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Original Article

Use of CBCT and panoramic radiography in the prediction of alterations in sensivity of the inferior alveolar nerve in third molars: A retrospective cross-sectional study

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ABSTRACT

Objectives: We investigated which type of orthopantomography (OPG) was best able to predict neurological alterations of the inferior alveolar nerve (IAN) during extraction of a lower third molar (3 M).

Methods: We analysed cone beam computed tomographies (CBCTs) that were performed at a private dental clinic in Cartagena, Spain over five consecutive years. The CBCTs, together with their corresponding OPGs, had been prescribed for the surgical extraction of a lower 3 M.

Results: We analysed a total of 342 CBCTs and their corresponding OPGs. After explaining the risk of changes in the IAN sensitivity, 37 patients refused to undergo surgical extraction. The incidence of sensitivity alterations in the 332 dental extractions was 62 (19%): 44 were paraesthesias of the IAN, and 18 were associated with darkening of the root and interruption of the cortical line.

Conclusion: When an OPG revealed darkening of the root and interruption of the cortical line, the risk of contact between the lower 3 M and the IAN—that is, the probability of changes in IAN sensitivity—increased by over three-fold.

1. Introduction

Precise imaging techniques such as cone beam computed tomography (CBCT) are often used in dentistry today (Choi et al., 2022). However, not all professionals have access to such techniques; access often depends on dentists' resources and the geographical region in which they work.

In addition, orthopantomography (OPG) is still being used in dentistry; many studies have analysed the quantity and quality of information provided by OPG (Vinayahalingam et al., 2019, Choi et al., 2022).

The extraction of the third molars (3Ms) is one of the most frequently performed surgical procedures (Del Lhano et al., 2020). When deciding whether to remove or preserve the 3Ms, it is essential to assess the risks and benefits of the procedure (Goyal et al., 2012; Huang et al., 2014).

One of the most important complications that can occur during the extraction of a lower 3 M is injury to the inferior alveolar nerve (IAN) (Agrawal et al., 2014). Neurosensory alterations of the IAN and/or a prolonged sensory deficit in the jaw, chin and lower lip on the affected side may ensue; these effects can be temporary or permanent (i.e., persisting for more than 6 months) (Bui et al., 2003, Kalantar Motamedi et al., 2015). The prevalence of temporary IAN lesions varies between 0.4 % and 8.4 % (Morant, 2000; Patel, 2009; Malkawi et al., 2011); the prevalence of permanent IAN lesions is around 1 % (Malkawi et. al, 2011). To avoid such complications, it is critical to preoperatively establish the relationship of the IAN with the mandibular canal (MC).

Abbreviations: 3M, third molar; CI, confidence interval; CBCT, cone beam computed tomography; CT, computed tomography; IAN, inferior alveolar nerve; MC, mandibular canal; OPG, orthopantomography; PPV, positive predictive value; NPV, negative predictive value.

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Radiological imaging is essential for diagnosis and surgical management; it allows the surgeon to evaluate the difficulty of the surgery and select the most appropriate technique (Rood & Shehab, 1990). Orthopantomography is the technique of choice to evaluate impacted lower 3Ms and to estimate the preoperative risk of IAN injury associated with a lower 3 M extraction (Patel, 2009; Del Lhano et al., 2020). It provides information about the degree of impact, the inclination, and the root morphology of lower 3Ms; it also highlights the spatial relationship of the 3Ms with the MC. (Del Lhano et al., 2020). However, OPG only provides this information in the sagittal plane. The 3 M, as well as the IAN, are likely to be contained within the most sharply rendered layer in imaging. Koong et al. (2006) described commonly observed features in OPG that can be used assess the relationship between the IAN and the lower 3Ms. Such features include a radiolucent band, loss of the mandibular border, changes in MC direction, MC narrowing, root narrowing, root deviation, bifid apex, a superimposed MC and a contact MC (Koong et al., 2006). These radiographic signs may be statistically associated with a higher frequency of the IAN injury during the removal of the lower 3Ms and are currently widely used for assessing the risk of neurological injury (Atieh, 2010; Palma Carrió et al., 2010; Kim et al., 2012; Huang et al., 2015; Liu et al., 2015; Su et al., 2017).

