Accuracy of Panoramic Radiograph for Determining the Relationship Between Mandibular Third Molar and Mandibular Canal: A Comparative Evaluation Using Cone-Beam Computed Tomography

Chinnachote Khemla* Chanchai Wongchuensoontorn*

Abstract

Objectives: The purposes of this study were to evaluate an accuracy of panoramic radiograph for determining relationship between lower third molar and mandibular canal comparing with cone-beam computed tomography (CBCT) and to study the relationship between signs on panoramic image and nerve involvement.

Materials and Methods: The study was a retrospective study of patients who were treated by extraction or surgical removal of mandibular third molar from January 2013 to December 2018. CBCT was performed to all eligible patients who showed preoperative panoramic radiograph of mandibular third molar roots approximated or superimposed to mandibular canal. Signs of nerve involvement on panoramic radiograph including darkening of root, deflection of root, narrowing of root, dark and bifid apex of root, interruption of white line of canal, diversion of canal, and narrowing of canal were compared to CBCT finding.

Results: There were 154 mandibular third molars from 106 patients in this study. Accuracy, sensitivity, specificity, positive and negative predictive values of panoramic radiograph were 73.4%, 83.1%, 60%, 74%, and 72.2%, respectively. A logistic regression analysis showed that darkening of root and interruption of white line of canal indicated significant correlation with nerve involvement ($p < 0.01$).

Conclusions: Although panoramic radiograph provides less accurate details than CBCT, it can give reliable preliminary information to evaluate relationship between mandibular third molar and mandibular canal. Moreover, darkening of root and interruption of white line could be used to predict nerve involvement.

Keywords: Panoramic radiography, Cone-beam computed tomography, Third molar, Mandibular Nerve

**Department of Oral Surgery and Oral Medicine, Faculty of Dentistry, Srinakharinwirot University, 114 Sukhumvit 23, Wattana, Bangkok, 10110, Thailand.*

Introduction

Mandibular third molar extractions are general procedures among oral surgery clinics. (1) Inferior alveolar nerve injury is a serious complication which occurred in range from 0.4% to 1.1% after removal of impacted mandibular third molar. (2,3) Although its incidence appeared to be low, it could have affected the patient's quality of life. Therefore, appropriate preoperative evaluation is essential for treatment planning.

Panoramic radiograph is mostly used as a standard investigation for preoperative evaluation before mandibular third molar surgery. (4,5) The advantages of panoramic radiograph are cheap price and low radiation dose. Moreover, panoramic radiograph can be performed in many clinics and hospitals all around. However, this radiography technique creates two-dimensional image; therefore, anatomical evaluation from this imaging technique has limitation. (6) Alternatively, cone-beam computed tomography (CBCT) can generate three-dimensional image using in many fields of dentistry which give more anatomical information than panoramic radiograph. CBCT can be used to assess and verify association between lower third molar and inferior alveolar canal, but it was not routinely used because of its cost compared to panoramic image. (4) Consequently, panoramic radiograph might be more favored to use as initial preoperative tool.

The close proximity between lower third molar and mandibular canal is a risk factor for inferior alveolar nerve injury. There are signs from panoramic radiograph that indicated involvement between lower third molar and mandibular canal. These signs consist of darkening of root, deflection of root, narrowing of root, dark and bifid apex of root, interruption of white line of canal, diversion of canal, and narrowing of canal. (7) There were many studies that investigated relationship between panoramic signs and nerve involvement, (4,8-15) but the outcomes had diversity in results.

The goals of this study were to evaluate an accuracy of panoramic radiograph for determining relationship between lower third molar and mandibular canal comparing with CBCT and to study a relationship between signs on panoramic image and nerve involvement.

Materials and methods

This research was designed as a retrospective study. Samples were collected from patients who were treated by surgical removal or extraction of mandibular third molar from January 2013 to December 2018. Panoramic radiographs were done for all patients to evaluate and make appropriate treatment plans. CBCT was performed to all patients who showed mandibular third molar roots approximated or superimposed to mandibular canal on panoramic radiograph. Patients with radiographic signs of incomplete root formation, periapical lesion, cyst, or tumor were excluded from the study. This study was reviewed and deemed exempt by Human Research Ethics Committee of Srinakharinwirot University (SWUEC/X-178/2563).

