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Evaluation and Perception of Digital Technologies in Endodontic Practice by Specialists in India

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ABSTRACT

To analyze the implementation and perception of digital technologies in endodontic practice among specialists in India through a structured and validated survey, evaluating their impact, level of knowledge, frequency of use, and factors influencing their integration into clinical practice. Three hundred eighty-three endodontic specialists were surveyed using a validated questionnaire previously used by The American Association of Endodontists and the

Royal Dutch Dental Association. The survey was distributed electronically and analyzed using descriptive statistics. The results showed that 98.7% of professionals use digital radiography, 72.3% use apex locators with radiographic confirmation, 71.3% use ultrasonic irrigation systems, and 46.48% use CBCT frequently. High acceptance was reported for surgical microscopy and CAD/3D printing technologies. Most professionals (77.26%) believe digital technologies significantly reduce clinical errors, 71.28% consider treatments more predictable, and 74.15% believe these technologies increase positive patient perception. This research concludes that endodontic practice in India is transitioning toward sustained digitalization with significant levels of knowledge and technological tool usage. However, challenges persist regarding equitable access, continuous training, and implementation standardization. These results suggest that digital technology integration effectiveness depends on professional training and infrastructure availability, being more beneficial when accompanied by systematic education programs.

KEYWORDS: Digital Technologies, Endodontics, CBCT, Surgical Microscopy, Digital Radiography

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INTRODUCTION

The integration of advanced digital technologies has enabled endodontics to undergo profound transformation in recent decades, giving rise to what is known as digital endodontics.[1] This specialty, concerned with the detection and treatment of dental pulp diseases and periapical tissues, has benefited significantly from advances in visualization methods that allow adequate diagnosis of root canal anatomy and periradicular structures.[2]

The digital workflow in endodontics refers to the integration of digital tools in all stages of the clinical process: diagnosis, planning, execution, and evaluation of treatments.[3] This transformation has been driven by technologies such as cone-beam computed tomography (CBCT), digital radiography, optical microscopes, mechanized rotary systems, 3D printing, and surgical planning software.[4] CBCT has become particularly valuable for accurate diagnosis of complex anatomical variations and periapical pathologies, with studies showing superior diagnostic accuracy compared to conventional radiography.[5,6]

Tools such as CBCT, digital radiography, computer-assisted design (CAD), 3D printing, mechanized instrumentation systems, optical microscopy, and surgical planning software are included in various stages of endodontic processing. This digital technology enables more precise images of dental anatomy, more efficient surgical planning, facilitates access to root canals even in cases of obliterations and allows less invasive procedures, increasing clinical success rates.[7] Through specialized software, the possibility of simulating treatments before performing them improves clinical decision-making and reduces risks.[8] Recent studies have demonstrated the effectiveness of dedicated endodontic software for CBCT analysis in evaluating root canal anatomy with high precision.[9]

Electronic apex locators (EALs) provide greater accuracy by measuring electrical resistance between the root canal and surrounding tissues, making them safer and more reliable than conventional methods.[10] EALs can be used as essential diagnostic tools to identify fractures, cracks, and root canal resorptions.[11] Several factors can affect electronic measurements, including the diameter of the apical constriction, instrument gauge, cervical pre-flaring, and the irrigating solution used during the procedure.[12]

Modern apex locators have shown excellent accuracy when validated against micro-computed tomography, particularly in complex anatomical situations.[13]

The development of nickel-titanium rotary instrumentation has revolutionized root canal preparation, with extensive research on cyclic fatigue resistance and optimal preparation protocols.[6,14] Surface treatments and metallurgical properties of these instruments continue to evolve, improving their clinical performance and safety.[15,16] Additionally, advances in irrigation protocols and activation systems have enhanced debridement efficacy and treatment outcomes.[14]

The adoption of digital technologies in endodontics, despite these benefits, is not uniform across all geographical contexts. In developing countries like India, implementation is conditioned by multiple factors, including access to technological infrastructure, operational costs, professional training, and attitudes or perceptions of dentists toward these tools.[17] Although various studies on digitalization in dentistry have been published internationally, there is a clear lack of systematic research on how this transformation is being applied in the Indian context, especially in endodontics. Recent reviews emphasize that digital dentistry can be either disruptive or destructive, depending on proper implementation and training.[18] Current research guidelines, such as the PRILE 2021 recommendations, emphasize the importance of standardized reporting in endodontic research to ensure reproducibility and clinical relevance.[19] This is particularly important when evaluating new digital technologies and their clinical applications.