The association between these radiographic features and the proximity of the 3 M root apex to the MC can be confirmed using the three-dimensional images of CBCT. Such imaging provides information about the distance between the IAN and the lower 3 M root apex (Neves et al., 2012). However, changes in the prediction of paraesthesia are minimal when practitioners analysed images in two dimensions (2D) (OPG) and three dimensions (3D) (CBCT); the data varied only from 7.7 % to 9.7 % (Mendonça et al., 2021).

The purpose of this study was to establish which type of OPG imaging is best at predicting a neurological injury of the IAN during the extraction of a lower 3 M. We hypothesized that OPG alone would allow practitioners to predict the risk of IAN injury during the extraction of a lower 3 M.

We also estimated the clearest OPG image—that is, the one that conferred the highest probability of IAN sensitivity changes.

2. Material and methods

2.1. Study design and sample

This retrospective, observational, and epidemiological study encompassed two years' worth of observations. We analysed all the CBCTs that had been performed at an oral surgery unit at a private dental clinic in Cartagena, Colombia between January 1st, 2020 and December 31st, 2022.

The study population included all disease-free patients aged 18 years or older who had received CBCT prior to the extraction of a lower 3 M. All of the patients had furthermore undergone OPG, which had revealed limited room between the root apex and the MC.

2.2. Variables

We analysed the OPGs and CBCTs of the patients. According to the criteria of Koong et al. (2006), the primary predictor of neurosensory alterations OPGs is the relationship between the root apex and the MC (IAN). The second primary predictor is close physical relationship with contact between the roots and the MC (IAN) in CBCT.

Using the patients' clinical histories, we also noted whether there had been an alteration in sensitivity (or another variable) of the IAN after a surgical intervention, the type of alteration, and its duration. Other demographic and clinical variables that we collected included patient gender, age and the degree of surgical complication. The last variable was estimated according to the protocol of Koerner (1994).

Given that this investigation was a retrospective study, the Ethics Committee of the University of Murcia ruled that ethical approval was not necessary.

2.3. Data-collection methods

The CBCTs that revealed a physically close association between the lower 3 M and the MC (IAN) and possible nerve alteration after extraction of the lower 3 M were included in this study.

Two experienced and masked observers participated in this study (JARR and JRM). The observers' decisions were congruent, on average, 89 % (*kappa* = 0.67) of the time.

2.4. Data analyses

We used inferential statistics to determine the diagnostic capacity of OPG alone. We used diagnostic indices of sensitivity and specificity; we also calculated positive and negative predictive values (PPVs and NPVs, respectively). The CBCT data were treated as a "gold standard.".

To determine the effect of demographic and clinical variables on predictions of the onset of nerve paraesthesia, we used a multivariate logistic regression model. A confidence level of 95 % was assumed; we presumed statistical significance for p values less than 0.05. We used the Statistical Package for the Social Sciences version 28.0 (SPSS® Inc., Chicago, IL, USA) for MS Windows.

3. Results

We initially obtained a total of 444 CBCTs spanning two years. After eliminating those that did not meet the inclusion criteria, three hundred and five of those CBCTs were analysed, along with their corresponding OPGs, to assess the apex relationship of the lower 3 M with the MC of 332 lower 3Ms that were surgically extracted (305 CBCTs for 332 dental extractions) (Fig. 1). Those 305 CBCTs were requested because practitioners, after seeing the OPG, suspected an intimate relationship between the lower 3 M apex and the MC. Twice as many women as men underwent surgery (66.3 % versus 33.7 %), The mean age of the patient cohort was 33.4 ± 5.2 years, and the patients ranged in age from 18 to 75 years.

The extractions, according to the Koerner Difficulty Index (Koerner, 1994), were of moderate (5–6) or high complexity (7–10) in 42.1 % and 42.5 % of cases, respectively.

Of all of the OPGs, 37 % exhibited the "change in MC direction" issue noted by Koong et al. (2006); 33 % exhibited the "darkening of the root and interruption of the cortical line" issue noted by the same authors.

Eighty-nine out of the 332 CBCTs revealed not close potential contact between the IAN and the root apexes. The remaining images (243; 73.2 %) exhibited intimate contact (0 mm); the IAN was lingual to the lower 3 M in most cases (30.1 %) (Fig. 2).

There were no neurological lesions visible in 270 out of 332 extractions (81.3 %). In the 62 cases of sensitivity alteration, 44 paraesthesia (71 %) and 9 hypoesthesias (14,5%) stood out. from the IAN. Of the 44 patients with paraesthesia, we found that 16.8 % exhibited image darkening of the root and interruption of the white line of the canal after doing a logistic regression model. Additionally, 7.7 % of cases were associated with image divergence of the MC in the OPG.

