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Digital transformation in endodontics: guided planning, artificial intelligence, safety, and professional training.

Digital Transformation in endodontics: guided planning, artificial intelligence, safety and professional training

Digital transformation in endodontics: guided planning, artificial intelligence, security and professional training

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SUMMARY

The digital transformation of endodontics is analyzed with an emphasis on Cone Beam Computed Tomography (CBCT), static guided planning, dynamic navigation, artificial intelligence, and data governance. The narrative review distinguishes between laboratory accuracy, clinical feasibility, and patient outcomes, examining indication, manufacturing, calibration, traceability, data protection, and training. Evidence shows a reduction in deviations in selected models, but does not yet authorize the transformation of geometric performance into a promise of clinical success. Responsible adoption requires validation, individualized protocols, professional supervision, and continuous evaluation.

Keywords: Digital endodontics; CBCT; guided endodontics; dynamic navigation; artificial intelligence.

ABSTRACT

This article analyzes digital transformation in Endodontics, focusing on Cone Beam Computed Tomography (CBCT), static guided planning, dynamic navigation, artificial intelligence, and data governance. The narrative review distinguishes laboratory accuracy, clinical feasibility, and patient outcomes while examining indication, manufacturing, calibration, traceability, data protection, and training. Evidence shows reduced deviations in selected models, but geometric performance cannot be presented as a promise of clinical success. Responsible adoption requires validation, individualized protocols, professional oversight, and continuous evaluation.
Keywords: digital Endodontics; CBCT; guided endodontics; dynamic navigation; artificial intelligence.

1 INTRODUCTION

Endodontics has incorporated microscopy, mechanized instrumentation, three-dimensional imaging, and...
3D printing and digital navigation. The combination of these technologies allows for planning access in complex anatomies and organizing information in greater detail. The advance, however, did not
It eliminates biological, radiological, or operational limitations and does not make every case an indication. for a guided flow.

Static guided endodontics combines CBCT and surface scanning to produce a guide.
physical navigation; dynamic navigation follows the instrument in real time. Both aim to reduce
Deviations and preserving structure in selected situations, especially calcified canals. Reviews

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and consensus points to potential, while also noting costs, learning curve and
dependence on data quality.

The digital transformation of Endodontics is analyzed here under four commitments: appropriate selection.
of the case, verifiable accuracy, radiological safety and delimitation of clinical responsibility.
It also discusses training and implementation, given the gap between owning a technology and using it.
Lack of quality constitutes one of the main risks of innovation.

The scientific relevance of the topic lies precisely in the difference between technological capability and utility.
clinically, a system may demonstrate less angular deviation in the laboratory and still depend, in practice, on the system itself.
Patient, mouth opening, stability, calibration, experience, and image quality. The review
seeks to keep these layers visible, analyzing the digital flow as a socio-technical chain in
Which software, equipment, team, and professional decision-making processes need to work in a coordinated manner.

2 METHODOLOGY

A narrative literature review was conducted on CBCT in Endodontics, static guided access,
Dynamic navigation, segmentation, intraoral scanning, guide design and printing, security.
Radiological and vocational education. The guiding question was: how to incorporate digital workflows
Preserving clinical indication, quality, and responsibility?

PubMed/MEDLINE, Scopus, and Google Scholar were consulted, in addition to documents from the American Journal of Medicine.
Association of Endodontists (AAE), of the American Academy of Oral and Maxillofacial Radiology
(AAOMR) and the American Dental Association. Terms in Portuguese and English encompassed guided
endodontics, dynamic navigation, static navigation, calcified canals, CBCT, digital workflow,
accuracy, training and radiation safety.

In vitro studies were analyzed as evidence of technical performance, without direct extrapolation.
for patient outcomes. Clinical studies and series were used with caution in light of
Small samples and heterogeneity. Professional recommendations underpinned the discussion of
indication and radiological exposure.

The results were synthesized into six axes: technological change; case selection; access
Static; dynamic navigation; operational safety; and specialist training. The graph (which one?)
reproduces the mean angular deviations found by Huth et al. (2024) in printed teeth.
three-dimensionally. Because this is laboratory research, the numbers compare precision.
Technical criteria, not clinical success rates.

The synthesis distinguished four levels of evidence: accuracy in models, clinical feasibility, outcomes.
tooth-centered and patient-centered outcomes. This separation avoided comparing measures of

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Trajectory with healing or survival. Updated recommendations were also examined.
AAE and AAOMR on selective use of CBCT, individualized protocols and the need for
Training for interpretation.

