



Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Residual enamel removal to improve outcomes of mandibular third molar coronectomy: A single-center retrospective cohort study

Kenichi Kurita^{a,*,1}, Hidemichi Yuasa^{a,1}, Shinichi Taniguchi^a, Motonobu Achiwa^a, Mitsuo Goto^b, Eri Kubota^a, Atsushi Nakayama^a, Atsushi Abe^{a,c,*}^a Department of Oral and Maxillofacial Surgery, Aichi Gakuin University, Nagoya, Japan^b Department of Maxillofacial Surgery, Aichi Gakuin University, Nagoya, Japan^c Department of Oral and Maxillofacial Surgery, Nagoya Ekisaikai Hospital, Nagoya, Japan

ARTICLE INFO

Handling Editor: Prof. Emeka Nkenke

Keywords:

Coronectomy
Dental enamel
Complication
Migration
Mandibular third molar
Survival rate

ABSTRACT

This study aimed to analyze post-coronectomy complications, chronological root survival rate (success rate) using Kaplan–Meier analysis, and postoperative radiographic signs for root extraction. A total of 555 mandibular third molar coronectomies were clinically and radiologically evaluated (mean follow-up period, 27.2 months; range, 1 month to 10.5 years). Complications were observed in 22 (4.0%) cases. Temporary inferior alveolar nerve damage was observed in one (0.2%) case, and 21 (3.8%) retained roots required extraction between 1 and 64 months after coronectomy due to dry socket (two cases, 0.4%), primary non-wound closure (10 cases, 1.8%), secondary root exposure (seven cases, 1.3%), and submucosal root eruption (two cases, 0.4%). Residual enamel after coronectomy was more significantly found on 13 (61.9%) of 21 extracted roots than on 30 (5.6%) of 534 surviving roots. Kaplan–Meier analysis revealed an overall survival rate of 93.8% at 5 years and 92.2% at 10 years. The 5-year survival rates differed significantly ($p < 0.001$) between the enamel-free (97.0%) and residual enamel-attached (58.3%) roots. The Cox proportional hazards model showed a hazard ratio of 20.87 (95% confidence interval, 8.58–50.72). The long-term outcomes of coronectomy were satisfactory, and a higher success rate is expected when the enamel is completely removed during coronectomy.

1. Introduction

Mandibular third molar coronectomy is performed to avoid inferior alveolar nerve damage (IAND). This procedure was first published in French, with an abstract in English (Ecuyer and Debien, 1984), and the full text in English was published later (Knutsson et al., 1989). The term “coronectomy” was first described in 2004 (Pogrel et al., 2004). This procedure became popular after results from the first randomized controlled clinical trial using this technique were reported (Renton et al., 2005). Nine systematic reviews have indicated the usefulness of coronectomy in preventing IAND (Long et al., 2012; Martin et al., 2015; Cervera-Espert et al., 2016; Dalle Carbonare et al., 2017; Ali et al., 2018; Barcellos et al., 2019; Pitros et al., 2020; Mann and Scott, 2021; Póvoa et al., 2021). Nevertheless, they emphasized the need for further

investigations of long-term outcomes. Therefore, studies with a large number of cases are warranted to provide evidence on complications, long-term success rate, and radiographic characteristics indicating coronectomy failure.

We started performing mandibular third molar coronectomy at our institution in 2005. In cases wherein the root of the third molar was confirmed as attached to the mandibular canal on computed tomography (CT), no major complications were observed within the first 3 postoperative years (Hatano et al., 2009; Goto et al., 2012; Kohara et al., 2015). Upon completing our research in March 2020, we performed 601 coronectomies, and the longest follow-up period was 10.5 years.

Therefore, this study aimed to 1) analyze the incidence and types of complications after coronectomy; 2) evaluate the survival rate of retained roots using Kaplan–Meier analysis, in which root extraction was

* Corresponding author. Department of Oral and Maxillofacial Surgery, Nagoya Ekisaikai Hospital, 4-66 Syounen-cho, Nakagawa-ku, Nagoya, 454-8502, Japan.

** Corresponding author.

E-mail addresses: ken.kurita@qc.commufa.jp (K. Kurita), MXE05064@nifty.ne.jp (H. Yuasa), shinichi_pyro2944129@yahoo.co.jp (S. Taniguchi), achi@he.mirai.ne.jp (M. Achiwa), mgoto@dpc.agu.ac.jp (M. Goto), erimakilondon@hotmail.com (E. Kubota), nkym8020@dpc.aichi-gakuin.ac.jp (A. Nakayama), atsushi.a@ekisai.or.jp (A. Abe).¹ Kenichi Kurita and Hidemichi Yuasa are equal contributors.<https://doi.org/10.1016/j.jcms.2024.06.003>

Received 8 September 2023; Received in revised form 29 January 2024; Accepted 8 June 2024

Available online 10 June 2024

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defined as the endpoint; and 3) identify postoperative radiographic signs for root extraction using a Cox proportional hazards model.