The images characterised as "darkening of the root and interruption of the cortical line" tended to correspond to longer-lasting cases of paraesthesia (mean duration: 78.9 ± 31.1 days). There were no permanent neurological injuries.

The CBCT images that exhibited a close proximity between apices of the lower 3 M and the IAN corresponded to cases that exhibited over a three-fold higher likelihood of sensitivity alterations ($p < 0.001$) (Table 1). In 46.4 % of cases in which CBCT was requested, the apex relationship of the lower 3 M with the MC was confirmed. That relationship had already been suspected in the OPG data.

When an image with darkening of the root and interruption of the white line of the canal in an OPG was observed, we noted that the risk of

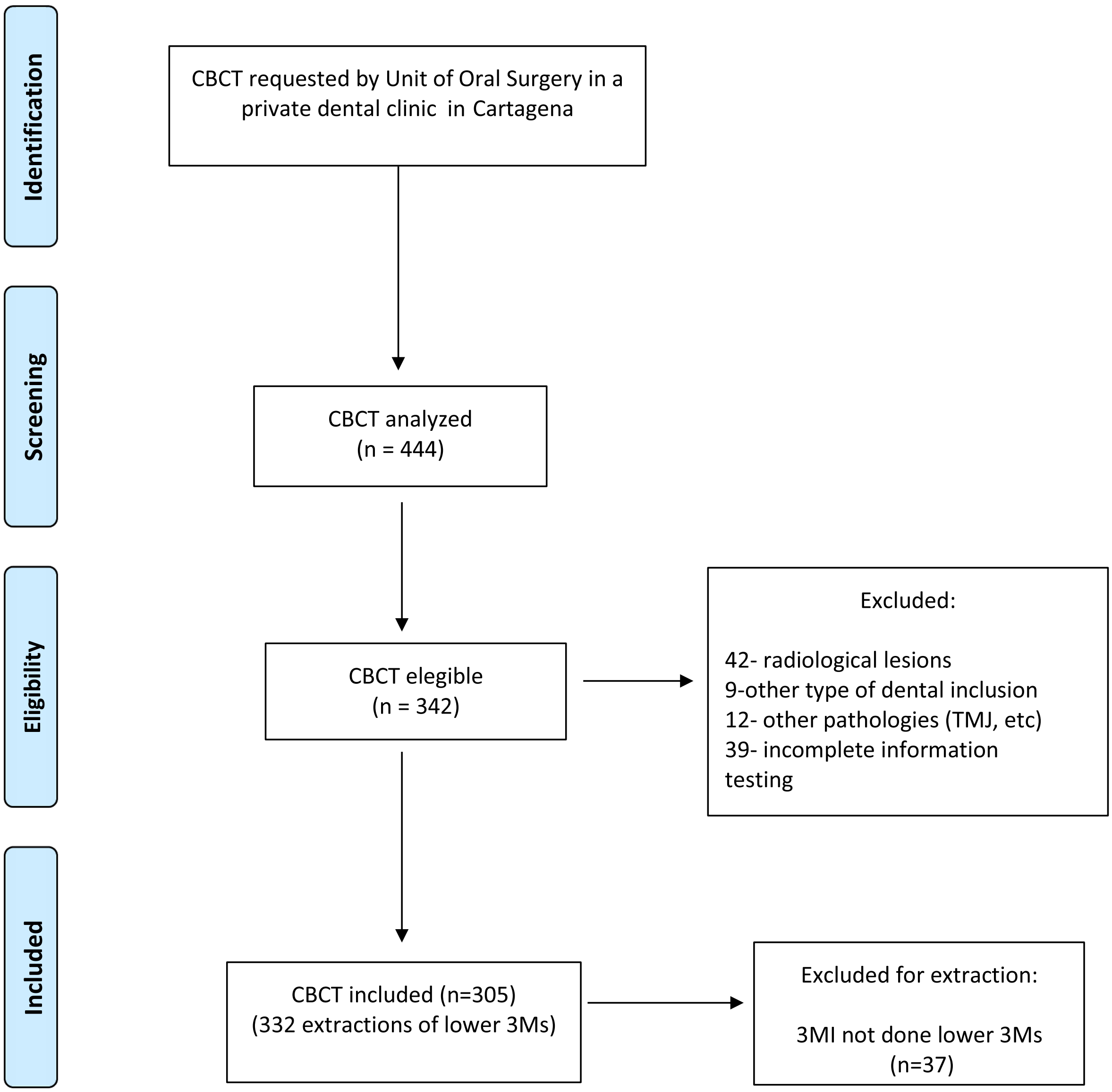

Fig. 1. Flowchart.

