Computed Tomography for the Assessment of the Potential Risk After Implant Placement in Fresh Extraction Sites in the Posterior Mandible

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Immediate implant placement (IIP) is considered a reliable procedure, with survival rates of 94.9%–98.4%. Nevertheless, in the posterior mandible, it poses a high risk of damage to anatomic structures. The aim of this study was to determine the risk of anatomic structures injury associated with IIP in the posterior mandible based on apical primary stability, respecting a safe distance from the inferior alveolar nerve and lingual plate, and to evaluate the influence of different factors on those risks. Pre-extraction cone beam computed tomography scans of 100 patients were retrospectively analyzed. Measurements were taken from tooth apices to lingual plate and to mandibular canal. Values of <4 mm of the former and <6 mm of the latter were categorized as considerable risk. Values of <2 mm at both measurements were considered high risk. Two-sided $P < .05$ was considered statistically significant. Mean root-to-alveolar canal distance was 7.6 $\pm$ 2.7 mm in the first molar, 6.5 $\pm$ 3mm in the second premolar, and 5.4 $\pm$ 3 mm in the second molar ($P < .005$). The mean distance to the outer lingual cortex was 3.9 $\pm$ 2.1 mm in the first molar and 3.2 $\pm$ 0.1 mm in the second molar. Thus, second molars were at higher risk of inferior alveolar nerve injury and lingual plate perforation during IIP. Background factors associated with higher IIP risk were female sex and age $<$ 40 years. In the mandible, the anatomic risk posed by IIP is greatest for second molars and lowest for first molars. Several background factors affect the distances between root apices and the mandibular canal.

Key Words: immediate implant placement, posterior mandible, cone beam computed tomography, mandibular canal, lingual plate perforation, inferior alveolar nerve injury

INTRODUCTION

Immediate implant placement (IIP) refers to the insertion of dental implants in a fresh extraction site on the same day of the extraction.[1] Updated systematic reviews and meta-analysis reported survival rates of 94.9%–98.4%[2–6] and success rates of 97.8%–100%.[7,8]

The main advantages of IIP in the nonesthetics zone are a reduced number of surgical interventions and earlier initiation of prosthodontic therapy.[8] Moreover, placement of a single implant in the posterior area leads to superior treatment outcomes (survival and success rates) than fixed partial dentures.[6] The main disadvantages of IIP are potential damage to the integrity of adjacent anatomic structures during the procedure[2] and difficulty in achieving primary closure.[9] Analyses of the optimal sites for IIP revealed that, although the posterior mandible is associated with a high implant survival rate,[10] it is at high risk of anatomic disruption (mandibular canal and submandibular fossa).[11–13] The reported probability of injuring the inferior alveolar nerve (IAN) during implant insertion, based on a literature review up to 2011, varies between 0% and 40%.[14,15] Furthermore, a recent literature review identified 25 case reports of severe hemorrhage in the floor of the mouth after IIP; 84% were caused by perforation of the lingual cortex. Emergency intubation or tracheostomy was needed in 68%.[16]

The recommended amount of native bone apical to the socket that is necessary to perform IIP is 6 mm: a minimum of 4 mm for apical anchorage, a prerequisite for primary stability,[17–20] and a 2-mm safety zone.[21] To analyze the suitability of IIP at different sites, the anatomic relationships within the mandible were measured directly in cadaver studies. Denio et al[22] reported a mean distance of 3.7 mm from the IAN to the apex of the second molar, 6.9 mm from the IAN to the first molar, and 4.7 mm from the IAN to the premolars. Littner et al[23] found that the distance from the mandibular canal to the apex was 3.5–5.4 mm below the root apices of the first and second molars. Accordingly, Froum et al[24] concluded that pre-extraction computed tomography (CT) might serve as a useful aid in the risk assessment of IAN injury and lingual plate perforation after IIP in the posterior mandible.

