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Usefulness of mandibular third molar coronectomy assessed through clinical evaluation over three years of follow-up

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Abstract. The aim of this study was to investigate the 3-year morbidity of coronectomy of the lower third molar and to monitor the behaviour and migration pattern of the retained roots postoperatively. A total of 92 patients (111 teeth) who had undergone a coronectomy between October 2005 and July 2009 were investigated. Patients were followed up at 3 months and 1, 2, and 3 years for clinical evaluation and dental computed tomography imaging of the coronectomy sites. In total, 10 cases (9%) required tooth root extraction within the 3 years after coronectomy. In seven of them, the distal pocket of the lower second molars remained connected to the roots within the first year. Of the cases in whom a pocket did not remain at an early stage, none showed peri-apical lesions on transmission images of the retained roots in the apical area, which usually result from necrosis of the pulp. Root migration increased in the first 2 years after coronectomy but stabilized between the second and third years. In addition, a significant difference was noted in root migration between patients of different ages and sex. Retained roots after coronectomy in the lower third molars led to no complications in terms of infection or the development of pathologies within the first 3 years postoperatively.

Key words: coronectomy; prevent paraesthesia; long-term safety; migration pattern of the retained roots.

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Extraction of the mandibular third molar, or wisdom tooth, is a relatively minor surgery performed daily in our oral and maxillofacial surgery department. The incidence of postoperative complications such as abnormal sensation and numbness is 1–5%.[1–3] Such symptoms can reduce the quality of life of patients and sometimes result in a malpractice lawsuit.[4] When performing a mandibular third molar extraction, accurate assessment of the positional relationship between the wisdom tooth and the mandibular canal is necessary to prevent the development of paraesthesia due to injury to the inferior alveolar nerve (IAN). In recent years, dental computed tomography (CT) has been used to obtain detailed information on the positional relationship between the wisdom tooth and the mandibular canal, making it possible to predict the risk of paraesthesia. However, the actual safety measure taken at many dental clinics to prevent paraesthesia is to perform the

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wisdom tooth extraction carefully. At the same time, coronectomy has received considerable attention in recent years.

When mandibular third molar extraction is likely to damage the IAN, a coronectomy is performed to remove only the crown of the tooth, leaving the root in place.[5–7] Compared with the conventional extraction method, coronectomy has been found to effectively prevent nerve damage in several randomized clinical trials.[8–10] Long et al. recently performed a systematic review and meta-analysis of coronectomy and the conventional extraction method and reported the utility of coronectomy as a surgical procedure for preventing nerve damage during wisdom tooth extraction.[10] Our department also performs coronectomy in patients showing contact between the mandibular canal and the third molar on dental CT, and the authors have previously reported the efficacy of coronectomy for preventing nerve damage.[11–13]

In this study, the authors assessed the retained roots and surrounding tissue on dental CT to investigate the long-term outcome (up to 3 years) of coronectomy in patients who underwent this procedure between 2005 and 2009.

Materials and methods

Subjects

Coronectomy was performed on 111 teeth in 92 patients (33 teeth in 29 men and 78 teeth in 63 women; mean age 33.8 years), between October 2005 and July 2009. This study included patients who had complete annual follow-ups for 3 years and excluded those who did not return for follow-up observation.

Indications for coronectomy and surgical method

Dental CT is performed in our department when a close positional relationship between the mandibular third molar and the mandibular canal is suspected on panoramic radiographs. Coronectomy is indicated in the presence of at least one of the following seven findings: deviation of the canal; narrowing of the canal; peri-apical radiolucent area; narrowing of the root apex; darkening of the root apex; curving of the root apex; and loss of lamina dura of the canal.

Dental CT images were obtained for 301 patients (365 teeth). The authors excluded patients for whom there was distance between the root and the IAN (146 teeth in 125 patients). When contact between the mandibular canal and the wisdom tooth was verified on dental CT, patients chose traditional extraction (46 teeth in 34 patients) or coronectomy (173 teeth in 142 patients).

Coronectomy was started using the same ordinary incision and tissue separation techniques used to extract an impacted tooth and form a mucoperiosteal flap. The crown of the tooth was then removed and the resection surface was trimmed to 3–4 mm below the edge of the bone to ensure no remaining enamel. Primary closure of the extraction wound was performed by periosteal release to ensure it was tension-free. The authors did not treat the pulp of the retained root.[8,12,13] All patients were operated on by the same specialist in oral and maxillofacial surgery certified in Japan. A 3-day course of antibiotics was prescribed after the coronectomy for the prevention of postoperative infection (cefcapene pivoxil hydrochloride hydrate).