2. Material and methods

2.1. Study design

A single-center retrospective cohort study was designed and implemented to address the research aims at our hospital. Coronectomy was performed by four surgeons certified by the Japanese Society of Oral and Maxillofacial Surgeons (JSOMS). Two authors certified by the JSOMS reviewed the demographic and clinical variables from the patients' medical records. They also discussed the clinical and radiographic findings and made the final diagnosis after achieving consensus.

This study was performed following the principles of the Declaration of Helsinki. Approval was granted by the appropriate ethics committee (approval number: 651, date: 2022.05.17). All procedures performed were part of routine care. All patients were informed of this study's aim and provided informed consent for study participation and study publication. This study is reported following the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (Von Elm et al., 2014).

2.2. Participants

Coronectomy was performed on 601 teeth at our hospital between October 2005 and March 2020. The postoperative examinations were completed in May 2020. This study included consecutive patients who underwent postoperative clinical and panoramic radiography examinations ≥ 1 month after coronectomy. Therefore, among these 601 coronectomies performed on 506 patients, 555 coronectomies (92.3%) in 470 patients were included. Overall, 46 coronectomies in 36 patients were excluded, as the patients lived far from our hospital and desired to receive postoperative treatment at local clinics. We asked these patients and their local dentists to contact us if postoperative complications occurred. However, no such reports were received.

2.3. Indications and techniques for coronectomy

We obtained dental CT scans in cases where the mandibular third molar roots were suspected to be close to the mandibular canal based on the following seven panoramic radiographic findings: canal deviation, canal narrowing, presence of a peri-apical radiolucent area, narrowing of the root apex, root apex darkening, curving of the root apex, and loss of the lamina dura of the canal (Renton et al., 2005). Additionally, we performed coronectomy in cases where dental CT indicated contact between the molar and mandibular canal. In this coronectomy cohort study, we excluded cases of pathological bone resorption around the tooth and/or pre-eruptive intra-coronal resorption (Szalma et al., 2022), as identified on pre-operative radiographic examination.

Coronectomy was performed following the standardized methods. Following the administration of local anesthesia, we elevated the buccal flap, removed the overlying bone, and transected three-fourths of the tooth using a round bur under irrigation. Next, we fractured the tooth using an extraction elevator. The root was shaved 3–4 mm below the alveolar bone margin. After irrigating with saline solution, a relief incision was made if required, and primary closure was performed. However, we did not treat the exposed dental pulp. According to our hospital protocol since 2005, the first postoperative panoramic radiograph was taken immediately after wound closure to confirm whether the crown was cut below the alveolar bone margin. Small enamel spikes on the cutting surface of the root were left, as we did not expect them to affect the success rates post-coronectomy, as shown in this study. A 3-day course of orally administered antibiotics was prescribed after coronectomy to prevent postoperative infection.

2.4. Postoperative evaluation

The patients agreed to undergo suture removal 7 days after coronectomy and further postoperative physical and panoramic radiographic examinations at 1, 3, 6, and 12 months and annually thereafter. Patients booked their next appointment at every follow-up visit. The patients were examined clinically following panoramic radiography, and periodontal probes were used to locate the exposed roots.

The success of coronectomy was assessed when the retained roots showed no abnormal signs. We defined root extraction or permanent IAND as a failure.

We defined primary non-wound closure as cases where the retained root was not primarily covered by the oral mucosa immediately after coronectomy. Secondary root exposure was defined as initial coverage of the root by the oral mucosa and exposure at a later time.

2.5. Study variables and case characteristics

The clinical outcome variables were IAND, complications requiring extraction of the retained root, and the survival of the retained roots.

The predictor variables were limited to three postoperative radiological signs as follows: residual enamel, migration of the retained roots, and pathological lesions around the retained root. This limitation was because our previous studies showed that the number of root extractions was small (Hatano et al., 2009; Goto et al., 2012; Kohara et al., 2015) and events per independent variables should be considered in the Cox proportional hazards model analysis (Peduzzi et al., 1995; Steyerberg et al., 1999; Steyerberg et al., 2000).

Case characteristics were sex, age, dental root morphology, axial angle of the tooth, Pell and Gregory classification, and pre-operative panoramic radiographic signs.

2.6. Statistical analyses

Univariate analysis was performed using the χ^2 test to compare differences in both case characteristics and in three postoperative radiographic signs (residual enamel, root migration, and pathological lesions) between the extracted and surviving root groups. We defined the endpoint as months until extraction of the retained root and calculated the overall survival rate of the retained roots using Kaplan–Meier analysis. The Kaplan–Meier curves were compared using the log-rank test. Furthermore, the Cox proportional hazards model was used to determine the hazard ratio of postoperative radiographic signs. Statistical analyses were performed with BellCurve for Excel Ver. 3.22 (Social Survey Research Information Co., Ltd. Tokyo, Japan). Statistical significance was set at $p < 0.05$.