The aim of the present study, performed in an Israeli population, was to determine the potential risk of IAN injury

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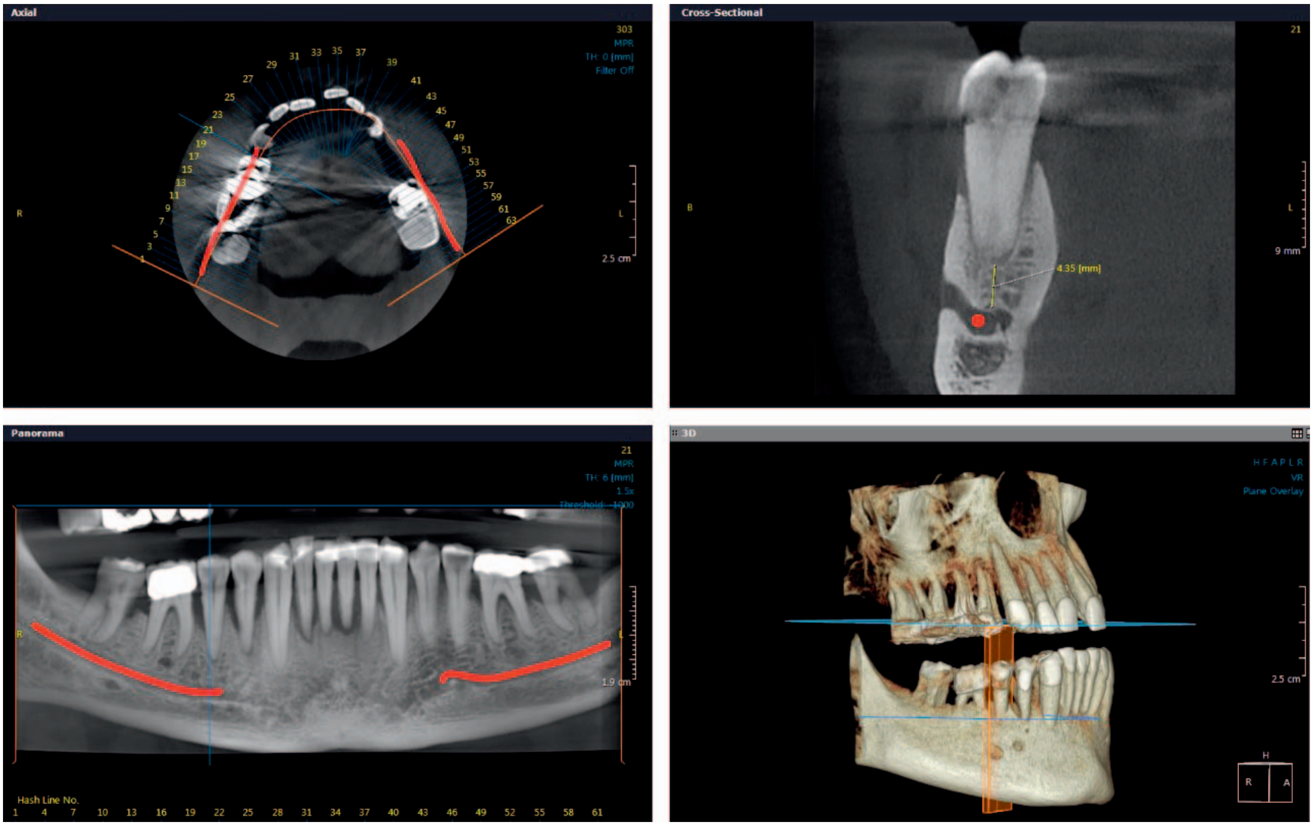

Figure 1. Measurement of root-to-alveolar canal in second mandibular premolar. Three dimensions, axial, panoramic, and cross-sectional cone beam computed tomography reconstructions.

and lingual plate perforation associated with IIP in the posterior mandible. The main outcome measure was the distance from the tooth apices to the mandibular canal and lingual plate. In addition, potential background factors were assessed to identify high-risk groups.

Materials and Methods

The research was conducted in the department of oral and maxillofacial surgery of a tertiary medical center in Israel for a 6-month period (February 2018–July 2018). One hundred random pre-extraction cone beam computed tomography (CBCT) scans of the mandibular arch of patients attending the department during the mentioned time period were selected according to the inclusion criteria. The chosen randomization method was block, using 2 scans at each group, for a total of 200 CBCT scans. The inclusion criteria were as follows: (1) scans including 2 of these teeth were eligible for the study (second mandibular premolar, first molar, second molar)[24]; (2) patients presenting at the department of oral and maxillofacial surgery; (3) patients requiring posterior mandible dental implants placement; (4) patients > 18 years old; (5) patients who did not go through chemotherapy or radiotherapy to the jaws; and (6) patient approval.