Evaluation and analysis

The coronectomy was assessed on the basis of clinical evaluation, panoramic radiography, and dental CT performed at 3 months and 1, 2, and 3 years after the procedure. Evaluation items are listed below.

Analysis of cases with root extraction

Histopathological testing was performed to investigate the conditions of cells and tissues in the root in cases where the extraction of the retained root was necessary during the postoperative observation period and where the root was extracted en bloc.

Condition of the retained roots and surrounding tissue at the 3-year follow-up

Gross clinical examination for infection was performed at 3 months and 1, 2, and 3 years after coronectomy. In addition, dental probes were used to directly palpate the surrounding tissue and periodontal probes were used to examine the distal pocket ($\geq$4 mm) of the mandibular second molar. Diagnostic imaging was performed to evaluate coronal bone formation over the retained root, the condition of the root apex, and contact with the mandibular canal.

Analysis of root migration during the 3-year follow-up

Dental CT images were used to set the baseline for calculating the distance of root migration. Three lines were identified on follow-up CT images: line 1 was tangent to the distal part of the mandibular second molar; line 2 connected the root apex and the centre of the crown in the mandibular third molar; and line 3 was perpendicular to line 1 and passed through the root apex of the mandibular third molar. If the root of the mandibular third molar was bifurcated, lines 2 and 3 were generated from the midpoint of the bifurcation. After placing these lines on the CT images, a specific formula was used to calculate the migration distance (Fig. 1).

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). Migration distances were compared using Friedman's repeated measures two-way analysis of variance (ANOVA).

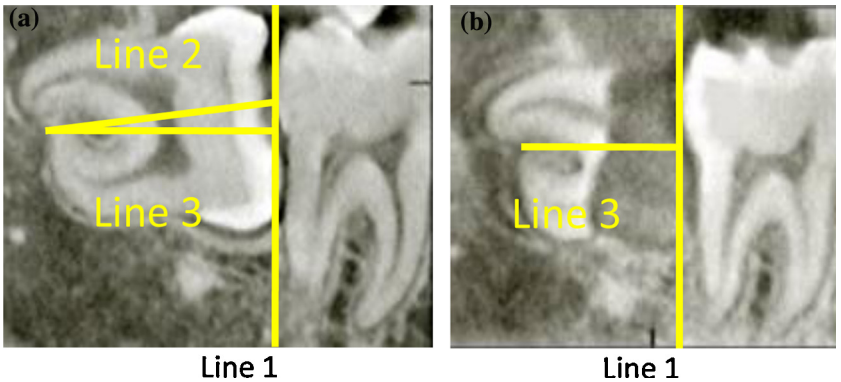

Fig. 1. Measurement of root movement. Line 1: tangential line on the distal part of the crown of the mandibular second molar. Line 2: line connecting the centre of the mandibular third molar crown and the midpoint between the proximal and distal roots. Line 3: perpendicular line connecting line 1 and the centre of the mandibular third molar root apex. (a) Preoperative. (b) Postoperative.

To reveal the factors influencing root migration, the Mann–Whitney *U*-test was used to compare results by sex as an independent variable, and Kruskal–Wallis one-way ANOVA was used to perform multiple comparisons of age, axial angle, root morphology, and depth of the impacted root. Significance was set at $P < 0.05$.

Results

Of the 173 teeth in 142 patients who had undergone coronectomy between October 2005 and July 2009, the authors followed 111 teeth (64.2%) in 92 patients. Despite our requests, 50 patients (62 teeth) did not return for follow-up observation for various reasons and were excluded from the study. None of the excluded patients contacted us even though all coronectomy patients had been requested to inform the department in the event of abnormal postoperative complications. The state of the impacted wisdom tooth and its positional relationship to the mandibular canal were analyzed using patient information and preoperative panoramic radiographs (Table 1). The mean age of the patients was 33.8 years.

Table 1. Patient characteristics. Data presented as percentages, with numbers in parenthesis.

