

Ph.D Thesis

**THE ROLE OF PANORAMIC RADIOGRAPHY IN THE PREDICTION OF
INFERIOR ALVEOLAR NERVE INJURY AFTER MANDIBULAR THIRD
MOLAR SURGICAL REMOVAL**

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INTRODUCTION

Lower third molar removal is one of the most frequent oral surgical procedures. Most of the common postoperative complications are mild and reversible, while inferior alveolar nerve (IAN) damage is one of the most serious consequences. Postoperative complications like swelling, trismus and pain are easy to manage, but the functional loss of sensory innervations of the lower lip may cause traumatic injuries and fibromas, scar tissue and mucocele formation on the mucosa. The cited frequency of IAN paresthesia ranges between 0.4% and 8.4%, whereas permanent risk usually stays below 1%. Damage to the IAN has been related to deep impactions, horizontal angulations, less-experienced surgeons and the close anatomic relationship between the third molar root and the mandibular canal.

IAN injury can result from a number of different actions, including the use of elevators, pressure directly or indirectly on the nerve or the use of burs, if the drilling reaches the nerve. Postoperative perineural inflammation can also cause neuro-functional disturbances. In cases of opened nerve canals, nerve injury is frequently present without any visible trauma. According to Tay and Go, direct visualization of an intact IAN bundle during third molar surgery indicates that the third molar was intimately associated with the IAN and poses a 20% risk of subsequent paresthesia. On the other hand, intraoperative hemorrhage within the socket and postoperative swelling or hemorrhage can cause an increase in IAN damage. Bleeding can result from disruption of the IAN bundle (direct trauma), indirect damage due to compression from postoperative swelling or hemorrhage, indicated by a delayed onset (after 24 to 48 hours). Predicting neurological complications before surgery is a common desire of surgeons and patients alike. Earlier investigations have shown that several risk factors need to be assessed before surgery to increase the predictive capacity of panoramic radiography, with the aim of avoiding intra- and postoperative neurological complications.

One of the aims of the radiographic examination is to predict direct connections (intimate relationships) between third molars and neurovascular bundles with the highest possible accuracy. Some investigators have examined intraoperative nerve damage (Blaeser et al., 2003) or the opened dental canal and exposed nerves during surgery (Sedaghatfar et al., 2005; Tantanapornkul et al., 2006; Bundy et al. 2009); others have examined the

intervening neurological complications as an outcome variable (Rood and Shehab, 1990; Valmaseda-Castellon et al., 2001; Gomes et al., 2008).

Darkening of the root was described earlier as an increased radiolucency due to impingement of the canal on the third molar whereas Mahasantipiya et al. (2005) and Tantanapornkul et al. (2009) showed that darkening can occur on radiographs without root grooves; moreover Tantanapornkul et al. stated that darkening of the root can even present itself as the thinning of the lingual cortical plate. Atieh's review article showed a pooled sensitivity of 51.2% and a pooled specificity of 89.6% for this sign. Blaeser et al's and Gomes et al's results affirmed that the darkening of the third molar root is one of the "strongest" signs in the predilection of IAN exposure or paresthesia.

OBJECTIVES

Our aim was to examine the correlation between preoperative panoramic radiographic signs (including four of the classic signs indicating a close spatial relationship between the IAN canal and a third molar, root curvature and the degree of root tip-inferior alveolar canal (IAC) overlap) and documented IAN functional disturbances in a case-control study and to determine the diagnostic value of panoramic radiography. Further aim was to focus on one of the most important panoramic signs and to estimate differences between isolated (when darkening was a single observation without adjacent "high risk" radiographic markers on radiographs) and multiple darkening cases (when this sign was together with other, previously mentioned "high risk" signs) and between IAN exposures in order to find adjacent factors on panoramic radiographs which improve the risk assessment in darkening cases.