contact between the root and the MC in the CBCT increased (odds ratio = 3.07). In other words, the probability of an alteration in the sensitivity of the IAN after lower 3 M extraction in the image was 3.07 times higher than in other types of images ($p = 0.008$) (Table 1).

Table 2 lists the diagnostic validity indices (sensitivity, specificity, and predictive values) with their 95 % confidence intervals for the apex relationship of the lower 3 M-MC for the CBCT data. We achieved a sensitivity of 81.2 % and a specificity of 33.2 %.

4. Discussion

It is critical to preoperatively evaluate the relationship between the lower 3 M and the IAN. The probability of triggering an alteration in the sensitivity of the IAN after the extraction of a lower 3 M in over three times higher in cases with OPG imaging revealing darkening of the root and interruption of the cortical line. When CBCT reveals apices of the lower 3 M in close proximity to the MC, there is a 3.29-fold higher probability for an alteration in sensitivity after extraction of the lower 3 M.

Some authors have noted that females are less likely to suffer from postoperative paraesthesia. However, other teams have noted no statistically significant relationship between gender and the incidence of postoperative paraesthesia (Leung and Cheung, 2011; Szalma et al., 2012); the same is true for our study ($p = 0.073$). Queral et al. (2005) noted a statistically significant relationship ($p < 0.05$) between patient age and the risk of IAN injury. Tay et al. (2004) suggested that the risk of paraesthesia increases by 6.9 % with each one-year increase in patient age. However, we did not find any statistically significant relationship between age (starting at roughly 25 years old) and the risk of suffering nerve damage ($p = 0.309$). That finding is similar to the results of other studies (e.g., Patel, 2009; Pogrel, 2012).

Several clinical investigations have determined specific radiographic features in OPGs that suggest a close relationship between the apex of the lower 3 M and the IAN (Rood and Shehab, 1990, Queral-Godoy et al., 2005). In our study, the most common radiological finding “change in MC direction” was present in 37 % of cases; Valmaseda et al. (2001) concluded that there was a close radiological relationship between the MC and the roots of the lower 3 M in 50.3 % of cases. Those authors noted that the most frequent image type was “loss of mandibular border,” followed by “changes in MC direction.” This finding is consistent with the results of Rood and Shebab (1990), who showed that these two features are associated with IAN lesions. Rood and Shebab (1990)

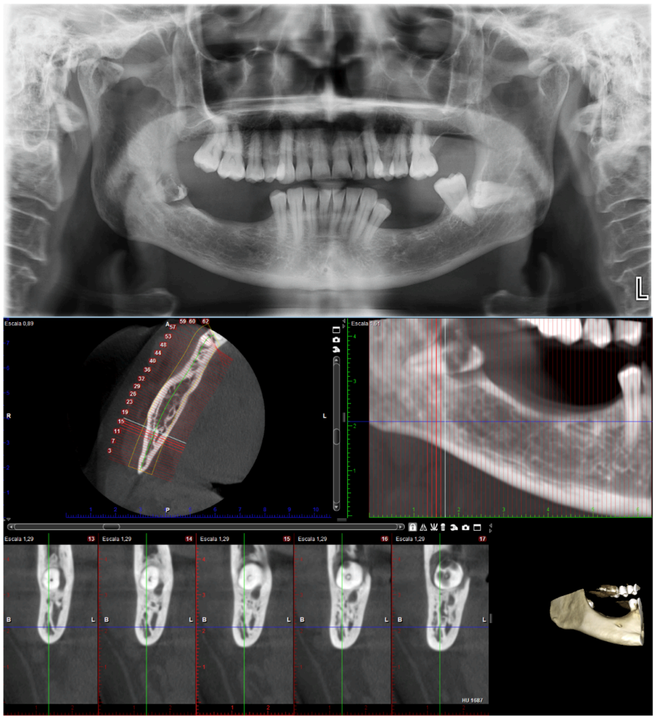

Fig. 2. Root apex lower 3 M-IAN relationship in the OPG and CBCT.

