

Research Article

Association between dentists' satisfaction and the accuracy of working length measurement on digital periapical radiographs: Study cross-sectional

Gefara Nuha Nazhifa¹, Felda Noor Sa'idah¹, Rurie Ratna Shantiningsih^{2,3*}, Rini Widyaningrum^{2,3}, Ryna Dwi Yanuaryska^{2,3}, Henny Retno Mayangsari³, Rellyca Sola Gracea⁴

*Correspondence:
rurieratna@uqm.ac.id

¹Undergraduate Study Programme Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia.

²Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia.

³Professor Soedomo Dental Hospital of Universitas Gadjah Mada, Yogyakarta, Indonesia.

⁴Doctoral School of Biomedical Sciences, KU Leuven, Belgium.

Submission: 28 March 2026

Revised : 27 April 2026

Accepted: 27 June 2026

Published: 30 June 2026

DOI: [10.24198/pjdrs.v10i2.69753](https://doi.org/10.24198/pjdrs.v10i2.69753)

ABSTRACT

Introduction: Accurate working length measurement is essential for successful endodontic treatment. Digital periapical radiography is widely used for working length determination; however, limited evidence is available regarding dentists' satisfaction with this method and its association with perceived measurement accuracy. This study aimed to investigate the association between dentists' satisfaction and perceived accuracy of working length measurements obtained using digital periapical radiography, with measurements obtained using an electronic apex locator (EAL) as a comparator. **Methods:** This cross-sectional study compared 44 paired working length measurements obtained using digital radiographs and an EAL using the Mann-Whitney test. Dentists' satisfaction was evaluated using a questionnaire based on the Technology Acceptance Model (TAM), with validity and reliability assessed using Pearson's correlation and Cronbach's alpha, respectively. Spearman's correlation analyzed the association between satisfaction and perceived accuracy. **Results:** No statistically significant difference was found between working length measurements obtained using digital periapical radiography and those obtained using an EAL ($p > 0.05$). After excluding two invalid items, the questionnaire demonstrated acceptable validity and reliability. Overall, 60% of respondents were very satisfied and 40% were satisfied with the use of digital periapical radiography for working length determination. Most respondents (67%) perceived the measurement accuracy as moderate, while 33% rated it as high. A significant positive correlation was found between dentists' satisfaction and perceived measurement accuracy ($r = 0.662$, $p = 0.007$). **Conclusion:** Dentists' satisfaction was positively associated with their perceived accuracy of working length measurement using digital periapical radiography. Dentists who perceived greater accuracy in working length measurement also reported higher satisfaction with the use of digital periapical radiography. In addition, no significant difference was found between working length measurements obtained using digital periapical radiography and those obtained using an EAL, suggesting that the two methods yielded comparable measurements under the conditions of this study.

KEYWORDS: Endodontics, digital dental radiography, dentist satisfaction, working length, electronic apex locator; technology acceptance model.

Hubungan antara kepuasan dokter gigi dan akurasi pengukuran panjang kerja pada radiografi periapikal digital: Studi cross-sectional

ABSTRAK

Pendahuluan: Penentuan panjang kerja yang akurat merupakan salah satu faktor penting dalam keberhasilan perawatan endodontik. Radiografi periapikal digital banyak digunakan untuk menentukan panjang kerja, namun bukti mengenai kepuasan dokter gigi dan hubungannya dengan persepsi terhadap akurasi pengukuran masih terbatas. Penelitian ini bertujuan untuk mengetahui hubungan antara kepuasan dokter gigi dan persepsi terhadap akurasi pengukuran panjang kerja menggunakan radiografi periapikal digital dibandingkan dengan pengukuran menggunakan elektronik apex locator (EAL). **Metode:** Studi potong lintang ini membandingkan 44 pasangan pengukuran panjang kerja dari radiografi digital dan EAL menggunakan uji Mann-Whitney. Kepuasan dokter gigi dievaluasi menggunakan kuesioner berbasis TAM, yang divalidasi melalui korelasi Pearson dan alpha Cronbach. Korelasi Spearman digunakan untuk menganalisis hubungan antara kepuasan dan persepsi akurasi. **Hasil:** Tidak terdapat perbedaan bermakna antara pengukuran panjang kerja menggunakan radiografi periapikal digital dan EAL ($p > 0,05$). Setelah dua item tidak valid dikeluarkan, kuesioner menunjukkan validitas dan reliabilitas yang dapat diterima. Sebanyak 60% responden sangat puas dan 40% puas terhadap pengukuran panjang kerja secara radiografis. Sebanyak 67% responden menilai akurasi pengukuran sedang dan 33% menilai tinggi. Terdapat korelasi positif yang bermakna antara kepuasan dokter gigi dan persepsi akurasi pengukuran ($r = 0,662$; $p = 0,007$). **Simpulan:** Hubungan positif ditemukan antara kepuasan dokter gigi dan persepsi mereka terhadap keakuratan penentuan panjang kerja menggunakan radiografi periapikal digital. Dokter gigi yang mempersepsikan tingkat keakuratan penentuan panjang kerja yang lebih tinggi juga melaporkan tingkat kepuasan yang lebih tinggi terhadap penggunaan radiografi periapikal digital. Selain itu, tidak ditemukan perbedaan yang signifikan antara pengukuran panjang kerja yang diperoleh menggunakan radiografi periapikal digital dan pengukuran yang diperoleh menggunakan EAL (Electronic Apex Locator), yang menunjukkan bahwa kedua metode tersebut menghasilkan pengukuran yang sebanding dalam kondisi penelitian ini.

KATA KUNCI: Endodontik; radiografi dental digital; dokter gigi; kepuasan; panjang kerja; elektronik apex locator; technology acceptance model.

