Migration of the root complex after coronectomy occurs within the first year after surgery: a 5-year radiographic analysis and protocol suggestion

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Objectives. Currently, there are no studies evaluating the radiographic follow-up protocol after coronectomy. This study aims to assess root migration after coronectomy of mandibular third molars in panoramic images taken 1, 3 and 5 years after surgery.

Study Design. This was a prospective cohort study of patients undergoing coronectomy of a mandibular third molar. The patients followed a 5-year follow-up regimen with panoramic examinations at 1, 3 and 5 years after the surgical intervention. Three observers assessed the panoramic images in a blinded randomized order to evaluate bone coverage; superimposition of the roots and the mandibular canal; and migratory changes of the roots. Descriptive statistics were used to describe changes. Furthermore, reproducibility among the observers was calculated.

Results. Sixty-two patients were included. Ingrowth of bone superior to the root complex during the first year was registered by all observers (observer 1: 100%; observer 2: 77.4%; and observer 3: 85.5%). Superimposition of the mandibular canal and the root complex in the panoramic images taken in the immediate postoperative period and after 1 year showed that 53.2% to 62.9% went from superimposition to no superimposition. Interobserver reproducibility was high.

Conclusions. Migration of the root complex occurs primarily within the first year after coronectomy. Therefore, a routine radiographic follow-up after 1 year only is recommended. (Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:357−365)

Coronectomy of mandibular third molars involves removal of the crown, leaving the root complex in the alveolar bone. With regard to long-term morbidity, this procedure is reported to be safe when a mandibular third molar is observed to be closely associated with the mandibular canal.[1-16] In particular, studies have found that coronectomy of a mandibular third molar was superior to complete removal with regard to frequency of inferior alveolar nerve (IAN) injury.[14] Additionally, studies have found that the most common morbidities encountered after coronectomy were infections, root exposure, need for reoperation, and migration of the root complex.[6,8,14,15] There is extensive literature on the morbidities related to clinical outcomes, such as nerve injury, infections, and reoperation, whereas migration of the root complex has not been fully elucidated. Furthermore, there seems to be no evidence-based radiographic protocol for postoperative control of the root complex.

Migration of the root complex is not a genuine complication of the coronectomy procedure but rather, a consequence of the natural eruption forces of the tooth when coronal resistance is removed.[17] However, migration of the root complex can necessitate intervention if it is exposed to the oral cavity. Therefore, the extent and pattern of the migration over time is important to understand, and consequently, if removal of the root complex is needed, the actual relationship between the root complex and the mandibular canal would be of interest. Previous studies have described an overall migration away from the mandibular canal at various time points, ranging from 1.6 mm to 4.0 mm.[1,2,4,12,18-21] The frequency of migration in these studies ranged from 13.2%[1] to 97%.[15] The migration analysis performed with a linear distance in the previous studies did not consider the rotation of the root complex, which was observed in the study by Pedersen et al., who reported a frequency of 65%.[15] A rotational movement induces an additional change in the relationship between the reference points of interest and thus complicates the analysis of the overall migration of the root complex. However, previous reports agree that most migration probably occurs within the first postoperative year; however, only 1 longitudinal study has been performed to investigate this.[21]

The purpose of the study was to perform an unbiased evaluation of root migration observed as changes in position after coronectomy of mandibular third molars comparing panoramic images taken 1, 3 and 5 years

Statement of Clinical Relevance

Currently, there are no guidelines for radiologic follow-up after coronectomy. It is important to know the potential morbidities after coronectomy to offer the patient optimal care and to avoid unnecessary restrictions.

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Received for publication Feb 2, 2019; returned for revision Mar 25, 2019; accepted for publication Apr 22, 2019.

2212-4403/$-see front matter
https://doi.org/10.1016/j.oooo.2019.04.013

after surgery to suggest and evaluate a radiographic protocol. We hypothesized that migratory movement would mainly occur during the first year after surgery and that the variables used for assessment of root migration were reproducible among observers.