3. Results

3.1. Case characteristics

The study population comprised 321 women (388 coronectomies) and 149 men (167 coronectomies), with a sex ratio of 1:0.46. The mean age at the time of coronectomy was 33.6 (range, 16–77) years, and the mean follow-up period was 27.2 months (range, 1 month to 10.5 years; median, 17 months). Among the 555 teeth, 77.5% showed a conical root shape, and 63.4% were horizontally impacted. However, no significant differences were noted in the case characteristics between the extracted and surviving root groups (Table 1).

3.2. Postoperative complications

Twenty-two cases (4.0%) showed complications after coronectomy; 21 retained roots were extracted, thereby resolving the complications (Table 2).

Neurosensory damage was observed in one (0.2%) case who reported

Table 1
Case characteristics.

Characteristic	All (n = 555) ^a	Extracted group (n = 21)	Surviving root group (n = 534)	p-value
Sex				
Female	388 (69.9)	15 (71.4)	373 (69.9)	1.00
Male	167 (30.1)	6 (28.6)	161 (30.1)	
Age (years)				
≤29	227 (40.9)	6 (28.6)	221 (41.4)	0.29
30–39	192 (34.6)	7 (33.3)	185 (34.6)	
≥40	136 (24.5)	8 (38.1)	128 (24)	
Dental root morphology				
Conical	430 (77.5)	17 (81)	413 (77.3)	0.66
Club	105 (18.9)	4 (19)	101 (18.9)	
Divergent	20 (3.6)	0 (0)	20 (3.7)	
Axial angle of the tooth				
Horizontal	352 (63.4)	14 (66.7)	338 (63.3)	0.84
Mesial inclination	126 (22.7)	5 (23.8)	121 (22.7)	
Perpendicular	77 (13.9)	2 (9.5)	75 (14)	
Pell and Gregory's classification				
IA	213 (38.4)	11 (52.4)	202 (37.8)	0.91
IB	23 (4.1)	0 (0)	23 (4.3)	
IC	1 (0.2)	0 (0)	1 (0.2)	
IIA	108 (19.5)	3 (14.3)	105 (19.7)	
IIB	113 (20.4)	3 (14.3)	110 (20.6)	
IIC	6 (1.1)	0 (0)	6 (1.1)	
IIIA	7 (1.3)	0 (0)	7 (1.3)	
IIIB	51 (9.2)	2 (9.5)	49 (9.2)	
IIIC	30 (5.4)	2 (9.5)	28 (5.2)	
No second molar	3 (0.5)	0 (0)	3 (0.6)	
Pre-operative panoramic radiographic signs				
Canal deviation	66 (11.2)	2 (9.1)	64 (11.3)	0.97
Canal narrowing	14 (2.4)	0 (0)	14 (2.5)	
Peri-apical radiolucent area	77 (13.1)	3 (13.6)	74 (13.1)	
Root narrowing	3 (0.5)	0 (0)	3 (0.5)	
Darkening of the root apex	47 (8.0)	1 (4.5)	46 (8.1)	
Curving of the root apex	30 (5.1)	1 (4.5)	29 (5.1)	
Loss of the lamina dura of the canal	351 (59.7)	15 (68.2)	336 (59.4)	

Values are presented as n (%), and p-values are based on a chi-square test for case characteristics.

^a Total number of patients = 470.

lower lip hypoesthesia. However, the symptoms resolved after 2 months. A dry socket (alveolar osteitis) was observed in two (0.4%) cases who complained of severe pain caused by infection around the operated field on postoperative day 7 (Table 2, Fig. 1). The wound was irrigated with saline solution, and an ointment containing Minocycline hydrochloride (Periocline®: Sunstar, Osaka, Japan) was applied to the socket. Nonsurgical treatment was continued for 1 month; however, the wound did not close spontaneously. Radiographs showed root migration, and the retained roots were easily extracted without complications.

Primary non-wound closure with exposure of the retained root occurred in 10 (1.8%) cases and became evident between 1 and 3 months after coronectomy (Table 2, Fig. 2). Five cases experienced symptoms postoperatively, four complained of slight pain, and one experienced acute infection requiring intravenous antibiotics. The lesion

was first treated locally with irrigation and pain medications. Repeat coronectomy or root extraction was considered in all cases because the wounds did not close and the roots were in contact with the inferior alveolar canal. Eventually, the roots were easily extracted as they were movable in the sockets. None of the cases experienced any complications following root extraction. Postoperative radiography after coronectomy showed root migration in 9 of the 10 cases.

Secondary root exposure occurred in seven (1.3%) cases (Table 2, Fig. 3): five roots were palpated with periodontal probes inserted into the distal pocket of the second molars, and two were exposed to the gingiva with mild infection. These exposures were detected between 5 and 35 postoperative months. However, the gingiva had covered all roots at the earlier examinations. Radiographs before re-operation showed root migration in all cases, and seven roots were extracted without complications.