INTRODUCTION

Endodontics is a dental specialty concerned with the treatment and preservation of teeth affected by pulpal disease.¹ The primary goal of endodontic treatment is to create conditions that allow infected root canals to heal while maintaining the health of periradicular tissues and preserving the tooth.² Because endodontic treatment focuses on the root canal system, its success largely depends on accurate working length determination.^{3,4} Accurate working length determination facilitates effective canal debridement while minimizing the risks of over-instrumentation, under-instrumentation, and post-treatment complications.^{5,6}

Determining root canal working length is a major challenge for clinicians during endodontic treatment. Working length is defined as the distance from a coronal reference point to the apical constriction,⁷ which is generally located approximately 0.5–1.0 mm coronal to the anatomical apex.⁸ Radiographic measurements are conventionally considered acceptable when they fall within ± 0.5 mm of the actual working length.⁹ Therefore, methods used for working length determination should provide reliable measurements while remaining practical, efficient, safe, and clinically applicable.¹⁰

Working length can be determined using either radiographic or electronic methods. Digital periapical radiography remains one of the most widely used imaging modalities in endodontic practice because it enables immediate image acquisition and allows linear measurements using integrated digital ruler software, thereby reducing measurement variability.^{1,2,5} In digital radiography, working length measurements are performed using a digital ruler integrated into the imaging software, which has been shown to reduce measurement variability.^{11–13} Electronic apex locators (EALs), in contrast, estimate the position of the apical constriction electronically and have demonstrated high measurement accuracy under appropriate clinical conditions. A previous study reported that EAL achieved an accuracy of approximately 95% in identifying the apical constriction, whereas digital periapical radiography demonstrated an accuracy of approximately 70%.¹⁴ Although both techniques are widely used, no single method has been universally accepted as the definitive approach for working length determination, and their complementary use is frequently recommended in clinical practice.¹

Most previous studies have focused on the objective accuracy of working length determination by comparing digital periapical radiography with EALs or anatomical reference standards. However, limited evidence is available regarding dentists' satisfaction with the accuracy of radiographic working length measurements used to support root canal treatment in routine clinical practice, and whether the accuracy of these measurements is associated with clinicians' acceptance of the technique. This represents an important research gap because clinicians' confidence in a measurement method may influence its acceptance, routine use, and clinical decision-making. Moreover, dentists' satisfaction is recognized as an important indicator of technology acceptance and may ultimately affect the quality and consistency of patient care.^{15–18} Therefore, evaluating both the objective accuracy of working length measurements and dentists' satisfaction provides a more comprehensive assessment of the clinical utility of digital periapical radiography.² The Technology Acceptance Model (TAM) is one of the most widely used theoretical frameworks for explaining users' acceptance of information technology.^{19–21} Technology acceptance is primarily determined by perceived usefulness, perceived ease of use, attitude toward use, and behavioral intention to use.²² These constructs have been extensively applied to evaluate users' acceptance of healthcare technologies.

In the context of endodontic treatment, dentists who perceive radiographic working length measurements as accurate and clinically reliable are more likely to adopt and routinely use this approach during treatment. Therefore, this study employed a TAM-based questionnaire to assess dentists' satisfaction and acceptance of radiographic working length measurements obtained from digital periapical radiographs. Furthermore, dentists' satisfaction scores were correlated with the objective accuracy of radiographic working length measurements, using the clinical working length determined with an EAL by the referring dentists during endodontic treatment as the reference standard.

Although previous studies have extensively evaluated the objective accuracy of working length determination methods, little attention has been given to clinicians' subjective perceptions and satisfaction regarding these measurements. The novelty of this study lies in integrating objective clinical accuracy comparisons (digital periapical radiography versus electronic apex locator) with a TAM-based assessment to evaluate dentists' satisfaction and technology acceptance in routine clinical practice. Therefore, this study aimed to investigate the association between dentists' satisfaction and the perceived accuracy of working length measurements obtained using digital periapical radiography, compared with measurements obtained using an electronic apex locator (EAL).

METHODS

This cross-sectional analytical study was conducted at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada, Yogyakarta, Indonesia, between January and October 2023. The study population comprised all dentists who referred patients to the department for root canal working length measurements using the digital periapical technique during this period. The study dataset consisted of 44 paired working length measurements obtained from patients referred by dentists to the Radiology Department for endodontic treatment planning. Each case included two working length measurements: (1) radiographic working length, measured on periapical radiographs using SOPRO® Imaging software (Acteon, France), and (2) clinical working length, determined during endodontic treatment using an EAL.

Purposive sampling was used because only dentists who routinely referred patients for working length assessment using digital periapical radiography and fulfilled the predefined eligibility criteria were relevant to the study objectives. To minimize selection bias, all eligible dentists during the study period were invited to participate, and standardized inclusion criteria were applied consistently to all participants. The inclusion criteria included dentists who referred patients for root canal working length measurement using digital periapical radiography with the bisecting angle technique, dentists who had root canal working length measurements performed using the SOPRO® Imaging software from Prof. Soedomo Dental Hospital, and dentists who agreed to participate in the research by providing informed consent. Participants were recruited using purposive sampling.

The minimum sample size for the correlation analysis was estimated using a formula for correlational studies: The sample size was determined using the sample size calculation formula for a correlation test, by calculating the square of the ratio of the sum of Z_α and Z_β to 0.5 multiplied by the natural logarithm of $(1+r)/(1-r)$, and then adding 3.²³ Where $Z_\alpha = 1.96$ (two-sided significance level of 5%), $Z_\beta = 1.28$ (power=90%), and the minimum expected correlation coefficient (r) was 0.50. Based on this calculation, the minimum required sample size was 37.79, which was rounded to 38 cases.