Panoramic radiographs were taken using OP100 D (Instrumentarium Imaging, Tuusula, Finland). CBCT images were gained with AZ3000CT (Asahi Roentgen Co., Kyoto, Japan). All radiographic images were evaluated by one observer (C.K.). The observer had seven years of experience as a specialist in oral and maxillofacial

surgery. Nerve involvement from panoramic radiograph was assessed using criteria of Rood and Shehab: (7)

1. Darkening of root was defined as there was decreased radiopacity of root at overlapping area of third molar root and canal.

2. Deflection of root was defined as there was deviation of molar root to mesial, distal, or other directions where it closed to canal.

3. Narrowing of root was defined as there was deep grooving or perforation of buccal or lingual aspect of molar root at overlapping area.

4. Dark and bifid apex of root was defined as there were double lines of periodontal space where it closed to canal.

5. Interruption of white line of canal was defined as there was discontinuity of radiopaque line of mandibular canal at area of root apex.

6. Diversion of canal was defined as there was an alteration of canal direction at area of molar root.

7. Narrowing of canal was defined as there was reduction in diameter of canal at area of molar root.

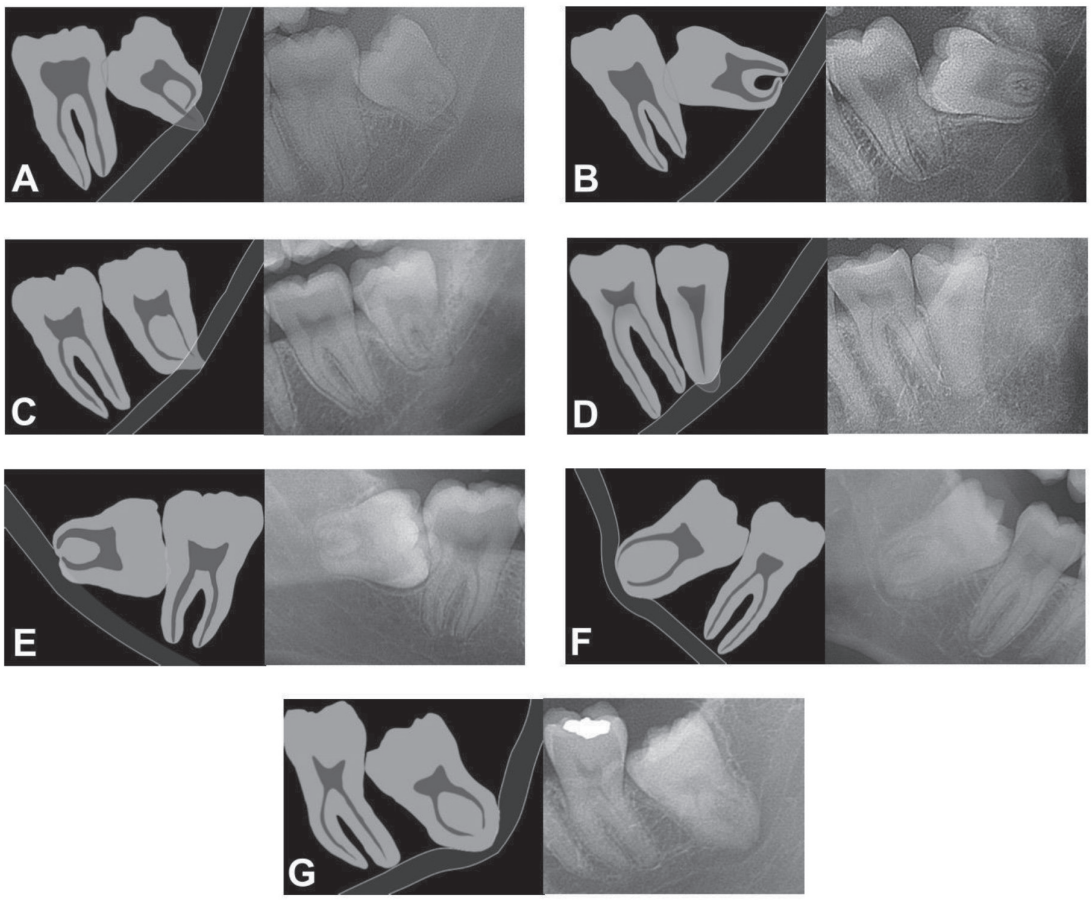

Fig 1. Panoramic radiographic signs of nerve involvement. (A) Darkening of root, (B) Deflection of root, (C) Narrowing of root, (D) Dark and bifid apex of root, (E) Interruption of white line, (F) Diversion of canal, (G) Narrowing of canal.

