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The effect of tooth loss on the cancellous bone pattern of the mandible and on the superior bony wall of the mandibular canal: a micro-CT study

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Abstract

Objectives: The aim of this study was to examine the effect of tooth loss on the cancellous bone pattern of the mandible and on the superior bony wall of the mandibular canal.

Methods: Twenty-four dry mandibles without any physical deformation were scanned with high-resolution micro-CT device. The second premolar, first, second, and third molar regions on the mandibular canal, the presence of the bony superior wall of the mandibular canal and the cancellous bone pattern of the mandible were examined on micro-CT images. The images were classified into three groups, Type I (trabecular pattern), Type II (osteoporotic pattern), and Type III (dense/irregular pattern). The presence of the bony superior wall of the mandibular canal was noted as absent or present.

Results: While 133 (91%) of the dentulous sections were showing Type I trabecular cancellous bone pattern; 25 (54%) of the edentulous sections were of Type I. The superior wall was visible in 90 (62%) of the dentulous regions and in 41 (89%) of the edentulous areas. The cancellous bone pattern of the mandible of the majority of dentulous and edentulous areas had a regular trabecular structure. Dense and irregular trabecular structure were encountered only in edentulous areas.

Conclusion: We suggest that there is a very strong relationship between the superior bony wall of the mandibular canal and the cancellous bone pattern of the mandible. We conclude that the trabecular structure of the mandible could change following tooth loss and this have an effect on the change of the structure and the presence of the superior wall of the mandibular canal.

Keywords: mandible; mandibular canal; micro-CT; tooth loss; trabeculae

Introduction

The mandibular canal (MC) is a bony canal beginning from the mandibular foramen and contains the inferior alveolar nerve (IAN) together with the inferior alveolar artery and vein.[1] The other term used especially by clinicians for the MC is the inferior alveolar canal. These two terms describe the same structure.[2]

In recent studies, many small accessory canals have been reported to accompany this canal. It has long been recognized that the branching pattern of IAN shows variations as well and multiple foramina or ducts may originate from the MC.[3–5] Accessory canals can be detected radiologically or during surgical procedures. In cases where the accessory MC is seen, the possibility of the presence of accessory mental foramen increases.[3,6–8] Haas et al.[9] reported two types of accessory MCs as; bifid MC (BMC) and its variant, trifid MC (TMC). In the BMC type, the MC is divided into two, in the TMC type, the accessory MC is divided into two, and there are three canals in total.[3] Apart from these, accessory mental foramen and lingual foramen are of other anatomical variations.[10]

IAN is vulnerable to iatrogenic injuries, so knowing the course of MC and IAN is very important for surgical

deomed.

procedures.[11] The risk of injury to the IAN is relatively high during implant placement, tooth extraction and other surgical procedures. In such a case, permanent damage may occur in structures such as palate, teeth, lips, and tongue innervated by IAN.[12] It is very important to determine the trabecular quality of the jawbone and the neighborhood of the anatomical structures before implant applications and jaw surgeries. For this reason, imaging of the region with cone-beam computed tomography (CBCT) is recommended before these operations.[13]

Based on gross anatomical observations, Iwanaga et al.[13] classified the cancellous part of the mandible as type I (trabecular pattern), type II (osteoporotic) and type III (dense-irregular pattern). Another study conducted by Iwanaga et al.[10] revealed that edentulous sections in both men and women were generally of type I trabecular pattern. The results also suggested that the superior wall of the MC may not be visible where the cancellous bone was osteoporotic and the dentulous areas were mostly of Type I. However, Type I was suggested to be the least common cancellous bone type in edentulous areas.[13] There are strong evidences in the literature that, the IAN loses its branches to the teeth, after the teeth are lost. In addition to this, as the bone remodels, the superior wall of the MC loses its trabecular structure and the superior wall becomes smoother. However, it was also shown by Iwanaga et al.[13] that the type 2 osteoporotic spongy pattern present in 30% of edentulous areas in women, and the superior wall of the MC was not smooth.

As the literature reveals some discrepancies related with the relation of the tooth loss and the cancellous bone pattern of the mandible; the aim of this study was to examine the effect of tooth loss on the trabecular structure of the mandible and its effect on the superior wall of the MC. Thus, we aimed to evaluate which one (tooth loss or loss of trabecular tissue) has more effect on the superior wall of the MC and to provide a prediction for the possibility of injury to the MC to the surgeons working at this region.