To evaluate the accuracy of radiographic working length determination and the referring dentists' satisfaction, an electronic questionnaire, together with an informed consent form, was distributed to all participating dentists who had referred patients for periapical radiographic examination to support root canal treatment. All respondents were dentists practicing at the same dental hospital where the study was conducted. Consequently, the radiographic and clinical working length data were obtained from a single institutional electronic dental record system, ensuring data consistency and accessibility.

However, because the number of eligible dentists referring patients for working length assessment during the study period was limited, all dentists who fulfilled the inclusion criteria were recruited. Consequently, a total of 15 dentists constituted the study sample and met the eligibility criteria during the study period (January to October 2023). Although the achieved sample size was smaller than the calculated minimum, including the entire accessible population reduced sampling error and maximized the representativeness of the available study population. This limitation is acknowledged when interpreting the findings.

Working length measurements on digital periapical radiographs were performed using the

digital ruler provided by the imaging software. The measurements were conducted by a calibrated dentist with experience in dental radiographic interpretation. To minimize measurement bias, all images were assessed using the same measurement protocol under standardized viewing conditions.

To evaluate measurement reliability, repeated working length measurements were performed on a randomly selected subset of radiographs after a two-week interval by the same observer. Intra-observer agreement was assessed using the intraclass correlation coefficient (ICC), with values above 0.75 indicating good reliability.

For each questionnaire, the investigators included the corresponding patient medical record number of the radiographic sample. This enabled respondents to verify both the radiographic working length measured using SOPRO® Imaging and the clinical working length recorded using the EAL in the patient's dental record before completing the questionnaire.

The accuracy of radiographic working length determination was assessed by asking respondents to select one of three predefined accuracy categories, as described in Table 1. The section assessing accuracy of root canal length measurement on digital periapical radiographs consisted of three categories of accuracy (low, fair, and high). The assessment categories were structured as shown in Table 1, based on previous studies.^{9,24}

Table 1. The criteria for assessing the accuracy of working length measurement.

Assessing of accuracy	Criteria
1 (Low)	$X > 1 \text{ mm}$
2 (Fair)	$0,5 \text{ mm} < X \leq 1 \text{ mm}$
3 (High)	$X \leq 0,5 \text{ mm}$

Note: X represents the difference between the working length measured using digital periapical radiography and the root canal working length measured using an apex locator by the dentist.

Respondents were further asked to evaluate their satisfaction with the radiographic working length measurement using a structured questionnaire adapted from the TAM.²⁵ The questionnaire assessed five dimensions of TAM: perceived ease of use, perceived usefulness, attitude toward use, behavioral intention to use, and job relevance (Table 2).

Table 2. Distribution of questionnaire items based on the TAM dimensions

No	TAM Dimension	Item Numbers	Favorable Items	Unfavorable Items
1	Perceived Ease of Use	1–2	1, 2	–
2	Perceived Usefulness	3–13	3, 4, 5, 9, 10, 11, 12, 13	6, 7, 8
3	Attitude Toward Use	14–18	15, 17, 18	14, 16
4	Behavioral Intention to Use	19–21	19, 20	21
5	Job Relevance	22–24	22, 24	23

The questionnaire comprised 24 items, including 17 favorable statements and 7 unfavorable statements distributed across the five TAM dimensions (Table 2). Responses were recorded using a four-point Likert scale consisting of *strongly agree*, *agree*, *disagree*, and *strongly disagree*.²⁶ Favorable and unfavorable items were scored inversely to minimize response bias (Table 3). The total questionnaire score was treated as an interval-scale data for statistical analysis.

Table 3. Likert scale scoring system

Favorable Item	Response	Unfavorable Item
4	Strongly Agree	1
3	Agree	2
2	Disagree	3
1	Strongly Disagree	4

RESULTS

Based on data recorded at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada, during the study period, there were 62 working length measurements using digital periapical radiography, originating from 15 referring dentists (Table 4). In general, each dentist submitted more than one request for working length measurement.

Table 4. Distribution of working length examination requests among respondents

Request Frequency Category	Number of Dentists	Percentage (%)	Total Submissions
1 time	5	33.3%	5
2 times	5	33.3%	10
3–4 times	3	20.0%	10
≥5 times	2	13.4%	37
Total	15	100.0%	62

A normality test using the Shapiro-Wilk test was performed on the 44 root canal working length measurements obtained using digital imaging software and EAL. The results of the Shapiro-Wilk test (Table 5) yielded a significance value of less than 0.05 ($p\text{-value} < 0.05$), indicating that neither set of measurements was not normally distributed.

Table 5. Results of the data normality test using the Shapiro-Wilk normality test

Methods		Shapiro-Wilk	
Statistics		df	Sig.
Digital Imaging Software	0,934	44	0,014
Electronic Apex Locator	0,932	44	0,013

Since the working length measurements were not normally distributed, the data were analyzed using the Mann-Whitney U test. The results of the Mann-Whitney U test yielded a $p\text{-value}$ of 0.291. As the $p\text{-value}$ exceeded the significance level of 0.05 ($p > 0.05$), no statistically significant difference was found between the working length measurements obtained using digital imaging software and those obtained using the EAL.

Prior to data collection, the questionnaire was evaluated for its validity and reliability. Construct validity was assessed using the Pearson product-moment correlation test, while internal consistency reliability was evaluated using Cronbach's alpha coefficient. The validity analysis demonstrated that 22 of the 24 questionnaire items were statistically valid ($p \leq 0.05$). Two items (Items 14 and 20) did not meet the validity criterion and were therefore excluded from subsequent analyses (Table 2).

The remaining 22 items were further evaluated for reliability. The questionnaire demonstrated good internal consistency, with a Cronbach's alpha coefficient of ≥ 0.70 , indicating acceptable reliability.²⁷ Consequently, only the 22 items that satisfied both the validity and reliability criteria were retained for assessing dentists' satisfaction with the accuracy of radiographic working length measurements.