The objective of this study was to evaluate the implementation and perception of digital technologies in endodontic practice among specialists in India, assessing their impact, level of knowledge, frequency of use, and conditioning factors for their integration.

MATERIALS AND METHODS

This study was quantitative, descriptive, and cross-sectional, aimed at analyzing the perception, knowledge, use, and barriers related to the adoption of digital technologies by endodontic specialists in India. The target population consisted of all endodontic specialists actively practicing in India, considering available records and databases from professional associations and national dental organizations. Since an exact number of active professionals in this area is not available, a probabilistic sampling strategy with an infinite population approach was chosen, widely accepted in studies with large undefined universes.

The minimum sample size was calculated using the formula for infinite populations, with a 95% confidence level, 5% margin of error, and an expected proportion of 0.5, yielding a minimum of 383 participants. This size ensures adequate representation and allows for valid statistical analyses.

For data collection, a survey previously validated by The American Association of Endodontists and the Royal Dutch Dental Association (KNMT), adapted by Marieke et al. (2021), was used.[20] The instrument was divided into three sections: demographic data including age, sex, and work sector, use of digital technologies comprising 11 items about frequency and type of technology used such as digital radiography, CBCT, intraoral scanner, and planning software, and perception and attitude evaluated through 7 items using a 5-point Likert scale ranging from 1 (Totally agree) to 5 (Totally disagree). In total, the questionnaire consisted of 21 structured questions.

The survey was distributed electronically through the Google Forms platform, directed to endodontic specialists in the main cities of the country. It was shared by email and professional networks including WhatsApp, institutional email, and professional association social networks over a 4-week period. Participation was voluntary, and confidentiality and anonymity of responses were guaranteed.

The inclusion criteria comprised being an endodontic specialist with a recognized degree in India, actively practicing clinically at the time of the study, having used at least one digital technology mentioned in the questionnaire, and signing virtual informed consent. The exclusion criteria included inactive or retired professionals, those who had not performed endodontic procedures in the last six months, specialists who had not used digital technologies in their practice, and those who did not agree to participate through informed consent.

STATISTICAL ANALYSIS

Data were exported from Google Forms to Microsoft Excel, where initial cleaning and coding were performed and transferred to SPSS version 23.0. Subsequently, they were processed for descriptive and inferential analysis. To analyze and compare the adoption of digital technologies among endodontic specialists, measures of central tendency and dispersion including median, interquartile range, mean, and standard deviation were calculated for all quantitative variables.

To analyze the impact of demographic factors on technology perception, responses from the 5-point Likert scale were grouped into favorable (strongly agree + agree) and unfavorable (disagree + strongly disagree) categories, with neutral responses analyzed separately. Cross-tabulation analysis was performed to identify patterns in technology adoption based on age groups, work sector, and years of experience.

The accuracy of digital technology perception was evaluated by calculating mean scores for each perception item, with lower scores indicating more positive attitudes toward technology integration. Comparison of mean perception scores between different demographic groups was performed using appropriate statistical tests based on data distribution characteristics.

The research followed ethical principles established by the Declaration of Helsinki. A virtual informed consent was presented at the beginning of the survey, which had to be accepted to access the questionnaire. The information collected was treated confidentially, for research purposes exclusively, and no identifiable personal data were stored. Data were processed using descriptive statistics with frequencies and percentages.

