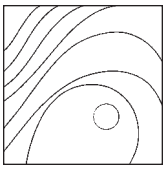
A New Concept of Safety Distance to Place Implants in the Area of the Inferior Alveolar Canal to Avoid Neurosensory Disturbance



Stuart J. Froum, DDS[1]/Marco Bergamini, DDS[2]
Natacha Reis, DDS[2]
Wendy Wang, BDS, MSc, MClinDent (Pros)[2]
Martin Leung, DDS[2]/Zev Kaufman, DDS[2]
Sang-Choon Cho, DDS[2]

Inferior alveolar nerve (IAN) damage following implant placement is a severe complication that can compromise a patient's quality of life. Previous studies have suggested that a safety zone of 2 mm, if maintained, might avoid this problem. This retrospective study evaluates implants placed in closer proximity to the IAN without resulting in any postoperative neurologic complications and suggests a new concept of safety distance. A total of 60 consecutive patients receiving 101 mandibular implants < 2 mm from the IAN were included in this study. All enrolled patients had a CBCT scan done for radiologic assessment before implant placement and following final restoration. Measurements were obtained through cross-sectional views using Simplant software. In patients without neurologic disturbances, a mean distance of +0.75 mm was seen from the closest portion of the implant to the nerve bundle. In cases where a direct transection and/or compression of the nerve was not observed, the patients did not experience neurosensory disturbances. Int J Periodontics Restorative Dent 2021;41:e139–e146. doi: 10.11607/prd.5626

[1]Advanced Program for International Dentists in Implant Dentistry, Ashman Department of Periodontology and Implant Dentistry, New York University College of Dentistry, New York, New York, USA; Private Practice, New York, New York, USA.
[2]Advanced Program for International Dentists in Implant Dentistry, Ashman Department of Periodontology and Implant Dentistry, New York University College of Dentistry, New York, New York, USA.

Correspondence to: Dr Stuart J. Froum, 17 W 54th Street, Suite 1C/D, New York, NY 10019, USA. Fax: 212-246-7599. Email: dr.froum@verizon.net

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A safety distance of 2 mm has been widely accepted as the standard measurement to prevent implant-related nerve injuries. This concept was introduced by Misch and Crawford[1] and by Bartling et al[2] through panoramic radiologic assessment. In these studies, the authors suggested that a distance of 2 mm should be maintained from the implant to the inferior alveolar nerve (IAN) due to the increased distortion and bi-dimensionality of radiographs showing the IAN.[1,2] An article on inferior alveolar nerve injury during implant placement suggested a formula to avoid this complication and also used a "safety zone" of 2 mm.[3]

Implant placement is the second most common cause for IAN damage, following the removal of impacted wisdom teeth.[4,5] This can be attributed to osteotomy preparation leading to direct transection of the canal or to nerve compression at the time of implant placement.[6] It is acknowledged that in volumetric horizontal and vertical bone deficiencies, the risks of neurologic injuries are increased due to the close proximity of the neurovascular bundle. To prevent this, CBCT scans became the standard of care for complex implant rehabilitations, allowing precision and tridimensional reconstruction of the implant site. Due to the extreme

accuracy of CBCT scans combined with technologic improvements in current treatment planning, many IAN injuries can be prevented. The precision of CBCTs allows an implant to be placed in proximity to the IAN without any neurologic damage.[7] In addition, with the help of these technologies, different surgical techniques have been introduced, such as nerve lateralization or implant placement lateral to the IAN to restore an edentulous atrophic posterior mandible.[8,9] In a recent study, it was observed that while 2 mm is recommended, there was no statistically significant distance determined to avoid neurologic complications with implants placed in close proximity to the nerve.[10] Therefore, with correct treatment planning, surgical execution, and using this 2-mm distance as a guide, it has been assumed that IAN injury can be avoided. To the present authors' knowledge, no reports in the literature suggest a different concept of safety distance.

This retrospective study aims to evaluate implants placed in close proximity to the IAN without any postoperative neurologic complications and to determine a safety distance concept based on measurements of the proximity of implants to the IAN.