Table 6. Distribution of respondents' total scores according to dentists' satisfaction level

Satisfaction Level	Frequency	Percentage (%)
Very Dissatisfied	0	0
Dissatisfied	0	0
Satisfied	6	40
Very Satisfied	9	60
Total	15	100

The distribution of dentists' satisfaction levels regarding the accuracy of radiographic working length measurements obtained from digital periapical radiographs is illustrated in Table 6. Table 6

shows that 60% of dentists who submitted requests for working length measurements were very satisfied with the measurements received, and 40% of dentists were satisfied with the measurements they received. No respondents reported being dissatisfied or very dissatisfied (Table 6). The total satisfaction scores were categorized using the Criterion-Referenced Assessment (CRA).¹⁷ The distribution of responses across the dimensions influencing dentist satisfaction can be seen in Table 7.

Table 7. Distribution of respondents' answers based on satisfaction dimensions

Criteria	Perceived ease of use dimension		Perceived usefulness dimension		Attitude toward use dimension		Behavioral intention to use dimension		Job relevance dimension	
	Value	%	Value	%	Value	%	Value	%	Value	%
Strongly disagree	1-2	0	1-11	0	1-4	0	1-2	0	1-3	0
disagree	3-4	0	12-22	0	5-8	0	3-4	0	4-6	0
Agree	5-6	40	23-33	47	9-12	87	5-6	67	7-9	73
Strongly agree	7-8	60	34-44	53	13-16	13	7-8	33	10-12	27
Total		100		100		100		100		100

Table 7 shows that the majority of respondents (60%) strongly agreed with the perceived ease of use dimension, while 40% of respondents agreed. There were no respondents who disagreed or strongly disagreed with the perceived ease of use dimension (Table 7). The results indicated that 53% of respondents strongly agreed and 47% agreed with the perceived usefulness dimension. There were no respondents who disagreed or strongly disagreed with the perceived usefulness dimension. Regarding the attitude toward use dimension, Table 7 shows that 87% of respondents agreed and 13% of respondents strongly agreed, and there were no respondents who disagreed or strongly disagreed with this dimension. For the behavioral intention to use dimension, 67% of respondents agreed and 33% strongly agreed, with no respondents disagreeing or strongly disagreeing. Table 7 indicated that 73% of respondents agreed and 27% strongly agreed with the job relevance dimension, and there were no respondents who disagreed or strongly disagreed.

Table 8. Distribution of respondents according to their assessment of working length accuracy.

Assessment of working length accuracy	Frequency	Percentage (%)
Low	0	0
Fair	10	67
High	5	33
Total	15	100

Table 8 shows that 67% of the assessments of working length measurement accuracy on digital periapical radiography were in the fair category, 33% were in the high category, and none were in the low category. Accuracy assessments are considered low when $X > 1$ mm, fair when $0.5 \text{ mm} < X \leq 1$ mm, and high when $X \leq 0.5$ mm (Table 1).¹¹⁻¹² The variable X represents the difference between the working length measured using digital periapical radiography and the root canal working length measured using an apex locator by the treating dentist. The working length accuracy assessments were obtained from the questionnaires completed by the dentists.

Table 9 shows that the Spearman correlation coefficient (r) between the total score of the dentist satisfaction questionnaire and the assessment of working length accuracy is 0.662, with a p-value of 0.007. The results of the Spearman correlation test indicate a strong ($r = 0.662$) and significant ($p < 0.05$) correlation between dentists' satisfaction and their assessment of working length accuracy on digital periapical radiography.

Table 9. Result of spearman correlation test

No	Evaluation parameter	Result of Spearman Correlation Test	Description
1	Sig- value (p)	0,007	<0.05 = significant correlation >0.05 = not significant
2	Correlation coefficient (r)	0,662	0.01–0.19: Not correlated 0.20–0.29: Weak correlation 0.30–0.39: Moderate correlation 0.40–0.69: Strong correlation >0.70: Very strong correlation
3	Direction of correlation	Positive	positive correlation: direct relationship negative correlation: indirect relationship

DISCUSSION

Comparison of working length measurements obtained from digital periapical radiographs and an EAL using the Mann–Whitney U test showed no statistically significant difference ($p=0.291$). This result indicates that radiographic working length measurements performed using digital imaging software are consistent with clinical measurements obtained using the EAL, supporting their clinical applicability for endodontic treatment planning. This finding is consistent with previous studies showing that periapical radiography and electronic apex locators yield comparable accuracy in determining root canal working length.⁵

The satisfaction level of dentists regarding the assessment of radiographic working length accuracy at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada, shows that the majority of dentists are highly satisfied (Table 6). This high level of satisfaction is consistent with the principles of TAM, where user acceptance is driven by perceived usefulness, ease of use, and overall operational efficiency.²⁰ The accuracy of diagnostic interpretation in digital radiography is one of the factors influencing dentist satisfaction.^{28,27,29}

The results of the Spearman correlation analysis in this study showed a Spearman correlation coefficient (r) of 0.662 and a p-value (p) of 0.007 ($p<0.05$) (Table 9). The results of the Spearman correlation test indicated a statistically significant association between the level of dentist satisfaction and the assessment of accuracy in working length measurement using digital periapical radiography. This relationship was positive, with a strong correlation, indicating that higher assessments of working length accuracy were associated with higher levels of dentist satisfaction. These results align with findings by Garabedian et al.,³⁰ who demonstrated that clinician satisfaction with digital systems in healthcare settings is strongly tied to system accuracy, usability, and operational performance in daily clinical tasks. One factor influencing dentist satisfaction with digital radiography is diagnostic accuracy.²⁹ Detailed and accurate interpretation of radiographs may affect dentists' satisfaction in the Radiology Department.³¹ The results for the attitude toward use dimension showed that 87% of respondents agreed and 13% strongly agreed that they had a positive and confident attitude toward using digital radiography software for working length measurement (Table 7).

