RELATIONSHIP BETWEEN ROOT APICES AND THE MANDIBULAR CANAL: CONE-BEAM COMPUTED TOMOGRAPHY ANALYSIS

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ABSTRACT

INTRODUCTION: The anatomical relations between the roots of the distal teeth and the mandibular canal (MC) are clinically important, as well as the possible complications when they are not taken into account. The three-dimensional analysis of the lower jaw is a key aspect in ensuring safe intervention in its distal sections.

AIM: The aim of this study is to investigate the relative location of the mandibular canal to the tooth apices, and the possible differences between males and females, different age groups, and between left and right half of the mandible.

MATERIAL AND METHODS: Cone-beam computed tomography (CBCT) scans from 100 patients were used to evaluate measurements from 600 teeth and respective MC areas.

RESULTS: Direct contact between the root tips and the MC was found in 3.9% of the examined apices and penetration in the MC – in 0.8%. The average reported distance between the apices and the MC is shortest at the distal roots of the second molars. The values, registered for the female patients, were significantly lower than those for the male patients. No statistically significant difference was noted between the measurements in the left and the right half. Significant difference between the age groups was found only in single areas.

CONCLUSION: Clinicians should be aware of the proximity of the root apices to the MC before attempting surgical and root canal procedures in the posterior mandible. Direct communication between the tips of the roots and the MC is not rare and may result in serious nerve injuries if underestimated.

Keywords: *cone-beam computed tomography, mandibular canal, inferior alveolar nerve, gender differences, root apex*

INTRODUCTION

Due to the presence of the inferior alveolar nerve (IAN) and the mental foramen, the posterior areas of the lower jaw represent zones exposed to high risk of injury during dental manipulations. This includes invasive surgical procedures, such as extraction of mandibular third molars (1) and placement of dental implants (2), as well as routine manipulations like root canal treatments and administration of local anaesthesia (3,4). Temporary or permanent damage to the nerve can occur as a result of this trauma, varying from neuropathic pain to partial or full loss of sensitivity in the respective area (5).

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The mandibular canal represents an anatomic structure, which extends bilaterally inside the ramus and body of the lower jaw. It originates from the mandibular foramen, localized along the medial surface of the ascending ramus. It runs obliquely forward and downward inside the ramus, and then – horizontally forward in the body of the jaw up to the mental foramen (6).

The IAN, situated inside it, is a branch of the mandibular nerve, which itself is the third branch of the trigeminal nerve. The nerve, together with an artery and vein of the same name, along with the lymphatic vessels form the neurovascular bundle inside the canal of the lower jaw. The artery lies parallel to the nerve and according to Kim et al. (7) is situated above it, together with the vein, in 80% of the cases, while in the remaining 20% – in a buccal position relative to the nerve. These conclusions are also confirmed by Pogrel et al. (4), who mention the possible presence of several veins, while there is a sole artery, situated lingually to the nerve and slightly above it. In the region of the mental foramen, the IAN splits into its terminal branches – the mental and incisive nerves.

The anatomical relations between the roots of the distal teeth and the mandibular canal (MC) are clinically important, as well as the possible complications when they are not taken into account. These can occur during complicated extractions, placement of dental implants, sagittal split osteotomy in the area, etc. and involve damaging the canal and the structures situated within it, with subsequent pain, sensory disorders, formation of traumatic neurinomas, intra- and postoperative bleeding, formation of haematomas (8,9). Complications can also occur after endodontic treatment, as a result of over-instrumentation beyond the tooth apex, extrusion of root canal filling material, or irrigation solutions in the MC (10). This can result in pain, loss of sensitivity, and/or necrosis of skin or mucosa (11). Complaints can persist for months and years, and in some cases they may well be irreversible, which significantly reduces the quality of life of the affected patients (12).

The three-dimensional analysis of the lower jaw is a key aspect in ensuring safe intervention in its distal sections and prevention of iatrogenic injuries (13). Most of the known imaging diagnostic methods have limited application, while cone-beam computed tomography (CBCT) is becoming a benchmark for the visualization and assessment of anatomical sites in the oral cavity and the spatial relations between them. Cone-beam computed tomography provides images with high quality and resolution with a relatively low radiation dose (14,15).

The application of CBCT offers opportunities for three-dimensional visualization of structures without superimposition of the images, distortion or enlargement, which are inherent to the conventional two-dimensional diagnostic methods (14,16,17).