Submucosal root eruption was diagnosed in two (0.4%) cases (Table 2, Fig. 4). The retained roots penetrated the bone but were entirely covered by the gingiva; the top edge of the root was palpated through the delicate gingiva. Symptoms included slight pain on palpation at 17 months and discomfort at 36 months. The retained roots were extracted at 18 and 64 months after coronectomy, as they were located away from the inferior alveolar canal, and no complications were observed after root extraction.

3.3. Postoperative radiographic findings after coronectomy

These findings are shown in Table 3. Forty-three (7.7%) of the 555 retained roots contained residual enamel spikes. Roots with and without enamel spikes were classified as the “residual enamel” and “enamel-free” groups, respectively. The proportion of roots with residual enamel was significantly greater in the extracted group (13 of 21 roots, 61.9%) than in the surviving root group (30 of 534 roots, 5.6%). Residual enamel on the first postoperative radiograph was persistently visible until the final examination. Root migration was observed in 523 of 555 roots (94.2%). No significant difference was found in the proportion of roots that exhibited migration between the surviving root group (503 of 534 roots, 94.2%) and the extracted group (20 of 21 roots, 95.2%). On radiographic examination, no major pathologies (osteomyelitis or cysts) were noted in any case.

3.4. Chronological root survival ratio

Kaplan–Meier analysis showed that the overall root survival rates at 5 and 10 years after coronectomy were 93.8% and 92.2%, respectively (Fig. 5). The log-rank test revealed that the survival rate of the enamel-free group was significantly higher than that of the residual enamel group ($p < 0.001$; Fig. 6). The root survival rate 5 years after coronectomy was 97.0% in the enamel-free group and 58.3% in the residual enamel group ($p < 0.001$). However, the log-rank test showed no significant difference between the survival rate of migrated and non-migrated roots ($p = 0.27$). The Cox proportional hazards model yielded a hazard ratio of 20.87 (95% confidence interval, 8.58–50.72). Moreover, the log-rank test was not applied to pathological lesions, as they were not found in all cases.

4. Discussion

This study observed complications in 4% of the cases over a mean follow-up of approximately 27 months. Overall, 21 (3.8%) retained roots required extraction, and residual enamel was found in 43 of 555 (7.7%) cases. Roots migrated in 523 (94.2%) cases, indicating a high migration ratio in both the surviving root (94.2%) and extracted (95.2%) groups. The overall root survival rate was 93.8% at 5 years and 92.2% at 10 years; 5-year survival rates differed significantly ($p < 0.001$) between enamel-free (97.0%) and residual enamel-attached (58.3%) roots.

Table 2
Characteristics of root extraction cases.

Case No.	Age	Sex	Reason for extraction	Symptoms	Time until diagnosis after coronectomy	Time until root extraction after coronectomy	Residual enamel	Root morphology	Migration	Complications after root extraction
1	44	Female	Dry socket	Severe pain, Infection	1 w	1 m	–	Conical	+	–
2	47	Female	Dry socket	Severe pain, Infection	1 w	1 m	–	Conical	+	–
3	38	Female	Primary non-wound closure		1 m	3 m	+	Conical	+	–
4	37	Male	Primary non-wound closure		1 m	3 m	+	Conical	–	–
5	38	Female	Primary non-wound closure	Slight pain	1 m	7 m	+	Conical	+	–
6	40	Female	Primary non-wound closure	Slight pain	1 m	10 m	–	Conical	+	–
7	34	Female	Primary non-wound closure		1 m	12 m	+	Club	+	–
8	31	Female	Primary non-wound closure	Mild pain, Infection	2 m	4 m	–	Conical	+	–
9	44	Female	Primary non-wound closure		3 m	3 m	+	Conical	+	–
10	46	Female	Primary non-wound closure		3 m	3 m	+	Conical	+	–
11	39	Female	Primary non-wound closure	Slight pain	3 m	12 m	+	Conical	+	–
12	33	Female	Primary non-wound closure	Slight pain	3 m	24 m	+	Conical	+	–
13	22	Male	Secondary root exposure into the pocket	Palpable root	5 m	14 m	+	Conical	+	–
14	28	Female	Secondary root exposure into the pocket	Palpable root	6 m	7 m	+	Conical	+	–
15	21	Female	Secondary root exposure into the pocket	Palpable root	7 m	7 m	+	Club	+	–
16	43	Male	Secondary root exposure into the pocket	Palpable root	24 m	29 m	–	Club	+	–
17	24	Female	Secondary root exposure into the pocket	Palpable root	35 m	37 m	–	Conical	+	–
18	45	Male	Secondary root exposure into the oral cavity	Mild pain, Infection	13 m	40 m	+	Conical	+	–
19	50	Male	Secondary root exposure into the oral cavity	Mild pain, Infection	24 m	24 m	–	Club	+	–
20	29	Male	Submucosal root eruption	Palpable root, Slight pain	17 m	18 m	–	Conical	+	–
21	24	Female	Submucosal root eruption	Palpable root, Uncomfortable feeling	36 m	64 m	+	Conical	+	–

w, weeks; m, months.