All seven signs were shown in Fig 1. When there was at least one sign, it was recorded as “presence” on panoramic radiograph. When there were no signs as mentioned previously, it was recorded as “absence.” Nerve involvement on CBCT was judged by evaluating radiopaque ring of mandibular canal in coronal plane. (4) The evaluation of nerve involvement was shown in Fig 2. If there was completely radiopaque ring of canal, it was judged as “no contact” on CBCT (Fig 2A). If there was discontinuity of radiopaque ring of canal, it was judged as “contact” on CBCT (Fig 2B). Evaluation of nerve involvement on panoramic radiograph and CBCT in each case was blinded to eliminate bias. Three months later, twenty samples were randomly selected, and they were assessed again. Intra-observer reliability was calculated with kappa statistic.

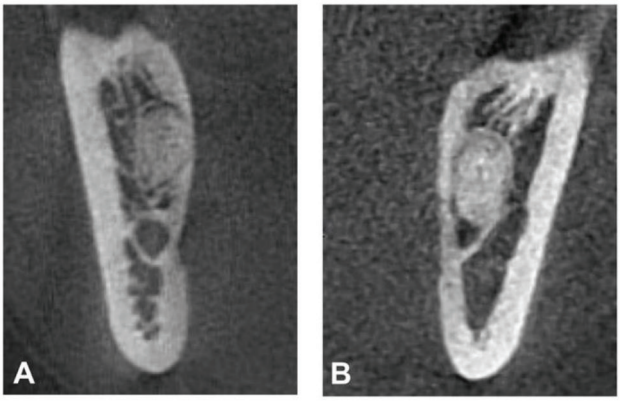

Fig 2. Evaluation of nerve involvement on CBCT. (A) Complete radiopaque ring of canal (no contact), (B) Discontinuity of radiopaque ring of canal (contact).

Accuracy, sensitivity, specificity, positive and negative predictive values were calculated for nerve involvement on panoramic radiograph comparing to CBCT. Logistic regression analysis was used to compute each sign on panoramic radiograph whether it was related to nerve involvement. Logistic regression analysis and kappa statistic score were calculated with IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). A p-value (p) less than 0.05 was considered to be significant. A kappa statistic score of less than 0.20 was assessed for poor agreement, 0.21 to 0.40 was for fair agreement, 0.41 to 0.60 was for moderate agreement, 0.61 to 0.80 was for good agreement, and 0.81 to 1.00 was for very good agreement. (16)

Results

During the study period, the samples were 154 mandibular third molars (cases) from 106 patients with a mean age of 26.07 ± 6.96 years and 73 cases (47.4%) were from female. Predominant lower third molars were on left side of mandible (52.6%). Pell and Gregory class 2 ramus relationship and class B depth were the most frequently found in 70 cases (45.5%) and 112 cases (72.7%) respectively. The class 3 ramus relationship and

class C depth were the least found in 24 cases (15.6%) and 15 cases (9.8%), respectively. Horizontal angulation was the most common angulation (57.2%), followed by mesioangulation (24.7%), vertical angulation (16.2%), and distoangulation (1.9%) (Table 1).

Table 1. Demographic information of study population.

Variable	Statistic
Samples	154
Age (years), mean ± SD (range)	26.07 ± 6.96 (18-51)
Gender	
Female	73 (47.4%)
Male	81 (52.6%)
Tooth	
Right lower third molar	73 (47.4%)
Left lower third molar	81 (52.6%)
Ramus relationship	
Class 1	60 (38.9%)
Class 2	70 (45.5%)
Class 3	24 (15.6%)
Depth of third molar	
Class A	27 (17.5%)
Class B	112 (72.7%)
Class C	15 (9.8%)
Angulation	
Mesioangulation	38 (24.7%)
Horizontal angulation	88 (57.2%)
Vertical angulation	25 (16.2%)
Distoangulation	3 (1.9%)

An intra-observer reliability was very good. Kappa statistic value in assessment of “presence” and “absence” on panoramic radiograph and evaluation of “contact” and “no contact” on CBCT was 0.85 and 1.00, respectively.