3. From Two-Dimensional Images to Digital Planning

Two-dimensional radiographs remain essential and meet a large part of the needs.
endodontic procedures. CBCT adds volumetric information when overlapping or anatomical aspects are present.
Complexity limits interpretation. The AAE highlights benefits in selected cases, after evaluation.
of the signs and symptoms present, especially in cases where two-dimensional examinations are not
sufficient for establishing a diagnosis and treatment plan, promoting accurate indication.
for the realization of the CBCT.
Between obtaining the image and digital planning, there is a careful process of segmentation.
tooth, canal, bone, and structures at risk. The quality of this step depends on the voxel, the artifacts, and the
Operator skill. Metallic materials can create distortions precisely where the information is.
most necessary.
Intraoral scanning provides the surface used to record tooth position and support guides.
The DICOM–STL fusion needs to be checked because small deviations in alignment can...
to have repercussions on the planned trajectory. The software's accuracy does not compensate for an incorrect record.
When planning, the clinical objective should be access compatible with the anatomy and preservation.
structural, without adopting minimally invasive cavities as an isolated objective. Cleaning, the
Shaping, irrigation, and obturation remain dependent on the anatomy and biology of the infection.
Digital documentation allows for the review of decisions and improved communication. To fulfill this
For this purpose, the file must maintain the version, parameters, and endodontist's approval. Images without
Traceability reduces the possibility of auditing and learning.
Spatial resolution is not the only attribute of an image. Contrast, noise, motion, and artifacts also play a role.
influence the identification of boundaries. In restored teeth, bundle hardening and striations can
to simulate or hide structures. Planning needs to take these limitations into account, because a
Visually clean segmentation may contain manual decisions made in low-resolution regions.
trust.
Automated segmentation tools can reduce time, but should allow for review in
Multiplanar cuts. The three-dimensional result tends to convey greater security than the...
The original data provided. Clinical approval needs to revert to the original volume, confronting the network.
using anatomy and marking regions where uncertainty interferes with the trajectory.

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4. Case Selection and Judicious Use of CBCT

Pulp calcification, suspected resorption, trauma, unusual and complex anatomy, complications and
Surgical planning is among the situations in which three-dimensional imaging can add value.
Information. This decision only makes sense when the clinical examination and radiographs are taken into consideration.
previous.

Benavides et al. (2024) recommend that radiographic examinations be performed when the benefit
The expected justification for exposure is needed. A limited field of view and parameters appropriate to the objective help.
to reduce the dose. Repetitions due to inadequate protocol should be treated as quality failures.
The entire volume requires interpretation, including findings outside the main region. When the
This professional does not have the training to interpret the entire image and should seek radiological support.
Responsibility does not disappear when processing is done remotely.

The comparison by Huth et al. (2024) helps to illustrate the difference between planning and execution.
The average angular deviation was 9.53 degrees with manual access, 2.82 degrees with dynamic navigation, and
1.12 degrees with static guidance. Since the experiment used printed teeth, the result is not...
It incorporates patient movement, mouth opening, moisture, or other clinical difficulties.

Case selection also requires evaluating mouth opening, guide stability, bur space,
extent of calcification and possibility of conventional treatment. A guided flow may be
It's technically possible, yet it may not be the best choice.

The updated guidance from the AAE and AAOMR (2025 Update) reinforces selection by nomination and
The patient adopts the principle of exposure as low as diagnostically acceptable. The document
It also recognizes artificial intelligence as a possible aid to interpretation. Support, in this sense,
This does not imply autonomous reading or the transfer of responsibility for incidental findings.

The need to repeat the test should be a quality indicator. Repetitions by movement,
Inadequate field or incompatible protocol increases exposure and cost. Before acquisition, the
The team needs to confirm the clinical question and prepare the patient; then, they must check if the volume
It truly allows one to answer the objective that justified the examination.

