-18). Two-dimensional images such as periapical and PR have evident deficiencies, especially depending on patient position (19,20) and corticalization quantity of the canal wall (20,21). Besides, computed tomography (CT) scans locate and measure more accurately with disadvantages of more radiation exposure and financial cost (18-21). Spiral computed tomography (SCT) shows the cortical margins of the neurovascular bundle more clearly when compared with other tomographies and panoramic images even in poor bone quality (18,21). SCT shows the boundaries of the mandibular canal, MF and its anterior loop more clearly even in older ages (18,21,22).

As far as we know, the position of MF has not yet been investigated by SCT to date. The aim of this retrospective study was to investigate the changes in anatomic landmarks at interforaminal region with aging and tooth loss, using the radiodiagnostic advantages of SCT, which can directly affect dental implant planning.

Material and Methods

Each patient was selected according to his/her dental status, age and gender from a population of 638 subjects who attended the Department of Periodontology and Department of Oral and Maxillofacial Surgery of Gulhane Military Medical Academy between March 2006 and March 2008. The patients who had unerupted mandibular premolar, deciduous teeth and systemic diseases related to bone such as osteoporosis, diabetes, renal disease, thyroid disease, and who were not a member of Caucasian race were not included in the study. In addition, the patients with a history of chronic or aggressive periodontitis were not included in dentate group.

The study was carried out with SCT images of 100 selected patients. Fifty of the patients were younger than 40 years of age (Younger age group). In both younger (mean 34.98±3.76) and older (mean 59.09±7.06) age groups, 25 of the subjects were fully dentate up to mandibular bicuspids contralaterally and the remaining 25 were completely edentate at interforaminal region including mandibular bicuspids. The average age distribution of each group is shown in Table I. SCT was performed with a sixteen channel multidetector Philips MX8000 IDT (Philips Medical Systems, Best, Netherlands). SCT was used at 120 kV and 221 mAs, with 0.5 sec rotation time, with 1.6 x 0.75 cm rectangular collimator, 1 mm slice thickness. The data were transferred to a network computer workstation (Philips Extended Brillance Workspace 2.0.11, Philips Medical Systems, Best, Netherlands). Processing conditions of the films were standardized by using Kodak-2180 (Eastman Kodak Company, Rochester, NY, USA) automatic developer.

Table I. Average age distribution of the age groups

Group	*n*	*Mean age*
Young (≤40), fully dentate interforaminal region	25	34.85±4.34
Young (≤40), completely edentulous interforaminal region	25	35.12±3.19
Older (>40), fully dentate interforaminal region	25	53.72±8.81
Older (>40), completely edentulous interforaminal region	25	64.46±5.32

Radiographic measurement procedure: To ensure consistency, all radiographs were selected and measured by one author (SS), with a previous experience in SCT interpretation and dental implant planning and treatment. Seven measurements were made in cross-sectional images of SCT to evaluate interforaminal region:

1- The shortest distance from the two lines passing through the most superior point of mental foramen and alveolar crest in edentulous or fully dentate interforaminal area (MF-AC) (Figure 1). In fully dentate interforaminal areas, the periodontal ligament of tooth, same level with mental foramen, started to be of equal width, was considered as the most superior border of the alveolar crest (23).

2- The shortest distance from the two lines passing through the most apical border of the mental foramen to the outer lower cortex of the mandible (MF-LC) (Figure 1).

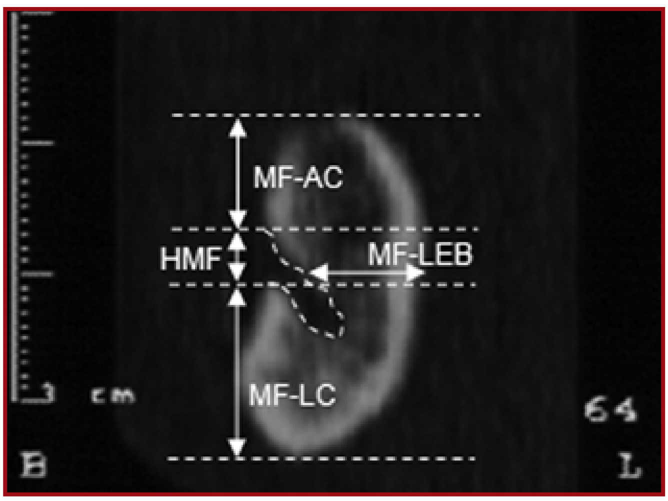

Figure 1. The evaluation of mental foramen in cross-sectional CT images: MF-AC: Mental foramen to alveolar crest. MF-LC: Mental foramen to lower cortex. HMF: The height of mental foramen. MF-LEB: Mental foramen to lingual external border

3- The highest distance from the coronal and apical border of mental foramina was evaluated to measure its height (HMF) (Figure 1).