Association between mandibular third molar and inferior alveolar canal might be found only by one or more panoramic radiographic signs in each case. Distribution of panoramic radiographic signs were shown in Table 2. The

most frequently radiographic sign was darkening of root found in 36 cases (23.3%), followed by interruption of white line of canal found in 22 cases (14.2%). The other signs (only one sign or combination signs) were least common in this study. There were 54 cases (35.0%) that preoperative panoramic radiographic images showed close relationship between mandibular third molar and mandibular canal but did not match any sign of Rood and Shehab criteria.

Table 2. Distribution of panoramic radiographic signs in the study in frequency order.

Sign(s) on panoramic radiograph	Number of cases	Percentage
DAR only	36	23.3%
INT only	22	14.2%
DAR & INT	9	5.8%
INT & NAC	5	3.2%
DAR & INT & DIC	4	2.5%
DER only	3	1.9%
DIC & NAC	3	1.9%
DIC only	2	1.3%
NAC only	2	1.3%
INT & DIC	2	1.3%
INT & DIC & NAC	2	1.3%
NAR only	1	0.7%
DAB only	1	0.7%
DAR & NAC	1	0.7%
DAR & NAR & NAC	1	0.7%
NAR & INT & DIC	1	0.7%
DAR & DIC & NAC	1	0.7%
DAR & DER & INT	1	0.7%
DER & INT & DIC & NAC	1	0.7%
DAR & DIC	1	0.7%
NAC & DAB	1	0.7%
None of panoramic sign	54	35.0%
Total	154	100%

DAR: darkening of root, DER: deflection of root, NAR: narrowing of root, DAB: dark and bifid apex of root, INT: interruption of white line, DIC: diversion of canal, NAC: narrowing of canal.

Table 3 presented the relation between panoramic radiographic signs (“presence” or “absence”) and CBCT signs (“contact” or “no contact”) on nerve involvement. The accuracy of panoramic radiograph for determining relationship between lower third molar and mandibular canal comparing with CBCT was calculated. Accuracy of this study was 73.4%. Sensitivity, specificity, positive predictive value (PPV) and negative predictive values (NPV) were 83.1%, 60%, 74%, and 72.2%, respectively.

Table 3. Relation between panoramic and CBCT signs on nerve involvement.

Panoramic	CBCT		
	Contact	No contact	Total
Presence	74	26	100
Absence	15	39	54
Total	89	65	154

The relationship between signs on panoramic radiograph and nerve involvement in CBCT was analyzed. A logistic regression analysis was performed to ascertain the panoramic signs on the likelihood that the seven panoramic signs could indicate nerve involvement (Table 4). It showed statistically significant on two panoramic signs (darkening of root and interruption of white line of canal) ($p < 0.01$). Beta coefficient values of darkening of root and interruption of white line of canal signs were 4.352 and 8.334 respectively.

Table 4. A logistic regression analysis of seven signs on panoramic radiographs.

Panoramic radiographic signs	Beta coefficient	95% confidence interval		p-value
		Lower	Upper	
Darkening of root	4.352	1.918	9.875	0.000
Diversion of canal	4.263	0.731	24.868	0.107
Narrowing of canal	1.930	0.405	9.196	0.409
Interruption of white line of canal	8.334	3.152	22.032	0.000
Narrowing of root	1.051	0.051	21.479	0.974
Deflection of root	5.302	0.463	60.657	0.180
Dark and bifid apex of root	1.851	0.096	35.607	0.683