Materials and Methods

This study has been performed on 24 dry adult mandibles obtained from Ankara University Faculty of Dentistry and Ankara Yıldırım Beyazıt University Faculty of Medicine. The dry bones were belonging to Anatolian people of unknown sex and age and did not have any physical deformation.

The dry bones were scanned with a micro-CT device (Bruker micro-CT, Kontich, Belgium) with following configuration and parameters: 1 mm aluminum filter, 80 keV, 125 µA, 10 µm resolution, exposure=47ms, rotation=180° and rotation step=0.400°. The three-dimensional reconstruction data was obtained by using NRecon reconstruction software (version 1.6.9.4; Bruker micro-CT). All measurements were carried out with CTAn software (version 1.17.7.2; Bruker micro-CT) and 3D images were created with CTVol software (version 2.3).

After all samples were scanned with micro-CT and their two-dimensional images were obtained in the axial plane with Nrecon software. Care was taken to avoid any artifacts in any sample so that it would not affect the measurements. 3D images were created with Ctvox software using images reconstructed with Nrecon. Scoring for the presence or absence of the superior wall of the MC was performed using these 3D images.

The body of mandibles were divided into four regions according to the tooth fitting on the MC (second premolar, first, second, and third molars). The superior wall of the MC in the region of each tooth was scored by two observers as visible or invisible. And total of 192 tooth regions (4 tooth regions on the right and 4 on the left, multiplied by 24) were scored and grouped according to the appearance of the cancellous bone pattern of the mandible on 3D images in the relevant region. The grouping was as follows; Type I: trabecular pattern; type II: osteoporotic; and type III: dense-irregular patterns as previously defined by Iwanaga et al.[13] (**Figure 1**).

Microsoft Excel, 15.33 version (Microsoft Corporation, Redmond, WA, USA) was used for the statistical analysis. Statistical significance was defined as $p < 0.05$. The relationship between the observed characteristics were documented by using chi-square test.

Results

The MCs of all dry bones were in the form of a single canal, originating from the mandibular foramen and ending in the mental foramen. Accessory mental foramen was not encountered in any of the specimens.