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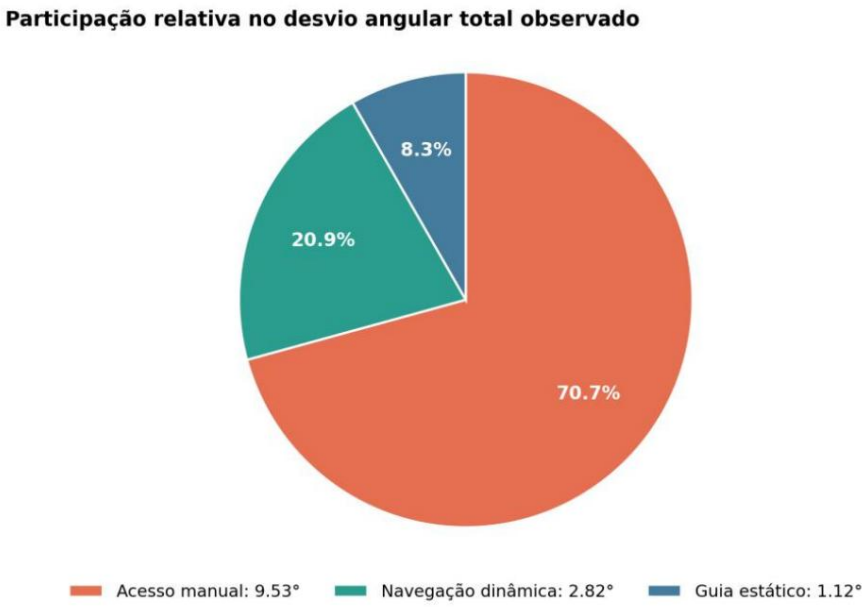

Graph 1 – Relative composition of the mean angular deviation observed by technique

Source: author's elaboration with data from Huth et al. (2024). In vitro study with printed teeth in 3D; the values do not represent clinical success.

5. Static Guided Endodontics

In static flow, tomographic and surface data are recorded, a trajectory is defined, and a...
The guide is designed to guide the drill bit. The method provides a physical reference and can help in...
location of blocked canals.
The result carries small accumulated variations from acquisition, alignment, design, manufacturing,
Drill bit placement and movement. Checking the guide in the mouth and ensuring stability are steps.
Criticisms. Correct printing does not guarantee adaptation if the scan is incomplete.
Ribeiro et al. (2022) identified precision advantages for guided systems, but highlighted
Limitations of evidence and heterogeneity. Laboratory studies favor experimental control;
Clinical reality adds saliva, restricted access, restorations, and variation in opening.
The technique may require coronal space and long burs, which limits posterior teeth. Heat,
Structure removal and diversion remain possible. Irrigation and intermittent progression should continue.
The system's protocol and the professional's judgment.
Once the canal is located, all the principles that guide endodontic treatment remain in effect.
Locating the light source doesn't solve disinfection, working length, apical anatomy, or restoration issues.
The guide is a tool for one step, not a complete treatment.
The guide design needs to ensure alignment between the drill bit, washer, and cylinder, as well as access for...

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Irrigation and inspection. Altering a clearance may improve mobility, but reduce control.
Parameters chosen out of habit or copied from another system should be avoided because hardware,
Resin, printing, and post-processing form a specific whole.
Manufacturing traceability includes resin batch, print orientation, washing, post-curing, and...
Inspection. A dimensional flaw can arise after proper planning. Record these
These steps allow you to differentiate between image, design, manufacturing, or installation errors and prevent all
The incident should be generically attributed to the clinical operator.

6. Dynamic Navigation and Real-Time Assistance

Unlike static navigation, dynamic navigation tracks the instrument and patient and presents the...
The trajectory is shown on screen. It allows adjustments during the procedure and eliminates the need for a printed guide, but
It depends on calibration, visibility, and visuomotor coordination.
Wei et al. (2023) differentiate between static and dynamic systems and propose recommendations for therapy.
Guided endodontics. The consensus emphasizes selection, planning, and training. Innovation should not
to be used without specific expertise.
Recent comparative studies indicate that navigation can increase accuracy and preserve the
structure in selected models. In vitro results do not equate to clinical success rates.
Long-term outcomes should include pain, healing, survival, and adverse events.
Dynamic techniques can facilitate trajectory changes, but tracking errors or loss of direction are also possible.
Calibration affects orientation. Protocols need to define checks before and during access.
In addition to a conversion plan to conventional technology.
There is also an ergonomic dimension that cannot be ignored. Operating while looking at the screen.
It modifies spatial perception and requires deliberate training. Simulation, progressive exercises and
Supervision is more suitable than initial training in complex cases.
Dynamic navigation produces real-time position data, but this abundance of information...
This can increase cognitive load. The operator alternates attention between screen, field, and tactile feedback.
Interface, tracking delay, and monitor placement all affect performance. Studies of
Ergonomics and training are necessary so that geometric precision is not achieved at the cost of...
fatigue or loss of clinical perception.
Calibration should be treated as an ongoing condition, not as a one-time event at the beginning.
Movement of the marker, inadvertent contact, or changes in positioning can degrade the...
correspondence. Protocols should include anatomical reference points and clear criteria for...
recalibrate, convert to another technique, or interrupt access.