	Patients ($n = 92$) Teeth ($n = 111$)
Gender	
Female	68.5 (63/92)
Male	31.5 (29/92)
Age, years	
≤29	33.7 (31/92)
30–39	41.3 (38/92)
≥40	25.0 (23/92)
Root morphology	
Conical	69.4 (77/111)
Enlarged	15.3 (17/111)
Club	15.3 (17/111)
Axial angle	
Horizontal	42.3 (47/111)
Angular	47.7 (53/111)
Vertical	9.9 (11/111)
Depth of impaction (Winters class)	
Position A	47.7 (53/111)
Position B	37.8 (42/111)
Position C	14.4 (16/111)
Radiographic signs of an increased risk of inferior alveolar nerve injury	
Deviation of the canal	19.8 (22/111)
Narrowing of the canal	30.6 (34/111)
Peri-apical radiolucent area	0.9 (1/111)
Narrowing of the root apex	1.8 (2/111)
Darkening of the root apex	25.2 (28/111)
Curving of the root apex	15.3 (17/111)
Loss of lamina dura of the canal	38.7 (43/111)

Development of postoperative paraesthesia

One subject (1.0%), a 28-year-old woman, developed hypoesthesia of the left lower lip on postoperative day 2, but the hypoesthesia improved after 2 months.

Extraction of retained roots

Of the 111 coronectomy cases, 10 roots (9.0%) in 10 patients (two men and eight women; mean age 37.8 years) were extracted for incomplete wound closure due to a remaining pocket connected to the root (Table 2). The roots in seven patients were palpable. The surgical wound in two patients was closed at one point, but the root was exposed and became palpable due to migration during the first postoperative year. The last patient developed pulpitis in the retained root due to a dry socket. Extraction of the retained roots was performed within 3 months of surgery in three patients, between 3 months and 1 year after surgery in five patients, and between 1 and 2 years in two patients. The surgical sites stabilized after 2 years, resulting in no need for root extraction. No postoperative sensory deficit developed in any patient. Histopathological examination of the root was possible in seven of the 10 cases, and the pulp and root appeared to have been vital in five cases. The patient with the dry socket showed mild infiltration of inflammatory cells in the pulp, and three patients showed dentine bridge formation over the vital pulp of the resected wisdom tooth.

Conditions of the retained roots and surrounding tissue at the 3-year follow-up

Diagnostic imaging findings, such as contact between the mandibular canal and the mandibular third molar apex, coronal bone formation of the retained root, and abnormal transmission images of nearby bones, were evaluated in 101 cases for up to 3 years after surgery (Fig. 2). Retained roots were no longer in contact with the mandibular canal in 56 cases (55.4%) at the 1-year follow-up, in 64 cases (63.4%) at the 2-year follow-up, and in 69 cases (68.3%)

Table 2. Extraction of retained roots.

Case	Age, years	Gender	Root morphology	Axial angle	Cause	Post-surgery month of extraction	Pulp	Dentine bridge
1	38	F	Horizontal	A	Incomplete wound closure	7	Vital	+
2	34	F	Angular	B	Incomplete wound closure	12		
3	39	F	Horizontal	A	Incomplete wound closure	12	Vital	+
4	38	F	Horizontal	A	Incomplete wound closure	3	Non-vital	–
5	37	M	Horizontal	C	Incomplete wound closure	3.5		
6	28	F	Horizontal	B	Root exposure	7		
7	40	F	Angular	A	Incomplete wound closure	10	Vital	–
8	33	F	Horizontal	A	Incomplete wound closure	24	Vital	+
9	44	F	Horizontal	B	Dry socket	1	Vital	–
10	43	M	Horizontal	A	Root exposure	29	Non-vital	–

