3-Dimensional Imaging for Lower Third Molars: Is There an Implication for Surgical Removal?

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Purpose: Surgical removal of impacted third molars may be the most frequent procedure in oral surgery. Damage to the inferior alveolar nerve (IAN) is a typical complication of the procedure, with incidence rates reported at 1% to 22%. The aim of this study was to identify factors that lead to a higher risk of IAN impairment after surgery.

Materials and Methods: In total 515 surgical third molar removals with 3-dimensional (3D) imaging before surgical removal were retrospectively evaluated for IAN impairment, in addition to 3D imaging signs that were supposed predictors for postoperative IAN disturbance. Influence of each predictor was evaluated in univariate and multivariate analyses and reported as odds ratio (OR) and 95% confidence interval (CI).

Results: The overall IAN impairment rate in this study was 9.4%. Univariate analysis showed narrowing of the IAN canal (OR, 4.95; $P < .0001$), direct contact between the IAN and the root (OR, 5.05; $P = .0008$), fully formed roots (OR, 4.36; $P = .045$), an IAN lingual course with (OR, 6.64; $P = .0013$) and without (OR, 2.72; $P = .007$) perforation of the cortical plate, and an intraroot (OR, 9.96; $P = .003$) position of the IAN as predictors of postoperative IAN impairment. Multivariate analysis showed narrowing of the IAN canal (adjusted OR, 3.69; 95% CI, 1.88 to 7.22; $P = .0001$) and direct contact (adjusted OR, 3.10; 95% CI, 1.15 to 8.33; $P = .025$) to be the strongest independent predictors.

Conclusion: Three-dimensional imaging is useful for predicting the risk of postoperative IAN impairment before surgical removal of impacted lower third molars. The low IAN impairment rate seen in this study—compared with similar selected study groups in the literature of the era before 3D imaging—indicates that the availability of 3D information is actually decreasing the risk for IAN impairment after lower third molar removal.

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Surgical removal of impacted third molars is a regular, perhaps even the most frequent, procedure in oral and maxillofacial surgery. Damage to the inferior alveolar nerve (IAN) is a typical complication of the procedure. Susarla and Dodson[1] stated that nerve damage after third molar surgery occurs in 1% to 22% of surgeries. Different factors have been discussed in the literature as causes of nerve damage, eg, age of the patient, inexperience of the surgeon, or deep impaction.[2-4]

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Several investigators have described radiologic signs that indicate a close relation between the lower third molar and the IAN in conventional[5] and 3-dimensional (3D)[1,6-8] radiographies. Since the development of computed tomography in 1972,[9,10] 3D imaging has become more and more routine and has been, of course, used before third molar removal.[11] Currently, cone-beam computer tomographic images seem to be significantly superior to panoramic images in sensitivity and specificity of diagnosis, resulting in a higher level of intrasurgical safety.[12,13]

The open question remains as to whether the extra radiation dose for 3D imaging is justified by the information gained. There is no evidence in the literature to date as to whether 3D imaging can predict the risk for IAN damage or whether it actually lowers the risk for patients undergoing third molar removal.

The aim of this study was to identify factors for IAN damage that are detectable by 3D imaging before surgical removal of lower third molars.

Materials and Methods

All surgical wisdom tooth removals performed at the Clinic for Oral and Maxillofacial Surgery at the University of Zurich, Switzerland, were retrospectively evaluated for approximately 11 years, from April 1994 to September 2006. Criteria for inclusion in this study were impacted lower third molars, projection of the tooth over the full width of the IAN on panoramic radiograph, 3D imaging before surgery, surgical removal performed by a board-certified oral or maxillofacial surgeon, and complete follow-up, including documentation of pre- and postoperative IAN function. Complete follow-up was defined as sessions occurring at least 3 weeks after the surgery and, if nerve impairment had occurred, until the patient had recovered. Any impairment lasting longer than 6 months was classified as permanent. Under these criteria, 515 lower third molars in 293 patients qualified for the evaluation. Excluded cases were also evaluated if any nerve damage was documented. From the documentation, all teeth had been removed by a lateral approach and buccal flap.