Table 1
Primary and secondary variables. Logistic regression results. Chi-square model = 16.68, df = 8, p = 0.033, Nagelkerke R2 = 0.25. CI: confidence interval; MC: mandibular canal.

	Odss ratio	CI 95 %*	*p*-value
Gender (men versus women)	1,76	0,95—3,25	0,073
Age	1,01	0,99–1,04	0,309
Koerner Difficulty Index	0,95	0,78–1,14	0,552
CBCT (Yes versus No)	**3,29**	1,74–6,23	< **0,001**
Relationship IAN-MC			
Root narrowing	1,59	0,75—3,05	0,641
Change in mandibular canal direction	1,23	0,51—2,99	0,646
Darketing of the root and interruption of the cortical line	**3,07**	1,34—7,07	**0,008**

Table 2
Diagnostic validity indices Logistic regression results. Chi-square model = 16.68, df = 8, p = 0.033, Nagelkerke R2 = 0.25. CI: confidence interval at 95 %.

	CBCT		
	Positive	**Negative**	**TOTAL**
Positive	125	119	244
Negative	29	59	88
Total	154	178	332
	Value	**CI (95 %)**	
Sensibility (%)	81,2	74,7	87,7
Especificity (%)	33,2	25,9	40,3
Positive predictive value (%)	51,2	44,7	57,7
Negative predictive value (%)	67,1	56,7	77,4

noted altered lip sensitivity in 8.8 % of interventions in which this feature was detected. On the other hand, Winstanley et al. (2008), Ghai and Choudhury (2018), and Saha et al. (2019) argued that the "darkening of the root and interruption of the cortical line" feature (i.e., the combination of the "loss of white line of MC" and the "radiolucent band" features) was the most predictive of contact between the lower 3 M and the MC. Valmaseda et al. (2001) noted statistically significantly more paraesthesia in cases in which the MC and the apices of the lower 3 M touched compared with cases that do not feature such touching. Those researchers reported an odds ratio of 6.38; we noted an odds ratio of 3.07, specifically for the feature "darkening of the root and interruption of the cortical line.".

The prevalence of sensory alterations of the IAN after extraction of the lower 3 M was lower than that of the lingual nerve; the prevalence of lingual nerve sensory alterations has been reported to vary between 0.15 % (Barone et al., 2019) and 23 % (Patel, 2009; Charan et al., 2013). The prevalence of the temporary IAN injury varies from 0.4 % to 8.4 % in the literature (Patel, 2009; Agrawal et al., 2014; Barone et al., 2019). We noted a prevalence of 15.6 %, however.

Some authors have reported that permanent sensitivity alterations of the IAN (i.e., lasting more than 6 months) occurred in 0.5–1 % of cases (Blaeser et al., 2003; Phillips et al., 2003); Valmaseda et al. (2001) reported a rate of 1.3 %. Queral et al. (2005) noted an injury rate of 1.1 %. Of those injuries, 2 % were anaesthesia, 16 % were dysesthesia, and 82 % were hypoesthesia. In half of cases, remission occurred after six months.

Orthopantomography has a relatively low sensitivity (ranging from 24–38 %) and a relatively high specificity (ranging from 96–98 %) for predicting nerve injury (Rood & Shehab, 1990; Barone et al., 2019). Matzen and Wenzel (2015) concluded that both computed tomography and CBCT were more accurate methods than OPG for diagnosing a contact relationship between the 3MI and the MC.

Rodriguez et al. (2017) suggested that in cases where proximity is observed in OPG between the lower 3 M and the IAN and the integrity of the cortical bone of the MC cannot be observed, CBCT is indicated. Cone beam computed tomography reveals the three-dimensional relationships between anatomical structures without overlaps (Ghaeminia et al., 2009; Tantanapornkul et al., 2009; Umar et al., 2013).

After verifying the true orientation of the IAN after lower 3 M removal surgery, Hasani et al. (2017) found that contact had been previously correctly diagnosed in 67.7 % of OPG cases and in 93.3 % of CBCT cases.

On the other hand, Petersen et al. (2016) found no statistically significant differences in neurosensory alterations in patients previously evaluated with OPG or CBCT. Many authors have noted that contact between a lower 3 M and the MC can be observed equally well in 2D and 3D images (Ghaeminia et al., 2011; Guerrero et al., 2012; Guerrero et al., 2014; Mendonça et al., 2021).