PATIENTS AND METHODS

The examination of "high-risk" specific and non-specific signs

Between January 2003 and December 2007, 3651 surgical removals of lower third molars were performed by the first author at the Department of Oral and Maxillofacial Surgery of the University of Pécs, Hungary. Before surgery, each patient was informed about possible

complications, including the potential risk of nerve damage during the procedure, and each patient provided full informed consent. Every intervention was carried out under local anesthesia. Envelope (sulcular) mucoperiosteal flaps were raised at superficial impactions, and triangular flaps were raised at deep impactions, followed by vestibular and distal bone removal. In high-risk cases, sectioned removal of teeth was called for. Bone removal and sectioning were performed with tungsten carbide round and fissure burs (HM141A and HM 160, Hager & Meisinger GmbH, Neuss, Germany). Sockets were irrigated with 20 ml of sterile saline solution at room temperature, and IAN exposure was checked during and after precisely focused, careful suction. Single interrupted sutures were placed. Where the IAN was visible, iodoform-impregnated drains were used to avoid possible nerve compression.

For the purpose of our research, a case-control study was used. Cases were defined as extractions with neurological disturbances after mandibular third molar removal (n=41 of the 3651 interventions). The controls (n=359) consisted of patients without any postsurgical neurological complications or subjective or objective neuro-functional complaints upon suture removal. Controls were selected randomly from the 3651 surgery patients. The size of the sample (n=400) was chosen to represent approximately 10% of the total procedures.

Patients with conventional panoramic radiographs (Planmeca Proline PM 2002 CC, Helsinki, Finland) were included in the study, and the films were analyzed by the first and the second authors (J.SZ. as oral surgeon and E.L. as endodontic and radiologic expert both with approximately 10 years of experience). Three months later, fifty radiographs were examined again. Intraexaminer and interexaminer reliability were calculated with kappa statistics.

The primary predictive variable was the presence or absence of one or more preoperative panoramic radiographic findings: *interruption of the superior cortical line of the canal wall, diversion of the canal, narrowing of the canal, darkening of the root* and cases when *two or more of the signs mentioned above were simultaneously present*. Other preoperative radiographic findings, such as the type of impaction (according to Pell and Gregory) and angulation (Winter's classification), and demographic factors such as patients' ages and genders were analyzed and compared with the control group's findings and demographics.

Root curvature was measured using the method elaborated by Bell et al., 2003. Relying on panoramic radiographs, the patients were classified into three groups. In group 1, the angle of root curvature was less than 45°; in group 2, the angle was between 45° and 90°

and in group 3, it was larger than 90°. Teeth were categorized according to the largest root curvature, either on the mesial or distal root. The relationship between the IAC and the third molar root tip was investigated in accordance with the well-described methods of Miloro and DaBell (2005) and Nakamori et al. (2008), but slightly modified categories were used. It was hypothesized that more prominent superimpositions involve a higher risk of neurological disturbances. Based on radiography, the relationship describing the extent of IAC and third molar root overlap was categorized as follows:

1. There is no visible contact between the root end and the IAC.
2. The root tip reaches the upper cortical boundary of the mandibular canal.
3. Root tips are superimposed by the IAC.
4. One of the root tips reaches over the inferior cortical line of the IAC.
5. The relationship is not clearly detectable.

The *outcome variable* was the presence or absence of IAN paresthesia after third molar surgery. Postoperative IAN functional problems were examined upon suture removal, one week after surgery. Subjective complaints (e.g., “numbness” in teeth and/or chin, “pins and needles” sensation) and objective findings, such as light touch, direction sense, two point discrimination and “pinprick” by the method of Zuniga (1998) were recorded. Postoperative care and the results of sensory testing are not presented in this study. The study design used in the present project was similar to the preceding studies of Blaeser et al., Sedaghatfar et al. and Gomes et al., with the exception of the risk assessment method based on root curvature and the extent of third molar root-IAC overlap.

The examination of the darkening of the root “high-risk” sign

A case-control model was constructed. 116 mandibular third molar surgical extraction cases -showing darkening of the third molar roots on presurgical panoramic radiographs- were selected for the case group and 193 cases without darkening were selected for control. The inclusion criterion for the control group was the presence of one or more “high risk” panoramic signs (e.g. interruption of the white line, diversion of the canal, narrowing of the canal). The control group was selected with the following criteria: homologous age, gender and impaction depth, with respect to the case group.

Darkening of the root cases were divided into two groups according to the panoramic findings:

Group 1 (isolated darkening): Darkening of the root was present as an isolated preoperative panoramic radiographic finding. There were no adjacent panoramic signs.