Materials and Methods

Data were obtained from the anonymous implant database and were extracted as deidentified information from the patient pool at the Ashman Department of Periodontology and Implant Dentistry at the New York University College of Dentistry (NYUCD), Kriser Dental Center. The Office of Quality Assurance at NYUCD certified the study ID. This study is in compliance with the Health Committee on Activities Involving Human Subjects.

A total of 60 consecutive patients that received mandibular implants and satisfied the inclusion criteria were enrolled in this retrospective study. Patients with implants that were placed at NYUCD were referred to the Ashman Department of Periodontology and Implant Dentistry for maintenance and evaluation. All enrolled patients had preoperative CBCT scans and those that presented with evidence of inflammation and/or radiographic evidence of bone loss received a postoperative CBCT scan for further radiologic assessment. Measurements were obtained from the cross-sectional view using Simplant software (Dentsply Sirona). This system allowed identification of anatomical reconstruction, localizing and tracking the path and trajectory of the IAN. Using this system and its measurement tool, distance from the IAN to the closest point of the implant was calculated by two investigators (M.B. and N.R.). When measurements differed by > 0.03 mm for the same implant, a third author (S.C.C.) evaluated the distance until an agreement between the three evaluators was reached.

Using the Simplant measurement tool, lines were drawn from the implant to the closest surface of the inferior alveolar canal (Fig 1). If there was no contact between the two structures and bone was detected between the implant and the inferior alveolar canal, the distance was determined as positive (+; Fig 2). Alternatively, if there was no separation between the two structures and the inferior alveolar canal was superimposed or intersected the implant, the value was considered to be negative (–; Fig 3).

The inclusion criteria were as follows: *(1)* aged ≥ 18 years; *(2)* had implants previously placed in the mandibular first/second premolar/molar position; *(3)* not experiencing any neurosensory changes following implant placement and healing; *(4)* experiencing neurosensory changes, including paresthesia, anesthesia, and dysesthesia, after implant placement; and *(5)* implant placement with a radiologic distance < 2 mm from IAN that returned to the Ashman Department of Periodontology and Implant Dentistry at NYUCD for routine follow-up.

The exclusion criteria were as follows: *(1)* lack of patient compliance; *(2)* patients refusal to take a CBCT scan after implant placement; *(3)* CBCT scans with poor quality or presence of scattering that interfered with the radiographic evaluation; *(4)* contraindications for taking radiographs (pregnancy or breastfeeding); and *(5)* implants placed with a radiologic distance ≥ 2 mm from the IAN.

Results

A total of 60 subjects qualified for the inclusion in this retrospective study (33 women and 27 men) with an average age of 66 years. A total of 101

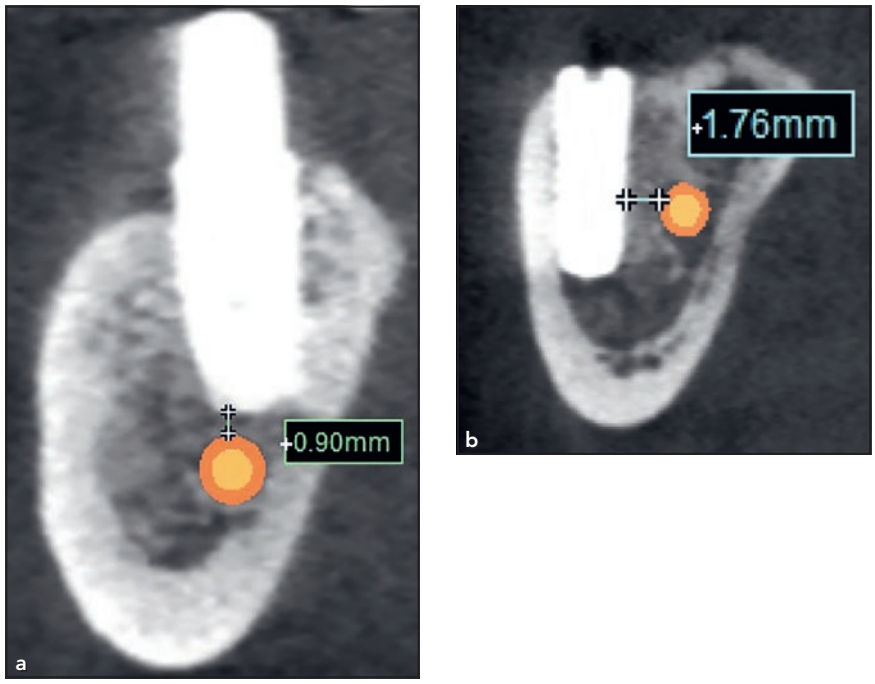

Fig 1 *Two separate examples of the shortest distance from the IAN to the implant.*