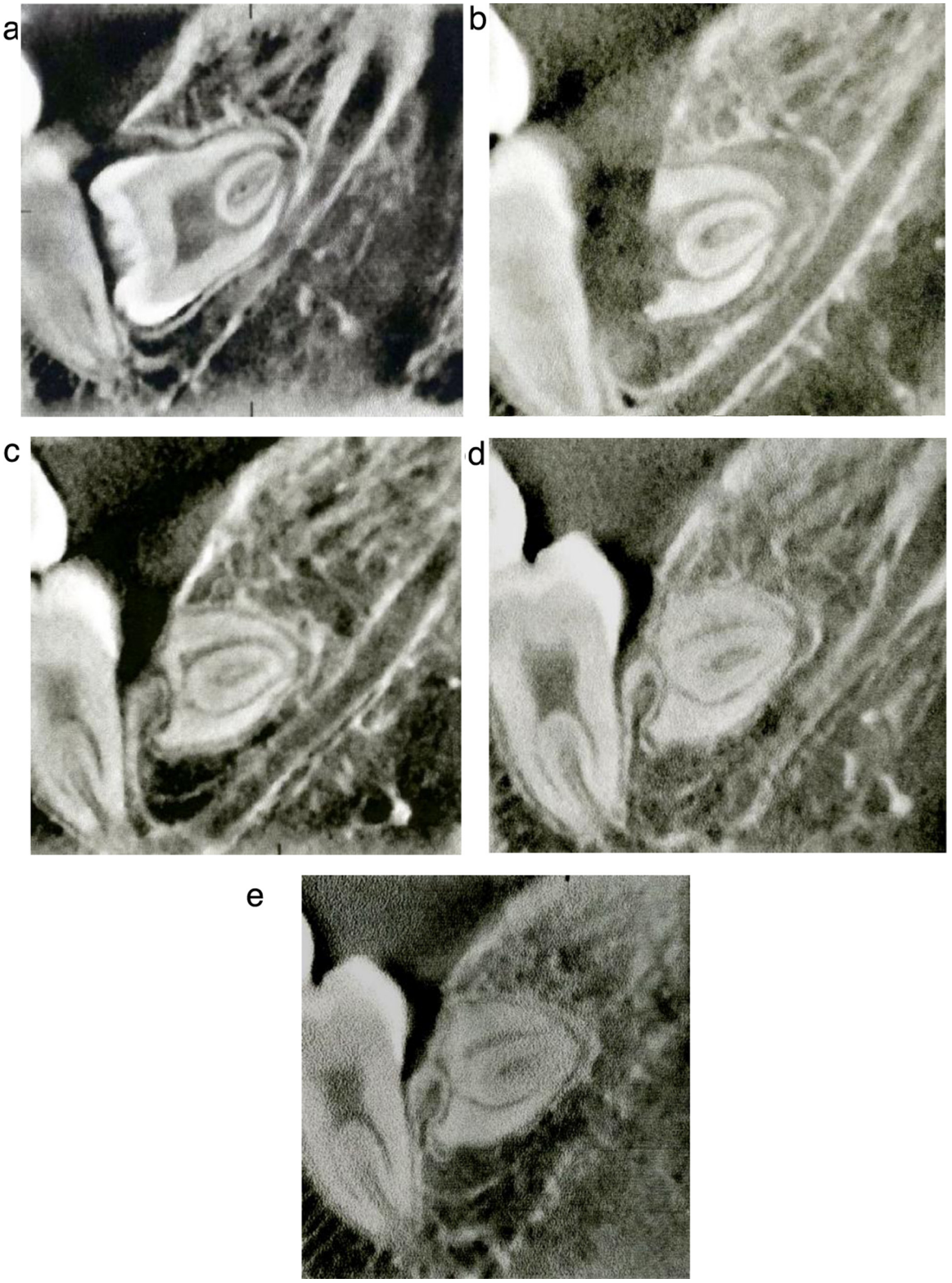

Fig. 2. A representative case: images obtained during 3 years of follow-up after coronectomy. These findings suggest active root migration and bone formation over the resected surface within the first year after surgery and that subsequent root migration decreases and eventually stabilizes. Transmission images of the area near the retained root apex showed no pathological findings at 3 years. (a) Preoperative. (b) 3 months postoperative. (c) 1 year postoperative. (d) 2 years postoperative. (e) 3 years postoperative.

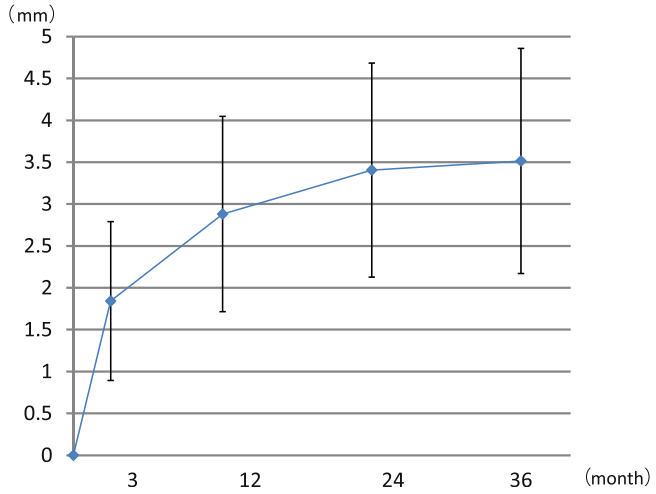

Fig. 3. Root migration during the 3 years after surgery. A significant difference was observed in the values between postoperative month 3 and year 1 ($P < 0.001$) and between years 1 and 2 ($P < 0.001$). However, no significant difference was observed between years 2 and 3.