AIM

The aim of this study is to investigate the relative location of the MC to the teeth apices, and the possible differences between males and females, between different age groups and between left and right half of the mandible with the use of data, provided by CBCT measurements.

MATERIALS AND METHODS

We have analysed 100 three-dimensional images of the lower jaw, taken at the X-ray Imaging Diagnostics Sector of the University Medical and Dental Center, Faculty of Dental Medicine, Medical University of Varna, Bulgaria. We have evaluated the ratios of the root apices of 600 teeth, situated distally to mental foramens (second premolars, first and second molars).

Cone-beam computed tomography scans were acquired by using Planmeca ProMax 3D (Planmeca, Helsinki, Finland). The exposure time of the device is 9–40 s, and the image reconstruction requires 2–55 s. The CBCT image is saved and read by the Planmeca Romexis software. Patients are registered in the software for processing of the images via an electronic card, which includes the name and age of the patient, as well as data from the 3D image.

The field of view (FOV) may vary between 130 x 90 mm and 130 x 160 mm. Voxels are isotropic, and their dimensions range from 75 to 600 μm.

Inclusion criteria: three-dimensional images, comprising the entire lower jaw of the patients examined, including the ramus and the mandibular foramen; patients with preserved teeth in the premolar and molar groups, bilaterally; patients without contraindications for conducting radiological examinations.

Exclusion criteria: missing 1 or more teeth from the group of the premolars and molars, bilaterally (except for third molars); patients less than 18 years of age; teeth with periapical pathology present; teeth with resorption of the roots or having undergone apical osteotomy; erupting teeth or teeth with incomplete root development; ectopically positioned teeth; molars with accessory roots (radix entomolaris, radix paramolaris); periodontally compromised teeth with extensive bony defects and significant bone loss; patients undergoing orthodontic treatment; presence of anatomic variations in the number of MCs – bifid and trifid canals.

The first 100 images examined, which met the criteria, were included in the present study.

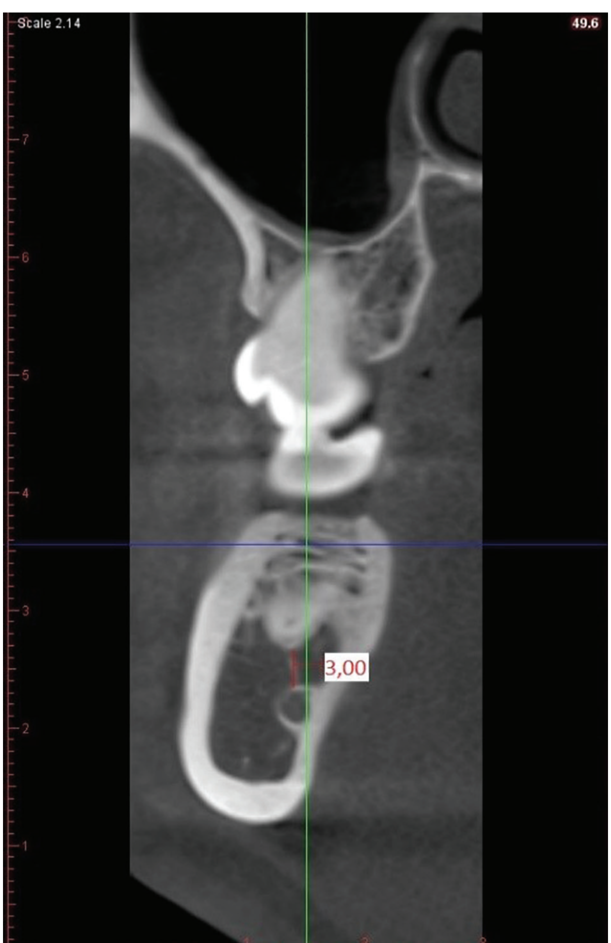

Fig. 1. Measurement of the shortest linear distance between the most prominent part of the root apex and the upper wall of the MC, cross-sectional view.

A total of 57 of them belonged to female patients (n=53) and 43 to male patients (n=43).

We further divided the patients into three age groups: group I – between 20 and 29 years old (n=43); group II – between 30 and 39 years old (n=39); group III – between 40 and 49 years old (n=17).