implants were placed in first and second mandibular molar or first and second premolar sites. Four patients presented with paresthesia in the lip, gingiva, or face, 1 patient presented with trigeminal neuralgia, and 55 patients presented without neurologic disturbances. Of the 60 patients, 71 implants were placed in molar sites and 30 were placed in the premolar sites. A mean distance of 0.75 mm (range: 0.14 to 1.8 mm) was seen from closest part of implant body to the nerve bundle in patients without neurologic disturbances. Alternatively, a direct correlation was found in patients presenting neurosensory changes when an invasion of an endosseous implant and the nerve bundle was detected. Table 1 summarizes the characteristics of the included patients, distance between the implants and IAN, and neurosensory evaluation of the subjects.

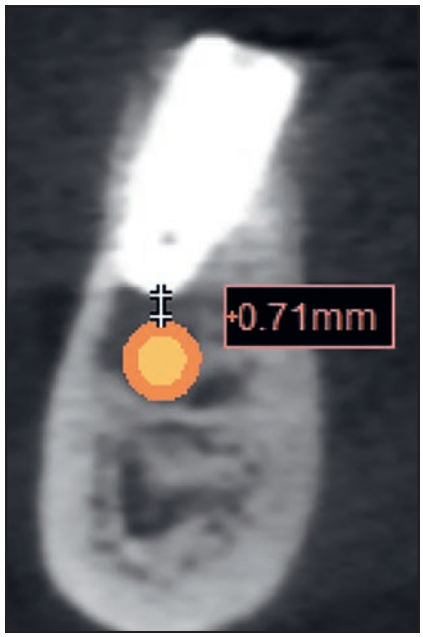

Fig 2 *Example of a positive distance between the IAN and implant, with no invasion of the IAN.*

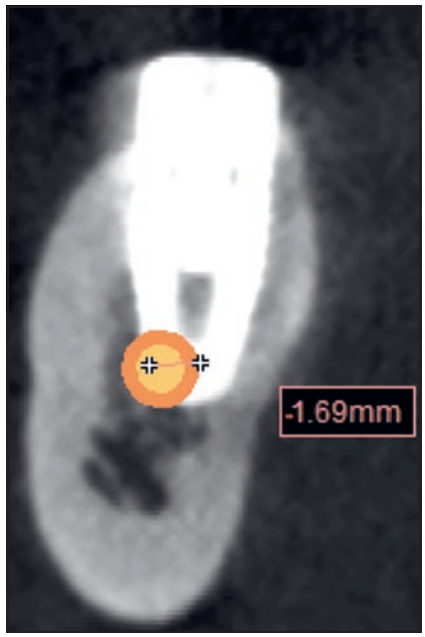

Fig 3 *Example of a negative distance between the IAN and implant, with an invasion of the IAN.*

Table 1 Characteristics of 60 Patients with Implants (N = 101) Placed in Close Proximity to the IAN

Sex	Age, y	Implant site[a]	Distance, mm	Neurosensory evaluation
F	68	36	+0.5	None
F	79	35 45	+0.57 +0.90	None
M	77	36	+1.1	None
M	67	36	+1.8	None
M	59	37	+1.66	None
F	18	45	+0.81	None
M	59	36	+0.34	None
M	88	45 35	+0.79 +0.82	None
F	58	35	+0.47	None
M	57	47	+1.2	None
F	87	46 47	+1.0 +0.2	None
F	76	37 36 46 47	+1.3 +0.4 +1.0 +0.6	None
F	71	36 35 34	+0.9 +0.6 +0.4	None
M	60	37 46	+0.9 +0.7	None
M	93	44 45	+1.0 +0.5	None
F	70	46	+1.3	None
F	71	37 45	+1.7 +1.1	None
M	92	37 36	+1.5 +0.9	None
M	54	44 45 46	+1.2 +1.1 +1.0	None
F	67	37 36	+1.2 +0.9	None
M	65	37 36	+1.2 +0.6	None
M	78	37 45	+0.4 +0.8	None
M	84	36 35	+1.0 +1.2	None
F	78	46	+0.9	None
F	88	36 46 47	+0.9 +1.4 +0.8	None

F = female; M = male.
[a]FDI tooth numbering system.