4- The shortest distance between the lingual border of mental foramen and inferior part of lingual external border of the mandible (MF-LEB) (Figure 1).

5- The distance between the most anterior point of contralateral mental foramens (MF-MF) (2). If there was any loop, it was measured from the most mesial point of the mental genu. MF-MF was measured in axial section of CT images.

6- Distance from the first and the last image of mental foramen (WMF).

7- If an anterior mental loop (ML) was observed at SCT, the distance from the first and last images which mandibular and mental canal were seen together or attached like "figure 8" or elongated mandibular canal apperance (Figure 2) (18,24).

Intervals between the above mentioned landmarks were measured by counting cross-sectional 1-mm thick slices. During MF-MF measurement, care was taken not to include the first and last slice of foramen mandible and MF, opening to the internal and external cortex, respectively (18,24).

All examinations were performed on a standard radiologic light box, under standardized viewing conditions.

Statistical analysis: The data were computerized and the statistical analysis was performed with a software program (SPSS 9, SPSS Inc., Chicago, IL, USA). The measured values from right and left sides were pooled in the same column for statistical analyses, displaying mean, standard deviations and range for all parameters in each group. Two-tailed independent *t* test was carried out to establish possible differences between younger and older subjects and fully dentate and edentate interforaminal regions. A p value greater than 0.05 was not considered significant.

Results

MF-AC: The values ranged from 5.5 to 22 mm, no significant difference being found between younger and older subjects (p>0.05); but when the same subjects were evaluated by their dental status, a significant difference was found (p<0.001) (Tables II,III).

MF-LC: The values ranged from 9.5 to 19 mm and no significant difference was found between younger and older subjects (p>0.05), but when the same subjects were evaluated by their dental status, a significant difference was found (p<0.001) (Tables II,III).

HMF: The values ranged from 2 to 6 mm, with a significant difference between younger and older subjects and between edentate and dentate groups (p<0.01) (Tables II,III).

MF-LEB: The values ranged from 3 to 6.5 mm, with no significant difference when the subjects were either evaluated by their age or dental status (p>0.05) (Tables II,III).

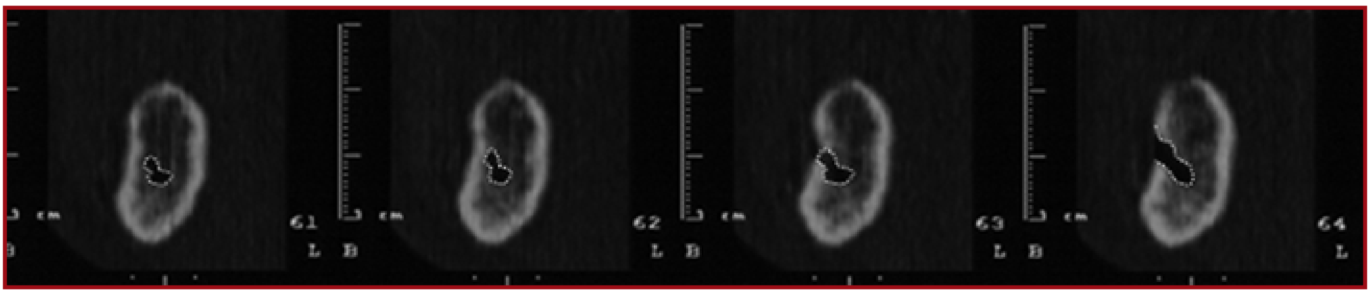

Figure 2. Anterior loop of the mental nerve appears in cross-sections 61 through 63, nerve exits in cross-sections 64. Loop has a "figure 8" shape with mandibular canal

Table II. Comparison of the value of average measurements (mm) on spiral computed tomography according to age