The CBCT examinations were not performed for the purpose of this study and the indications for their assignment could not be defined.

The analysed images were orientated relative to the axial, sagittal, and frontal planes. Orientation was done by changing the axis of the image until the moment of achieving parallelism between the longitudinal axis of the tooth and the frontal plane (highlighted in green in *Fig. 1*). Where required, images were re-orientated relative to the frontal plane for each of the teeth examined and their respective roots.

In this position, through a detailed examination of the sagittal slices (cross sections), using the option for linear measurement of the image processing software Planmeca Romexis, we measured the ratio between the root apices of the distal teeth of the lower jaw (second premolars, first and second molars) and the upper wall of the MC.

For the teeth from the molar group, we separately assessed the ratio of the mesial and distal roots to the upper wall of the MC. The line we would draw measured the shortest linear distance connecting the most protruding part of the tooth apex and the highest point of the upper wall of MC of the respective sagittal slice (*Fig. 1*).

The unit of measurement we used was millimetres (mm).

Statistical Analysis

Right and left symmetry was evaluated by using Pearson correlation coefficients (r) with paired t-tests. Differences between males and females were compared using independent t-tests. The different age groups were compared using analysis of variance (ANOVA). P values less than 0.05 were considered statistically significant. IBM SPSS Statistics v19 was used for the analyses.

RESULTS

The average reported distance between apices and the MC is shortest at the distal roots of the second molars (2.45±2.19 mm), followed by the mesial roots of the second molars (3.09±2.16 mm), second premolars (3.64±1.98 mm), distal roots of the first molars (4.54±2.17 mm), and the greatest – at the mesial roots of the first molars (4.90±2.09 mm) (*Fig. 2*).

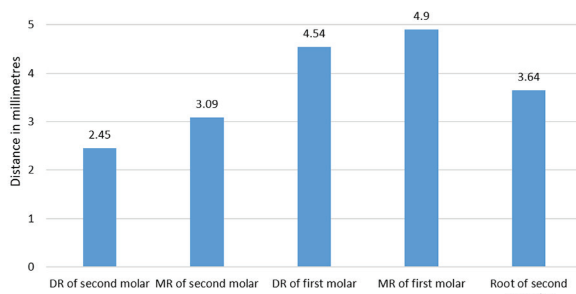

Fig. 2. Average distance between root apices and mandibular canal in mm, measured on CBCT images.

Out of the total 1000 roots examined – 8 protruded into the MC and 39 were in direct contact with the upper wall of the MC.

The remaining 953 roots (95%) were situated at a distance from the MC (*Fig. 3*).

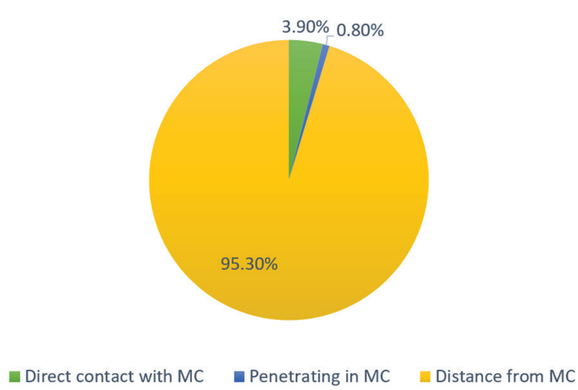

Fig. 3. Distribution of apices, according to their relations to the upper wall of the MC.

Regarding the direct contact of the apices with the MC – such was observed for 39 of the total of 1000 roots examined (3.9%). Out of them, 25 were of distal roots of the second molars (64%), 9 were of mesial roots of the second molars (23%), 4 were of the second premolars (10%), and only 1 was at the mesial root of the first molar (3%). Direct contact with the canal was not observed at any of the distal roots of the first molars (*Fig. 4*).

Penetration into the MC was observed in 0.8% (8 roots) of the total number of examined roots.

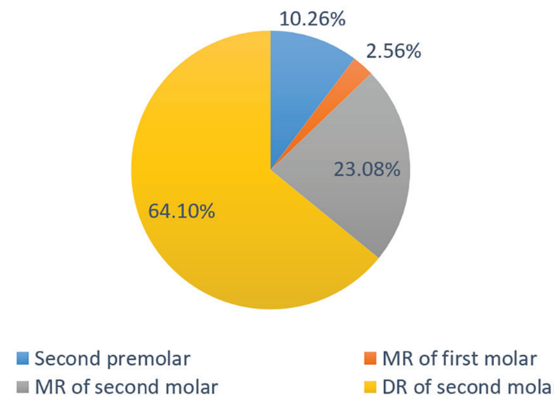

Fig. 4. Apices in direct contact with MC – distribution by teeth groups and respective roots.