MATERIALS AND METHODS

Study design

To address the research purpose, we designed and implemented a prospective follow-up study. The study population consisted of 62 patients undergoing coronectomy of mandibular third molars at the Section of Oral Surgery and Oral Pathology, Department of Odontology and Oral Health, Aarhus University (Aarhus, Denmark) between 2005 and 2012.

Study sample

To be included in the study sample, 3 inclusion criteria had to be met: (1) indication for removal of a mandibular third molar,[22] (2) history of a coronectomy of the mandibular third molar, and (3) follow-up within the 5-year standard follow-up program at the department.

All patients had a panoramic image taken if the clinical examination indicated a need for removal of a mandibular third molar. If the panoramic image indicated a close association between the roots of the third molar and the mandibular canal, according to the criteria suggested by Rood and Shehab,[23] cone beam computed tomography (CBCT) was performed with a Scanora 3-D unit (Soredex, Helsinki, Finland) with 6×6 field of view and 0.133 resolution. If there was no bony separation between the roots of the third molar and the mandibular canal observed on CBCT, or a critical position of the mandibular canal was identified, we decided to perform a coronectomy according to the method described by Pedersen et al.[15] Postoperatively, the patients followed a 5-year follow-up regimen: a panoramic examination was performed on the day of surgery to confirm the desired result of the coronectomy. Subsequently, panoramic examinations were performed 1, 3 and 5 years after the surgical intervention. Thus, the total number of panoramic images analyzed in the present study was 248 (4 for each patient). The images were segmented panoramic images performed with a ProMax unit (Planmeca, Helsinki, Finland) with a charged coupled device−based image receptor.

Study variables

Three observers (M.H.P., L.H.M., and L.H.P.) assessed the 248 panoramic images in a blinded randomized order by using high-quality monitors in a dimmed light room. The 3 observers were calibrated on the basis of a discussion of 20 cases (not included in the present study). The following parameters were used as primary outcome variables to assess root migration: superimposition between the root complex and the mandibular canal (yes/no); position of the mesiocervical and the distocervical part of the root complex; and the mesial and distal apex was assessed, with the alveolar crest and the mandibular canal as the reference structures: superior to the alveolar crest; in contact with the alveolar crest; less than 1 width of the canal superior to the upper border of the mandibular canal; $^1/_2$ to 1 width of the canal superior to the upper border of the canal; 0 to $^1/_2$ width of the canal superior to the upper border of the canal; touching the upper border of the canal; located in the upper half of the canal; located in the lower half of the canal; touching the lower border of the canal; or inferior to the canal) (Figure 1). If only 1 root component was present, the registrations were performed for 1 root apex. Finally, presence of bone superior to the root complex (yes/no) and presence of radiolucency in relation to the root complex (yes/no) were assessed.

Data collection methods

Data were collected and registered in the REDCap[24] electronic data capture tools hosted at Aarhus University and imported to STATA (*Stata Statistical Software: Release 14, 2015*. Stata Corp., College Station, TX). Data were decoded into the 4 time points: immediate postoperative period and 1, 3 and 5 years postoperatively.

Data analyses

Descriptive statistics were used to assess if there was a change in superimposition between the root of the third molar and the mandibular canal; change in position of the mesiocervical part, the distocervical part, the mesial apex, and the distal apex to assess the migration pattern of the root complex. Moreover, descriptive statistics were used to assess if there was a change in bone superior to the root complex and if there was presence of radiolucency around the root complex. This was performed for all observers for all periods: (1) from immediate postoperative period to 1 year control, (2) from 1 year to 3 years control, and (3) from 3 years to 5 years control. Reproducibility among observers was calculated and expressed pairwise as percentage accordance.

RESULTS

A total of 62 patients were included in the study (23 males and 39 females; mean age 28.6 years; range 16.7−41.1 years). In 33 cases, the left-side third molar was treated and in 29 the right side.