A total of 192 tooth regions were examined in this study. Of these 192 regions; 146 were dentulous and 46 were edentulous. In some jaws, the third molars were impacted or not fully erupted. These regions were included in the dentulous areas in the study. While the appearance of the cancellous bone pattern of the mandible was Type I (trabecular) in 133 (91%) of the dentulous sections, 13 (9%) were Type II (osteoporotic). Type III was not found in the dentulous sections. Of the edentulous sections, 25 (54%) were Type I (trabecular), 5 (11%) were
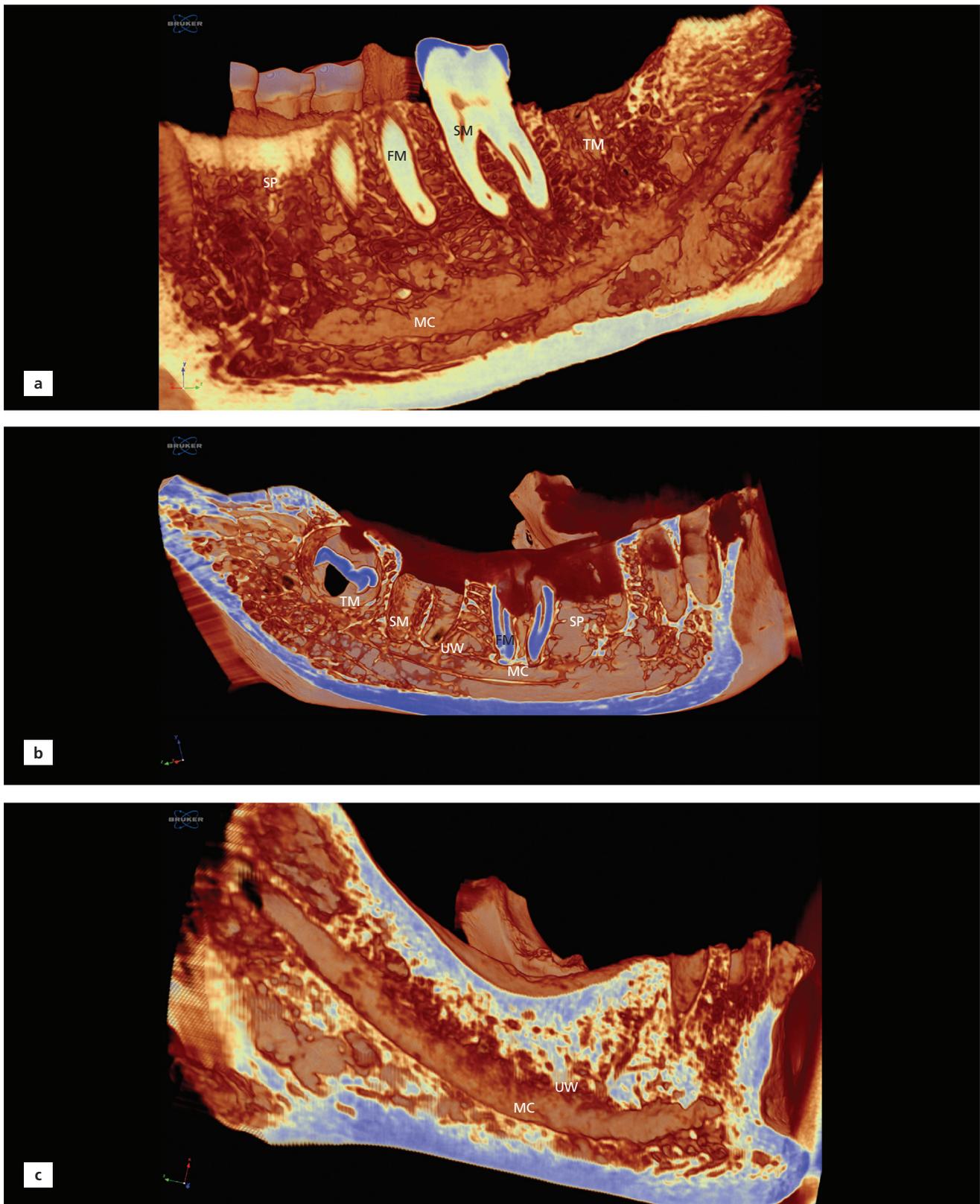
Figure 1. Cancellous bone pattern of the mandibles on micro-CT images of the mandibles. (**a**) type I trabecular pattern; (**b**) type II osteoporotic pattern; (**c**) type III dense-irregular pattern (edentulous). **FM:** first molar; **MC:** mandibular canal; **SM:** second molar; **SP:** second premolar; **TM:** third molar; **UW:** superior wall of the mandibular canal.

Table 1

Cancellous bone pattern of dentulous and edentulous areas and superior wall of mandibular canal.

	Type I	Type II	Type III	Visible superior wall	Non-visible superior wall
Dentulous sections	133 (91%)	13 (9%)	0	90 (62%)	56 (38%)
Edentulous sections	25 (54%)	5 (11%)	16 (34%)	41 (89%)	5 (11%)

Type II (osteoporotic), and 16 (34%) were Type III (dense-irregular). While type I was present in the majority in both dentulous and edentulous regions, it was seen that it was much more dominant in dentulous regions. Interestingly, while Type III was not found in the dentulous regions, approximately one third of the edentulous regions were found to be type III. It was observed that alveolar processes have disappeared in mandibles that have lost all their teeth. In these mandibles the body has become thinner and the trabecular structure of these thin bodies has become denser. This caused Type III to be more common in edentulous areas. The relationship between the dentulous and edentulous parts and the trabecular structure was found to be statistically significant (p=0.000) (**Table 1**).