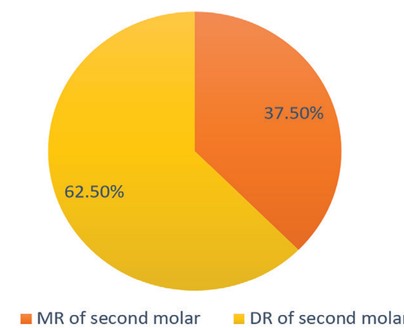

Fig. 5. Apices penetrating into MC – distribution by teeth groups and respective roots.

All of them belonged to second mandibular molars, in 5 of the cases the distal roots were involved and in the remaining 3 – the mesial ones (*Fig. 5*).

Differences Related to the Side of the Mandible

No statistically significant difference was noted between the measurements in the left and the right half, rather, symmetry was noted in both jaw halves (*Table 1*). In the area of the molars, the values in the right jaw half were lower than those in the left one, but with no statistical significance.

Differences Related to Gender

The average values, which we registered for the female patients, are statistically significantly lower than those reported for the male patients. This was observed for the examined roots of all groups in both halves of the jaw (*Table 2, Table 3*).

The greatest differences we found were at the mesial roots of the second molars on the right side, where the average value reported for women was 2.25±1.66 mm, and that for men – 4.02±2.24 mm. The average value of the difference reported was 1.77.

Age-Related Differences

We found that the value of significance level was $p<0.05$ in only single areas, and namely ones corresponding to: distal roots of tooth 47 – between group I and group III; between group II and group III; mesial roots of tooth 47 – group II and group III. For them we reported higher values in the third age group, when compared to the first and second ones. For the remaining areas examined the obtained results showed that $p>0.05$, therefore, the differences found in the average measured values did not considerably differ (*Table 4, Table 5*).

The greatest differences were observed in the area of the distal roots of the second molars on the right side (tooth 47), where the average value reported for patients aged between 40 and 49 years was 3.76 mm, and for patients from the other two age groups – 2.07 mm each.

DISCUSSION

Iatrogenic injuries of the third branch of the trigeminal nerve represent a widely known and complex problem in modern dentistry (18,19). The precise scope of this medical problem is not completely clarified, but according to data from studies, between 34% and 70% of the patients who have suffered iatrogenic injury report persisting, chronic neuropathic pains (20). These are characterised by multiple sensory disorders, which may include paresthesia, hypesthesia, hyperalgesia, allodynia, etc.

Table 1. Average distance between root apices and mandibular canal, differences related to the side of the mandible.

Teeth Groups and Respective Roots	Distance from Apex to MC ± SD in mm – Right Side	Distance from Apex to MC ± SD in mm – Left Side
Distal root of second molar	2.37 ± 2.18	2.53 ± 2.21
Mesial root of second molar	3.01 ± 2.11	3.17 ± 2.21
Distal root of first molar	4.44 ± 2.27	4.63 ± 2.08
Mesial root of first molar	4.89 ± 2.27	4.91 ± 1.91
Root of second premolar	3.74 ± 2.07	3.53 ± 1.88

Table 2. Average distance between the root apices and the mandibular canal, differences related to gender, right side of the lower jaw.

Teeth Groups and Respective Roots	Distance from Apex to MC ± SD in mm – Male, Right side	Distance from Apex to MC ± SD in mm – Female, Right side	P Value
Distal root of second molar	3.13 ± 2.50	1.79 ± 1.71	
Mesial root of second molar	4.02 ± 2.24	2.25 ± 1.66	
Distal root of first molar	5.14 ± 2.47	3.92 ± 1.97	< 0.05
Mesial root of first molar	5.82 ± 2.41	4.19 ± 1.89	
Root of second premolar	4.61 ± 2.19	3.07 ± 1.73	

Table 3. Average distance between the root apices and the mandibular canal, differences related to gender, left side of the lower jaw.