As shown in Table I, the majority of changes in superimposition between the root of the third molar and the mandibular canal occurred during the first year. It appeared that the root complex erupted in a coronal direction and was seen as superimposition between the root complex and mandibular canal postoperatively and that there was no superimposition at later time points. Observer 1 had 60 cases with superimposition between the third molar and

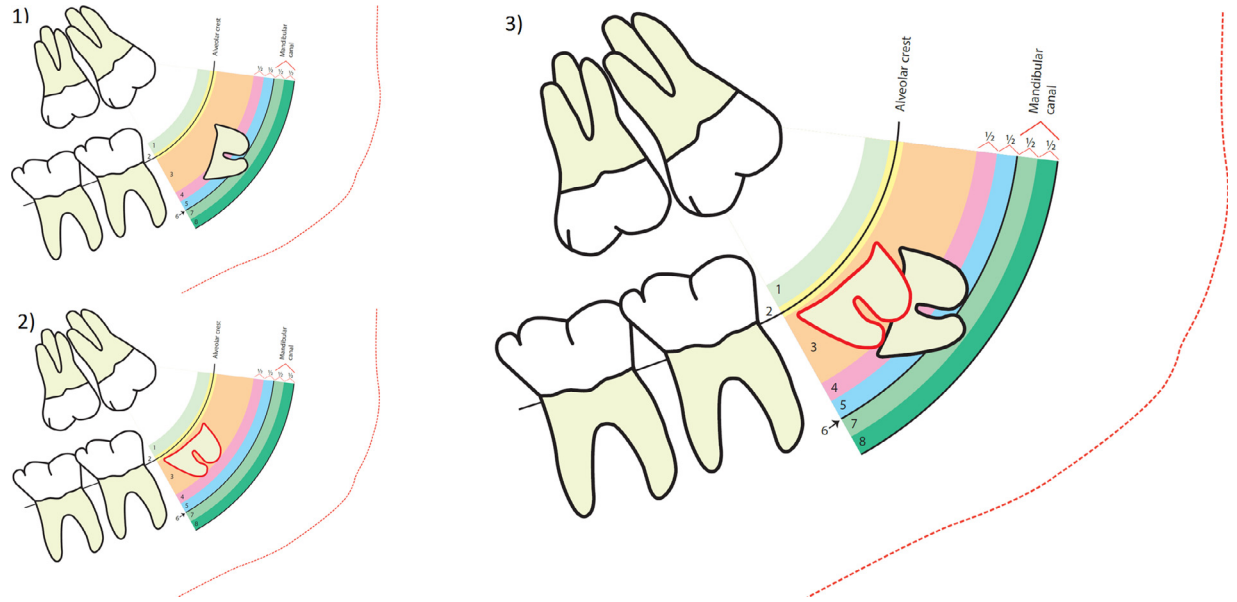

Fig. 1. Example of the position of the root complex postoperatively (1) and at the 5-year follow-up (2). Part 3 shows the superimposition of the 2 situations. The colored bands illustrate the possible areas in which the root complex could be positioned for the cervical as well as the apical points.

the mandibular canal postoperatively (96.7%). At the first follow-up, 23 had superimposition (37.1%). Observer 2 had 58 (93.5%) cases with superimposition postoperatively and 29 (46.8%) at the first follow-up. Observer 3 had 57 (91.9%) cases with superimposition postoperatively and 26 (41.9%) at the first follow-up. All observers had a few cases that changed from no superimposition between the root of the third molar and the mandibular canal at one time point to superimposition at the following time point. Overall, a change in the position of the cervical and apical points of the root complex was most frequent during the first year, as reported by all observers (seen as a change from the postoperative image to the panoramic images performed 1 year postoperatively). For all the observers, there was a mean of 29.3 cases (47.2%) that changed position to a more superior position (range 18 cases [29%] to 39 cases [62.9%]). For all observers, the mean change in position was 8.6% (range 3.2%−17.8%) between follow-up at 1 and the 5 years control. Changes in the position of the cervical and apical points are shown in Tables II and III, with observer 1 as an example.