Mandibular coronectomy is essential for the prevention of IAND. The overall incidence of IAND in 2176 coronectomized teeth was reported as 0.59% (Póvoa et al., 2021). A lower IAND frequency was observed in the present study (one of 555 cases, 0.2%), with temporary damage observed in only one case. The low incidence of IAND in our cohort may be attributed to a high level of surgical skill, as only four selected oral and maxillofacial specialists performed coronectomy in this study.

We used Kaplan–Meier analysis to evaluate the chronological success rate of coronectomy. Satisfactory overall success rates of 93.8% and 92.2% were observed at 5 and 10 years after coronectomy, respectively. Root extraction was selected as the endpoint for Kaplan–Meier analysis, as all complications, except IAND, were treated by extracting the retained root. The incidence of root extraction was 3.8% in this study, which was similar to the rate of 5.1% reported by a systematic review of 15 papers with 2026 cases (Barcellos et al., 2019). Nevertheless, as coronectomy is a relatively new procedure, there is a lack of studies with long-term results (Monaco et al., 2015a; Leun and Cheung, 2016; Pedersen

et al., 2018; Monaco et al., 2019; Pitros et al., 2019). Therefore, further reports using Kaplan–Meier analysis are expected, given the growing popularity of coronectomy.

We evaluated postoperative radiographic signs associated with root extraction. As previous reports have suggested that migration, residual enamel, and pathological lesions are prognostic factors (Steyerberg et al., 1999; Steyerberg et al., 2000; Patel et al., 2013; Frenkel et al., 2015; Leung and Cheung, 2016; Barcellos et al., 2019; Lee et al., 2021), we compared these three variables between the extracted and surviving root groups. However, only the presence of residual enamel differed significantly between the two groups. Therefore, residual enamel was compared using Kaplan–Meier analysis and the Cox proportional hazards model (Peduzzi et al., 1995). The results indicated that residual enamel significantly reduced the success rate of coronectomy. Residual enamel was more frequently found in the extracted group (13 of 21 roots, 61.9%) than in the surviving root group (30 of 534 roots, 5.6%). Dental enamel, embryologically derived from the ectoderm, may be

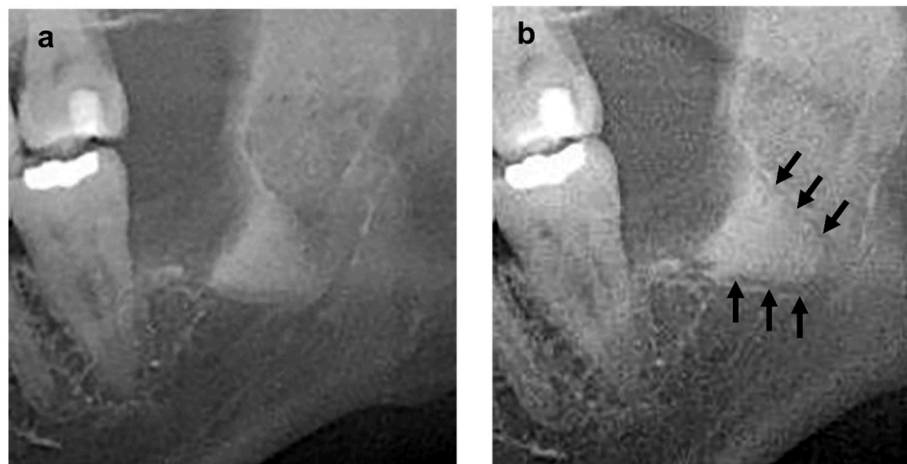


Fig. 1. Dry socket in Case 2 (a) First postoperative radiograph. (b) One month after coronectomy. The radiolucent area along the root showed migration of the retained root (arrows).