In each case, 2 evaluators (oral and maxillofacial residents), who were blinded to the aim of the study, measured the distance from the tooth apices to the mandibular canal and to the outer lingual cortex twice. The measurements were made on the cross-sectional slice representing the middle of the tooth regarding premolar and the middle of the root regarding molars and were calibrated using a software ruler and a third evaluator (oral and maxillofacial surgeon) who reanalyzed 15 scans randomly.[24] The study protocol was approved by the Helsinki Committee of Rabin Medical Center (approval number 0396-16-RMC).

Two categories of potential risk were defined: considerable and high risk. The considerable-risk threshold of the bone apical to the socket was defined as 6 mm, 4 mm for the apical anchorage, and a 2-mm safety zone. The high-risk threshold was defined as a 2-mm safety zone only. The distances of the mesial and distal molar roots, as defined by the height from the inferior alveolar canal, were measured separately using OnDemand3D, version 1 software (Cybermed Inc, Tustin, Calif). To assess the risk of IAN injury, a vertical line was traced from the most inferior point of the apices of the mandibular teeth to the superior border of the inferior alveolar canal, depending on the tooth long axis. This was designated the root-to-alveolar canal (RAC) distance. When the RAC distance measured <6 mm, IIP was categorized as considerable risk, and when the distance measured <2 mm, it was categorized as high risk (Figure 1). To assess the risk of lingual plate perforation, a horizontal line was drawn between the tooth apices. The distance from the shortest point (the most lingual point) on this line to the outer cortex was measured. The data were recorded on a tooth-by-tooth basis. This was designated

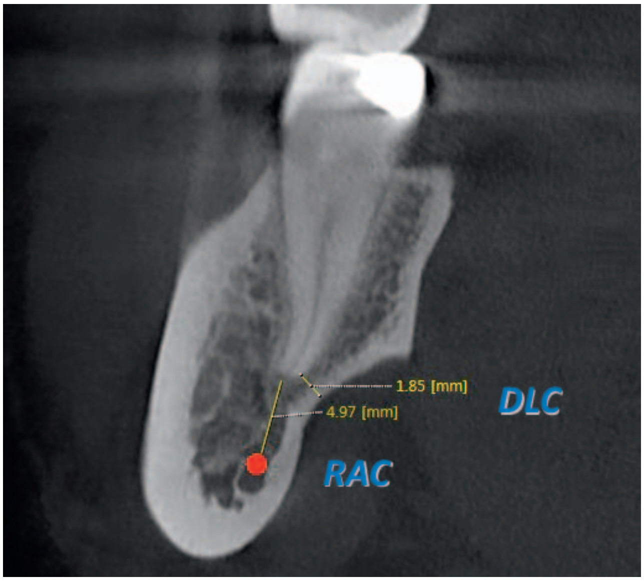

Figure 2. Measurement of distance to the outer lingual cortex and root-to-alveolar canal in first mandibular molar. Cross-sectional cone beam computed tomography reconstruction.

the distance to the outer lingual cortex (DLC). When the DLC was <4 mm, IIP was categorized as a considerable risk of lingual plate perforation. When DLC was <2 mm, IIP was categorized as high risk (Figure 2).

Data regarding age, sex, medical history, ethnicity, smoking habits, and unique information of the patients were collected from the medical files to evaluate the influence of those factors on the outcome parameters. Statistical analysis was generated using SAS software, version 9.4. Continuous variables are presented as mean and standard deviation and categorical variables as number and percent. Student *t* test was used to compare continuous variables between study groups; for categorical variables, we used the Fisher exact test (for 2 values) or χ^2 test (for >2 values). Two-sided $P < .05$ was considered statistically significant.

Results

The study included 100 patients, 56 females and 44 males, with an average age of 46.7 ± 13.9 years). Thirty-two patients were younger than 40 years old and 68 patients were older than 40 years of age. A total of 332 mandibular teeth were assessed on the 100 CBCT scans: 141 (43%) second premolars, 86 (26%) first molars (172 roots), and 105 (31%) second molars (209 roots). Inter-rater reliability between the 2 evaluators (κ coefficient) was 0.79. The calculation of the mean RAC distance was based on 332 teeth (522 roots), and the calculation of mean DLC was based on 165 teeth. The distribution of the teeth/roots by the patient background variables is shown in Table 1.

