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Digital dentistry in oral rehabilitation: precision, clinical efficiency, and the limits of evidence in contemporary restorative workflows.

Digital Dentistry in Oral Rehabilitation: Accuracy, Clinical Efficiency and Evidence Limits in Contemporary Restorative Workflows

Digital dentistry in oral rehabilitation: precision, clinical efficiency and limits of evidence in contemporary restorative work flows

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Abstract

Digital dentistry has altered the way clinical data is captured, integrated, and converted into restorations, but the adoption of scanners, software, and CAD/CAM systems does not eliminate the uncertainties of the diagnostic and restorative process. This article critically examines the available evidence on intraoral scanning, complete digital workflows, impressions on extended arches, patient experience, photogrammetry, and clinical validation. The methodology consists of a structured narrative review of systematic reviews and meta-analyses published between 2021 and 2025, complemented by reference literature. The studies show consistent benefits in efficiency and comfort in certain indications, while accuracy is strongly dependent on the clinical setting, arch length, acquisition strategy, technology used, and study design. It is concluded that digital competence does not consist of replacing conventional methods, but in recognizing where the evidence supports the digital workflow, where it remains heterogeneous, and where clinical validation remains indispensable.

Keywords: digital dentistry; intraoral scanning; CAD/CAM; precision; dental prosthesis; photogrammetry; digital workflow.

Abstract

Digital dentistry has changed how clinical data are captured, integrated, and converted into restorations, but the adoption of scanners, software, and CAD/CAM systems does not eliminate diagnostic and restorative uncertainty. This article critically examines the available evidence on intraoral scanning, complete digital workflows, full-arch impressions, patient experience, photogrammetry, and clinical validation. The method consists of a structured narrative review of systematic reviews and meta-analyses published between 2021 and 2025, complemented by reference literature. Studies show consistent benefits in efficiency and comfort in selected indications, while accuracy remains strongly dependent on the clinical scenario, arch extension, acquisition strategy, technology used, and study design. Digital competence therefore does not mean replacing conventional methods, but recognizing where evidence supports digital workflows, where it remains heterogeneous, and where clinical validation continues to be indispensable.

Keywords: digital dentistry; intraoral scanning; CAD/CAM; accuracy; prosthodontics; photogrammetry; digital workflow.

Introduction

Digitization in dentistry is often presented as a linear transition from analog to digital.

digital. This narrative is compelling, but scientifically incomplete. A digital stream is not a technique.

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unique: includes capture, processing, alignment, design, library, manufacturing and validation, and each
This stage has its own sources of error.
Bernauer, Zitzmann and Joda (2023), in an updated systematic review on complete digital workflows
In the field of fixed prosthetics, they located only 16 eligible clinical studies among 394 initial records.
identified. Technological expansion, therefore, was faster than the production of clinical trials.
capable of responding to all indications. The authors found more consolidated evidence for
specific scenarios, especially posterior monolithic crowns.
Accuracy also cannot be treated as a fixed characteristic of a scanner. Vitai et al. (2023),
A network meta-analysis of 53 articles and 26 scanners demonstrated that the accuracy of scans
Full-arch arch support varies depending on the clinical condition. This article starts from this heterogeneity to...
Discuss eight dimensions of digital dentistry: acquisition, accuracy, efficiency, extended arches,
Patient experience, photogrammetry, CAD/CAM integration and validation.

2. Methodology

A structured narrative review was conducted focusing on systematic reviews and meta-analyses on
Digital workflows applied to prosthetics and oral rehabilitation. Priority was given to works indexed in
PubMed and published in journals with explicit methodology.
The core set includes Bernauer, Zitzmann and Joda (2023), Vitai et al. (2023), Ma et al. (2023),
Matos et al. (2023), Cai et al. (2024), Joensahakij et al. (2024) and recent reviews on photogrammetry.
The studies were analyzed according to the outcome investigated: trueness, precision, clinical time, satisfaction.
Discomfort, full workflow performance, and differences between printing methods. These outcomes
They were not treated as equivalents.
The distinction between in vitro and in vivo evidence was maintained. Laboratory studies allow for control.
rigorous and geometric comparison, but they do not fully reproduce saliva, movement, access,
tissues and operator behavior.
Technological evolution was also considered. Results obtained with previous generations of
Scanners should not be automatically transferred to new equipment, and recent revisions
They may present different conclusions from syntheses published a few years earlier.
The article avoids promoting commercial brands. The emphasis is on principles of indication, validation, and
Critical reading of the evidence, applicable regardless of the manufacturer used.

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3.1 What does precision mean in a digital workflow?

In digital dentistry, accuracy is often divided into trueness and precision. Trueness describes the proximity of the result to a reference; precision describes consistency between Repetitions. A system can produce repeatable results and still exhibit deviation. systematic.

This distinction is crucial because a scanner doesn't 'measure' an entire mouth in one go. It It captures successive images or surface data and combines them using algorithms. The larger the area, The greater the possibility of accumulated stitching errors.

Vitai et al. (2023) included 53 articles and compared 26 scanners in different arc scenarios. complete. The authors concluded that accuracy varies depending on the type of arc and found significant differences between devices.