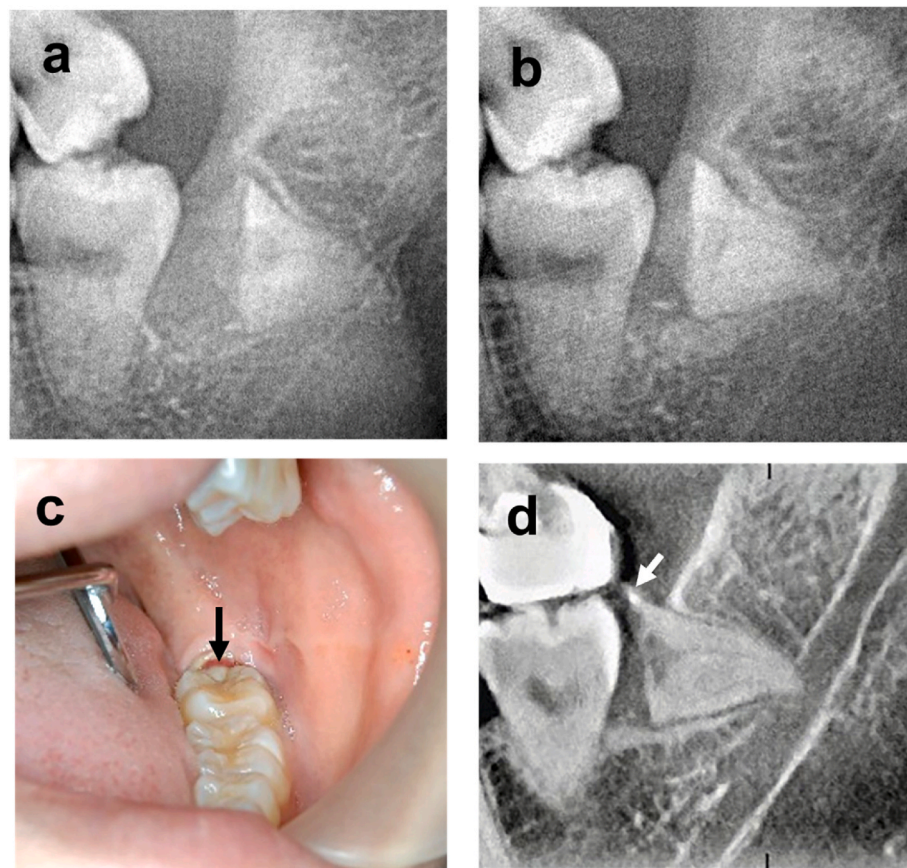


Fig. 2. Primary non-wound closure in Case 12 (a) First postoperative radiograph. (b) The wound was not closed completely, and part of the root was palpated by probing through the wound at 3 months after coronectomy. The root migrated medially. (c) Two years after coronectomy. The root (black arrow) was exposed into the oral cavity. (d) Residual enamel (white arrow) was confirmed on the computed tomography radiograph before root extraction.

eliminated from the human body through a foreign body reaction. However, 30 asymptomatic retained roots with residual enamel needed further careful follow-up because of the risk of future complications.

Postoperative radiographic examination showed that the small spikes of the residual enamel detected immediately after coronectomy persisted without resorption until the final examination. The frequency of root removal due to residual enamel has been reported as 9.5% (10 of 105 roots) (Barcellos et al., 2019). As this study frequently detected

residual enamel (13 of 21 extracted roots, 61.9%), a more careful approach should have been performed to ensure complete removal during coronectomy (Monaco et al., 2015b). Since 2015, intra-operative peri-apical radiographs have been recommended to confirm the absence of residual enamel immediately after coronectomy (Frenkel et al., 2015; Monaco et al., 2015b). However, at the start of this cohort study in 2005, we established a protocol wherein intra-operative peri-apical radiographs were not obtained to reduce radiation exposure. If we had taken

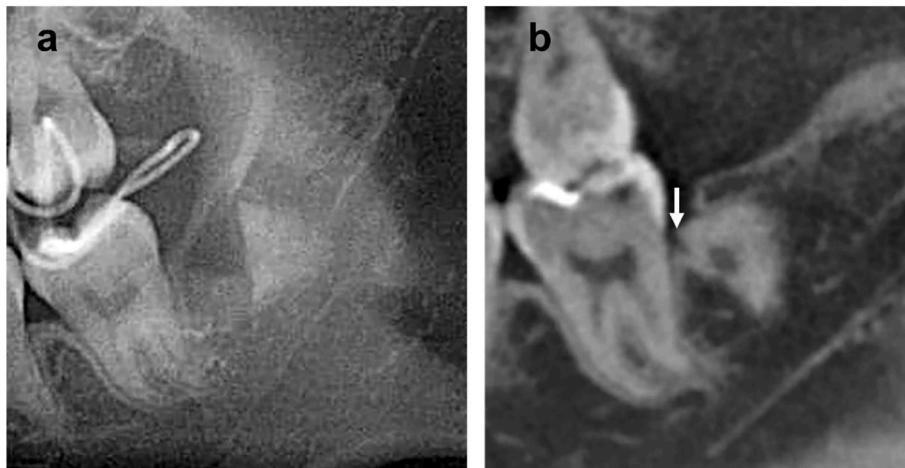


Fig. 3. Secondary root exposure into the pocket in Case 17 (a) First postoperative radiograph. The top edge of the root is located under the alveolar ridge. (b) Computed tomography radiograph at 35 months after coronectomy. The top edge of the root (white arrow) was palpated in the distal pocket of the second molar tooth at regular postoperative examination.