RESULTS:

The sample consisted of 383 endodontic specialists, with 63.97% women (n=245) and 36.03% men (n=138). The age distribution showed predominance of the 25-34 years group with 48.56% (n=186), followed by 35-44 years with 28.98% (n=111) (Figure 1). Most respondents (87.47%) work in the private sector. Regarding digital technology use, 98.69% of respondents use digital radiography. For clinical magnification, 41.51% use surgical microscopes, 30.81% use loupes, and 27.68% use no magnification system (Figure 2)

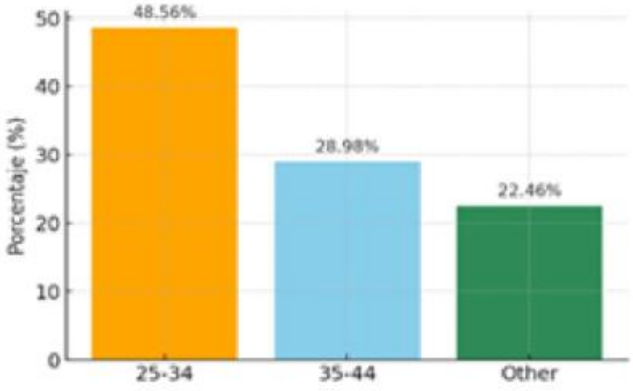

Figure 1: Distribution by age groups

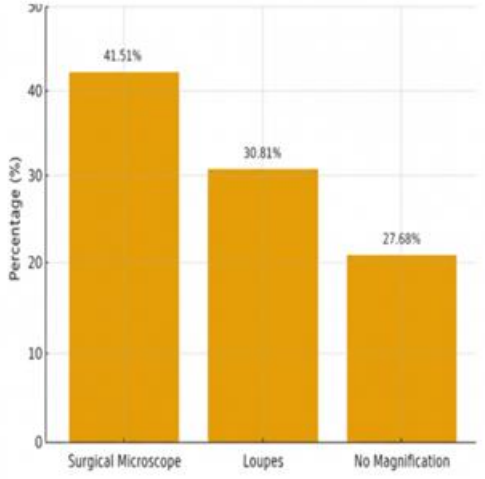

Figure 2: Use of magnification in endodontics

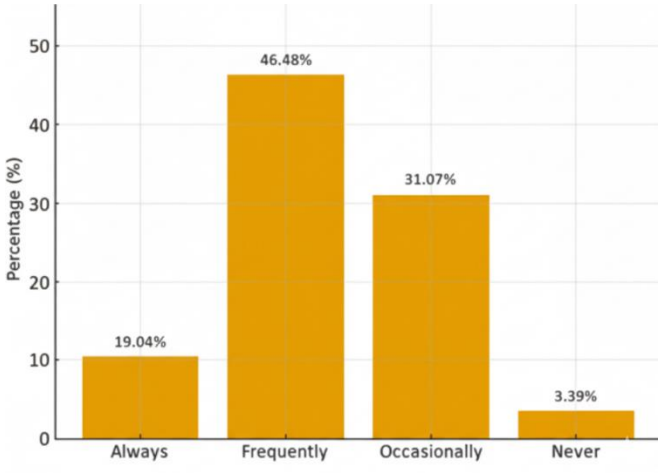

Figure 3: Frequency of CBCT use

In working length determination, 72.33% use apex locators with radiographic confirmation, 26.37% use only electronic locators, and 1.31% rely solely on radiographs. Regarding irrigation systems, 95.56% report using complementary systems, with ultrasonic being most used (71.28%), followed by Endo Activator (19.06%).

CBCT use frequency showed 46.48% use it frequently, 31.07% occasionally, 19.06% always, and 3.39% never (Figure 3). For surgical microscope experience, 34.47% self-evaluate as high level, 36.03% medium, 21.68% low, and 7.83% have no experience. In root canal preparation, 48.56% use hybrid methods (combining rotary and manual), 35.25% use pure rotary instrumentation, 12.01% reciprocating, and 4.18% manual techniques. For obturation, gutta-percha injection technique is most used (43.08%), followed by lateral condensation (34.99%).