The superior bony wall of the MC was classified as present or absent. The superior wall of the MC was visible in 131 (68%) of all the regions, and was not visible in 61 (32%). While the superior wall was visible in 113 (72%) of the type I regions, was not visible in 45 (28%). In addition to this, while the superior wall was not visible in 16 (89%) of the type II regions, it was visible only in 2 (11%). The superior wall was visible in all type III regions. The relationship between the trabecular formation and the visibility of the superior wall was found to be significant according to the chi-square test (p=0.000). The superior wall was visible in 90 (62%) of the dentulous regions and in 41 (89%) of the edentulous region, whereas, the superior wall was not visible in 56 (38%) of the dentulous regions and not visible in 5 (11%) of edentulous regions. The relationship between the dentulous and edentulous regions, and the visibility of the superior wall was found to be significant according to the chi-square test (p=0.001) (**Table 2**).

Discussion

Present literature reveals some discrepancies related with the relation of the tooth loss and the cancellous bone pattern of the mandible and the presence or absence of the superior wall of the MC in cases with tooth loss. Bertl et al.[14] determined that 65% of the superior wall and 81% of the lower wall of the MC are covered with bone. Schwarz et al.[15] found that the walls of the MC are mostly of trabecular type. Iwanaga et al.[16] examined 80 tooth regions of 20 dry mandibles with CBCT and classified the superior wall of the MC. The images of 5 samples could not be examined due to artifacts, and the superior wall of the MC could not be visualized in the CBCT images of 5 of the remaining 75 images. They observed that superior wall of MCs with osteoporotic trabeculae was less visible in CBCT, and the detection rate of superior wall of the MCs with smooth trabecular formation was higher than other groups. The difference between the two groups was found to be statistically significant.[10] Accordingly, they reported that, as the trabeculae weakens, the incidence of MC in CBCT decreases. We also visualized the superior wall of the MC in relation with the cancellous bone pattern of the mandibles with micro-CT. We made all our evaluations visually by taking virtual sections from 3D images with Ctvox software. We paid particular attention to the absence of artifacts in the images, re-scanned the samples, and reconstructed the obtained data if needed. Thanks to the high resolution of micro-CT, we were able to see even small canals that emerged from the MC in dry bones with dense trabecular formation. Likewise in the study of Iwanaga et al.[10] we found that the higher the trabecular density, the higher the probability of the superior wall to be seen. As

Table 2

Superior wall of mandibular canal according to cancellous bone pattern.

	Type I	Type II	Type III
Visible superior wall	113 (72%)	2 (11%)	16 (100%)
Non-visible superior wall	45 (28%)	16 (89%)	0

the trabecular formation weakens, the bony boundaries of the MC became unclear.

Iwanaga et al.[16] investigated why the MC was sometimes clearly seen on radiological images and sometimes not. As a result of the study, they stated that mostly dentulous regions are type I and edentulous regions are type IV (smooth pattern).[16] In a serial of studies made on mandibles, Iwanaga et al.[10,13,16] determined that wall formation of the MC in edentulous areas could be seen more clearly with CBCT. The difference between the dentulous and edentulous areas was thought to be due to the remodeling of the area after the tooth is lost.[10,16] While the tooth is present, IAN passes through the trabeculae-like superior wall of the MC to innervate the tooth. When the tooth is extracted, the IAN does not need to cross the superior wall of the MC, as it loses the branches that innervate the tooth, and the superior wall of the MC loses its trabecular pattern and becomes smooth.[10,17,18] In our study, the superior wall was clearly visible in most edentulous areas, while the trabecular structure was dense and irregular. The trabeculae were regular in most of the dentulous areas (Type I) and in addition, the majority had a superior wall formation. We found that the superior wall of the MC can be seen more clearly, while the edentulous areas have a dense and irregular trabecular formation with remodeling. However, the superior wall was clearly visible in dentulous areas as long as the trabecular formation was not weak, and this was considerably higher (62%) in dentulous areas. We found that there was a very strong correlation between the superior wall formation of the MC and the trabecular density.

Conclusion

Implant applications and other surgical operations related to the jaw are of frequent interventions in dentistry and there is always a risk of damage to the MC and thus to IAN. Therefore, it is important to have an idea about the trabecular formation of the jaw and the superior wall of the MC. As a result of our study, we concluded that there is a very strong connection between the trabecular formation of the mandible and the superior bony wall of the MC. The superior wall of the MC becomes more pronounced as the trabecular density increases in the dentulous and edentulous regions. In addition, we observed that the trabeculae was denser in edentulous regions and the superior bony wall of the MC was more prominent.

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