	Younger (≤40) subjects (n=50)*	*Older (>40) subjects* (n=50)*	*Significance*
MF-AC (mm)	12.16±3.45 (8.5-22)	11.92±3.89 (5.5-21)	Not significant
MF-LC (mm)	14.53±3.45 (10-19)	14.32±3.07 (9.5-18)	Not significant
MF-MF (mm)	62.88±6.92 (45-89)	65.32±6.78 (48-90)	p<0.001
WMF (mm)	3.62±1.12 (2-5)	2.53±1.31 (2-5)	p<0.01
HMF (mm)	3.67±1.22 (2-5)	2.21±1.31 (2.5-6)	p<0.01
MF-LEB (mm)	5.49±1.32 (3-6.5)	5.28±1.62 (3-6.5)	Not significant

*: Values are given as mean±standard deviation (range)
MF-AC: Mental foramen to alveolar crest, MF-LC: Mental foramen to lower cortex, MF-MF: Between contralateral mental foramens, HMF: The height of mental foramen, WMF: Width of mental foramen, MF-LEB: Mental foramen to lingual external border

Table III. **Comparison of the value of average measurements on spiral computed tomography according to dental status of the subject population**

	Edentate interforaminal region (n=50)*	*Fully dentate interforaminal region* (n=50)*	*Significance*
MF-AC (mm)	8.14±3.27 (5.5-17.5)	15.94±4.07 (11.5-22)	p<0.001
MF-LC (mm)	12.65±3.82 (9.5-14.5)	16.20±2.70 (10-19)	p<0.001
MF-MF (mm)	66.78±7.01 (45-90)	61.42±6.69 (45-90)	p<0.001
WMF (mm)	2.39±1.15 (2-5)	3.76±1.28 (2-5)	p<0.01
HMF (mm)	2.25±1.32 (2-6)	3.63±1.21 (2.5-6)	p<0.01
MF-LEB (mm)	5.37±1.35 (3-6)	5.40±1.59 (3-6.5)	Not significant

*: Values are given as mean±standard deviation (range)

MF-AC: Mental foramen to alveolar crest, MF-LC: Mental foramen to lower cortex, MF-MF: Between contralateral mental foramens, HMF: The height of mental foramen, WMF: Width of mental foramen, MF-LEB: Mental foramen to lingual external border

MF-MF: The values ranged from 45 to 90 mm, with a significant difference related to age and dental status ($p<0.001$) (Tables II,III).

WMF: The values ranged from 2 to 5 mm, with a significant difference according to age and dental status ($p<0.01$) (Tables II,III).

ML: The prevalence and the length of ML is 30% and 3.11±1.62 mm (range between 1 to 7 mm), respectively. The prevalence of mental loop in younger, older, fully dentate and edentate groups was 28%, 32%, 31% and 29%, respectively, with no significant differences among the groups ($p>0.05$). The average length of mental loop in younger, older, fully dentate and edentate groups was 3.05±1.51 mm, 3.16±1.73 mm, 3.14±1.56 mm and 3.08±1.68 mm, respectively. There were no significant differences among the groups ($p>0.05$).

Discussion

During dental surgical procedures at interforaminal region such as dental implant placement and harvesting bone graft from symphysial area, it is important to know the exact location of MF and the amount of surrounding alveolar bone, in order not to damage mental nerve (1,2). To determine the location of MF and to measure the quantity of available bone, periapical radiographs and PR are usually used but these radiography techniques have magnification and distortion problems (8,9,19,20). MF displacements were seen in periapical radiographs and PR, when compared with anatomical measurements mainly because of the position of the X-ray and patient head, respectively (8,9). CT is a more precise imaging technique and SCT has the capability of showing the cortical margins of the neurovascular bundle more clearly when compared with other tomographies and panoramic images even in poor bone quality (18,21). The purpose of this study was to determine the exact location of anatomic landmarks and the available bone varying with age and dental status at interforaminal region. The present study is unique and significant in that it has a large population evaluated in SCT as entire measurements must be known before dental implant placement at interforaminal region.