This high proportion of positive attitudes aligns with technology acceptance literature showing that user acceptance and confidence in digital tools stem directly from system dependability and ease of operational integration.³⁰ Attitude toward use reflects whether someone likes or dislikes something.³⁰ For the behavioral intention to use dimension, 67% of respondents agreed and 33% strongly agreed. Respondents reported an intention to reuse the digital radiography software for working length measurement and recommend its use to professional colleagues. Someone who is genuinely satisfied with a result will recommend it to others and reuse that service.³² Interest in repeated use may arise after users experience the usefulness of a service.³³ An individual's satisfaction can be observed behaviorally through their intention for repeated usage (repurchase intention).³⁴ Repurchase intention is the continued use of a service due to the fulfillment of one's expectations (satisfaction).³⁵

This intention for repeated usage is also supported by data on digital periapical radiography

working length measurements at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada. There were 15 dentists who participated in this study, and, on average, each dentist submitted working length measurement requests more than once. Based on the analysis of satisfaction dimensions in terms of job relevance, 73% of respondents agreed and 27% strongly agreed that the use of digital radiography software for working length measurement was relevant to their work as dentists and enhanced their professional performance. This strong consensus on professional utility aligns with technology acceptance literature, which demonstrates that the perceived relevance of digital tools to core clinical duties significantly enhances user satisfaction and technology adoption.³⁰ Job relevance has a positive impact on perceived ease of use and usefulness dimensions and correlates with satisfaction.²¹

The assessment of working length accuracy in digital periapical radiography at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada, was mostly in the fair category, with 67% of respondents (10 dentists) classified as fair and 33% (5 dentists) classified as high. This distribution of accuracy reflects common challenges reported in endodontic radiography, where minor geometric distortions during the bisecting angle technique can lead to slight discrepancies in working length determination compared to electronic apex locators.⁹ The result of this study indicated working length measurement using software in digital periapical radiography at the Radiology Department of Prof. Soedomo Dental Hospital, Universitas Gadjah Mada, mostly fell within the fair category, which means that the difference in working length measurement using digital periapical radiography compared to the working length using an apex locator falls within the range of >0.5 to ≤ 1 mm ($0.5 \text{ mm} < X \leq 1 \text{ mm}$).¹¹⁻¹²

This assessment of working length accuracy is an evaluation by the responding dentists regarding how well the measurement of root canal length corresponds to their accuracy expectations. In this study, the results indicate that there was no significant difference between the working length measurements obtained using the two different methods (Table 5). This comparability aligns with systematic review evidence demonstrating that digital radiography and electronic apex locators achieve equivalent precision in determining endodontic working length, despite operating through different technical principles.³ The EAL is more efficient because it is effective, does not induce a gag reflex, and does not involve radiation exposure, unlike digital radiography. The efficacy of the EAL was high, and it can even be used when the root canal is filled with irrigating solution and blood. However, both digital radiography and EAL methods have similar efficacy and accuracy, providing measurements close to the actual working length.⁵ Combining both methods may provide a more comprehensive assessment than using either method alone.

One factor that could lead to the relationship between two variables not falling into the very strong relationship category is that 67% of the assessments of accuracy by respondents were in the fair category and 33% were in the high category (Table 8), while the level of dentist satisfaction with the assessment of working length accuracy shows that 60% of dentists were very satisfied, and 40% were satisfied (Table 6). This divergence between objective performance scores and user satisfaction is consistent with health technology acceptance research, which shows that subjective user expectations and overall clinical utility often exert a stronger influence on user satisfaction than technical precision alone.³⁶

Based on this study, although some dentists rated working length measurement accuracy as fair, they still reported being very satisfied with the measurement results. Satisfaction with a result is also influenced by subjective factors, which may lead some dentists to feel that the working length measurement results meet their expectations.³⁶ Satisfaction can also be formed from previous experiences, so some dentists may have formed their satisfaction with the service when they received previous working length measurement results.³⁷ Another reason that could explain the relationship between these two variables due to the absence of data on dentist satisfaction levels among assessments classified as having low accuracy.

Factors that can lead to inaccuracies in measuring working length using digital periapical radiography include the quality of radiographic images used for interpretation.¹ Many studies have reported the quality of radiographic images can improve diagnostic accuracy.³⁶ Radiographs can

produce less accurate measurements of working length due to the curvature of the root canal and the fact that the apical foramen is not always located at the root apex. In addition, observer variability and differences in clinical experience may also affect the accuracy of radiographic working length measurements.¹³ The subjective tendency of observers when interpreting radiographs can affect the level of accuracy of radiographic working length measurements.³⁷

The use of the bisecting angle technique in radiographic imaging can lead to inaccuracies in measuring working length. According to Garg and Garg *et al.*,¹ the parallel technique has been reported to be superior to the bisecting angle technique in providing radiographic images of tooth apical anatomy. This is consistent with the fact that the parallel technique can provide better working length measurements.¹³ The limitation of the bisecting angle technique is that distortion can occur because of errors in horizontal and vertical angulation. Errors in vertical angle placement can lead to elongation or shortening of tooth images on radiographs.³⁸ In the parallel technique, there is an aid, such as a film holder, that provides a standardized reference for angulation and can reduce the risk of vertical distortion.^{39,40}

Although most working length assessments were categorized as having fair accuracy, the overall level of dentist satisfaction was high. This apparent discrepancy may be explained by the nature of TAM, which evaluates users' perceptions of a technology rather than its objective diagnostic performance. In this study, satisfaction reflected dentists' perceptions of the digital periapical radiography system in terms of perceived ease of use, perceived usefulness, attitude toward use, behavioral intention to use, and job relevance, rather than the accuracy of the working length measurements alone.^{20,30}

Furthermore, dentists' satisfaction may be influenced by the practicality and efficiency of digital periapical radiography in routine clinical practice. Even when the measured accuracy is classified as fair, the technique provides immediate image acquisition, facilitates image interpretation and communication, and integrates well into the clinical workflow. These advantages may contribute to positive user perceptions despite limitations in measurement accuracy. Therefore, high satisfaction should not be interpreted as indicating high diagnostic accuracy but rather as reflecting favorable user acceptance of the technology. This finding also suggests that objective diagnostic performance and subjective user acceptance represent complementary but distinct aspects of technology evaluation. Both should be considered when assessing the clinical applicability of working length determination methods.