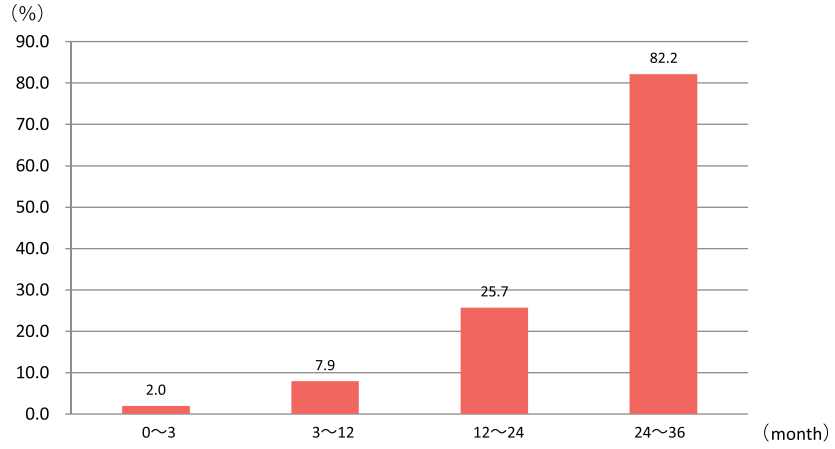

Fig. 4. Percentage with no root migration during each period. No root migration was observed in 25.7% of cases from year 1 to year 2 of follow-up, and in 82.2% of cases from year 2 to year 3 of follow-up.

at the 3-year follow-up. Coronal bone formation was visible in 86 cases (85.1%) at the 1-year follow-up, 99 cases (98.0%) at the 2-year follow-up, and 99 cases (98.0%) at the 3-year follow-up. In the two cases with no bone formation at the 3-year follow-up, part of the crown could not be removed because it was attached to the IAN. However, as there was no root exposure into the oral cavity and no findings indicative of infection, these patients were placed under observation. In addition, no abnormal radiolucent images were observed in the bone surrounding the retained root in all cases. Three years postoperatively, the pocket of the mandibular second molar in eight of the 101 cases (7.9%) was ≥4 mm; five of these eight cases had a prosthetic crown. Advanced periodontal disease was thought to be the cause of the pocket in the remaining three patients, who were placed on follow-up observation because no pus or inflammation of the surrounding gum was observed.

Root migration during the 3 years after surgery

In the 101 cases, mean root migration was 1.84 mm at the 3-month follow-up, 2.88 mm at the 1-year follow-up, 3.41 mm at the 2-year follow-up, and 3.51 mm at the 3-year follow-up, with a significant difference in the values between postoperative month 3 and year 1 ($P < 0.001$) and between years 1 and 2 ($P < 0.001$) (Fig. 3). However, no significant difference was observed between years 2 and 3.

No root migration was observed in 25.7% of cases from the 1-year to the 2-year follow-up and in 82.2% of cases from the 2-year to the 3-year follow-up (Fig. 4). These findings suggest active root migration and bone formation over the resected surface within the first year after surgery and that subsequent root migration decreases and eventually stabilizes.

At the 3-year follow-up, factors significantly associated with root migration were sex and age (Table 3). The migration distance was 3.71 mm in women and 3.08 mm in men, with a significant difference between the sexes ($P = 0.030$). Migration by age group was 4.28 mm, 3.21 mm, and 2.83 mm for subjects aged ≤29 years, 30–39 years, and ≥40 years, respectively. A significant difference was observed between subjects aged ≤29 years and those aged 30–39 years ($P = 0.001$) and between subjects aged ≤29 years and those aged ≥40 years ($P < 0.001$). No significant differences in root morphology, axial angle, or depth of impacted root were observed at 3 years after surgery.