According to previous reports, there is significant change in the location of MF according to the systemic conditions (10), gender (10,14,15) and race (1-3). Depending on these previous reports, comparable population of systemically healthy female and male subjects were included in all groups which were kept as large as possible, with no racial variety including only Caucasian race. Some investigators stated that the age-related bone resorption begins at about forties (11). In accordance with these studies the age groups were planned as younger (≤40) and older (>40) in this study. There are clear distinctions between the studies regarding the anatomic location of mental foramina in relation to dental status, race, age and gender of the subjects and diagnostic methods used for evaluation (1-17). Comparison of this study with the previous investigations is difficult, because the boundaries of anatomical landmarks were not defined clearly (4,12) or selected differently (2,3,6-9,13,14). Regarding the above mentioned distinctions between the studies, we will discuss each measurement one by one to eliminate confusion.

MF-AC: Prior to the eruption, the foramen is located closer to the upper margin alveolar crest, and it descends lower than half way between the upper and lower borders of mandible with time (4). Some previous studies stated that in older ages with edentelous mandible, it is situated closer to the alveolar crest owing to physiologic alveolar atrophy, sometimes top of the alveolar crest (1,4,5). In previous reports cusp tip (3,7), apex of lower bicuspid (8,9) or cemento-enamel junction (CEJ) (2) superior to MF was selected as a landmark, not allowing the comparison of edentulous patients with dentate ones.

Besides, alveolar crest around the extracted tooth is important to determine the length of immediate dental placement instead of CEJ especially in patients with periodontitis. Previous studies have also shown significant variation in MF-AC level, ranging between 0 to 22 mm (2,4,12,14). In our study mean length were 11.92 mm and 12.16 mm in older and younger groups, respectively, with no significant difference. When the same patient population was evaluated according to their dental status the distance was 8.14 mm and 15.94 mm in edentulous and fully dentate groups, respectively, being significantly higher in the dentate group. Although different reference points were used, comparable results were obtained by other studies. Neiva et al. found this distance to be 15.52 mm in 22 Caucasian dentate mandibles at the mean age of 79.1 (2). Oğuz et al. in a study of 34 dried young (30-40 years old) Turkish adult male mandibles, found MF-AC to be 14.45 mm (12). Gershenson et al. reported MF-AC, as 13.77 mm and 5.43 mm in dentate and edentate adults, respectively (4). Our findings were similar with these studies, which supports the idea that the dental status of the mandible can be more important than the age in evaluating the distance of MF-AC. According to our study, there was no significant difference between younger and older groups, each of which has equal numbers of dentate and edentate subjects ($p>0.05$). Karaağaçlıoğlu et al. have stated that the mandibular ridge decreases more significantly in older age (>60); however all examined subjects were edentelous male subjects older than 40 years of age (11). MF-AC can be affected by age in edentelous mandibles, linearly decreasing with the elapsed period of edentulism.

MF-LC: The mandibular canal shows a convex downward contour when coursing through the body of mandible, get closest to the lower edge of mandible at first molar level and then moves upwards when approaching mental foramina (1,24). In previous reports MF-LC level varied between 5 to 21.5 mm (2-6,12,13). There are conflicting results about the distance of MF-LC. Xie et al. stated that the basal bone below the MF was not affected by dental status and age in men but it was found to be significantly smaller in old edentulous women when compared with old dentate or young dentate women (6). Soikonen et al. found that mental foramina was situated 3.8 mm lower in edentulous mandibles than in dentate jaws and stated that the foramen is moving through the lower cortex (5). However, in both of these studies they did not evaluate the MF-AC level, only investigating basal bone atrophy and stating downwards movement of mental loop according to the age and dental status (5,6). Nevertheless in our study we observed resorption in both distances (MF-AC and MF-LC) according to the dental status but the results were not related with age in the same subject population. This agrees with the report of Kingsmill et al. who found a correlation between alveolar bone and basal bone height (25). They stated that the basal bone is not in a constant position throughout lifetime and can change with tooth loss as alveolar bone. Therefore, it is unsafe to measure other landmarks from lower cortex (25,26).

MF-MF: Although this distance has paramount importance in determining the number and width of dental implants in interforaminal region, it was evaluated scarcely in studies on mental foramina (2). We did not find any references in the literature comparing the age or dental status in relation to MF-MF. In some studies it was observed that mental foramina moves distally in jaws continuing to atrophy, which is in accordance with our study (5,13,15).