Table IV shows that the presence of bone superior to the root complex changed during the control period. In general, bone formation appeared during the first year (seen as absence of bone postoperatively and presence of bone at the 1-year follow-up) for all observers (observer 1: 100%; observer 2: 77.4%; and observer 3: 85.5%). Radiolucency in relation to the root complex was a rare finding among the observers, as only 1 or 2 cases were found at each time point, depending on the observer. Figure 2 shows a representative case of the radiographic follow-up of a coronectomy of a right side mandibular third molar with a coronal migration.

In general, there was a high interobserver reproducibility ranging from 46.8% to 100% for observer 1 vs observer 2; 45.2% to 98.4% for observer 1 vs

Table I. Cross tabulation showing superimposition between the root complex and the mandibular canal at the different periods for the 3 observers

Observer		*Observation time Postoperative period → 1 year*		*Observation time 1 year → 3 years*		*Observation time 3 years → 5 years*	
		No	*Yes*	*No*	*Yes*	*No*	*Yes*
1	No	2	0	35	4	34	3
	Yes	37	23	2	21	5	20
2	No	3	1	26	6	28	3
	Yes	29	29	5	25	2	25
3	No	2	0	28	5	26	5
	Yes	31	26	3	26	2	29

Table II. Migration movement for the cervical points at each follow-up for observer 1

Examination type		*Postoperative period control*		*1 year control*	*3 years control*	*5 years control*	
		n =	*Start %*	*n =*	*n =*	*n =*	*End %*
Relation between mesiocervical point and mandibular canal	1. Superior to the alveolar crest	0	0%	0	0	0	0%
	2. In contact with the alveolar crest	8	12.9%	35	34	33	53.2%
	3. >1 width of the canal superior to the upper border of the mandibular canal	31	50%	17	20	20	32.3%
	4. ½–1 width of the canal superior to the upper border of the canal	11	17.7%	7	5	7	11.3%
	5. 0–½ width of the canal superior to the upper border of the canal	10	16.1%	3	3	2	3.2%
	6. Touching the upper border of the canal	2	3.2%	0	0	0	0%
	7. Located in upper half of the canal	0	0%	0	0	0	0%
	8. Located in lower half of the canal	0	0%	0	0	0	0%
Relation between distocervical point and mandibular canal	1. Superior to the alveolar crest	0	0%	0	2	2	3.2%
	2. In contact with the alveolar crest	1	1.6%	39	37	33	53.2%
	3. >1 width of the canal superior to the upper border of the mandibular canal	31	50%	23	22	26	41.9%
	4. ½–1 width of the canal superior to the upper border of the canal	27	43.6%	0	1	1	1.6%
	5. 0–½ width of the canal superior to the upper border of the canal	3	4.8%	0	0	0	0%
	6. Touching the upper border of the canal	0	0%	0	0	0	0%
	7. Located in upper half of the canal	0	0%	0	0	0	0%
	8. Located in lower half of the canal	0	0%	0	0	0	0%

Table III. Migration movement for the apical points at each follow-up for observer 1