Teeth Groups and Respective Roots	Distance from Apex to MC ± SD in mm – Male, Left Side	Distance from Apex to MC ± SD in mm – Female, Left Side	P Value
Distal root of second molar	3.11 ± 2.52	2.10 ± 1.85	
Mesial root of second molar	3.88 ± 2.44	2.64 ± 1.86	
Distal root of first molar	5.48 ± 1.93	4.00 ± 1.97	< 0.05
Mesial root of first molar	5.67 ± 1.77	4.34 ± 1.82	
Root of second premolar	4.35 ± 1.94	2.92 ± 1.59	

Table 4. Average distance between the root apices and the mandibular canal in mm, age-related differences, right side of the lower jaw.

Teeth Groups and Respective Roots	Distance from Apex to MC ± SD in mm Group I (n = 43), Right Side	Distance from Apex to MC ± SD in mm Group II (n = 39), Right Side	Distance from Apex to MC ± SD in mm Group III (n = 17), Right Side
Distal root of second molar	2.07 ± 2.35	2.07 ± 1.89	3.76 ± 1.95
Mesial root of second molar	2.90 ± 2.40	2.74 ± 1.82	3.84 ± 1.93
Distal root of first molar	4.28 ± 2.60	4.39 ± 1.96	4.94 ± 2.14
Mesial root of first molar	4.83 ± 2.48	4.83 ± 2.04	5.24 ± 2.36
Root of second premolar	3.73 ± 2.37	3.51 ± 1.81	4.38 ± 1.87

Table 5. Average distance between the root apices and the mandibular canal in mm, age-related differences, left side of the lower jaw.

Teeth Groups and Respective Roots	Distance from Apex to MC ± SD in mm Group I (n = 43), Left Side	Distance from Apex to MC ± SD in mm Group II (n = 39), Left Side	Distance from Apex to MC ± SD in mm Group III (n = 17), Left Side
Distal root of second molar	2.15 ± 2.34	2.74 ± 2.19	3.07 ± 1.93
Mesial root of second molar	2.96 ± 2.45	3.40 ± 2.14	3.21 ± 1.82
Distal root of first molar	4.53 ± 2.45	4.70 ± 1.70	4.74 ± 2.00
Mesial root of first molar	4.75 ± 2.07	5.07 ± 1.82	4.96 ± 1.84
Root of second premolar	3.49 ± 2.20	3.62 ± 1.71	3.42 ± 1.49

Patients, suffering from iatrogenic injury of the trigeminal nerve, report significant disturbances when performing daily activities such as speaking, eating, and consuming liquids, which lead to reduced quality of life and inevitably to significant psychological problems (21).

Information about an existing communication or direct contact between the root apices of the distal teeth of the lower jaw and the MC is extremely important for the dentist when planning both surgical manipulations, as well as non-invasive procedures in these areas.

The opportunity for prevention of similar severe complications is a leading factor for the implementation of CBCT as a method of choice and a standard for perioperative diagnostics for manipulations, directly influenced by the position of the MC and the neurovascular bundle situated inside it.

Knowledge of the ratios between the apices of teeth and the MC in advance provides the opportunity for making an accurate diagnosis, predicting the risk of nerve exposure, selection of the treatment method, surgical technique, and surgical access.

This is namely the purpose of the present study – to provide us with the necessary information – working in which sections would result in higher risk of occurrence of IAN-related complications. Where applying CBCT is not possible, taking into account such summarized and systematized information would be beneficial for clinicians in the process of planning interventions in the distal regions of the mandible.

In our study the average measured distance between the apices and the MC is shortest in the area of the distal roots of the second molars (2.45±2.19 mm).

Littner et al. (22) also mention that the shortest distance is measured in the region of the distal roots of the second molars, but their study found no direct contact with any of the teeth examined. This is probably due to imperfections of the methodology they used (two periapical radiography images).

The shorter distance between the roots of the second molars and the upper border of the MC is also confirmed by Sato et al. (23), who analysed 75 dried mandibles, but for the purpose of the study they were examined with panoramic radiography imaging. They observed contact of the molars with the MC in only one of the cases. Again, due to the imperfections of two-dimensional imaging diagnostic technique, the information is of limited value.