Table 1 *(cont)* Characteristics of 60 Patients with Implants (N = 101) Placed in Close Proximity to the IAN

Sex	Age, y	Implant site[a]	Distance, mm	Neurosensory evaluation
F	69	35	+0.9	None
F	65	45	+0.7	None
M	53	45 46 37 36	+0.7 +0.6 +1.1 +1.1	None
F	89	46	+0.9	None
M	68	47	+1.4	None
M	80	37 36	+0.6 +0.4	None
F	75	46 47	+0.9 +0.5	None
M	75	37 36 35	+1.0 +0.4 +0.7	None
M	91	37 36 45 46 47	+0.7 +0.6 +0.6 +0.6 +1.3	None
M	57	37 46	+1.6 +1.1	None
M	74	45 46	+0.5 +1.3	None
M	85	46 47	+1.5 +0.6	None
M	35	36	+1.0	None
F	40	45	+1.4	None
M	55	45	+1.6	None
M	58	45	+1.4	None
F	67	46 47	+0.72 +1.76	None
F	45	37	+0.59	None
M	60	47	+1.0	None
M	72	44	+0.5	None
F	55	44	+0.5	None
F	50	47	+0.57	None
F	60	36 35	+1.62 +0.71	None
F	58	37	+0.90	None
M	73	47	+1.0	None

F = female; M = male.
[a]FDI tooth numbering system.

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Table 1 *(cont)* Characteristics of 60 Patients with Implants (N = 101) Placed in Close Proximity to the IAN

Sex	Age, y	Implant site[a]	Distance, mm	Neurosensory evaluation
F	77	36 47	+0.14 +0.42	None
M	74	35	+1.01	None
M	55	36	+1.65	None
M	70	46	+0.14	None
F	49	47	+1.49	None
F	60	36 34	–1.68 –0.5	Paresthesia
F	61	37 36 35	–0.71 –0.53 –1.19	Neuralgia
F	45	36	–1.69	Paresthesia
F	55	46	–0.2	Paresthesia
M	40	37 36	–0.69 –0.56	Paresthesia

F = female; M = male.
[a]FDI tooth numbering system.

Although only 5 of the 60 patients had neurosensory problems (too small a population to evaluate statistical significance), the average age of these patients was 52.2 years (range: 40 to 61 years). The average depth of implant penetration into the nerve (as measured on the axial section) was –0.86 ± 0.50 mm (range: –1.69 to –0.02 mm). However, the findings on these patients suggest that the younger the patient, the greater the penetration, and the more likely to have sensory deficit.

Discussion

According to the results of the present study, even if a thin layer of cortical bone (range: 0.14 to 1.8 mm) was present and there was no invasion of the IAN bundle, the patients did not experience any change in nerve sensation. Nevertheless, when an invasion of the IAN was detected, this was correlated with the presence of neurologic disturbances. Thus, based on the statistical analysis, the 2-mm rule, while effective in preventing IAN disturbances, may not be considered the standard for modern implantology if there is no invasion of the canal. In fact, the average safety distance seen in the present study was 0.75 mm.

Neurologic injury can lead to a transient or persistent loss of function, depending on the level of injury, thus compromising the patient's function and quality of life. The prognosis of recovery from IAN damage depends on the diagnostic timing and level of injury.[11] Nerve damage can be classified in three different stages: neuropraxia, axonotmesis, and neurotmesis. In neuropraxia injuries, there is an alteration of conduction without loss of axonal continuity that is normally transient and occurs in traction or compression of the nerve. Axonotmesis involves axonal damage with loss of myelination, and it is usually related to more severe symptoms. Thus, in these cases, the pattern of recovery is more complicated and may not be complete. On the other hand, neuropraxia is a direct transection of the neurovascular bundle, resulting in loss of function.[12] In the results of several studies, neuro-

praxia injuries were usually related to the compression of the nerve due to close proximity of the implant with the IAN, while neurotmesis injuries were directly associated with a direct transection with a blade or a drill during the osteotomy preparation.[13,14] In neuropraxia cases, studies suggested that return of subjective sensations may occur with early removal of the implant. Early treatment is therefore critical in cases of nerve damage.[15] Nevertheless, in cases of IAN compression, the results of implant removal were shown to be promising even after a significant amount of time. Elian et al reported a return of sensations after implant removal in a patient who had been experiencing paresthesia for 4.5 years.[16]