Examination type		*Postoperative period control*		1 year control	*3 years control*	*5 years control*	
		n =	*Start %*	*n =*	*n =*	*n =*	*End %*
Relation between mesial apex and the mandibular canal	9. >1 width of the canal superior to the upper border of the mandibular canal	0	0%	1	2	2	3.2%
	10. ½–1 width of the canal superior to the upper border of the canal	0	0%	10	15	12	19.4%
	11. 0–½ width of the canal superior to the upper border of the canal	2	3.2%	12	9	11	17.7%
	12. Touching the upper border of the canal	11	17.7%	21	17	18	29%
	13. Located in upper half of the canal	20	32.3%	11	11	12	19.4%
	14. Located in lower half of the canal	8	12.9%	3	3	2	3.2%
	15. Touching the lower border of the canal	7	11.3%	2	2	3	4.8%
	16. Inferior to the canal	14	22.6%	3	3	2	3.2%
Relation between distal apex and the mandibular canal	9. >1 width of the canal superior to the upper border of the mandibular canal	0	0%	7	7	6	10.2%
	10. ½–1 width of the canal superior to the upper border of the canal	1	1.8%	5	8	9	17.3%
	11. 0–½ width of the canal superior to the upper border of the canal	2	3.5%	18	13	13	22%
	12. Touching the upper border of the canal	3	5.3%	15	12	16	27.1%
	13. Located in upper half of the canal	26	45.6%	8	13	10	16.9%
	14. Located in lower half of the canal	8	14%	1	1	1	1.7%
	15. Touching the lower border of the canal	10	17.5%	2	4	3	5.1%
	16. Inferior to the canal	7	12.2%	1	0	1	1.7%

Table IV. Cross tabulation showing presence of bone superior to the root complex at the different periods for the 3 observers

Observer		*Observation time Postoperative period → 1 year*		*Observation time 1 year → 3 years*		*Observation time 3 years → 5 years*	
		No	*Yes*	*No*	*Yes*	*No*	*Yes*
1	No	0	62	0	0	2	1
	Yes	0	0	3	59	0	59
2	No	9	48	5	4	0	10
	Yes	0	5	5	48	2	50
3	No	8	53	2	6	7	4
	Yes	0	1	9	45	5	46

observer 3; and 57.9% to 100% for observer 2 vs observer 3. There was higher reproducibility among observers in assessing the presence of bone superior to the root complex, superimposition between the root complex and the mandibular canal, and radiolucency in relation to the root complex compared with the position of the mesial and distal parts of the root complex as well as the position of the mesial and distal apex, when interpreting the percentage accordance. Tables V, VI and VII.