The mean RAC distance for each root type ranged from 5.2 mm for the mesial root of the right second molar to 7.7 mm for the roots of the right first molar (Table 2). The mean RAC distance values for each tooth type were 6.5 ± 3 mm for second premolars, 7.6 ± 2.7 mm for first molars, and 5.4 ± 3 mm for second molars (Table 2). The differences were statistically significant ($P < .005$; Table 3).

Considerable risk for IAN injury was found to be 48% in second premolars, 32% in first molars, and 64% in second molars. High risk was found to be 7.1%, 2.9% and 15.8%, respectively (Table 2).

The mean DLC distance for each root type ranged from **3** mm for the roots of the second molars to 4 mm for the roots of the right first molar (Table 2). The mean DLC distance values for each tooth type were 3.9 ± 2.1 mm for first molars and 3.2 ± 0.1 mm for second molars (Table 2). The differences were not statistically significant ($P < .005$; Table 4).

Considerable risk for lingual plate perforation was found to

Table 1

Demographic data of 100 patients undergoing immediate implant placement

		Sex		Age (yr)	
Tooth/Root Type	All	Female	Male	≤40	40+
Total teeth	100	56	44	32	68
Total roots	522	283	239	170	352
Number of roots by tooth type					
Second premolars	141	72	69	42	99
First molar roots	172	94	78	66	106
Second molar roots	209	117	92	62	147
Total lingual plate	165	92	73	55	110
Number of lingual plates by tooth type					
First molar	61	34	27	25	36
Second molar	104	58	46	30	74

Table 2

Risk for immediate implant placement (IIP) by root/tooth type*

Tooth/Root Type	Number	Dimensions (mm), SD	Risk for IIP	High Risk for IIP
Risk of IAN injury (RAC < 6 mm), high risk of IAN injury (RAC < 2 mm)				
Second premolar	141	6.5 (3)	48%	7.1%
35 (Left)	69	6 (2.9)	55%	13%
45 (Right)	72	7 (3)	42%	1.4%
First molar	172	7.6 (2.7)	32%	2.9%
36D	43	7.5 (2.8)	37%	0%
36M	43	7.4 (2.6)	35%	2.3%
46M	43	7.7 (2.9)	26%	4.7%
46D	43	7.7 (2.6)	30%	4.7%
Second molar	209	5.4 (3)	64%	15.8%
37D	53	5.6 (3)	62%	15.1%
37M	53	5.6 (3)	60%	11.3%
47M	52	5.2 (2.9)	69%	17.7%
47D	51	5.3 (2.9)	63%	19.2%
Risk of lingual plate perforation (DLC < 4 mm), high risk of lingual plate perforation (DLC < 2 mm)				
First molar	61	3.9 (2.1)	70%	18%
46L	32	4 (2.3)	72%	20.7%
36L	29	3.8 (2)	69%	15.6%
Second molar	104	3.2 (0.1)	76%	44%
47L	52	3 (2.1)	83%	46.2%
37L	52	3 (1.9)	69%	42.3%

*IAN indicates inferior alveolar nerve; RAC, root-to-alveolar canal; DLC, distance to the outer lingual cortex.

Table 3

Mean root-to-alveolar canal (RAC) by clinical modifiers

Parameter	Total	Sex		P Value, t Test	Age (yr)		P Value, t Test
		Female	Male		<40	40+	
RAC distance (mm), all evaluated teeth/roots							
N	522	283	239		170	352	
Mean (SD)	6.4 (3)	5.9 (3)	7.1 (2.9)	<.001	5.7 (2.5)	6.8 (3.2)	<.001
RAC distance (mm), by tooth type							
Seconde premolar							
N	141	72	69		42	99	
Mean (SD)	6.5 (3)	6.1 (3.5)	7 (2.3)	.051	5.7 (2.4)	6.9 (3.2)	.013
First molar							
N	172	94	78		66	106	
Mean (SD)	7.6 (2.7)	7.2 (2.7)	8 (2.7)	.048	6.7 (2)	8.1 (2.9)	<.001
Second molar							
N	209	117	92		62	147	
Mean (SD)	5.4 (3)	4.7 (2.5)	6.4 (3.2)	<.001	4.6 (2.5)	5.8 (3)	.004

be 70% in first molars and 76% in second molars. High risk was found to be 18% and 44%, respectively (Table 2).