Group 2 (multiple darkening): Darkening of the root and one or more of the adjacent panoramic radiographic signs (diversion of the canal, narrowing of the canal, and interruption of the superior cortical line) were simultaneously present.

Control cases were also divided into two groups according to the panoramic findings:

Group 3: Presence of an isolated single “high risk” sign with the exception of darkening of the root.

Group 4: Simultaneous presence of two or more “high risk” signs with the exception of darkening of the root.

The IAN visualization was documented after extraction. Sockets were irrigated with 20 mL sterile saline solution at room temperature in combination with precise focused suction. The exposed IAN bundles were examined under loupe magnification using a headlight. The direct visualization of the suspected neurovascular bundle was decided as an IAN exposure, when the following criteria were partially or totally fulfilled: mesiodistal oriented tubular, pale or whitish structure at the expected level of the socket (estimated according to the panoramic radiographs). Non-tubular, lingually observed soft tissues without mesiodistal orientation were rather decided to be lingual plate perforations. Preoperative radiographs were analyzed by (J.Sz.) and (E.L.) respectively. Conventional panoramic radiographs were taken before each operation (Planmeca Proline PM 2002 CC, Helsinki, Finland). Images were analyzed with a light box and loupe magnification was available for observers. Three months later, fifty radiographs were examined again. Intraexaminer and interexaminer reliability were calculated.

Data collection and statistical analyses were carried out with SPSS 15.0 (SPSS Inc., Chicago, USA) and StatsDirect 2.7.2 (StatsDirect Ltd., Altrincham, UK) software.

The association of each variable with the presence of IAN injury was tested by the Mann-Whitney two sample rank-sum test for age and either Pearson’s chi-square test or Fisher’s

exact test for gender and predictive variables. Fisher's exact test was applied when 2x2 table cells with an expected frequency below 5 were more than 20%.

Univariate odds ratios (ORs) of variables associated with IAN paresthesia were calculated. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were computed for each radiographic sign indicating a close spatial relationship between the IAC and a third molar. Predictive values regarding the definitive prevalence of IAN paresthesia in our department during the study were also estimated. The predictive values were estimated according to Bayes' theorem.

All of the variables associated with IAN paresthesia (according to bivariate analysis) were introduced into a multiple logistic regression model. Forward stepwise algorithms were used, with the rejection of those variables that did not fit the model significantly. Multivariate ORs and 95% confidence intervals were also calculated for the significant signs.

The association of isolated and multiple darkening cases and control groups with the presence of nerve exposure was tested by Pearson's chi-square test. Univariate odds ratios (ORs) of variables associated with IAN exposure were calculated.

A P value less than 0.05 was considered significant. Cohen's kappa statistic was used to calculate intra- and interobserver agreement. A kappa value of less than 0.40 was considered to show poor agreement; a value of 0.40-0.59, fair agreement; a value of 0.60-0.74, good agreement and a value of 0.75-1.00, excellent agreement.

RESULTS

“High-risk” specific and non-specific signs

Patients with neurological disturbances constituted our case group (39 patients, 41 cases). The patients had a mean age of 30.0 ± 8.8 years (range 19-66 years), and 31 were females. In two patients, injuries occurred on both sides. The control group was selected from randomly chosen patients without postsurgical complications (228 patients, 359 cases). Controls had a mean age of 28.4 ± 11.8 years (range 15-77 years), and 130 of them were females.

Patients with IAN injury were significantly older than those without (Mann-Whitney two sample rank-sum test: $P=0.020$). Of all the surgical procedures, 61% (244/400) were

performed on women. There was a significant association between gender and IAN paresthesia. In the IAN injury group, there were significantly more females than in the control group (Pearson's chi-square test: $P=0.008$).

The frequencies of significant radiographic signs in the study sample were: 1) interruption of the superior cortical line, $n=56/400$ (14.0%), 2) diversion of the canal, $n= 23/400$ (5.8%), 3) narrowing of the canal, $n= 22/400$ (5.5%), 4) darkening of the root, $n= 49/400$ (12.3%) and 5) two or more signs together, $n= 61/400$ (15.3%).