The limitations of this study are the very limited number of dentist respondents, which restricts the ability to generalize these findings to a broader population of dental professionals. Additionally, this research did not account for the variability among different radiologists and dentists in their subjective interpretation of the apical constriction. Subjective observer bias and differences in clinical experience with digital radiographic interpretation may have influenced the accuracy assessments and the determined endpoints of the working length measurements.

The findings of this study indicate that dentists reported a high level of satisfaction with digital periapical radiography for working length assessment despite the accuracy assessments of the measurements being predominantly classified as fair. This apparent discrepancy suggests that clinician satisfaction is influenced by factors beyond diagnostic accuracy alone. Within the framework of TAM, users' acceptance of a technology is determined by perceived usefulness and perceived ease of use, which subsequently shape attitudes toward using the technology and the intention to continue its use. Consequently, dentists may express high satisfaction because digital periapical radiography is practical, readily available, easy to interpret, and efficiently integrated into routine clinical workflows, even when its measurement accuracy is not consistently optimal.

These findings emphasize that objective diagnostic performance and user acceptance represent complementary but distinct dimensions of technology evaluation. While measurement accuracy remains fundamental for successful endodontic treatment, clinicians' confidence in, and acceptance of, a diagnostic method also influence its implementation in daily practice. Therefore, digital periapical radiography should not be evaluated solely on the basis of technical accuracy but also on its usability and its ability to support clinical decision-making. Nevertheless, the predominance of fair accuracy indicates that radiographic assessment should be interpreted

cautiously and, whenever possible, complemented by EAL or other validated methods to improve working length determination. From a clinical perspective, the results suggest that digital periapical radiography remains a valuable adjunct for working length assessment because of its accessibility, efficiency, and favorable user acceptance. However, clinicians should recognize that high satisfaction does not necessarily reflect superior diagnostic accuracy. Instead, treatment decisions should integrate radiographic findings with clinical examination, EAL measurements, and professional judgment to support appropriate endodontic treatment planning.

Future research should include a larger and more diverse sample of dentists and patients to improve the generalizability of these findings and strengthen statistical power. Comparative studies evaluating the bisecting-angle and paralleling techniques under standardized clinical conditions would help determine whether differences in radiographic technique translate into clinically meaningful improvements in working length accuracy and user satisfaction. In addition, future investigations should incorporate validated technology acceptance instruments together with objective measures of diagnostic performance to further elucidate the relationship between clinician perceptions and actual measurement accuracy. Exploring the influence of software characteristics, including image enhancement functions, calibration systems, and digital measurement tools, may also provide valuable insights for optimizing digital endodontic protocols and improving both diagnostic performance and user experience.

Future studies should recruit larger and more diverse samples of dentists and clinical cases to improve the external validity of the findings. In addition, future research should evaluate inter- and intra-observer agreement in working length assessment to determine the consistency of clinicians' interpretations. Comparative studies involving different radiographic techniques, such as the paralleling and bisecting-angle techniques, as well as objective reference standards for working length determination, would further clarify the relationship between clinicians' perceived accuracy, technology acceptance, and objective measurement performance.

CONCLUSION

A positive association was observed between dentists' satisfaction and their perceived accuracy of working length assessment using digital periapical radiography. Dentists who perceived higher accuracy in working length assessment also reported higher levels of satisfaction with the use of digital periapical radiography. In addition, no significant difference was found between working length measurements obtained using digital periapical radiography and those obtained using an EAL, suggesting that the two methods produced comparable measurements under the conditions of this study. The implication of these findings is that integrating digital periapical radiography into routine endodontic workflows may enhance dentists' satisfaction and diagnostic confidence. Furthermore, the use of digital imaging systems alongside EALs may support clinical decision-making while potentially improving the efficiency and quality of endodontic care.

Acknowledgement: The authors would like to express their sincere gratitude to the institution, all participants, and everyone who provided permission, assistance, and support throughout the research process and manuscript preparation. The authors also gratefully acknowledge all those who contributed to the successful completion of this study.

Author Contributions: Conceptualization, G.N.N., F.N.S., R.R.S., and R.S.G; methodology, G.N.N., F.N.S., and R.R.S.; software, R.R.S.; validation, G.N.N., F.N.S., R.D.Y and R.R.S.; formal analysis G.N.N. and F.N.S.; investigation, G.N.N. and F.N.S.; resources, G.N.N. and F.N.S.; data curation, G.N.N. and F.N.S.; writing original draft preparation, G.N.N. and F.N.S.; writing review and editing, G.N.N., R.R.S., R.D.Y., R.W.; visualization, G.N.N. and F.N.S.; supervision, R.R.S., R.W., and H.R.M.; project administration, R.R.S.; funding acquisition, R.R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding

Institutional Review Board Statement: Ethical approval of this study was obtained from the Research Ethics Committee of the Faculty of Dentistry and Prof. Soedomo Dental Hospital, Universitas Gadjah Mada (Ref No. 69/UN1/KEP/FGK-RSGM/EC/20

Informed Consent Statement: consent was obtained from all subjects involved in the study.