Modifiers

Sex

Female patients had a significantly lower mean RAC distance than male patients overall (5.9 vs 7.1 mm, $P < .001$; Table 3) and specifically for second premolars (6.1 vs 7 mm, $P = .05$), first molars (7.2 vs 8 mm, $P = .048$), and second molars (4.7 vs 6.4 mm, $P < .001$; Table 3). They also had a significantly lower DLC overall (3 vs 3.7 mm, $P = .042$) and specifically for second molars (2.6 vs 3.4 mm, $P = .044$; Table 4).

Comparison of female and male patients for potential risk of IAN injury during IIP yielded higher values in females: considerable risk was overall (58% vs 38%; $P < .001$, χ^2 test and Fisher exact test; Table 4) and specifically for second premolars (61% vs 35%; $P = .002$, χ^2 test; $P = .001$, Fisher exact test) and second molars (73% vs 52%; $P = .002$, χ^2 test; $P = .001$, Fisher exact test; Table 5). Similarly, higher values were found in females regarding high risk: overall (11.7% vs 6.3%; $P = .034$ χ^2 test; $P = .013$, Fisher exact test; Table 6) and specifically for second premolars (12.5% vs 1.5%; $P = .011$, χ^2 test; $P = .001$, Fisher exact test; Table 6).

Age

RAC distance was significantly lower in patients aged less than 40 years than in older patients, overall (5.7 vs 6.8 mm, $P < .001$; Table 3) and specifically for second premolars (5.7 vs 6.9 mm, $P = .013$), first molars (6.7 vs 8.1 mm, $P < .001$), and second molars (4.6 vs 5.8 mm, $P = .004$; Table 3). Patients aged less than 40 years also had a lower DLC (3 vs 3.4 mm, $P = .293$). The overall and tooth results were not statistically significant (Table 4).

IIP posed a statistically significant higher considerable risk in the younger group, overall (59% vs 44%; $P = 0.002$, χ^2 test; $P = .002$, Fisher exact test; Table 5) and specifically for second premolars (62% vs 42%; $P = .034$, χ^2 test; $P = .016$, Fisher exact test) and first molars (44% vs 25%; $P = .008$, χ^2 test; $P = .004$, Fisher exact test; Table 5). Similarly, higher values were found in patients aged less than 40 years regarding high risk overall (8.3% vs 9.7%; $P = .598$, χ^2 test; $P = .114$, Fisher exact test). The overall and tooth-specific results were not statistically significant (Table 6).

Discussion

In cases of extraction of mandibular posterior teeth, where esthetics is not a primary concern, IIP has proven to be a

Table 4

Mean distance to the outer lingual cortex (DLC) by clinical modifiers

Parameter	Total	Sex		P Value, t Test	Age (yr)		P Value, t Test
		Female	Male		<40	40+	
DLC (mm), all evaluated teeth							
N	165	92	73		55	110	
Mean (SD)	3.3 (2.1)	3 (2.1)	3.7 (2.1)	.042	3 (2.1)	3.4 (2.1)	.239
DLC (mm), by tooth type							
First molar							
N	61	34	27		25	36	
Mean (SD)	3.9 (2.1)	3.7 (2)	4.1 (2.2)	.422	3.7 (2.2)	4 (2.1)	.66
Second molar							
N	104	58	46		30	58	
Mean (SD)	3.2 (0.1)	2.6 (2)	3.4 (2)	.044	2.43 (1.9)	2.6 (2)	.09

Table 5

Risk of inferior alveolar nerve during immediate implant placement*

Total	Sex: Female	Sex: Male	*P* Value, χ^2, Fisher	Age (yr): <40	Age (yr): 40+	*P* Value, χ^2, Fisher
Rate of RAC < 6, all evaluated roots, n (%)						
256/522 (49%)	164/283 (58%)	92/239 (38%)	<.001 <.001	100/170 (59%)	156/132 (44%)	.002 .002
Rate of RAC < 6, by tooth type, n (%)						
Second premolar						
68/141 (48%)	44/72 (61%)	24/69 (35%)	.002 .001	26/42 (62%)	42/99 (42%)	.034 .016
First molar						
55/172 (32%)	35/94 (37%)	20/78 (26%)	.105 .036	29/66 (44%)	26/106 (25%)	.008 .004
Second molar						
133/209 (64%)	85/117 (73%)	48/92 (52%)	.002 .001	45/62 (73%)	88/147 (60%)	.081 .028