For these signs, the sensitivities ranged from 14.6% to 68.3%, and the specificities ranged from 85.5% to 96.9%. The positive predictive values in the study groups were between 27.3% and 55.1%; the negative predictive values were between 90.7% and 96%. Predictive values were also calculated regarding the definitive prevalence of the IAN paresthesia in this study, 41 paresthesias out of the 3651 surgical extractions (1.1%). Positive predictive values of significant radiographic signs, taking the 1.1% prevalence of IAN injury into account, decreased to between 3.6% and 10.9%, while the negative predictive values increased to between 99.0% and 99.6%.

In 243 out of the 400 cases, the angles between root tips and tracings were found to be smaller than 45° . In 108 cases the angle was between 45° and 90° , and in 49 out of the 400 cases the largest curvature was more than 90° , according to the corresponding panoramic images. Fisher's exact test showed a significant relationship between major (group three) root curvatures and the presence of postoperative IAN paresthesia ($P=0.015$). The calculated univariate adjusted odds ratio for this sign was 2.65.

In 58 out of the 400 cases, there was no contact between the third molar root and the IAC visible on panoramic radiographic images. In 56 cases, the roots reached the superior cortical boundary of the IAC, in 233 cases there was an overlap between the third molar and the IAC and in 46 out of the 400 cases, a minimum of one the root tips reached over the inferior cortical line of the IAC. In the deepest impaction cases (when the root tip reaches over the inferior cortical line of the canal wall), nerve dysesthesia was present in 31.7% of the cases, indicating a significantly higher chance of developing paresthesia (Fisher's exact test: $P<0.001$, $OR=1.96$). Moreover when there was a positive distance between the root and the IAC, paresthesia was not observed (Fisher's exact test: $P<0.010$). Applying the logistic regression model and forward stepwise algorithms, the Pell-Gregory classification, age and three of the "classic" signs (interruption and diversion of the canal and darkening of the root) were identified and included as significant variables. The following variables were excluded from this model: gender, Winter's classification, root

curvature, the extent of root tip-IAC overlap, narrowing of the canal and cases when more than two signs occurred together. After this, multivariate adjusted odds ratios and 95% confidence intervals (95% CIs) of the “classic” signs were calculated. Interruption of the superior cortical line ($P < .001$; OR: 8.38, 95% CI: 3.15- 22.28), diversion of the canal ($P = .001$; OR: 9.20, 95% CI: 2.44- 34.64), darkening of the root ($P < .001$; OR: 35.88, 95% CI: 13.18 97.68).

Both the intraexaminer (0.82 and 0.80) and interexaminer (0.79) reliability results were considered excellent in this course of the investigation.

Darkening of the root “high-risk” sign

The study sample consisted of 309 patients, 144 males and 165 females with a mean age of 26.7 ± 7.9 years (range 21-59 years). Overall 116 patients presented root darkening on panoramic radiographs (consisting of groups 1 and 2) and 193 patients (consisting of groups 3 and 4) showed other “high risk” panoramic signs indicating a close spatial relationship between the third molar root and dental canal. Out of the 309 extractions the IAN was visible in 47 cases (47/309, 15.3%), 32 times (32/116, 27.6%) in darkening cases and 15 times (15/193, 7.8%) in control patients. Visible IAN injury or excessive bleeding during surgery was not documented in the study. Reversible paresthesia occurred in 4 patients (4/47=8.5%) and paresthesia resolved at the latest within the first 4 months in every case.

According to the bivariate analysis, darkening (either as single or multiple sign) was significantly associated with IAN exposure ($P < .001$, Chi-square test; univariate adjusted odds ratio and 95% confidence interval [OR 95% CI]: 4.52; 2.32-8.79). The chance of IAN exposure was found to be significantly higher ($P = .001$, Chi-square test; OR 95% CI: 5.15; 1.8-14.65) in group 2 (multiple darkening) than in group 1 (single darkening). Moreover the chance for IAN exposure was significantly higher ($P < .001$, Chi-square test; OR 95% CI: 5.58; 2.4-12.93) in group 2 (multiple darkening) than in group 4 (multiple high risk signs without darkening). Both the interexamination (0.84 and 0.81) and intraexamination (0.77) reliability results were considered excellent in this course of the investigation.