Three-dimensional images for all included teeth were reviewed by 2 observers and evaluated for the following criteria:

- spatial relation between the tooth and the IAN
  - IAN lateral
  - IAN lingual
    - IAN lingual without perforation of cortical plate
    - IAN lingual with perforation of cortical plate
  - IAN between apically open roots (inter-root IAN course)
  - IAN inside apically closed roots (intraroot IAN course)
- distance from the IAN to the tooth: direct contact versus cancellous bone in between
- diameter of IAN canal: constant diameter versus obvious decrease in diameter
- maturation: fully formed roots versus immature roots
- type of angulation (vertical, mesial, distal, horizontal, transversal)
- number of roots
- side

The postoperative IAN function as documented in a patient's chart was evaluated for impairment (permanent or temporary) or full function on postoperative consultations.

The study design fulfills the criteria of paragraphs 4a and b according to guidelines (version 21.5.2010.2010) of the cantonal ethics committee of Zurich and therefore is exempted from institutional review board approval. The study design thereby fulfills the guidelines of the Declaration of Helsinki concerning ethical principles for medical research involving human subjects.

Univariate logistic regression analysis was applied in a first step to identify the factors predicting postoperative nerve impairment and to compute the odds ratio (OR) for each factor including the 95% confidence interval (CI). The influence was accepted as statistically significant at $P < .05$. Afterward, a forward stepwise logistic regression analysis was computed for the identified predictors to find associations between them and to provide adjusted ORs. The results were crosschecked with a backward stepwise logistic regression analysis. All statistical analysis was performed with PASW Statistics 18 for Windows (SPSS Inc, Chicago, IL).

Results

The female-to-male ratio was 156 (53%) to 137 (47%) for patients and 294 (57%) to 221 (43%) for teeth. The left-to-right ratio was 266 (52%) to 249 (48%).

At the first postoperative consultation—which was usually 1 week after surgery— 47 (9.4% of 515) removals had resulted in an impairment of the IAN. In no case was the damage permanent over a follow-up period longer than 12 weeks. Among the excluded cases, there was no documented nerve impairment. No case was excluded due to incomplete postoperative follow-up.

An overview concerning the frequency of the evaluated factors in the main group and in the subgroups (those with and without postoperative nerve impairment) is shown in Figures 1 and 2. Figure 1 shows factors regarding the anatomy of the

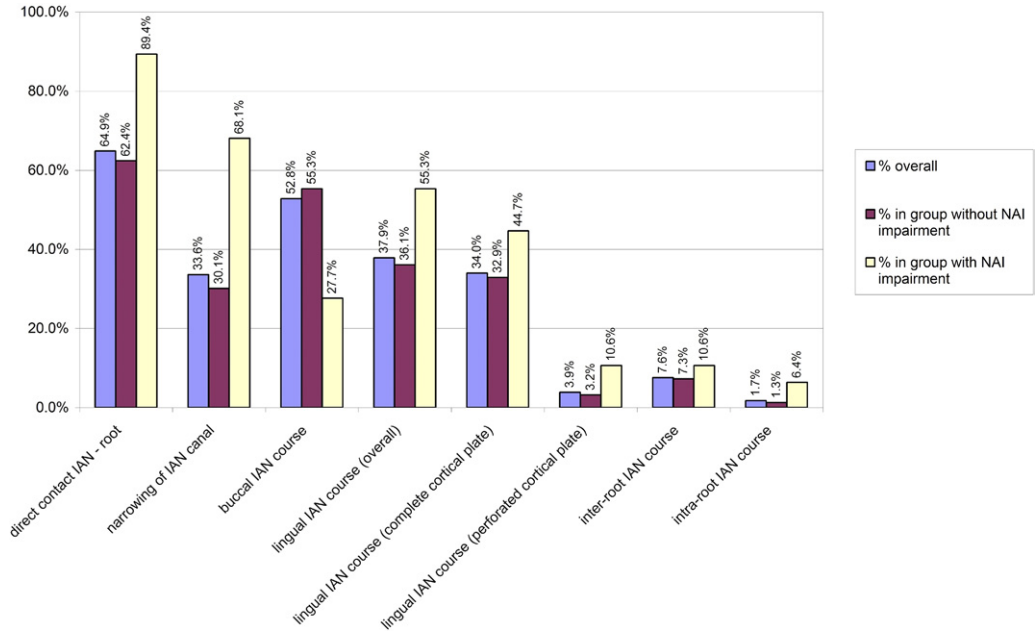

FIGURE 1. Frequency of evaluated factors regarding the IAN canal in the overall group (*blue bars*) and in the subgroups with (*yellow bars*) and without (*red bars*) postoperative IAN impairment. IAN, inferior alveolar nerve.