*RAC indicates root-to-alveolar canal.

predictable and valuable treatment modality,[25] with high survival rates of 95%–98%.[3,6,26,27] However, in the inferior alveolar canal and the concavity of the submandibular fossa, bone availability may be limited, potentially leading to complications of IIP. Injury to the IAN can cause partial or permanent paraesthesia,[28–31] and perforation of the lingual cortical plate can cause vascular trauma and the consequent development of a sublingual or submandibular hematoma, excessive bleeding, or infection. Lingual nerve damage is also a major concern.[32] For instance, in the study of Chan et al,[11] the predicted incidence of lingual plate perforation during implant placement was 1.1%–1.2%.

When seeking to achieve primary stability in native bone apical to the extraction site, CT scans taken before tooth extraction may be an important aid for planning treatment with IIP.[33,34] This study was intended to provide the dental practitioner with additional tools for successful IIP in the posterior mandible. To assess the risk of IIP with standard diameter implants, we calculated the mean distances from the tooth apices to the mandibular canal and outer cortex of the lingual plate on CBCT scans of patients before extraction. The results showed that in general, in all teeth examined, there was no difference in IIP risk between the distal and mesial roots (Table 2). The highest mean RAC distance was found for the first molar (7.6 ± 2.7 mm) and the lowest was for the second molar (5.4 ± 3 mm; Tables 2 and 3), with the second premolar falling in between (6.5 ± 3 mm). The mean distance differences presented in this study and in the study of Denio et al[22] varies between 1.8 mm from the IAN to the apex of the premolars to 0.7 mm from the IAN to the first molar. The latter study was based on 22 mature dried human mandibles, which can explain the differences in the absolute values of the measurements between the 2 studies. Nevertheless, Chrcanovic et al,[12] Denio et al,[22] and this study reported a similar ranking of RAC distance by tooth type. The mean RAC distances for the second premolar and the first molar presented in this study and in the study of Denio et al[22] suggests that IIP is safe in these sites. However, the high standard deviations (approximately 3 mm) point to a need for case-by-case evaluation. In the study of Froum et al,[24] standard deviations of the mean were similar,

Table 6

High risk of inferior alveolar nerve during immediate implant placement*

Total	Sex: Female	Sex: Male	*P* Value, χ^2, Fisher	Age (yr): <40	Age (yr): 40+	*P* Value, χ^2, Fisher
Rate of RAC < 2, all evaluated roots, n (%)						
48/522 (9.2%)	33/283 (11.7%)	15/239 (6.3%)	.034 .013	14/170 (8.3%)	34/352 (9.7%)	.598 .114
Rate of RAC < 2, by tooth type, n (%)						
Second premolar						
10/141 (7.1%)	9/72 (12.5%)	1/69 (1.5%)	.011 .001	2/42 (4.8%)	8/99 (8.1%)	.483 .239
First molar						
5/172 (2.9%)	2/94 (2.1%)	3/78 (3.9%)	.505 .281	1/66 (1.5%)	4/106 (3.8%)	.391 .277
Second molar						
33/209 (15.8%)	22/117 (18.8%)	11/92 (12%)	.178 .063	11/62 (17.7%)	22/147 (15%)	.615 .141

*RAC indicates root-to-alveolar canal.

emphasizing the wide range of RAC distance values in the human population.

Regarding IIP of standard diameter implants, 4 mm of native bone is required for primary stability. Our results suggest that the potential risks posed by IIP was highest in the second mandibular molar in terms of damage to the IAN (considerable risk, 64%; high risk, 15.8%) and perforation of the lingual cortex (considerable risk, 76%; high risk, 44%), particularly the right second molar (69% and 17.7% and 83% and 46.2%, respectively). In the first mandibular molar, there was a low risk of IAN damage (considerable risk, 32%; high risk, 2.9%). However, the risk of perforation of the lingual cortex, albeit lower than for the second mandibular molar, reached 70% in considerable-risk and 18% in high-risk groups (Table 2). This finding is of high clinical importance because severe bleeding from an arterial injury can be life threatening. Accordingly, Lin et al[35] found that the mandibular second molar was at a 3.8-fold higher risk of IAN injury than the mandibular second premolar. Froum et al[24] reported a 73% risk of IAN injury for second molars compared with 65% for second premolars and 53% for first molars. However, the corresponding rates in the area apical to the posterior mandible teeth were considerably lower than ours: 31% for second molars and 7% and 9% for second premolars and first molars, respectively.[24] These discrepancies may be attributed to the different methodologies used and the different population that were tested. Froum et al[24] assessed the risk of lingual plate perforation by virtually placing an implant of 4 mm in diameter and measuring the horizontal distance to the lingual plate. By contrast, we measured the vertical distance from the root apices to the outer cortex of the lingual plate directly on the CBCT scan.