DISCUSSION

Predicting neurological complications before surgical intervention is a common desire of surgeons and patients alike. The surgeon should consider aggravating factors that may make extractions more difficult. The shape and number of the roots, bone quality, preoperative inflammation, Pell-Gregory and Winter's classifications (position and angulation) and the patient's age, gender and general health status can influence the procedure. Several investigators have found older age to cause an increased risk of IAN injury, whereas others have failed to detect any connection between age and nerve paresthesia. Our results show that patients with IAN paresthesia were significantly older than those without. Tay and Go stated that an increase in age of one year raised the odds ratio of developing paresthesia by 6.9%. Valmaseda-Castellon et al. concluded that surgery in older patients may be more severe and that the healing process could be poorer. Similarly to Nakagawa et al.'s observations, which concluded that the highest risk patients were women whose panoramic radiographs show an absence of the superior cortex of the canal wall, female gender was found to be significantly associated with postoperative IAN paresthesia in the present study. One of the possible reasons for this is that the thinner mandibles (i.e., less buccolingual thickness) of women provide less distance between the tooth and the mandibular canal, increasing the risk of nerve injury. Valmaseda-Castellon et al. did not find a connection between gender and paresthesia, and Tay and Go stated that females have a lower risk of developing paresthesia (OR=0.41).

Radiological assessment is essential for evaluating the topographic relationship between the mandibular canal and the impacted third molar, and panoramic images are most commonly used for this purpose, but the limitations of two-dimensional imaging are well discussed. Panoramic radiography has several projection-geometrical characteristics that may decrease its accuracy. Namely, it provides information only on the position of the IAC in the vertical plane, it has variable magnification, lingually positioned structures are projected upward and it produces a sharp image layer (focal trough) of limited width. Moreover, the IAC is frequently positioned at the periphery of this focal trough, located buccally or lingually from the IAC. Several authors have confirmed the essential value of panoramic radiographs in detecting an intimate relationship between the third molar root and the mandibular canal, while Gomes et al. have concluded that they do not provide images reliable enough for predicting nerve lesions.

Blaeser et al. found that darkening of the root, interruption of the superior cortex of the canal wall and diversion of the IAN canal are significant radiological signs predisposing a patient to IAN injury. Rood and Shehab confirmed two more signs: deflected roots and narrowing of the root. Sedaghatfar et al. confirmed these results, but they did not find deflection of the roots to be a statistically significant indicator of nerve exposure and injury. In Monaco et al.'s radiographic and axial computed tomography (CT) investigation, changes in the root image and diversion or narrowing of the canal proved to be highly predictive of a true relationship between third molars and the dental canal. Valmaseda-Castellon et al. found that only the deflection of the mandibular canal was significantly associated with IAN injury, whereas Tantanapornkul et al.'s multivariate logistic regression results identified only interruption of the canal wall. Nakagawa et al. stated that absence of the superior canal wall on the panoramic images demonstrated direct contact between the third molar root and the mandibular canal on 3D-CT in 64.5% of all cases. In Susarla et al.'s multivariate model, none of the panoramic radiographic signs were associated with increased risk of IAN injury.

Our study identified the following signs according to univariate logistic regression analysis: *interruption of the superior cortical line of the canal wall, diversion of the canal, narrowing of the canal, darkening of the root* and cases where *two or more signs were present together*. These signs are significantly associated ($P < 0.05$) with inferior alveolar nerve paresthesia, whereas the multivariate logistic regression model identified only three signs: *interruption of the superior cortical line of the canal wall, diversion of the canal and darkening of the root* ($P < 0.001$). Similar to Sedaghatfar et al., our univariate analysis confirm an elevated chance of IAN injury when more than one sign is present by panoramic radiography, but the multivariate regression model failed to identify two or more signs to be significant. The most predictive sign was the darkening of the root (sensitivity: 65.9%, specificity: 96%, positive predictive value: 55.1%, multivariate adjusted OR for injury: 35.8, 95% CI: 13.18-97.68).