Regarding perceptions of digital technologies: 77.26% consider they significantly reduce clinical errors, 71.28% believe they allow more predictable treatments, 68.67% think they improve quality in complex cases, and 74.15% believe they increase positive patient perception.

DISCUSSION

The results demonstrate a clear trend toward adoption and integration of digital technologies in Indian endodontic practice, aligning with current scientific literature trends. The high frequency of digital radiography, apex locators, and CBCT use reflects a paradigm shift in how professionals' approach endodontic diagnosis, planning, and treatment.[21] This widespread adoption of CBCT is consistent with international studies showing its superior diagnostic capabilities for detecting complex root anatomies and periapical pathologies.[5,22] The frequent use of CBCT in Indian endodontic practice aligns with recent findings highlighting this tool's value in detecting complex root anatomies, resorptions, fractures, and other endodontic pathologies that may go unnoticed in conventional radiographic studies.[23,24] Systematic reviews and meta-analyses have consistently demonstrated the diagnostic superiority of CBCT over conventional radiography for root fracture detection and periapical lesion assessment.[22,24] The predominance of surgical microscopy use, although not universal, reflects evolving technical training consistent with evidence showing that surgical microscopes significantly improve operative field visualization.[25] Professional experience plays an important role in technology use. Most professionals' report medium to high microscope proficiency levels, suggesting an ongoing learning curve and highlighting continuous training needs. This becomes relevant in the Indian context, where resource availability varies significantly between public and private sectors.[26] The correlation between experience and technology adoption aligns with findings from comparative studies using different methodological approaches including clearing techniques, CBCT, and micro-CT analysis.[27]

Regarding professional perception, respondents agreed that digital technologies improve diagnostic precision, reduce errors, and increase treatment efficiency. These perceptions are supported by scientific evidence indicating that incorporating artificial intelligence, augmented reality, and other digital developments contribute not only to improving clinical outcomes but also to facilitating decision-making in highly complex cases.[28] Recent advances in metallurgical testing and instrumentation design have further enhanced the reliability and safety of endodontic procedures.[16]

The demographic finding that a large percentage of respondents are aged 25-34 years may explain the high acceptance of digital tools, as younger dentists show greater openness toward technological adoption.[29] This finding aligns with reports that India is experiencing transformation in oral health services due to digital advancement, although challenges persist related to access inequality and technological infrastructure gaps.[30] The integration of digital workflows requires careful consideration of both technical capabilities and educational requirements, as emphasized in recent comprehensive reviews of digital dentistry evolution.[18]

The high adoption rates of modern irrigation systems and activation protocols observed in this study reflect current evidence-based practices that emphasize the importance of effective debridement and disinfection.[14] The preference for hybrid instrumentation techniques combining rotary and manual methods suggests a thoughtful approach to treatment planning that considers individual case requirements while incorporating technological advances in NiTi instrumentation.[6,15]

It is important to note that this research followed current guidelines for endodontic research reporting to ensure methodological rigor and reproducibility.[19] The findings contribute to the growing body of evidence supporting digital technology integration in endodontic practice while highlighting the importance of adequate training and infrastructure support for successful implementation.

CONCLUSION

The results revealed variable effects of digital technology integration depending on the professional and institutional context evaluated. Most Indian endodontic specialists demonstrate high acceptance and frequent use of digital technologies, with statistically significant differences in adoption patterns related to age, experience, and work sector. Digital radiography, CBCT, and apex locators showed highest integration rates, while surgical microscopy and CAD/3D printing technologies showed growing but not universal adoption.

Professional perception is highly favorable toward digital technologies, with most specialists recognizing their benefits in reducing clinical errors, improving treatment predictability, and enhancing patient experience. However, significant challenges

remain regarding equitable access, continuous professional education, and implementation standardization across different practice settings.

These findings indicate that Indian endodontic practice is undergoing sustained digital transformation, though success depends on addressing infrastructure, training, and resource accessibility barriers. Future research should evaluate long-term clinical outcomes and develop strategies to ensure equitable access to advanced technologies across all practice sectors.

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