WMF and HMF: Previous reports found the size of mental foramina in a range of 0.75 to 6.5 mm (1,4,7-9,11,12,16). Gershenson et al. found the diameter of round shaped MF to be 2.12 mm and 1.83 mm in dentulous and edentulous adult subjects, respectively, which is lower than our results (4). Neiva et al. found WMF to be 3.59 mm in 22 old dentate Caucasian skulls, which is similar to our dentate subjects (2). We found a significant difference related to age and dental status, being wider and higher in both dentate and young groups.

MF-LEB: We did not observe any significant differences related to age or dental status. Ulm et al. measured the distance between the mandibular canal and lingual external border in 6 different locations in 43 edentelous mandibles showing different degrees of alveolar ridge resorptions (27). Their results ranged between 2.87 to 5.92 mm, not finding any significant difference even between the depressed ridge and the alveolus after the extraction, similar to our study (27). Kingsmill et al. have stated that the mandibular changes related with dental status affects the alveolar height more when compared to its bucco-lingual width, which is in accordance with our findings (25).

ML: The prevalence and the length of ML have significant variations between the studies. This wide variation in results may be related to racial variety, bone quality and diagnostic techniques (1,18). We did not found any difference related to the age and dental status. In the review of MF, it is stated that there must be a safety zone 2 mm above and mesial to the mental foramina (1). However in our previous report (18) and present study we found the length of

ML to be longer than 3 mm, in accordance with other studies (2,28). The authors of this study think that the length of the safety zone for MF must be re-evaluated.

One unique feature of CT is its cross-sectional imaging, giving information not only about the buccolingual width of the alveolar bone but also about the quality of alveolar bone and determining the anatomical landmarks like mandibular foramen, mandibular canal, MF, anterior loop of mental nerve, incisive canal and lingual canal (18-20,22,24,29). Jacobs et al. identified the MF in all cases, with good visibility in 97% of them in CT scans (22) but in their other report they observed only 49% of MF with good visibility in PR (30). SCT gave more accurate values not only than PR, but also than hypocycloidal and spiral tomography (21).

By the assistance of the superior features of SCT it is concluded that MF-AC and MF-LC measurements can change according to the dental status of the individual, not with age. When the patients are compared only according to their age, the difference related with the dental status can be overlooked (Tables II,III). Although shortened vertical distances of MF-AC and MF-LC creates disadvantage by placing shorter dental implant; longer MF-MF, narrower WMF, lower HMF and constant MF-LEB can yield advantage for more or wider dental implant placement in edentate and older subjects at interforaminal region. The prevalence and the length of the mental loop may not depend on age or dental status. We found the length of mental loop to range from 1 to 7 mm, and according to our findings the safety zone must be at least 3 mm.

Acknowledgment

The authors thank Mrs. Melike Bahcecitapar at the Department of Statistics, Faculty of Science, Hacettepe University for her statistical support in analyzing the data.