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7. QUALITY, RISKS AND GOVERNANCE OF THE FLOW

For the flow to be secure, it is necessary to recognize where it can fail: acquisition, recording,
Segmentation, trajectory, export, manufacturing, installation, and execution. Checklists help, but
They need to be linked to acceptance criteria and the authority to stop the process.
Data protection deserves particular attention because DICOM and associated files may contain...
Identifiers. Remote transfer requires security, access control, and clear agreements. Files
They should be minimized and retained as needed clinically and legally.
Software and navigation systems should be used in accordance with their intended purpose, instructions, and...
Applicable regulations apply. Updates may change algorithms and compatibility. Clinics
They need to control versions and validate changes before using them on patients.
Technical services can segment, align, and design according to prescription, but clinical approval is required.
It is the responsibility of the attending dentist. Outsourcing the computational stage does not transfer diagnosis or...
therapeutic decision.
Adverse events and near misses need to fuel improvements. A guide that doesn't hold up, a record
Any questionable or unsafe trajectory should be documented. A safety culture depends on...
Transparency, not concealment of rework.
Interoperability is also a matter of security. Exported files can be lost.
Orientation, scale, or metadata, and software updates can modify algorithms without making them permanent.
The change is evident to the user. A planned use case in a specific version needs to remain
linked to that configuration until completion or until it undergoes new documented validation.
Governance of artificial intelligence requires understanding the purpose, the training population, and the...
Metrics and limitations. An overall hit rate does not inform performance in rare or unusual anatomies.
Images with artifacts. The professional needs to be able to review the output and disagree with it. Systems that
They conceal uncertainty or fail to preserve a decision trail, making them poorly suited to procedures.
irreversible.

8. Capacity Building and Sustainable Implementation

The decision to adopt these tools should stem from the team's skills and the specific cases they face.
They can truly benefit, and not from commercial pressure. A clinic can start by reading...
CBCT and supervised planning before manufacturing guides. The progression allows for the identification of limits.
local.

A solid training program needs to integrate anatomy, radiology, software, design, printing,

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Safety and communication. Knowing commands is not the same as understanding the clinical effect of each one.
parameter. Continuing education must keep pace with the evolution of platforms.
Teachers and mentors play a relevant role in demonstrating reasoning and boundaries. Well-defined cases...
Successes are not enough; failures, conversions, and contraindications also need to be discussed.
Critical thinking reduces the uncritical fascination with technology.
Implementation indicators include time, need for repetition, guide adaptation, deviation,
Canal location and complications. Biological results require follow-up. Economics.
Time investment should be evaluated along with the cost of equipment and training.
Networks between clinics, academic centers, and technical providers can expand access to
competencies without requiring each unit to internalize the entire process. The division of labor needs
To preserve traceability and clinical approval.
Deliberate simulation allows training not only for the ideal trajectory, but also for predictable failures.
Exercises may include loss of calibration, guide without settlement, incompatible file and
The need for conversion. Learning improves when the student explains why they interrupted the...
flow, and not only when it completes a cavity with a small deviation.
The implementation should compare performance before and after adoption. Planning time,
Repetition, deviation, complications, cost, and patient experience need to be considered.
separately. If the technology reduces one step and creates rework in another, the overall assessment may
to be unfavorable despite occasional demonstrations of speed.

9 ARTIFICIAL INTELLIGENCE, VALIDATION AND THE FUTURE OF DIGITAL ENDODONTICS

Artificial intelligence is already being investigated for change detection, segmentation, and support for...
planning. Its potential contribution lies in consistency and the ability to process large amounts of information.
image volumes. However, the performance It depends on the quality and representativeness of
Data used in development. Results obtained from a single piece of equipment or population should not be used.
to be assumed in another environment without external validation.
Automation can shift the error instead of eliminating it. Imperfect manual segmentation is visible.
During work, a plausible automatic output can go unchallenged. Interfaces should
To show confidence, allow for correction, and keep a record of human intervention. A
Responsibility remains with whoever uses the result to make decisions and take action.
The likely future is not entirely automated, but hybrid. Software can propose structures,
trajectories or warnings, while the specialist assesses indication, anatomy, risks and biological coherence.
This division is only safe when the team understands what the system does and what it cannot do.

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to infer from the available data.