For all tooth types, the mean RAC distance values were lower, and the corresponding IIP risk rates were higher, in female than in male patients (67% vs 51%) and in younger (age $<$ 40 years) than in older patients (67% vs 51%). Kawashima et al[36] concluded that, in women, the distance from the root apices to the mandibular canal was significantly shorter than in men. Analysis by age revealed that among the men, the distance from the second molar root apex to the mandibular canal was significantly shorter in the $<$21-year age group than in the $>$40-year group ($P < .01$); among the women, the distance was significantly shorter in the $<$21-year group than in both the 18- to 40-year group and the $>$40-year group ($P <$ .05). Kovisto et al[37] found that in patients older than 49 years, the distance of both second molar roots to the mandibular canal was shorter in women than men. In addition, patients younger than 18 years were characterized by a shorter distance of the apical roots of the premolar and first molar to the mandibular canal than older patients. Given the findings of both these studies[36,37] together with the present study, we speculate that the distance between the root apices and the mandibular canal increases through bone remodeling as patients age. Herranz-Aparicio et al[38] also assessed the influence of age on bone dimensions and found a negative correlation between age and buccolingual width 2 mm apical to the alveolar crest. Other causes that may explain these results are occlusal wear and compensatory eruption over the years.

The periosteal functional hypothesis of Moss[39] may explain why males have a higher mean RAC distance in the mandible. Moss assumed that hypertrophy of the periosteal matrices leads to corresponding osseous enlargements and that periosteal skeletal units respond directly and actively to the functional status of their related matrices. In bone tissues, such responses alter the size and shape of the skeletal units by means of bone remodeling. As males have larger and stronger mastication muscles than females, we can assume that the increased activity and enlargement of the mastication muscles in males led to the corresponding osseous enlargements and higher mean RAC distance.

In this study, we refer to standard diameter implant placement; therefore, we used 6-mm RAC and 4-mm DLC as the considerable-risk threshold and 2-mm RAC and DLC for high risk or the safety zone. Wide and short implant placement is a predictable treatment option and commonly used because of high 5-year survival rates ($>$92%).[40] To overcome the challenging safety roles we encounter in our study, one can suggest the use of wider implants to ensure primary stability in the root socket without apically drilling. IIP of wide and ultra-wide implants (6 mm) in the molar region is not well documented. Ketabi et al[3] concluded that ultra-wide implants were found to have a significantly higher failure rate than implants of 4–6 mm diameter. However, Hattingh et al[41] emphasized that ultra-wide-diameter implants have a predictable outcome. Because there is no consensus in this issue, wide implant IIP was not suggested as the first choice of treatment. To evaluate the proper width and success rate of this solution, further research is needed.

The strengths of this study were the evaluation of a large amount of data and the detailed definition of the measurement points. We also performed all measurements twice to get reliable and repeatable outcomes. In this study, virtual dental implants were not positioned on the CBCT software, which precluded the validation of our results against the correct position of future dental implants. This was probably the major limitation of our study. Future researchers should focus on this factor and the preoperative treatment plan as a whole. The findings will make it possible to evaluate and validate the accuracy and clinical contribution of the measurements presented in this study.

Conclusions

The anatomic risk in the mandible posed by IIP is greatest for second molars and lowest for first molars. Background factors associated with a relatively shorter distance between root apices and the mandibular canal include female sex and age less than 40 years. The performance of CBCT before IIP can help clinicians avoid the potential complications of this procedure. The higher risk should be kept in mind when planning IIP in these patient groups.

Abbreviations

CBCT: cone beam computed tomography
CT: computed tomography
DLC: distance to the outer lingual cortex

IAN: inferior alveolar nerve
IIP: immediate implant placement
RAC: root-to-alveolar canal

Note

The authors declare no conflicts of interest.

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