Discussion

One of the main goals of this study was to assess an accuracy of panoramic radiograph for determining relationship between mandibular third molar and mandibular canal comparing with CBCT. Sensitivity and specificity values are used to determine the accuracy of panoramic radiograph for diagnosing proximity of mandibular molar root and mandibular canal. PPV and NPV are used for evaluating possibility to indicate nerve involvement or not involvement. Sensitivity, specificity, PPV, and NPV varied in many studies as summarized in Table 5. These values might be difficult for comparison among previous studies because of different methodology especially standard evaluation. Studies of Nakagawa et al, 2007 (11) and Shahidi et al., 2013 (17) used CBCT as standard evaluation, while some studies (4,9,14,15,18,19) used direct visualization of nerve as standard evaluation. Also, some studies (8,14, 20-22) used postoperative paresthesia of inferior alveolar nerve as standard evaluation. CBCT can provide preoperative information for surgical planning, and it is less aggressive technique than others. Therefore, CBCT is considered a gold standard for evaluation of inferior alveolar nerve involvement nowadays. Although direct visualization of inferior alveolar nerve might be the most accurate method to determine nerve involvement, the operation might be harmful to the inferior alveolar nerve. Moreover, postoperative paresthesia of inferior alveolar nerve is a delayed sign which might or might not be related to nerve involvement. In many clinical cases, inferior alveolar nerve was seen in surgical field after removing mandibular third molar, but there was no postoperative alteration of sensation. Therefore, using postoperative paresthesia as standard evaluation might not be suitable for evaluating proximity between mandibular third molar and mandibular canal in accuracy test.

In our results, sensitivity and PPV of panoramic radiograph were 83.1% and 74%, respectively. These values indicated that panoramic radiograph has high accuracy to be used for diagnosing the involvement between mandibular molar root and mandibular canal. Moreover, specificity and NPV were 60% and 72.2%, respectively. These values implied that panoramic radiograph could be used for evaluating the separation of lower third molar root from mandibular canal in cases that CBCT is not available or affordable. The results of this study are partly similar to the study of Nakagawa et al., 2007 (11) with the exception that their study demonstrated lower sensitivity (64%) and NPV (35%). In addition, the study of Shahidi et al. 2013 (17) which showed sensitivity of 24.1% to 79.3%, specificity of 60% to 80%, PPV of 93.3% to 97.1%, and NPV of 13.3% to 83.3%, depending on each panoramic sign, although they used the same standard evaluation. This could be because Nakagawa et al.'s study used only one sign (interruption of white line of canal) for panoramic radiograph evaluation, and Shahidi et al.'s study used four panoramic signs for evaluation (darkening of root, interruption of mandibular canal wall, mandibular canal diversion, and root dilaceration), while our study used seven signs for evaluation proximity of two structures.

Table 5. Comparisons of number of samples, sensitivity, specificity, predictive values, and standard measurement with previous studies.

Author	Number of samples	Sensitivity	Specificity	PPV	NPV	Standard measurement
This study	154	83.1%	60%	74%	72.2%	CBCT
Nakagawa et al., 2007 (11)	73	64%	65%	86%	35%	CBCT
Shahidi et al., 2013 (17)	132	24.1-79.3%	60-80%	93.3-97.1%	13.3-83.3%	CBCT
Ghaeminia et al. 2009 (4)	53	100%	3%	44%	10%	IAN exposure
Bell et al., 2003 (9)	300	66%	74%	NA	NA	IAN exposure
Sedaghatfar et al., 2005 (15)	423	17-75%	66-91%	7-24%	95-98%	IAN exposure
Hasani et al., 2017, 2019 (18,19)	60	97.6%	NA	67.8%	NA	IAN exposure
Tantanapornkul et al., 2007 (14)	142	70%	63%	31%	90%	IAN exposure and neurosensory disturbance
Valmaseda-Castellon et al., 2001 (8)	1,117	85.7%	47.8%	2.2%	99.6%	Neurosensory disturbance
Gomes et al., 2008 (20)	260	11-33%	80-98%	5.6-20%	94-97%	Neurosensory disturbance
Blaeser et al., 2003 (21)	25	50-80%	54-82%	1.7-2.7%	99%	Neurosensory disturbance
Szalma et al., 2010 (22)	400	14.6-68.3%	85.5-96.9%	3.6-10.9%	99-99.6%	Neurosensory disturbance

IAN: inferior alveolar nerve, NA: data not available, CBCT: cone-beam computed tomography

Our results are comparable to several literatures which used direct visualization of nerve (inferior alveolar nerve exposure) as standard evaluation. They have found that sensitivity values ranged from 66% to 100%. (4,9,14,18,19) However, the study of Sedaghatfar et al., 2005 (15) found that sensitivity had wide range of values (17% to 75%) due to calculation of sensitivity, specificity, PPV, and NPV for each panoramic radiographic sign. Specificity of the present study (60%) is slightly lower than several literatures (9,14,15) which ranged from 63% to 91%, while PPV of this study (74%) is higher than some literatures (4,14,15,18,19) which ranged from 7% to 44%. The possible cause was large numbers of false positive samples in the previous literatures. NPV was varied in many studies (4,14,15,18,19) which ranged from 10% to 98%. NPV of this study (72.2%) is concordant with that range. The difference in ethnicity, sample size, and anatomical variation might affect different outcomes between the present study and previous studies.