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nerve canal. Figure 2 displays factors relating to the tooth configuration.

Binary logistic regression analysis showed the distance between the IAN and the root as a risk factor for IAN impairment. If there was no identifiable cancellous bone between the IAN and the lower third molar, the risk for IAN impairment increased (OR, 5.05; $P = .0008$). Also, an observable narrowing of the IAN canal on 3D imaging led to an increased risk (OR, 4.95; $P < .0001$).

For statistical testing of IAN courses, the buccal IAN position was set as the reference because it

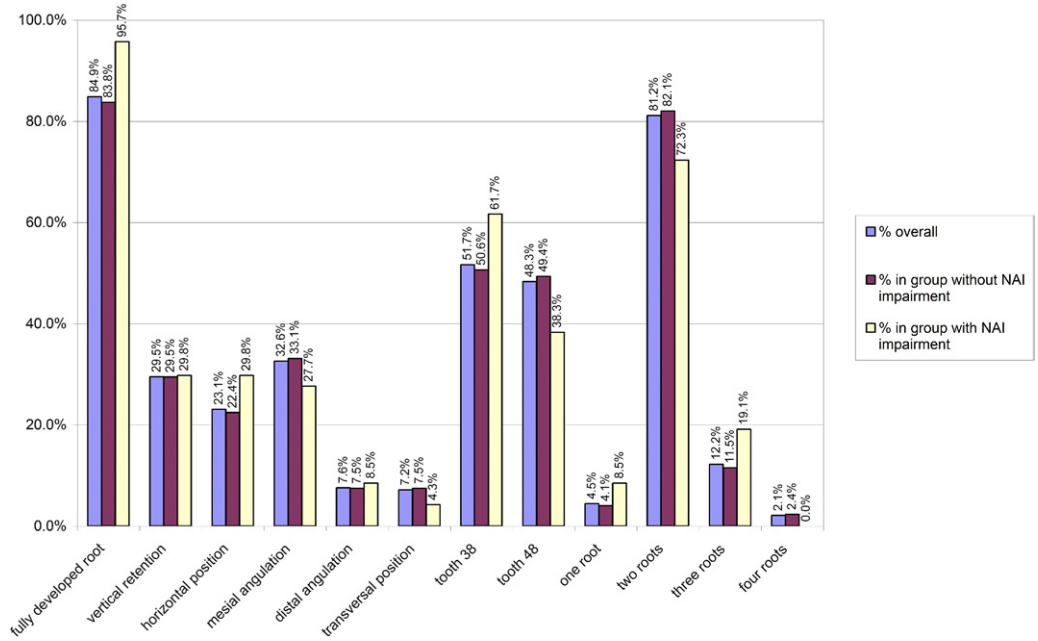

FIGURE 2. Frequency of evaluated factors regarding tooth configuration in the overall group (*blue bars*) and in the subgroups with (*yellow bars*) and without (*red bars*) postoperative inferior alveolar nerve impairment.

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Table 1. ASSOCIATION BETWEEN RISK FACTORS

Factor	IAN Position				
	Buccal	Interroot	Intraroot	Lingual Without Perforation of Cortical Plate	Lingual With Perforation of Cortical Plate
Total	272	39	9	175	20
Narrowing of IAN canal					
Applies	44 (16.2%)	19 (48.7%)	7 (77.8%)	86 (49.1%)	17 (85%)
Expected in 33.6%	91.4	13.1	3.0	58.8	6.7
Direct contact between nerve and root					
Applies	136 (50%)	36 (92.3%)	9 (100%)	135 (77.1%)	18 (90%)
Expected in 64.9%	176.4	25.3	5.8	113.5	13

NOTE. Percentages are calculated as percentage of the number of teeth with the specified IAN position.
Abbreviation: IAN, inferior alveolar nerve.