References

1. Tarnow D, Greenstein G. The mental foramen and nerve: clinical and anatomical factors related to dental implant placement: a literature review. J Periodontol 2006; 77: 1933-1943.
2. Neiva RF, Gapski R, Wang HL. Morphometric analysis of implant-related anatomy in caucasian skulls. J Periodontol 2004; 75: 1061-1067.
3. Kim IS, Kim SG, Kim YK, Kim JD. Position of mental foramen in Korean population: A clinical and radiographic study. Implant Dent 2006; 15: 404-411.
4. Gershenson A, Nathan H, Luchansky E. Mental foramen and mental nerve: Changes with age. Acta Anat 1986; 126: 21-28.
5. Soikkonen K, Wolf J, Ainamo A, Qiufei X. Changes in the position of mental foramen as a result of alveolar atrophy. J Oral Rehabil 1995; 22: 831-833.
6. Xie Q, Wolf J, Soikkonen K, Ainamo A. Height of mandibular basal bone in dentate and edentelous subjects. Acta Odontol Scand 1996; 54: 379-382.
7. Phillips JL, Weller RN, Kulild JC. The mental foramen: Part 1. Size, orientation and positional relationship to the mandibular second premolar. J Endod 1990; 16: 221-223.
8. Phillips JL, Weller RN, Kulild JC. The mental foramen: Part 2. Radiographic position in relation to the mandibular second premolar. J Endod 1992; 18: 271-274.
9. Phillips JL, Weller RN, Kulild JC. The mental foramen: Part 3. Size and position on panoramic radiographs. J Endod 1992; 18: 383-386.
10. Toshihiro H, Ishijima T, Yoshiko H, Toshihiko Y. Osteoporosis and reduction of residual ridge in edentelous patients. J Prosthet Dent 1993; 69: 49-56.
11. Karaagacıoglu L, Ozkan P. Changes in mandibular ridge height in relation to aging and length of edentulism period. Int J Prosthodont 1994; 7: 368-371.
12. Oguz O, Bozkır MG. Evaluation of location of mandibular and mental foramina in dry, young, adult human male, edentelous mandible. West Indian Med J 2002; 51: 14-16.
13. Aktekin M, Celik HM, Celik HH, Aldur MM, Aksit MD. Studies on the location of the mental foramen in Turkish mandibles. Morphologie 2003; 87: 17-19.
14. Guler AU, Sumer M, Sumer P, Bicer I. The evaluation of vertical heights of maxillary and mandibular bones and the location of anatomic landmarks in panoramic radiographs of edentelous patients for implant dentistry. J Oral Rehabil 2005; 32: 741-746.
15. Al Khateeb, Hamasha AA, Ababneh KT. Position of the mental foramen in northern regional Jordanian population. Surg Radiol Anat 2007; 29: 231-237.
16. Yosue T, Brooks LS. The appearance of mental foramina on panoramic radiographs. I-Evaluation of patients. Oral Surg Oral Med Oral Pathol 1989; 68: 360-364.
17. Yosue T, Brooks LS. The appearance of mental foramina on panoramic and periapical radiographs. 2- Experimental evaluation. Oral Surg Oral Med Oral Pathol 1989; 68: 488-492.
18. Kaya Y, Sencimen M, Sahin S, Okcu KM, Doğan N, Bahcecitapar M. Retrospectıve radiographıc evaluation of the anterior loop of the mental nerve: comparison between panoramic radiography and spiral computerized tomography. Int J Oral Maxillofac Implants 2008; 23: 919-925.
19. Frederiksen NL. Diagnostic imaging in dental implantology. Oral Surg Oral Med Oral Pathol 1995; 80: 540-554.
20. Mardinger O, Chaushu G, Arensburg B, Taicher S, Kaffe I. Anatomic and radiologic course of the mandibular incisive canal. Surg Radiol Anat 2000; 22: 157-161.
21. Lindh C, Petersson A, Klinge B. Measurements of distances related to the mandibular canal in radiographs. Clin Oral Implants Res 1995; 6: 96-103.

22. Jacobs R, Mraiwa N, vanSteenberghe D, Gijbels F, Quirynen M. Appearance, location, course, and morphology of the mandibular incisive canal: An assessment on spiral CT scan. Dentomaxillofac Radiol 2002; 31: 322-327.
23. Björn H, Halling A, Thyberg H. Radiographic assessment of marginal bone loss. Odontol Revy 1969; 20: 165-179.
24. Rothman SLG. Dental applications of computerized tomography: surgical planning for implant placement. In: Rothman SLG (ed). Computerized Tomography of the Mandible. Chicago: Quintessence, 1998: 39-64.
25. Kingsmill VJ, Boyde A. Variation in the apparent density of human mandibular bone with age and dental status. J Anat 1998; 192: 233-244.
26. Kingsmill VJ, Boyde A. Mineralisation density of human mandibular bone: Quantitative backscattered electron image analysis. J Anat 1998; 192: 245-256.
27. Ulm CW, Solar P, Blahout R, Matejka M, Watzek G, Gruber H. Location of the mandibular canal within the atrophic mandible. Br J Oral Maxillofac Surg 1993; 31: 370-375.
28. Hwang K, Lee WH, Song YB, Chung IH. Vulnerability of the inferior alveolar nerve during genioplasty: An anatomic study. J Craniofac Surg 2005; 16: 10-14.
29. Kircos LT, Misch CE. Diagnostic imaging and techniques. In: Misch CE (ed). Comtemporary Implant Dentistry. St Louis: Mosby, 1993: 73-87.
30. Jacobs R, Mraiwa N, vanSteenberghe D, Sanderink G, Quirynen M. Appearance of the mandibular incisive canal on panoramic radiographs. Surg Radiol Anat 2004; 26: 329-333.