The sensitivities and specificities of the significant radiographic signs in the present study concurred with the previous results found in the literature. The current study established the observation that these signs have low sensitivity and specificity, independently of the exact outcome (i.e., IAN injury, nerve exposure or paresthesia).

Predictive values are important indicators for surgeons, because they represent the likelihood that a positive test result indicates injury or that a negative test result excludes injury.

The positive predictive value (PPV) in this study was the probability that postoperative IAN paresthesia will occur when a high-risk radiographic sign is present, and the negative predictive value (NPV) was the probability that paresthesia will not occur if a high-risk radiographic sign is absent. Positive (27.3%-55.1%) and negative predictive values (90.7%-96.0%) in the present study, factoring in the 10.3% (41/400) prevalence of the observation (i.e., IAN paresthesia), were comparable to those reported by other investigators. The relatively high predictive values in the present study might be due to higher case numbers. It is important to discuss our predictive values regarding the current prevalence of IAN paresthesia because PPVs and NPVs may have wide, dynamic ranges according to the outcome's frequency. Considering the 1.1% prevalence of IAN paresthesia in the entire surgery group (3651 extractions) in the present study, PPVs decreased to between 3.6% and 10.9%, while NPVs increased to above 99%. According to these results, the predictive force of panoramic radiography is quite low.

Along with several other specialists in the field, we believe that the absence of these significant signs upon radiographic examination provides the most reliable information to the surgeon. Namely, the absence of any of the significant signs indicates a minimal chance for IAN paresthesia, whereas the presence of one or more signs is not a reliable indication of possible paresthesia. The strongest sign, both in Blaeser et al.'s study and in our, was the darkening of the root. Blaeser et al. reported that this sign was seen in 82 out of 250 cases (32.8%), whereas in the present study, this sign was seen in just 49 cases out of 400 (12.3%). The sample in Blaeser et al.'s study consisted only of 8 cases and 17 controls, so the observations must be compared carefully. Öhman et al. found that a dark band on plain radiographs is an important indicator of grooving of the tooth by the canal and justifies pre-operative CT examination, although grooving can be present without this radiographic sign. However, Tantanapornkul et al. stated that this sign reflects cortical thinning or perforation of the lingual cortical plate (in 80% of the cases), rather than grooving of the tooth (occurring in just 20% of the cases).

Based on our observations and others' suggestions, the analysis of panoramic radiographs needs to include other modifying and influencing factors such as the number and shape of the roots, bone quality, type (Pell-Gregory classification) and angulation (Winter's classification) of impaction, relation to the second molar and demographic factors (e.g., age and gender). Our findings suggest that the degree of root tip-IAC overlap and root curvature should be observed before surgical intervention. The data support risk assessment based on the classic radiographic signs indicating a close spatial relationship.

Major (group three) root curvatures presented a higher risk (24.4% compared to 10.9%, OR=2.65) for paresthesia based on univariate analysis however the multivariate logistic regression analysis failed to confirm this. The correlation seems to be more indirect and presumably multicausal. Higher curvatures often mean more difficult extractions with more bone removal, usually requiring more manipulations near the nerve (root fracture and the necessity of dissection are more frequent) and increasing the risk of nerve injury. Furthermore, the chance of direct connection of the root end and the IAC may be more frequent in major root curvature cases, because root development can be modified by the dense mandibular canal. Tay and Go stated that patients who had curved roots had a higher risk of developing paresthesia (OR=2.54) and Jerjes et al.'s findings also suggested that root curvatures may support the surgeon's risk assessment. In contrast the diagnostic accuracy of panoramic radiography in Bell et al.'s study was found to be poor in terms of the demonstration of the exact anatomic forms of third molars and they concluded that root angulations can frequently be over- or underestimated. Moreover, Better et al. did not find root curvatures to be sufficiently important to justify the patient's referral for further CT examination.

The effect of root tip-IAC overlap has been investigated by several authors previously. Paresthesia and IAN exposure were found to be present more frequently in "deep superimposition" cases. Our results, based on the univariate analysis indicate that clinicians should be more careful if the root tip reaches over the lower cortical line of the dental canal, because in such cases paresthesia occurred significantly more frequently (31.7% compared to 9.2%, $P < 0.001$), but the multivariate logistic regression model failed to prove its significance.