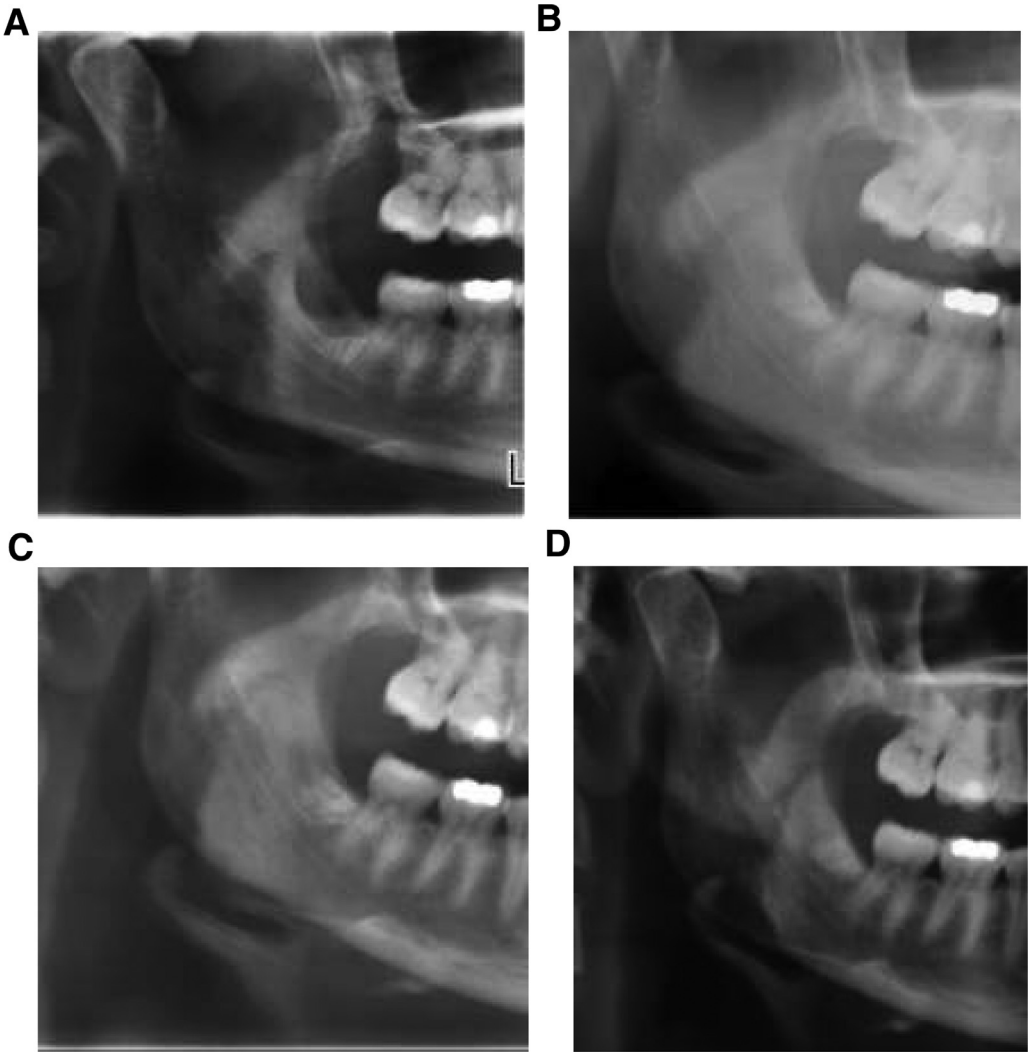

Fig. 2. Example of radiographic follow-up of a coronectomy of a right side mandibular third. **A,** The postoperative image. **B,** At 1-year follow-up. **C,** At 3-year follow-up, **D,** At 5-year follow-up.

Table V. Reproducibility between observer 1 and observer 2 for all parameters expressed as percentage accordance

Parameter	*Postoperative period control*	*1 year control*	*3 years control*	*5 years control*
	% Agreement	*% Agreement*	*% Agreement*	*% Agreement*
Bone superior to root complex	91.9%	85.5%	85.5%	96.8%
Overprojection between the root complex and the mandibular canal	93.5%	85.5%	87.1%	82.3%
Radiolucency in relation to root complex	97.6%	96.8%	98.4%	100%
Location of the mesiocervical point of the root complex	69.4%	67.7%	71.0%	62.9%
Location of the distocervical point of the root complex	62.2%	72.6%	74.2%	75.8%
Location of the mesial apex	59.7%	48.4%	54.8%	46.8%
Location of the distal apex	63%	50.9%	61.4%	64.4%

Table VI. Reproducibility between observer 1 and observer 3 for all parameters expressed as percentage accordance

Parameter	*Postoperative period control*	*1 year control*	*3 years control*	*5 years control*
	% Agreement	*% Agreement*	*% Agreement*	*% Agreement*
Bone superior to root complex	98.4%	87.1%	80.7%	80.7%
Overprojection between the root complex and the mandibular canal	96.8%	90.3%	83.9%	79%
Radiolucency in relation to root complex	96.8%	98.4%	95.3%	98.4%
Location of the mesiocervical point of the root complex	62.9%	67.7%	58.1%	59.7%
Location of the distocervical point of the root complex	69.3%	69.4%	64.5%	69.4%
Location of the mesial apex	61.3%	53.2%	59.7%	45.2%
Location of the distal apex	59.3%	47.4%	67.9%	50.9%

Table VII. Reproducibility between observer 2 and observer 3 for all parameters expressed as percentage accordance

Parameter	*Postoperative period control*	*1 year control*	*3 years control*	*5 years control*
	% Agreement	*% Agreement*	*% Agreement*	*% Agreement*
Bone superior to root complex	90.3%	82.3%	75.8%	80.7%
Overprojection between the root complex and the mandibular canal	93.6%	91.9%	90.3%	90.3%
Radiolucency in relation to root complex	97.4%	98.4%	100%	98.4%
Location of the mesiocervical point of the root complex	80.7%	67.7%	61.3%	61.3%
Location of the distocervical point of the root complex	79%	62.9%	72.6%	82.3%
Location of the mesial apex	58.1%	64.5%	67.7%	59.7%
Location of the distal apex	57.9%	55.9%	68.3%	72.1%