Future research needs to go beyond geometric measurements. Clinical trials and cohort studies should raise...
data such as monitoring of healing, dental survival, pain, adverse events,
Total time and cost. It is also necessary to report registration errors, converted cases, and patients.
Excluded, because omitting these occurrences produces an incomplete view of applicability.
Equity issues deserve attention. Equipment, licenses, and training focus on...
certain centers, and innovation can widen differences if it is presented as a requirement.
universal. Reference networks and technical services can share capacity, provided that
Preserve data protection, quality, and clinical accountability.
Digital maturity will be recognized less by the quantity of equipment and more by the...
The ability to justify, validate, and review its use. A clinic that rejects an inappropriate workflow.
Demonstrates competence comparable to that of someone who handles a complex case. Responsible innovation.
This includes knowing when the conventional technique remains the best choice.

CONCLUSION

The digital transformation of endodontics expands the ability to visualize anatomy and plan access routes.
complex. Its most promising use is in selected situations where information
Three-dimensionality and orientation can reduce uncertainties.
Two-dimensional radiographs remain relevant. CBCT should be indicated with justification and
appropriate parameters. The availability of a technology is not sufficient reason for
exhibition.
Static guided endodontics can be helpful in calcified canals, but its accuracy depends on the entire process.
The data and manufacturing chain. Each step adds uncertainty and needs to be verified.
Dynamic navigation offers flexibility and real-time feedback. Conversely, it has a...
High equipment cost, requires calibration and visuomotor training. Favorable laboratory studies.
They need to be accompanied by long-term clinical evidence.
No guided technique can replace the biological principles of treatment. Locating the canal is only...
one step. Disinfection, shaping, obturation, restoration, and follow-up remain.
determinants.
Digital services can expand the technical capacity of clinics, provided they operate under prescription.
and dentist approval. Diagnosis and clinical decision-making should not be delegated to the provider.
software or processing.
Sustainable implementation requires training, version control, data protection, indicators, and...

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Failure logs. Teachable and auditable processes are more important than demonstrations.

Technology isolated.

Artificial intelligence can support segmentation and interpretation, but it needs external validation.

Transparency and oversight. Convincing solutions should not be confused with anatomical truth.

The more irreversible the decision, the greater the possibility should be of verifying the original data and reconstruct the path leading up to the recommendation.

The economic evaluation also needs to cover the entire chain. Licensing, procurement, training, Maintenance, manufacturing, repetition, and professional time all contribute to the cost. Savings in one step can... to be cancelled due to incompatibility or rework; therefore, local indicators are indispensable for to decide whether to continue the investment.

The body of evidence indicates that digital endodontics should be incorporated as a tool for Responsible decision-making. Technical precision, radiological safety, data protection, and critical training. They need to move forward together. The future of the specialty does not depend on replacing human judgment. but to offer the specialist more accurate information, traceable and really useful and applicable to care.

REFERENCES

AMERICAN ASSOCIATION OF ENDODONTISTS; AMERICAN ACADEMY OF ORAL AND MAXILLOFACIAL RADIOLOGY. AAE and AAOMR Joint Position Statement: Use of Cone-Beam Computed Tomography in Endodontics 2025 Update. Journal of Endodontics / Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, 2025/2026.

BENAVIDES, E. et al. Optimizing radiation safety in dentistry: clinical recommendations and regulatory considerations. Journal of the American Dental Association, vol. 155, no. 4, p. 280-293, 2024.

CONNERT, T. et al. Guided Endodontics: potential and limitations. Australian Dental Journal, 2025.

HUTH, KC et al. Comparing accuracy in guided endodontics: dynamic real-time navigation, static guides and manual approaches for access cavity preparation – an in vitro study using 3D printed teeth. Clinical Oral Investigations, vol. 28, art. 212, 2024.

RIBEIRO, D. et al. Guided Endodontics: static versus dynamic computer-aided techniques – a literature review. Journal of Personalized Medicine, vol. 12, no. 9, 2022.

SU, Y. et al. Guided endodontics: accuracy of access cavity preparation and discrimination of angular and linear deviation on canal accessing ability. BMC Oral Health, vol. 21, art. 606, 2021.

VASUDEVAN, A. et al. Dynamic navigation in guided endodontics: a systematic review. European Endodontic Journal, vol. 7, no. 2, p. 81-91, 2022.

WEI, X. et al. Expert consensus on digital guided therapy for endodontic diseases. International Journal of Oral Science, vol. 15, 2023.

ZUBIZARRETA-MACHO, Á. et al. Accuracy of computer-aided dynamic navigation compared to computer-aided static procedure for endodontic access cavities. Journal of Clinical Medicine, vol. 9, no. 1, art. 129, 2020.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO 14971:2019: medical devices — application of risk management to medical devices. Geneva: ISO, 2019.

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