Darkening of the root was determined as the single most important warning sign of IAN exposure or injury (Rood and Shehab 1990; Blaeser et al., 2003; Sedaghatfar et al., 2005; Bundy et al., 2008; Szalma et al., 2010) whereas the following researchers failed to confirm these results. Valmaseda-Castellon et al. (2001) found that only the deflection of the mandibular canal was significantly associated with IAN injury, Tantanapornkul et al. (2007) identified that only the interruption of the canal wall was significant. Nakagawa et al. (2007) stated that the absence of the superior canal wall on the panoramic images demonstrated direct contact between the third molar roots and the mandibular canal, whereas Susarla et al. (2004) found none of the panoramic radiographic signs to be associated with increased risk of IAN injury. Darkening of the root was defined by Bundy et al. as follows: this radiographic sign occurs as a result of intimate contact between the

tooth and canal causing radiographically evident loss of tooth root density. Öhman et al. stated that a dark band is an indicator of grooving of the tooth by the canal, although it can be present without this radiographic sign. However Tantanapornkul et al. stated that this sign reflects cortical thinning or perforation of the lingual cortical plate (in 80% of the cases) rather than grooving of the tooth (occurring in just 20% of the cases). Several authors demonstrated previously, that cases when two or more signs are simultaneously present on panoramic radiographs, it will result in an increased risk for IAN exposure or injury, whereas the significance of a different combination of these signs was not investigated before. The present study suggests that darkening of third molar root together with adjacent “high risk” signs carries the highest risk for IAN exposure, significantly more than the darkening of a single root or when other “high risk” signs are together without darkening of the root. Our findings correlate with Tantanapornkul et al’s conclusions: when ≥ 1 adjacent “high risk” signs were present with root darkening, IAN exposure might be predicted despite the fact that darkening was the only the sign of lingual cortical perforation.

Ph.D. THESES

1. The determination of „high-risk” specific signs and their relation with IAN paresthesia.

- According to our multivariate adjusted regression analyses we determined three of the classic “high-risk” signs strongly related to IAN paresthesia: *interruption of the superior cortical line of the IAC, narrowing of the canal and darkening of the third molar root.*
- Bivariate and multivariate analyses showed clearly that the strongest sign is the darkening of the root, based on univariate and multivariate odds ratios, sensitivities, specificities and predictive values.

2. The determination of adjacent “high-risk” markers of panoramic radiography.

- We proved that the preoperative examination of root curvature and the degree of root tip-inferior alveolar canal (IAC) overlap can help the preoperative risk assessment by calculating the possible chance of IAN paresthesia.

3. The diagnostic value of the darkening of the root “high-risk” sign.

- We proved that the combination of different “high-risk” markers is significant; moreover we demonstrated that the combination of darkening of the root with other “high-risk” markers is significantly the strongest sign. We suggested that the darkening of the root sign should be divided, classified into single and multiplex forms.

4. The cumulative diagnostic and predictive value of panoramic radiography in the prediction of IAN paresthesia.

- According to our research results we can conclude that the relatively low positive predictive values of “high-risk” signs indicate panoramic radiography for an inadequate diagnostic method predicting IAN paresthesia after mandibular third molar surgery. However the preoperative analysis of PRs seems to be mandatory.