DISCUSSION

The purpose of the study was to perform an unbiased evaluation of root migration, seen as a change in position after coronectomy of mandibular third molars through comparison of panoramic images taken 1, 3 and 5 years after surgery. The study demonstrated that migratory movement mainly occurred during the first year after surgery and that the variables used for the assessment of root migration were reproducible among observers. Radiographic follow-up is recommended immediately after surgery as well as 1 year postoperatively.

The present study did not analyze the factors that influence root migration. Few studies have done this, and in general, the primary factor to influence the extent of the migration is the age of the patient.[11,25-27] In younger patients, greater root migration is expected.[14] Other factors, such as sex, morphology of the root complex, eruption status, and depth of impaction, have not been shown to have any effect on the

extent of the root migration.[21] Therefore, as reported by Pogrel,[28] it is important to consider the age of the patient when determining the treatment options for mandibular third molars, as coronectomy in younger individuals in their teens may cause later complications. Thus, younger individuals should be informed about the potential risk of excessive root migration leading to a second surgical intervention. Even if a more excessive root migration occurs, the risk for development of pathology leading to surgical intervention is low. Mean age of the patients in the present study was 28.6 years (range 16.7−41.1 years). This age range is typical for patients with indications for mandibular third molar removal, and consequently, the pattern of migration found in this study is considered representative for daily dental practice. Formation of bone coronal to the resected root surface during the first year was another characteristic finding in the present study. This is in accordance with another recent study, in which bone formation coronal to the root surface was seen in 99.2% of the cases.[25] This may be valuable knowledge to the surgeon when explaining the fate of the root complex to the patient.

Coronectomy has been reported to be an alternative to complete surgical removal of mandibular third molars to reduce the risk of injury of the IAN,[1,7,19] and postoperative morbidity associated with the 2 techniques is comparable.[15] However, the migration pattern of the root complex has not been fully clarified. In the present study, migration of the root complex was assessed over a period of 5 years, according to a standard protocol. The largest amount of migration (calculated as a change in the position of the root complex in the radiographic assessments at the different time points) occurred in a coronal direction during the first year after intervention. On average, 94% of the third molars were assessed to superimpose the mandibular canal, as seen on postoperative panoramic images, and after 1 year, this was reduced to 41.9%. Moreover, the position of the cervical and apical points of the root complex changed in a coronal direction during the first year, as reported by all the observers in our study. Previous studies have reported similar findings with regard to migration of the root complex.[3,7,12,18] Leung et al. included 356 coronectomy procedures and reported that 91.1% of the root complexes migrated during a period of 0 to 6 months after intervention and in a period of 6 to 12 months after the intervention, 61.4% of the root complexes migrated. However, 24.3% of the root complexes migrated in a period of 12 to 24 months after the intervention and reached a steady state 2 years postoperatively.[21] In our sample, a few cases migrated in a caudal direction, assessed as, for example, the absence of superimposition between the root of the third molar and the mandibular canal at one time point and the presence of the superimposition between the third molar and the mandibular canal at the subsequent time point. This may not seem logical; however, it is speculated that a rotation of the root complex could be an explanation, together with different patient positioning during panoramic exposure as well as measurement errors. This was, however, seen in only a very few cases and has not been reported in other studies.