Discussion

When dental CT findings suggest contact between the mandibular canal and the root apex, and thus a risk of iatrogenic nerve injury during conventional tooth extraction, a coronectomy is performed to remove only the crown and preserve the root of the tooth. Previous studies,[8–13] including a systematic review and meta-analysis,[10] have shown that coronectomy is more effective than conventional tooth extraction for preventing nerve damage. However, the long-term outcome of coronectomy has yet to be elucidated,[13] and retained roots and the surrounding bone can develop infections such as apical periodontitis and osteomyelitis in the long term.

In the study conducted by Goto et al., histological findings showed that retained roots that had to be extracted were vital and that a dentine bridge had formed on the resected surface of the root exposing the pulp.[14] However, no inflammatory reaction was observed in the pulp. Animal studies have shown live pulp in the retained root after coronectomy.[15] In addition, teeth roots that were subjected to dental pulp treatment and were left in the bone were shown to have a poor prognosis; therefore, dental pulp treatment is unnecessary.[16,17] Sencimen et al. treated the root canal of patients with mineral trioxide aggregate after coronectomy and found that the outcome of coronectomy was better in patients who did not receive this treatment.[18] Based on these

Table 3. Factors associated with root migration. Factors that correlated significantly with root migration were gender, age, and root morphology.

	3 months	1 year	2 years	3 years
Average root migration (mm)	1.84[a]	2.88[a]	3.41[a]	3.51
Gender				
Male	1.71	2.52[b]	2.97[b]	3.08[b]
Female	1.90	3.04[b]	3.60[b]	3.71[b]
Age, years				
≤29	2.23[c]	3.50[c,d]	4.11[c,d]	4.28[c,d]
30–39	1.71	2.66[d]	3.13[d]	3.21[d]
≥40	1.46[c]	2.28[c]	2.76[c]	2.83[c]
Root morphology				
Conical	1.90	3.01	3.58[e]	3.67
Club	1.94[f]	3.06[f]	3.53[f]	3.74
Enlarged	1.50[f]	2.16[f]	2.53[e,f]	2.63
Axial angle				
Angular	2.15	3.23	3.77	3.96
Vertical	1.73	2.59	3.23	3.23
Horizontal	1.64	2.68	3.18	3.25
Depth of impaction (winters class)				
Position A	2.10	3.13	3.67	3.80
Position B	1.57	2.60	3.17	3.27
Position C	1.80	2.90	3.27	3.33

[a] Significant difference between 3 months and 1 year, and between 1 year and 2 years.
[b] Significant difference between males and females.
[c] Significant difference between those aged ≤29 years and those aged ≥40 years.
[d] Significant difference between those aged ≤29 years and those aged 30–39 years.
[e] Significant difference between conical and enlarged root morphology.
[f] Significant difference between club and enlarged root morphology.

findings, it is likely that coronectomy with no pulp treatment will remain the standard procedure and that the retained root will not affect the surrounding tissues.

It has been reported that after coronectomy the retained root migrates towards the oral cavity over time. Pogrel et al. reported that 30% of roots migrated away from the mandibular canal,[19] while Dolanmaz et al. reported that the migration distance reached 4 mm during the first 2 years after coronectomy.[20] In this series, the roots migrated ≥3 mm during the first year after surgery and additionally by 0.5–1 mm in the following year. Root migration stabilized after postoperative year 2, and 82.2% of the cases showed no root migration between postoperative years 2 and 3. These findings suggest that root migration decreases over time. Leung and Cheung used panoramic radiography to show root migration during the 3-year period following coronectomy.[12] Although the mean migration distance over 3 years was larger in our study, both studies showed a larger migration distance during the first year, which decreased gradually in the second year to almost non-existent thereafter. Similarly, Leung and Cheung reported that after postoperative year 2, none of the cases required root extraction due to exposure into the oral cavity.[12] Based on these studies, postoperative year 2 may be the turning point in terms of root exposure due to migration.

The mean migration distance of 3.5 mm in this study implies that root exposure may be prevented if teeth are resected 4 mm below the edge of the bone. Consistent with this notion, Renton et al. obtained good results when they resected teeth 3–4 mm below the edge of the bone,[8] and the retained roots were covered by bone in 98.0% of cases at the 3-year follow-up. In the remaining two cases with no bone formation, the resection site was below the edge of the bone, but enamel remained around the neck of the tooth below the crown, with the growth of granulation tissue, but not bone. In the absence of infection or exposure of the root to the oral cavity, there is no indication for root retrieval. Instead, patients in the present study were placed under careful observation due to the potential for postoperative infection. Coronal bone formation would seem to indicate that no further migration is likely to happen[21] and the risk of infection has decreased.