There were false negative cases in this study (15 cases). They showed absence of panoramic radiographic sign but appeared contact on CBCT. These cases were found mostly in class I ramus relationship (66.7%), class B depth (80%), and horizontal angulation (60%). This might be because these groups accounted for a large number of cases so there were chances to find more false negative cases than other groups.

In our finding, the most common panoramic sign is darkening of root at 23.3%, follow by interruption of white line at 14.2%. Tassoker, 2019 (12) found that the most frequently observed panoramic sign was interruption of canal wall at 44%, followed by darkening of root at 22%. In our study, darkening of root and interruption of white line of canal are panoramic signs that significantly indicate contact between mandibular third molar and mandibular canal. Similarly, Neves et al. 2012 (23) stated that darkening of root and interruption of white line could identify this relationship. Likewise, Tantanapornkul et al., 2016 (10) reported that isolated interruption of mandibular canal wall or combination with darkening of root indicated direct contact between mandibular third molar and mandibular canal. Nakagawa et al., 2007 (11) and Jung et al., 2012 (13) found that the loss of the border of white line potentially increased risk of nerve involvement. In addition to Hasani et al., 2017, 2019 (18,19) and Szalma et al., 2010 (22) similarly showed that the best predictor for evaluating inferior alveolar nerve involvement was interruption of white line and darkening of root, respectively. However, our results about relationship of two structures were in contrasted with Tassoker, 2019 (12) who found that panoramic sign of diversion of mandibular canal wall was significantly related to nerve involvement.

Another main goal of this study was to examine a relationship between signs on panoramic image and nerve involvement. According to logistic regression analysis (Table 4), it has shown that panoramic radiograph can effectively estimate close association between lower third molar and mandibular canal especially when darkening of root and interruption of white line of canal signs are found preoperatively. Moreover, our results suggest that darkening of root and interruption of white line of canal signs are 4.352 and 8.334 times more likely to indicate nerve involvement, respectively, than absence of these signs. These

results are supported by few literatures. Nunes et al.'s study, 2021 (24) has shown that four panoramic radiographic signs significantly indicated intimate contact between two structures. These four signs consisted of darkening of root, deflection of root, narrowing of root, and interruption of white line of mandibular canal. The odd ratios of these signs were 24.16, 64, 16, and 29.42, respectively. Moreover, the study of Shahidi et al., 2013 (17) has shown that darkening of root, interruption of mandibular canal wall, mandibular canal diversion, and root dilaceration indicated nerve involvement with odd ratios of 4.92, 5.75, 2.86, and 5.28, respectively.

Although this study included quite large number of subjects and compared findings from the panoramic radiograph with CBCT, a current gold standard, it carried some limitations. First limitation was the alternative perspective of standard evaluation on assessment of panoramic radiograph's accuracy. There were few literatures that used CBCT as a standard evaluation. Therefore, comparisons between this study and other studies with same methodology were limited. Another limitation was sample size in some groups, particularly class 3 ramus relationship, class C depth, and distoangulation groups, appeared to be low. Further study may be required in order to find out association between these factors and nerve involvement in larger sample size.

In conclusion, panoramic radiograph has sufficient accuracy to use as a preoperative tool for evaluating close relationship between mandibular third molar and mandibular canal. Darkening of root and interruption of white line of canal are important signs to predict nerve involvement. When these signs appear on panoramic radiograph, nerve involvement is highly suspected.

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Corresponding author:
Dr. Chinnachote Khemla
Department of Oral Surgery and Oral Medicine, Faculty of Dentistry, Srinakharinwirot University, 114 Sukhumvit 23 Rd, Wattana, Bangkok, 10110, Thailand.
Tel: (662) 649 5000 ext. 15063
E-mail: chinnachote@g.swu.ac.th

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