Data Availability Statement: data is unavailable due to privacy or ethical restrictions

Conflicts of Interest: Not applicable

REFERENCES

1. Setzer FC, Li J, Khan AA. The use of artificial intelligence in endodontics. *J Dent Res.* 2024;103(9). <https://doi.org/10.1177/00220345241255593>
2. Kusumawati KY, Yanuarieska RD, Shantiningsih RR. The accuracy of extraoral periapical radiography on determining the working length in endodontic treatment: narrative review. *J Radiologi Dentomaksilofasial Indonesia (JRDI).* 2022;6(1):8. <https://doi.org/10.32793/jrdi.v6i1.770>
3. Rangappa A, Arul B, Somasundaram J, Natanasabapathy V. The precision of radiographic and electronic working length estimation methods in endodontics: A systematic review of clinical studies. *Endodontology.* 2024;36(4):307–314. DOI: https://doi.org/10.4103/endo.endo_5_24
4. Bhagat E, Agnihotri Y, Das A, Das S, Panda S, Hota S. Accuracy of an Electronic Apex Locator (EAL) in Measuring the Working Length of Root Canals in Comparison With Radiographs: An In Vivo Study. *Cureus.* 2024;16(5); <https://doi.org/10.7759/cureus.60283>
5. Soerachman B, Sidiqa AN, Endro Wahyudi H. Perbandingan Akurasi Pengukuran Panjang Kerja Menggunakan Metode Radiografi Dan Elektronik Pada Perawatan Endodontik. *Jurnal Ilmiah dan Teknologi Kedokteran Gigi (JITEKGI).* 2022;18(2):51-6.
6. Reddy K, Kumar V, Sharma R, Patel S. Evaluation of the efficacy of different systems in determination of root canal working length: A comparative study. *World J Dent.* 2021;12(5):399–402. <https://doi.org/10.5005/jp-journals-10015-1860>
7. Alarifi NA, Alqahtani AM, Alharbi AZ, Alanazi MH, Alanazi AM, Alharbi AF, Alanazi NF, Aloatibi KM, Alatallah FS, Alali HA, Koaban AM. Comparative Accuracy of Electronic Apex Locators and Conventional Radiography for Working Length Determination in Permanent Teeth: A Systematic Review. *Cureus.* 2025;17(10); <https://doi.org/10.7759/cureus.93997>
8. Georgiou P, Vlachou AM, Georgaki M, Angelopoulos C. A literature review on the uncommon use of extraoral periapical radiography. *Appl Sci.* 2024;14(21):9850. Doi: <https://doi.org/10.5005/jp-journals-10015-18600.3390/app14219850>
9. Khan GI, Khan MT, Ehsan S, Fayyaz A, Malik HA, Hussain S. Accuracy of Working Length Measured by Apex Locator and Digital Radiography. *Journal of The Pakistan Dental Association.* 2021 \;30(1); <https://doi.org/10.25301/JPDA.301.24>
10. Dakkaki J, Rouggani FZ, Lahlou M, Mayou R, Ghamrane S, Hamza M, et al. Determination of Working Length in Endodontics: Epidemiological Survey of Dentists in the Private Sector in Casablanca. *EC Dental Science.* 2022;21:16-31.
11. Ali A, Bhosale A, Pawar S, Kakti A, Bichpuriya A, Agwan MA, Agwan MA. Current trends in root canal irrigation. *Cureus.* 2022 \;14(5); <https://doi.org/10.7759/cureus.24833>
12. Khanagar SB, Alfadley A, Alfouzan K, Awawdeh M, Alaqla A, Jamleh A. Developments and performance of artificial intelligence models designed for application in endodontics: A systematic review. *Diagnostics.* 2023 Jan 23;13(3):414; <https://doi.org/10.3390/diagnostics13030414>
13. Yen M, Yeung AW. The performance of paralleling technique and bisecting angle technique for taking periapical radiographs: a systematic review. *Dentistry Journal.* 2023 \;11(7):155; <https://doi.org/10.3390/dj11070155>
14. Nekoofar MH. Advances in Working Length Determination. *Endodontic Advances and Evidence-Based Clinical Guidelines.* 2022 Sep 22:218-42; <https://doi.org/10.1002/9781119553939.ch10>
15. Nurbaiti S, Hadiyani S, Sari DM, Faizah S, Octaviani R, Dawiyah AM. Analisis kepuasan pasien terhadap pelayanan di Instalasi Radiologi: Sebuah tinjauan pustaka. *J Radiologi.* 2025;1(1):1-8. <https://doi.org/10.36729/bi.v1i1.1287>
16. Almutairi M, McKenna G, O'Neill C. Satisfaction with dental care services in Great Britain 1998–2019. *BMC Oral Health.* 2022;22(1):308; <https://doi.org/10.1186/s12903-022-02343-7>
17. El Haiba N, El Hijazi M, Benyahya I. Comparative evaluation of three working length determination techniques: In vitro study. *Open Access Libr J.* 2026;13(1):e1114912. <https://doi.org/10.4236/oalib.1114912>
18. Xu Y, Chen Z, Wang L. Association between telemedicine adoption and physician job satisfaction: Cross-sectional study. *J Med Internet Res.* 2024;26:e51234. <https://doi.org/10.2196/51234>
19. Alshammary F, Alsadoon BK, Altamimi AA, Ilyas M, Hassan I, Alam MK. Perceptions towards use of electronic dental record at a dental college, University of Hail, Kingdom of Saudi Arabia. *The J Contemporary Dent Practice.* 2021;21(10):1105-12; <https://doi.org/10.5005/jp-journals-10024-2891>
20. Lee AT, Ramasamy RK, Subbarao A. Understanding psychosocial barriers to healthcare technology adoption: A review of TAM technology acceptance model and unified theory of acceptance and use of technology and UTAUT frameworks. *Healthcare (Basel).* 2025;13(3):250. <https://doi.org/10.3390/healthcare13030250>
21. Lee JW, Tan JY, Bello F. Technology acceptance model in medical education: systematic review. *JMIR Medical Education.* 2025 Jul 16;11(1):e67873; <https://doi.org/10.2196/67873>
22. Kim J, Kim J, Youn B. Using a Technology Acceptance Model to Explore the Intention to Use Digital Health Technologies Among People With Disabilities: Cross-Sectional Survey Study. *J Med Internet Res.* 2025;27:e79595. <https://doi.org/10.2196/79595>
23. Darmawan AE, Widyaningrum R, Priyono B, Hanindriyo L. Hubungan antara kualitas pelayanan radiografi panoramik dengan tingkat kepuasan pasien: studi cross-sectional. *Padjadjaran J Dent Res Stud.* 2023;7(3):223-9. <https://doi.org/10.24198/pjdr.v7i3.49745>
24. Ramezani M, Bolbolian M, Aliakbari M, Alizadeh A, Tofangchiha M, Faegh SM, et al. Accuracy of three types of apex locators versus digital periapical radiography for working length determination in maxillary premolars: An in vitro study. *Clinics and Practice.* 2022 Dec 12;12(6):1043-53; <https://doi.org/10.3390/clinpract12060107>
25. Fadlan M, Lahindah L. The Effect of Technology Adoption and Service Quality on Patient Satisfaction (Case Study on Digital Dentistry Adoption at Densthetica Clinic West Sumatra). *Dinasti Int. J. Econ. Finance Account.* 2025;5(6):6139-48. <https://doi.org/10.38035/dijefa.v5i6>
26. Simamora B. Skala Likert, Bias Penggunaan dan Jalan Keluarnya. *J Manajemen.* 2022;12(1):84-93. <https://doi.org/10.46806/jman.v12i1.978>
27. Rodrigues KS, Silva JVM, Cruz AD. Intraoral digital dental radiology in Brazil: challenges and adoption by dentists. *Discover Health Systems.* 2025;4:128. <https://doi.org/10.1007/s44250-025-00307-6>