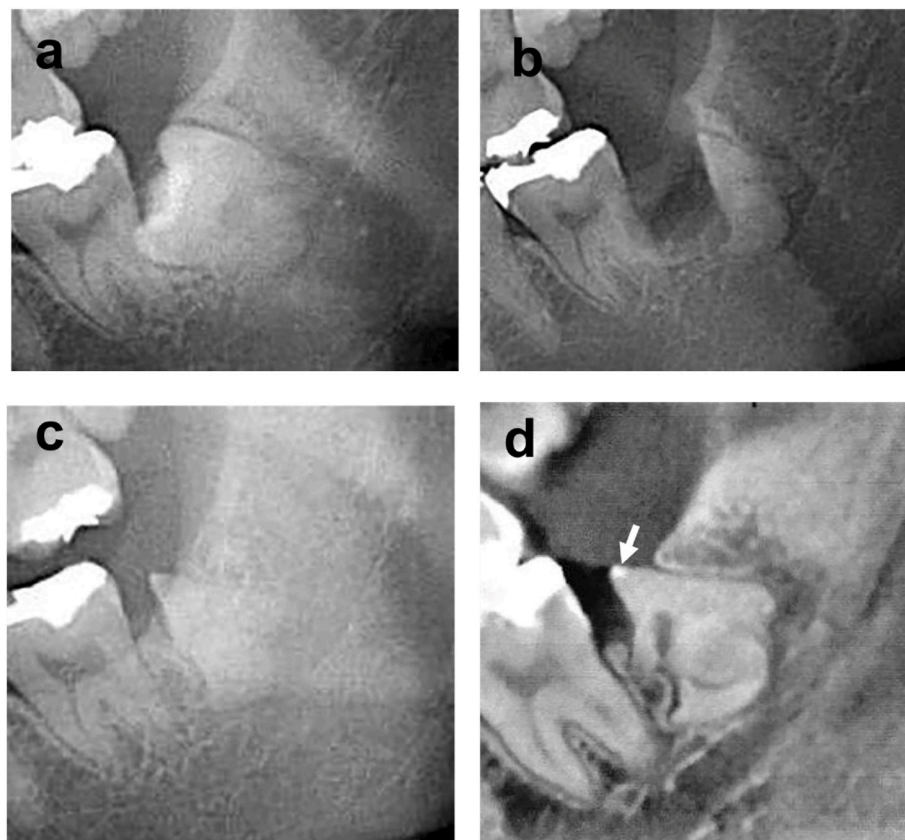


Fig. 4. Submucosal root eruption in Case 21. (a) Pre-operative radiograph. (b) First postoperative radiograph. The top edge of the root is located under the alveolar ridge. (c) The top edge of the root was palpated under the oral mucosa at 36 months after coronectomy. (d) Residual enamel (white arrow) was depicted on the computed tomography radiograph.

intra-operative peri-apical radiographs and excluded the residual enamel spikes completely, a higher overall success rate of approximately 97.0% would have been attained at 5 years postoperatively.

Dry socket following coronectomy is reportedly less frequent than that following conventional third molar extraction (Pitros et al., 2020). Previous studies have reported an incidence of 1.12% (16 of 1428 coronectomies) (Póvoa et al., 2021), whereas our study showed a lower rate of 0.4% (two of 555 cases). The lower incidence in our study may be

attributed to the prescription of postoperative antibiotics. In most cases, the dry socket healed without extraction of the retained root (Patel et al., 2013). Nevertheless, we found that the two retained roots were movable in the sockets during re-operation and were easily extracted due to root migration and the conical root form, although they were attached to the inferior alveolar canal. Therefore, repeat coronectomy is recommended when conservative treatment fails. However, we suggest that extracting the retained root is an option when a conical-shaped root shows

Table 3
Postoperative radiographic signs.

	All (n = 555) ^a	Extracted group (n = 21)	Surviving root group (n = 534)	p-value
Residual enamel	43 (7.7)	13 (61.9)	30 (5.6)	<0.001
Root migration	523 (94.2)	20 (95.2)	503 (94.2)	0.93
Pathological lesions	0 (0)	0 (0)	0 (0)	N/A

Values are presented as n (%), and p-values are based on a chi-square test for postoperative radiographic signs.

^a Total number of patients = 470; N/A, not applicable.

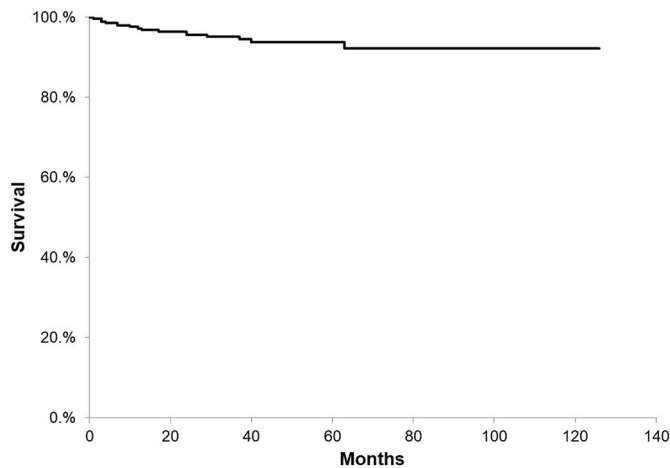


Fig. 5. Overall root survival.