ABBREVIATIONS

95%CI: confidence interval

CT: computed tomography

CBCT: cone beam computed tomography

IAC: inferior alveolar canal

IAN: inferior alveolar nerve

NPV: negative predictive value

OR: odds ratio

PPV: positive predictive value

PUBLICATIONS

PUBLICATIONS RELATED TO THE Ph.D.THESIS

1. **SZALMA J**, LEMPEL E, JEGES S, SZABÓ G, OLASZ L: The Prognostic Value of Panoramic Radiography of Inferior Alveolar Nerve Damage after Mandibular Third Molar Removal. Retrospective study of 400 cases. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010; 102: 294-302. **IF₂₀₀₉ 1.499**
2. **SZALMA J**, LEMPEL E, JEGES S, OLASZ L: Darkening of Third Molar Roots: Panoramic Radiographic Associations with Inferior Alveolar Nerve Exposure. *J Oral Maxillofac Surg* 2011.február 1. [Epub ahead of a print] doi:10.1016/j.joms.2010.09.009 **IF₂₀₀₉ 1.58**
3. **SZALMA J**, OLASZ L: Response to "Localization of mandibular canal by buccal object rule". *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010; 109: 799-800. (letter to the editor) **IF₂₀₀₉ 1.499 x ¹/₄**
4. **SZALMA J**, LEMPEL E, CSUTA T, BÁRTFAI D, JEGES S, OLASZ L: The effect of the extent of root curvature and inferior alveolar canal-root tip overlap to the risk assessment after mandibular third molar surgery. *Fogorv Szle*. 2010; 103: 43-48.
5. **SZALMA J**, LEMPEL E, CSUTA T, VAJTA L, JEGES S, OLASZ L: The specific panoramic radiographic signs and their relation with inferior alveolar nerve injuries after mandibular third molar surgery. *Fogorv Szle*. 2011; 104: 27-33.

PUBLICATIONS INDEPENDENT FROM THESIS

1. LEMPEL E, **SZALMA J**, JEGES S, KENDE D, KRAJ CZÁR K, NAGY ÁK, TÓTH V: Direkt kompozit restaurációk retrospektív vizsgálata USPHS kritériumrendszer alapján. *Fogorv Szle*. 2011. (accepted)
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1. **Szalma J**, Lempel E, Csuta T, Nyárady Z, Jeges S, Olasz L: The Effect Of The Extent Of Root Curvature And Inferior Alveolar Canal-Root Tip Overlap To The Risk Assessment After Mandibular Third Molar Surgery. J Craniomaxillofac Surg 2010; 36: 211 **IF 1.36**
2. **Szalma J**, Böddi K, Lempel E, Szabó Z, Nyárady Z, Olasz L, Takátsy A: Protein Identification From Submandibular Salivary Stones With Maldi-Tof Mass Spectrometry. J Craniomaxillofac Surg 2010; **IF 1.36**
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Oral presentations

- A „gyökér-sötétedési” jel szerepe a nervus alveolaris inferior sérülések várható megítélésében alsó bölcsességfog eltávolításakor

A Magyar Arc-, Állcsont- és Szájsebészeti Társaság XIV. Nemzeti Kongresszusa, Előadás, 2010. szeptember 30. Kecskemét
- Macroscopical, biochemical and ultrastructural analysis of submandibular sialoliths: scanning electron microscope and maldi-tof/ms examination

7. Nemzetközi Danubius Szájsebészeti Konferencia és a Magyar Arc-, Állcsont- és Szájsebészeti Társaság XII. Nemzeti kongresszusa, Előadás, 2008.október 16-18. Budapest (Awarded by *Dr. Béres Károly Alapítványi Díj III.place*)
- Bölcsességfog eltávolítás idegsérülés szövödményei

A Magyar Arc-, Állcsont- és Szájsebészeti Társaság XI. Nemzeti Kongresszusa, Előadás, 2007. november 30. Balatonalmádi (Awarded by *Dr. Béres Károly Alapítványi Díj III. place*)

- Az implantációs kezelési terv nehézségei
Előadás, MFE Fogpótlástani Társaság XVII., a Magyar Fogorvosok Implantológiai Társaságának VII. és a Magyar Parodontológiai Társaság XV. Közös Fogászati Kongresszusa, Szent-Györgyi Albert 70 éve elnyert Nobel díja emlékére, Előadás, Szeged, 2007. október 11-13.
- Számfeletti fogak eltávolításával szerzett tapasztalataink
MFE Gyermekfogászati és Fogszabályozási Társaság XIX. Symposium III. Tóth Pál Vándorgyűlés, Előadás, Pécs - 2007. október 4-6.
- Bölcsességfog eltávolítások idegsérülés szövődményei
Előadás, DENTAL 2007. Budapest, Stefánia Palota. 2007. szeptember 6.-7.-8.
- Sialoadenitises és sialolithiasisos betegek követéses vizsgálata során szerzett tapasztalatok.
Retrospektív klinikai vizsgálat.
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