Mean length of migration of the root complex from the mandibular canal was assessed in a few studies.[3,11,19] The results of this approach are difficult to assess because a high number of factors influence the accuracy of measurements. For example, each image should be calibrated to determine a magnification factor, and the size of each pixel will only be an estimate because the cross diameter will change at each location. Furthermore, patient movement and patient position errors should be eliminated, and the same angle of exposure at each examination should be ensured. As shown by Schropp et al.,[29] a standard magnification factor cannot be used in panoramic imaging because it differs from region to region. Therefore, the results of the studies that present linear measurements, but without mentioning these factors or calculating interrater agreement, might not represent the true movement of the root complex.[7,21] Additionally, rotation of the root complex would make linear measurement uncertain because no reference point can be identified. Consequently, in the present study, we decided to categorize the evaluation of root migration on the basis of specific radiographic findings by using the mandibular canal as a reference structure. This was not to determine a distance but, rather, to give clinically relevant information about when the migration of the root complex settles and how many migrate to a noncritical relationship to the mandibular canal. This information could be helpful if reoperation is needed and to provide a basis for a radiographic follow-up protocol.

This was a radiographic study, and in the absence of a well-defined standard for describing migration of the root complex after coronectomy, we included 3 observers to assess the images. To our knowledge, this study is the first to calculate and categorize the migration of the root complex in this way. The blinding of the images was important to ensure that the observers' assessments were unbiased. In general, there was good interobserver reproducibility for all parameters. The interobserver reproducibility was highest for the analyses of dichotomous variables and lowest for those with more options. Even though reproducibility was low for some parameters, the reproducibility level is considered acceptable. Kappa statistics were not performed to determine reproducibility. This resulted from a prerequisite that the observers did not make any guesses while performing the analyses, making the percentage accordance a better way to determine interobserver reproducibility.[30]

One of the motivations for developing this protocol for radiographic follow-up of coronectomy procedures

was to comply with the general principle of minimal X-ray exposure.[31] The treatment protocol for coronectomy described in previous studies have included an intraoral or panoramic image after surgery to confirm correct performance of coronectomy and to serve as a baseline for subsequent control.[12,15,21] On the basis of the results from the present study, we propose radiographic follow-up at 1 year postoperatively because only minor changes occur after 1 year. Subsequently, radiographic examination should only be performed if clinical symptoms appear.[15] One may question whether a radiographic examination 1 year postoperatively is needed at all because migration of the root complex rarely leads to pathologic conditions. However, studies have shown that there could be a potential risk of the root complex moving toward the second molar causing marginal bone loss or resorption; thus, performing a radiographic examination 1 year after the intervention seems to be justified.[32]

In this study the decision to perform a coronectomy was based on CBCT findings. The need for CBCT should be debated. A recent study showed that in 12% of the included cases, the treatment plan changed from complete removal to coronectomy or the opposite,[33] whereas another study reported the frequency of change in treatment plans, including coronectomy, was between 30% and 50%.[34] Lack of bony separation between the root of the third molar and the mandibular canal, as seen on CBCT, was the primary reason for choosing coronectomy rather than complete removal of the tooth in the previous study.[33] However, the study only focused on the radiographic examination result and not on patient outcome. Recently, it was demonstrated that there is no evidence that the risk of a postoperative sensory disturbance of the IAN is better predicted by a CBCT image compared with a panoramic image.[35] Therefore, the decision regarding complete removal or coronectomy can be based on a panoramic image when a close relationship between the root of the third molar and the mandibular canal is present because the positive predictive value for a nerve impairment are comparable between preoperative radiography and CBCT.[35] Thus, routine use of CBCT should be avoided and restricted to selected cases.[36] However, no evidence is available to indicate if the surgical technique during a coronectomy is changed when a CBCT image is available compared with a treatment based on a panoramic image. Similarly, patient outcome after coronectomy has not been shown to depend on the intervention being based on a CBCT image or a panoramic image. Further research is needed to assess the potential benefit of CBCT in the surgical planning of coronectomy.

CONCLUSIONS

Migration of the root complex occurs primarily within the first year after coronectomy and radiographic follow-up at 1 year postoperatively is recommended. Future studies with larger study samples are needed to determine whether demographic variables, such as sex and age, influence root migration.

FUNDING

This study was funded by Aarhus University and the Foundation for Dental Research, Danish Regions.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.oooo.2019.04.013.

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