Mendonça et al. (2021) noted that the decision to extract lower 3Ms was not affected by the availability of OPG compared with CBCT. Those authors did state, however, that the availability of imaging alters indications for intraoperative procedures such as osteotomies or crown sections. Having CBCT imaging data available therefore does not reduce the probability of causing temporary nerve paraesthesia. However, neurosensitive disturbances but may be independent of the presence of radiological features due to errors in surgical technique (e.g., rotation during dislocation, rotating instruments, etc.) (Kipp et al., 1980; Leung and Cheung, 2011). On the other hand, it is possible that no nerve injury may occur, even in the presence of features indicating a close proximal relationship between the 3 M and the MC (Ghaeminia et al., 2011) because the radiological features of such proximity do not always indicate IAN intraoperative exposure. Such exposure is considered by many authors to be one of the primary factors increasing the risk of paraesthesia. Exposure of the neurovascular bundle has also been linked to the location of the MC (Ghaeminia et al., 2011, Ghai and Choudhury, 2018).

Ghai and Choudhury (2018) defined the most common location of the IAN in CBCT data as being inferior in 47.2 % of cases. Those same authors also noted a vestibular position in 26.4 % of cases, which is consistent with our results. Similarly, Ghaeminia et al. (2011) reported a higher incidence of nerve injury when the MC was located lingually to a lower 3 M. Better et al. (2004) noted that the information provided by CBCT did not affect either the treatment plan or the surgical technique.

Surgeons who only have OPG data available for treatment planning should be more careful during the surgical procedure; there are limitations of two-dimensionality and image overlays (Del Lhano et al., 2020). However, some studies, for example, Ghaeminia et al. (2011) and Eyrich et al. (2011), have suggested that the additional information provided by CBCT could change the surgical approach and thereby help prevent IAN injury.

The presence of a close physical relationship between the roots of a lower 3 M and the MC necessitates care. Periodic radiographic reviews and modifications to the direction of dislocation can help prevent the apices from rotating and traumatising the IAN (Ghaeminia et al., 2009); a coronectomy can also be conducted to prevent damaging the IAN (Commissionat and Roisin-Chausson, 1995). Commissionat and Roisin-Chausson (1995) advocated performing a coronectomy in order to avoid eliminating the apices. Matzen and Wenzel (2015) increased the number of coronectomies when faced with CBCT data and reported a larger number of cases of paraesthesia when only 2D examinations were available.

We recorded PPVs and NPVs of 51.2 % and 67.1 %, respectively. However Hang et al. (2015) and Su et.al. (2017) reported PPVs ranging from 7.5 to 37.X% and NPV ranging from 3.1–97.7 %. The presence of risk indicators in radiographic imaging is not a good predictor of damage, however, given the low incidence of nerve injury, even in elderly patients with radiographic features of risk (Liu et al., 2015; Su et al., 2017).

5. Conclusions

We have highlighted the potential role of OPG, alone or in concert with CBCT, as a diagnostic tool to preoperatively evaluate the position of a lower 3 M and its physical relationship with the MC.

When we observed darkening of the root and interruption of the cortical line in OPG data, we noted an increased risk of contact between the root and the IAN compared with cases imaged with CBCT. The probability of altering the sensitivity of the IAN after an extraction of a lower 3 M with imaging that revealed darkening of the root and interruption of the cortical line was over three-fold higher in OPG imaging compared with other types of images. In particular, we found that 16.8 % of cases of nerve paraesthesia were associated with OPG images that reflected darkening of the root and interruption of the cortical line. We found that 7.7 % of cases of nerve paraesthesia were associated with OPG images that reflected changes in MC direction.

Orthopantomography data have a high diagnostic validity (sensitivity, specificity, and predictive values) when it comes to correctly diagnosing the risk of nerve injury. Such data have a sensitivity of 81.2 % and a specificity of 33.2 %. When CBCT imaging reveals apices of a lower 3 M close to the MC, there is a 3.29-fold higher probability that an alteration in sensitivity will manifest after the extraction of the lower 3 M.

Use of artificial intelligence

Not applicable.

Funding

Not applicable.

Ethical statement

This work have been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

This work meets all the ethical requirements required for scientific work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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