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was the most common anatomy (50.5%). An intraroot course was responsible for a higher rate of IAN impairment (OR, 9.96; $P = .003$). A lingual IAN course increased the risk of IAN impairment with (OR, 6.64; $P = .0013$) or without (OR, 2.72; $P = .007$) perforation of the lingual cortical plate. Interroot course was short of being significant (OR, 2.93; $P = .054$).

Regarding the tooth and its root configuration, only the factor of fully developed roots was significant (OR, 4.36, $P = .045$) for an IAN impairment.

The multivariate forward stepwise regression analysis showed narrowing of the IAN canal (OR, 3.69; $P = .0001$) and direct contact between nerve and roots (OR, 3.10; $P = .025$) as independent influential factors. Further analysis showed a close association between these 2 factors and the risk factors of IAN course (Table 1).

An overview of all factors, ORs and corresponding 95% CIs, and *P* levels are presented in Table 2.

Discussion

The aim of the study was to identify predictors that lead to an increased risk for IAN injury. Several were identified, and 2 of those were independent in multivariate analysis.

Narrowing of the IAN canal increased the risk for postoperative IAN impairment (adjusted OR, 3.69). This information is new to the literature and the evidence (95% CI, 1.88 to 7.22; $P = .0001$) was strong.

The absence of cancellous bone between the nerve and the tooth, in other words, direct contact between the 2 structures, was another independent factor. This was to be expected from the literature,[12,14] and the

Table 2. FACTORS INFLUENCING RISK OF INFERIOR ALVEOLAR NERVE IMPAIRMENT

Factor	Applies in Teeth Without IAN Impairment (of 468)	Applies in Teeth With IAN Impairment (of 47)	Univariate Logistic Regression Analysis		Multivariate Forward Stepwise Regression Analysis	
			P Value	OR (95% CI)	*P* Value	OR (95% CI)
Narrowing of IAN canal	141 (30.1%)	32 (68.1%)	<.0001	4.95 (2.60-9.42)	.0001	3.69 (1.88-7.22)
Direct contact between nerve and root	292 (62.4%)	42 (89.4%)	.0008	5.05 (1.96-13.0)	.025	3.10 (1.15-8.33)
Fully developed roots	392 (83.8%)	45 (95.7%)	.045	4.36 (1.04-18.4)		
IAN position			.0013			
Buccal IAN position	259 (55.3%)	13 (27.7%)	—	1 (reference)		
Interroot course of IAN	34 (7.2%)	5 (10.6%)	.054	2.93 (0.98-8.73)		
Intraroot course of IAN	6 (1.3%)	3 (6.4%)	.003	9.96 (2.24-44.4)		
Lingual IAN position without perforation of cortical plate	154 (32.9%)	21 (44.7%)	.007	2.72 (1.32-5.58)		
Lingual IAN position with perforation of cortical plate	15 (3.2%)	5 (10.6%)	.0013	6.64 (2.09-21.1)		

Abbreviations: CI, confidence interval; IAN, inferior alveolar nerve; OR, odds ratio.

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present study showed the factor to be independent of other findings and quantified the risk (adjusted OR, 3.10).

We know from conventional radiography that situations suggesting a close nerve-tooth relation have a higher risk for postoperative nerve impairment. However, the literature shows that the relation cannot safely be judged in panoramic imaging.[6,7,12,13]

Interestingly, there was a significant increase in IAN impairment from the lingual course of the IAN canal in relation to the lower third molar, as previously reported by Jhamb et al.[12] Because the situation of the nerve in a lingual position is not so rare, this is a clinically important finding. We were able to calculate the OR.

After the lingual course, univariate analysis showed more factors that predict postoperative IAN impairment but were not shown as independent. Basically all IAN positions other than buccal increase the risk, although the interroot course was short of being significant ($P = .054$). This is clinically important because the course of the IAN is easy to judge on 3D images and because the surgical technique is always assessed by the surgeon. However, we found that the IAN position has a close association with the 2 independent predictors, namely direct contact and narrowing of the IAN canal.