Periodontal disease and cyst formation near the apex of the mandibular second molar may destroy coronal bone formation. In this study, the distal pocket of the mandibular second molar was pathologically deep (≥4 mm) in eight cases (7.9%) at the 3-year follow-up; five of these cases had lowered gingiva due to a prosthetic crown and three had advanced periodontal disease. Careful observation is necessary for patients with a non-vital mandibular second molar with a prosthetic crown extending below the gingival margin and with poor periodontal condition. It is, therefore, important to promote thorough oral hygiene to ensure stable coronal bone formation.

Surgical sites do not always close properly after coronectomy.[12] In such cases, the retained root can be palpated using a dental probe and is susceptible to infection. In this study, the root was palpable in seven cases due to improper wound closure. After confirming that the root had moved away from the mandibular canal during the first year after surgery, the authors extracted the root in all cases. The patients were informed of the pathology of the retained root prior to extraction and were instructed to keep the site clean during the waiting period. the Authors also routinely examined the surrounding tissue for acute infection. These findings suggest that proper oral hygiene can delay extraction until the root has migrated away from the mandibular canal, even if the root is exposed to the oral cavity.

One patient (1.0%) developed hypoesthesia of the lower lip. In this case, preoperative CT images showed that the tooth was impacted in the vertical position and the mandibular canal was running alongside the root, as if being pushed by one side of the impacted tooth root. Consequently, it was difficult to operate the extraction tools, and vibration and

compression during coronectomy might have damaged the nerve. It is, therefore, necessary to handle surgical tools carefully in cases where dental CT images show the mandibular canal being pressed by the deeply impacted mandibular third molar. It is also necessary to avoid surgical tools with low revolutions and high torque and to avoid forceful dislocation of a root. However, the incidence of hypoesthesia in the lower lip is significantly lower in coronectomy compared with conventional root extraction,[1–3] suggesting that coronectomy is an extremely effective means of avoiding IAN injury.

Leung and Cheung analyzed the factors affecting root migration 2 years after coronectomy and found a small non-significant difference between the sexes.[12] In contrast, sex and age in the present study significantly affected root migration at the 3-year follow-up. Compared with patients aged ≤29 years, the migration distance was significantly and age-dependently decreased in patients in their 30s and 40s, presumably because of factors such as densification and sclerosis of the surrounding bone and fibrosis of the periodontal membrane. Considering that the wisdom tooth root apex completes its development around the age of 18–25 years, the force of eruption might also have affected root migration. The migration distance was significantly greater in women than in men, possibly because the bone density of the cancellous bone area in the mandible is reportedly lower in women. Furthermore, the incidence of IAN injury due to tooth extraction is higher in women,[22] presumably because of the thinner buccal and lingual cortical bone in the mandible and, therefore, a shorter distance between the mandibular canal and the mandibular third molar root apex in women. Therefore, coronectomy is performed proactively in women with a suspected interaction between the mandibular canal and the mandibular third molar.

Techniques to reduce the incidence of IAN injury during wisdom tooth extraction have been investigated for many years,[23,24] and recent studies have developed two-stage tooth extraction protocols to reduce the risks.[25] Although this can reduce the risk of nerve injury, patients need to undergo two surgical procedures, with difficulty in the second procedure. In contrast, coronectomy normally requires a single procedure and has a reduced risk of IAN injury.

The present study showed favourable outcomes of coronectomy 3 years after surgery and that exposure of the retained root may happen during the first 2 years, if at all. In addition, the root rarely migrates after 2 years. Coronal bone formation was particularly good in terms of surgical safety. Proper oral hygiene and regular follow-ups are necessary to ensure stable coronal bone formation in subsequent years. The authors plan to further investigate the long-term outcome of retained roots after coronectomy.

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Competing interests

No competing interests.

Ethical approval

The present study was performed at the university dental hospital, with the approval of the ethics committee of Aichi Gakuin University (No. 157). All patients and volunteers were informed of the aims of the study and provided their consent before participation.

Patient consent

Written patient consent was obtained to publish the clinical photographs.

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