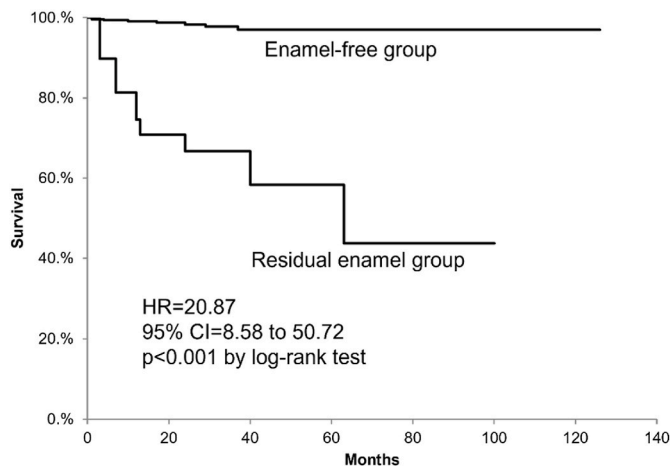


Fig. 6. Root survival in enamel-free and residual enamel groups. HR, hazard ratio; CI, confidence interval.

migration and mobility in the socket.

Since 10 cases showed primary non-wound closure 3 months after coronectomy, we considered repeating coronectomy or root extraction. Repeat coronectomy was initially indicated; however, the roots were easily removed as they were not firmly attached to the sockets. In addition, no complications were observed after root extraction. Therefore, to treat primary non-wound closure, we recommend conservative treatment first. Re-operation involving repeat coronectomy or extraction of the root is the next option. The final decision regarding repeat coronectomy or root extraction should be made during re-operation, considering root migration, form, and mobility.

Secondary exposure of the retained roots to the oral cavity is typically observed 6 months after coronectomy (Frenkel et al., 2015; Leung and Cheung, 2016; Pedersen et al., 2018; Pitros et al., 2019). In this study, five and two retained roots were exposed to the pocket and oral cavity between 5 and 35 months after coronectomy; these seven roots were initially covered by healthy gingiva at the 3-month examination. Therefore, we suspect that migration may have been the cause of oral exposure, as reported in previous studies (Barcellos et al., 2019; Póvoa et al., 2021).

To the best of our knowledge, this is the first report on submucosal root eruption after coronectomy. The two cases with migration were found at 17 and 36 months after coronectomy at a regular postoperative examination; these roots would have eventually been exposed to the oral cavity if they had not been detected. Previous studies have reported delayed exposure of roots 5–7 years post-coronectomy (Leung and Cheung, 2016; Pitros et al., 2019).

Notably, several studies have suggested a relationship between root migration and root survival rate (Long et al., 2012; Martin et al., 2015; Cervera-Espert et al., 2016; Dalle Carbonare et al., 2017; Ali et al., 2018; Barcellos et al., 2019; Pitros et al., 2020; Mann and Scott, 2021; Póvoa et al., 2021); however, the present study did not demonstrate a significant association. This may be because most roots (94.2%) were classified as positive or negative for migration on postoperative panoramic radiographs. Therefore, this method may be inadequate for confirming whether migration is a cause of root exposure. Nevertheless, we believe migration was a primary factor for eventual extraction, as 20 of the 21 (95.2%) extracted roots had migrated. Moreover, additional factors, such as residual enamel, may accelerate the exposure of retained roots because residual enamel was found in 13 cases (61.9%), as shown in Table 3.

The limitations of this study include its single-center design, the absence of ethnic and geographical diversity in the cohort, and the limited sample size. Therefore, caution is required when generalizing this study’s results to other populations. Further studies are needed to identify additional factors associated with retained root exposure.

5. Conclusion

This study revealed favorable long-term results for mandibular third molar coronectomy. The incidence of IAND (0.2%) was low, and the uncomplicated removal of the retained roots easily treated other complications (3.8%). Furthermore, no major silent lesions, such as osteomyelitis or cysts, were found on postoperative radiographs. The overall success rate of coronectomy was 92.2% at 10 years postoperatively. However, when enamel was completely removed during coronectomy, a higher success rate of 97.0% was observed at ≥5 years after the procedure. Further studies with longer follow-ups and larger cohorts are needed to validate our findings.

Author contributions

K. Kurita, H. Yuasa, and A. Abe contributed to the conception, design, data acquisition, interpretation, and analysis. They also drafted and critically revised the manuscript. S. Taniguchi and M. Achiwa contributed to data acquisition and interpretation and performed all statistical analyses. M. Goto, E. Kubota, and A. Nakayama contributed to the conception and design and critically revised the manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

Ethical approval

This study was performed per the ethical standards in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This study was approved by the ethics committee of Aichi Gakuin University (No. 651). All procedures performed in this study

were a part of routine care.

Funding

None.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent to publish

Not applicable.

Data availability statement

The datasets used and/or analyzed during the current study are available from the first author, Kenichi Kurita, on reasonable request.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgments

We would like to thank Editage (www.editage.com) for English language editing.

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