In five patients in the present study, postoperative CBCT scans displayed a direct and clear perforation of the cortical layer protecting the IAN canal, with consequent invasion of the endosseous implants into the nerve bundle. Four patients presented with symptoms of paresthesia of the lip, chin, or face, and one patient showed clear symptoms of trigeminal neuralgia as a consequence of surgical trauma. It is assumed that in four of the five patients, the symptoms might be related to an axonotmesis type of nerve injury due to less trauma to the IAN and to the partial recovery after implant removal. Nevertheless, in the case of trigeminal neuralgia, this may be considered a neurotmesis type of nerve injury due to the more severe symptoms and reduced recovery. Thus, it is suggested that every clinician systematically perform surgical radiographic imaging with a direction indicator and/or a drill following the first osteotomy in order to evaluate the direction and depth of the drills, localize the position of the nerve, and re-angulate the osteotomies. This should help reduce the incidence of nerve injuries.

Nevertheless, due to modern advancements, including CBCT scans and precise surgical devices that are used to control the depth of the drills and guide the placement of the implants, different surgical techniques have been introduced. These include nerve transposition, nerve lateralization, or implants placement lateral to the nerve to restore an edentulous atrophic posterior mandible with fixed implant-supported restorations.[17] Often, these techniques are the only possible treatments that enable patients to have a fixed restoration. In a recent systematic review, Abayev and Juodzbalys[8] outlined the advantages of implants placed lateral to the IAN, including the potential to have a longer and wider implant diameter, as well as a reduction in treatment time compared to the use of bone grafting techniques. One of the key elements that these techniques offer is enhancing the vertical height, permitting the placement of a longer implant, which may increase the longevity of the restoration.[8] This is in accordance with the results of a recent systematic review and meta-analysis, where it was determined that short-diameter implants (< 6 mm) in function for > 3 years presented an increased incidence of failure.[18]

Furthermore, Başa and Dilek determined that the bone thickness protecting the inferior alveolar canal is 0.88 ± 0.18 mm, covered mainly by a layer of type D3 bone. Proper identification of the canal bone thickness via CBCT scans and proper surgical maintenance of the surrounding cortical bone showed promising results in preventing neurologic disturbances.[19] With the help of these diagnostic tools, different placement aids, such as precise surgical guides, drills with stoppers, or noncutting drills, can be used to maintain a proper anatomical distance from the IAN.[20] In addition, dynamic navigation has been introduced to improve the accuracy of surgical treatment. This can provide the clinicians a real-time navigation tool to improve the precision of implant surgeries and avoid anatomical landmarks such as the inferior alveolar canal, arteries, and maxillary sinuses when placing implants.[21] However, the present study showed that a 2-mm safety zone may not be necessary if there is no intersection of drills or implants with the IAN.

Conclusions

In patients without neurologic disturbances whose implants were located < 2 mm from the IAN, an average distance of 0.75 mm (range: 0.14 to 1.8 mm) was seen from the implant to the nerve bundle. At these distances, it was observed that the patient did not experience any neurosensory changes in cases where no compression or direct transection of nerve bundles were

detected. Alternatively, in cases where a direct transection and/or compression of the nerve occurred, the patient experienced neurosensory disturbances. The ideal minimum average distance from the neurologic bundle was found to be 0.75 ± 0.65 mm; however, implants may be placed closer to the inferior alveolar canal without neurosensory problems. Although a safety distance of 2 mm may be used when placing an implant in close proximity to the IAN, this study demonstrated that an average distance of 0.75 mm could be considered a new safety distance in certain cases. These results must be verified with more studies using measurement devices to determine how much distance between the osteotomy preparation or implant is necessary to avoid neurosensory complications of implants that are placed in close proximity to the IAN.

Acknowledgments

The authors declare no conflicts of interest.

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