The study of Denio et al. (24), done on mandibles from cadaver donors, determined second premolars and second molars as the teeth, which were situated closest to the MC, with average values 4.7 mm and 3.7 mm, respectively. In turn, the mesial roots of the first molars were the most distantly situated from the MC, with an average value of 6.9 mm. These values are considerably higher than the ones registered in our study. This may be due to differences in the accuracy of the direct and the radiographic methods of study, different number of units included in the study, differences between the individual populations, etc.

Based on the data provided by Simonton et al. (25), 3% of first molars are in direct contact with the MC with one or both of their roots. In our study, we observed only 1 mesial root of the first molar, which was situated in direct contact with the canal, and for none of the distal roots of the first molars did we register any similar data.

Regarding the measured distances in the left and right mandibular half, we observed no statistically significant differences. Therefore, we can assert that there is symmetry in terms of the position of the apices relative to the MC in both jaw halves.

This is in agreement with the results obtained by other authors (26,27,28), as well.

However, we noted a tendency for lower average values registered on the right jaw half than on the left. This was observed for all examined areas, except for the second premolars.

When juxtaposing the measured distances from the apices to the MC between the two sexes, we found them to be statistically significantly shorter in women, relative to the ones in men, and this was valid for all roots we examined ($p<0.05$).

We can explain this fact with the generally greater sizes of the bones in men and the lesser amount of bone mass in women. Furthermore, studies show that women start losing bone at an earlier age and at a faster rate (29).

Kawashima et al. (28) found similar results in their CBCT study of 155 patients. The measured distance between the distal root apices of the second molars and the MC was significantly shorter in women (average values of 2.51 mm) than in men (average values of 3.21 mm). Identical data can also be found in the studies of other authors (5,25,26,27).Clinically, this finding indicates higher risk of iatrogenic injury to the nerve for female patients.

When comparing data obtained from the three age groups, we found that significant difference was observed only for the distal and mesial roots of tooth 47, where higher values were reported in the third age group, relative to the first and second ones.

Despite the fact that in the remaining areas we registered no statistically significant differences, we noted a tendency for the average values of the patients from the third age group to be higher than the ones of the other two. This was observed in almost all examined locations, except for the mesial roots of the second and first molars on the left, and the second premolars of the same side. It has been noted that in the youngest patient group no highest values were registered for any of the analysed areas.

Kovisto et al. (5) also remarked that for the patients under the age of 18 they examined, the distances between the posterior teeth and the MC were shorter than the ones of patients older than 18.

For patients falling within the age group <21 years, the study of Aksoy et al. (26) also demonstrated lower values than those in the age groups >21 years.

Previous studies confirm the increase of the vertical dimensions of the jaw along with the eruption of the permanent teeth (22).

Other authors attribute this to the apposition of bone during tooth eruption, as well as to the bone remodelling and apical migration of the canal with age (28).

Bürklein et al. (27) observed the same phenomenon and explained it with the fact that the skeletal growth in both sexes can continue through the late adolescence, and the vertical growth of the mandible reaches its maximum between 36 and 45 years of age.

Simonton et al. (25) found that the distance between the MC and the roots of the first molar increases with age and reaches its peak (for women in the age group 40–49 years; for men 50–59 years), after which it starts to decrease again. They explain this with the ongoing growth of the craniofacial complex and its subsequent decrease, as a result of hormonal changes and overall reduction of the bone mass in older patients.

In our study, the greatest differences were observed in the area of the distal roots of the second molars on the right side, where the average value reported for patients in the group between 40 and 49 years was 3.76 mm, and for patients of the other two groups – 2.07 mm each.

Due to the limited number of CBCT images of patients above the age of 50 involved in our study, we believe that additional examinations are needed in this field in order to provide more explicit data.

CONCLUSION

Clinicians should be aware of the proximity of the root apices to the MC before attempting surgical and root canal procedures in the posterior mandible. Direct communication between the tips of the roots and the MC is not rare and may result in serious nerve injuries if underestimated.

Measurements from CBCT scans in our study show the MC to be closest to the apex of the distal root of the mandibular second molar. Female patients have significantly shorter distances and more often show direct communication between root apices and MC. Therefore, they have potentially higher risk of suffering nerve damage.

The preoperative three-dimensional analysis provides exact, distortion- and superimposition-free images of the relevant anatomic structures. If a CBCT scan cannot be performed, consideration of a knowledge base may be helpful in avoiding iatrogenic damage to IAN.

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