28. Faraj BM. Root canal curvature as a prognostic factor influencing the diagnostic accuracy of radiographic working length determination and postoperative canal axis modification: an in vitro comparative study. *BMC Oral Health*. 2021;21(1):90; <https://doi.org/10.1186/s12903-021-01446-x>
29. Mourão PS, Fernandes IB, Moreira LV, Machado GF, Falci SGM, de Souza GM, Ramos-Jorge ML. Conventional methods and electronic apical locator in determining working length in different primary teeth: systematic review and meta-analysis of clinical studies. *Evid Based Dent*. 2025;26:116.
30. Hendricks JW, Smith A, Peres SC, Sasangohar F. Workers' acceptance of digital procedures: an application of the technology acceptance model. *IIE Transactions on Occupational Ergonomics and Human Factors*. 2023;11(1-2):59-68; <https://doi.org/10.1080/24725838.2023.2240342>
31. Suparno NR, Faizah A, Zahra HA. Evaluasi Kualitas Radiograf Periapikal Teknik Bisektris: Kesalahan Penempatan Sudut Penyinaran dan Film. *Jurnal Imejing Diagnostik (JIImeD)*. 2024;10(1):1–9. <https://doi.org/10.31983/jimed.v10i1.10554>
32. Li B, Dudley AG, Lauderdale CJ, Shannon CN, Pope JC. Hidden consequences of patient satisfaction: a survey of pediatric surgeons. *J Pediatr Surg*. 2021;56(9):1524–1527; <https://doi.org/10.1016/j.jpedsurg.2021.03.010>
33. Garabedian PM, Rui A, Volk LA, Neville BA, Lipsitz SR, Healey MJ, et al. A multiyear survey evaluating clinician electronic health record satisfaction. *Applied Clinical Informatics*. 2023;14(04):632-43; <https://doi.org/10.1055/s-0043-1770900>
34. Mühlbacher A, Stolk E. Patient-reported satisfaction, experiences, and preferences: same but different?. *Value in Health*. 2023;26(1):1-3; <https://doi.org/10.1016/j.ival.2022.10.005>
35. Liang H, Xue Y, Zhang ZR. Patient satisfaction in China: a national survey of inpatients and outpatients. *BMJ open*. 2021 1;11(9):e049570; <https://doi.org/10.1136/bmjopen-2021-049570>
36. Dubale AT, Mengestie ND, Tilahun B, Walle AD. User Satisfaction of Using Electronic Medical Record System and Its Associated Factors among Healthcare Professionals in Ethiopia: A Cross-Sectional Study. *BioMed Res Int*. 2023;2023(1):4148211; <https://doi.org/10.1155/2023/4148211>
37. Kaur G, Thomas AR, Samson RS, Varghese E, Ponraj RR, Nagraj SK, et al. Efficacy of electronic apex locators in comparison with intraoral radiographs in working length determination-a systematic review and meta-analysis. *BMC Oral Health*. 2024;24(1):532; <https://doi.org/10.1186/s12903-024-04259-w>
38. Nabihah KK, Lubis MNP. The correlation of the change in vertical angulation of the beam in the bisecting technique to the length of the tooth. *J Radiol Dentomaksilofas Indonesia*. 2023;7(1):15–20. <https://doi.org/10.32793/jrdi.v7i1.978>
39. Yeung AWK, Wong NSM, Bornstein MM. The performance of paralleling technique and bisecting angle technique for taking periapical radiographs: A systematic review. *Dent J*. 2023;11(7):155. <https://doi.org/10.3390/dj11070155>
40. Suparno NR, Faizah A, Zahra HA. Evaluasi kualitas radiograf periapikal teknik bisektris: Kesalahan penempatan sudut penyinaran dan film. *J Imej*. 2024;10(1). <https://doi.org/10.31983/jimed.v10i1.10554>