From a surgical point of view, it can be derived that a different surgical approach (eg, a lingual flap) cannot influence the rate of nerve impairment because the independent predictors are not sufficiently addressed by this change of surgical strategy. In contrast, knowledge about the exact location of the IAN bundle is a very important factor because this information provides knowledge about regions safe for quick removal of bone and danger zones where special care has to be used.

The study showed that fully developed roots increase the risk for postoperative nerve impairment. This was to be expected because fully developed roots are likely to have closer contact to the IAN bundle. In consequence, this risk factor could not be shown to be independent. However, among other known reasons, eg, postoperative swelling and pain, this is another argument for early removal of wisdom teeth.

This study could not confirm the influence of side as reported by Baqain et al.[3] Mesial angulations were suspected by Miloro and DaBell[15] as a factor for postoperative paresthesia of the IAN, mainly because of a closer vicinity of the teeth to the nerve, which was shown in their study. The presented data do not support this suspicion because no angulation type emerged as a predictor.

Because no cases were excluded due to insufficient follow-up, the impairment rate of 9.4% is realistic. This rate is in accordance with the existing literature in which, for example, Genu and Vasconcelos[16] reported a rate of 8% in 50 teeth. However, the rate of IAN impairment is difficult to judge because of variations from 1% to 22% due to different inclusion criteria for teeth.[1] Another difficulty is the different level of surgeons' experience in the different studies, which has been shown to be a factor in different postoperative complications, including nerve paresthesia.[17] In sum, one has to be very careful when comparing complication rates within different studies.

However, earlier 2-dimensional imaging studies that focused on a situation comparable to the present inclusion criteria of "projection of the tooth over the full width of the IAN in panoramic radiograph" reported complication rates of 15% to 25%.[14,18,19] Therefore, we believe that 3D imaging lowers the risk under the selection bias of "high-risk" panoramic radiography of this study. To be absolutely certain about this, a control group without 3D imaging would be essential but is in our judgment not applicable due to ethical concerns. Of course, there are several more factors that need to be controlled in such a study, eg, experience of the surgeon.

We believe that the level of almost 10% postoperative nerve impairment results from the combination of selection bias due to strict inclusion criteria that increase risk and 3D imaging, which might lower the risk by, eg, an adapted surgical technique or, in an institutional setting, assignment of a more experienced surgeon.

The basic weakness of this study is its retrospective character. There may be selection bias that cannot be judged retrospectively. There is no detailed information available regarding modifications of a surgical approach influenced by 3D imaging results. We suspect that "risky" patients should be assigned to more experienced surgeons and that the indication for separation of a tooth be expanded based on, eg, a close relation. Also, modifications of approach and degree of bone removal might have been performed. However, the study design was not able to show that these patients were operated on with special care or by an especially experienced surgeon. We believe that these disadvantages are outbalanced by the large number of analyzed teeth and by the clear statistical results.

Interestingly enough, the predictors increased the risk, despite the prior 3D imaging and the consecutive knowledge about the situation. In contrast, any permanent lesion was avoided.

Overall, the exact evaluation of risk factors is important information for patients, especially concerning individual risk assessment and decision making. It may also lead to different surgical approaches, eg, coronectomy, for high-risk cases as described by several investigators in recent years.[20-24]

In conclusion, this study provides data about several factors that increase the risk of IAN impairment after surgical removal of inferior third molars. Regarding the overall rate of postoperative IAN dysfunction, this study shows low impairment rates compared with the literature of the era before 3D imaging. We believe this is due to the integration of information from 3D imaging into the surgical strategy. When risk factors are detected or cannot be excluded in conventional 2-dimensional radiography, 3D imaging is justified to improve risk assessment and surgical decision making. Patients meeting any of the known criteria, ie, diversion of the IAN canal, darkening of the root where the IAN canal crosses the root, and apparent interruption of the white line bordering the IAN canal where it crosses the root, might especially benefit from 3D imaging. Moreover, the legal demand for more detailed information on the incidence of potential complications is met and automatically documented by the imaging study.

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