In partially edentulous cases with implants, the meta-analysis found differences in relation to to the references and between scanners. This demonstrates that the scientifically useful question is not 'the Is digital scanning accurate?', but 'it is accurate enough for this indication, to this extent'. And with this protocol?'

Geometric precision also needs to be linked to clinical outcome. Small deviations can be irrelevant in a single crown and clinically important when they accumulate along a... long arc.

Digital competence therefore begins with language. Understanding what the study actually measured It avoids transforming a statistical property into a generic clinical promise.

3.2 Intraoral scanning in dentate and partially edentulous arches

Intraoral scanners offer particularly consistent performance in limited areas, in The acquisition process is short and anatomical references are abundant. The difficulty It grows as the arch becomes more extensive or presents long, toothless regions.

Vitai et al. (2023) showed that the condition of the arc modifies accuracy. This explains why studies Tests performed on fully toothed models cannot be automatically used to justify Performance in edentulous patients.

The scanning strategy also matters. Sequence, speed, distance from the sensor, presence Saliva levels and the ability to maintain visual references can influence data alignment.

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In 2024, Cai et al. compiled 49 studies on fingerprints and conventional impressions in arches.
edentulous. The meta-analysis showed that the comparison between methods depended on the method of
Measurement and configuration of implants, in addition to presenting significant heterogeneity.
The authors considered the accuracy clinically acceptable in edentulous arches in certain
conditions, but they requested more clinical studies. This formulation is important: acceptability in a
Meta-analysis does not equate to the universal superiority of the method.
Therefore, the extent of the arch needs to be treated as a clinical variable. The greater the distance of
When acquiring a new product, the greater the concern should be with validating the entire set of components.

3.3 Clinical efficiency: where digital demonstrates the most consistent advantage

Clinical time is one of the most frequently evaluated outcomes in digital workflows. Bernauer,
Zitzmann and Joda (2023) observed that temporal efficiency was the most frequently reported outcome among the
Complete workflow clinical studies.
Ma et al. (2023), in a systematic review of ten in vivo studies on fingerprint-related
Regarding implants, they found an average reduction of 8.59 minutes in the procedure for full arches.
comparison with conventional printing in the studies analyzed.
This gain needs to be interpreted within the overall process. A faster acquisition might be...
followed by the need for corrections, rescans, laboratory adjustments, or validations.
additional. Therefore, chair time and total treatment time are not necessarily
equivalents.
In well-indicated situations, the elimination of impression trays, materials, model pouring, and transport.
Physical therapy reduces steps. Electronic transmission also decreases the interval between the doctor's office and
laboratory.
Digital efficiency also depends on the learning curve. Experienced operators tend to...
completing acquisitions with greater consistency, while teams in adaptation may present
longer times.
Therefore, speed is a real benefit, but it should be treated as one dimension among several. The best
The best technique is not necessarily the fastest; it's the one that combines time, accuracy, and predictability.
and the possibility of correction.

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3.4 Patient experience and reported outcomes

Conventional printing can produce nausea, discomfort, a feeling of suffocation, or a taste.
unpleasant for some patients. Digital scanning changes this experience by replacing
optical acquisition molding material.
Matos et al. (2023) included 11 studies in meta-analyses of patient-reported outcomes.
Preference was given to intraoral scanning, and significant differences were also observed.
Symptoms found include discomfort, nausea, unpleasant taste, and difficulty breathing.
This dataset is relevant because patient experience influences adherence and perception.
of quality. In evidence-based dentistry, preference does not replace accuracy, but should
to be considered when two options offer acceptable clinical performance.
Preferences may also vary depending on the indication. Long scans or the need for...
Multiple repetitions can reduce some of the perceived advantage.
Patient-reported outcomes require appropriate instruments and questions. An experience
More comfort does not automatically imply greater longevity of the restoration.
The best decision integrates these plans: if two techniques are clinically appropriate, the experience of
The patient can guide the choice. When a technique presents a risk of inadequate accuracy, comfort
Isolation should not prevail.

3.5 Extensive arches, edentulism, and the frontier of evidence

Full arch cases are among the most important topics of discussion in dentistry.
digital. The absence of dental references and the large distance between capture areas favor error.
accumulated.
A 2021 review on full-arch scans for multi-implant restorations.
found wide variability in trueness and precision and concluded that, in that set of studies,
Many results still exceeded the proposed limits of clinical acceptability.
In 2024, however, Cai et al. arrived at a more favorable interpretation for some scenarios.
showing how technological evolution and methodological differences modify the landscape.
Joensahakij et al. (2024), when reviewing 23 in vitro studies comparing conventional and digital methods
In full arcs, they found divided results: twelve studies favored digital techniques,
Six favored conventional methods and five reported comparable performance.
This distribution is more informative than any slogan. It shows that the field is in
transition and that superiority depends on the technology, the clinical situation and the method of measurement.

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When the evidence is heterogeneous, the most scientific approach is to validate. Clinical trials, Verification structures and hybrid methods remain useful in situations where the cost of a Cumulative distortion is high.

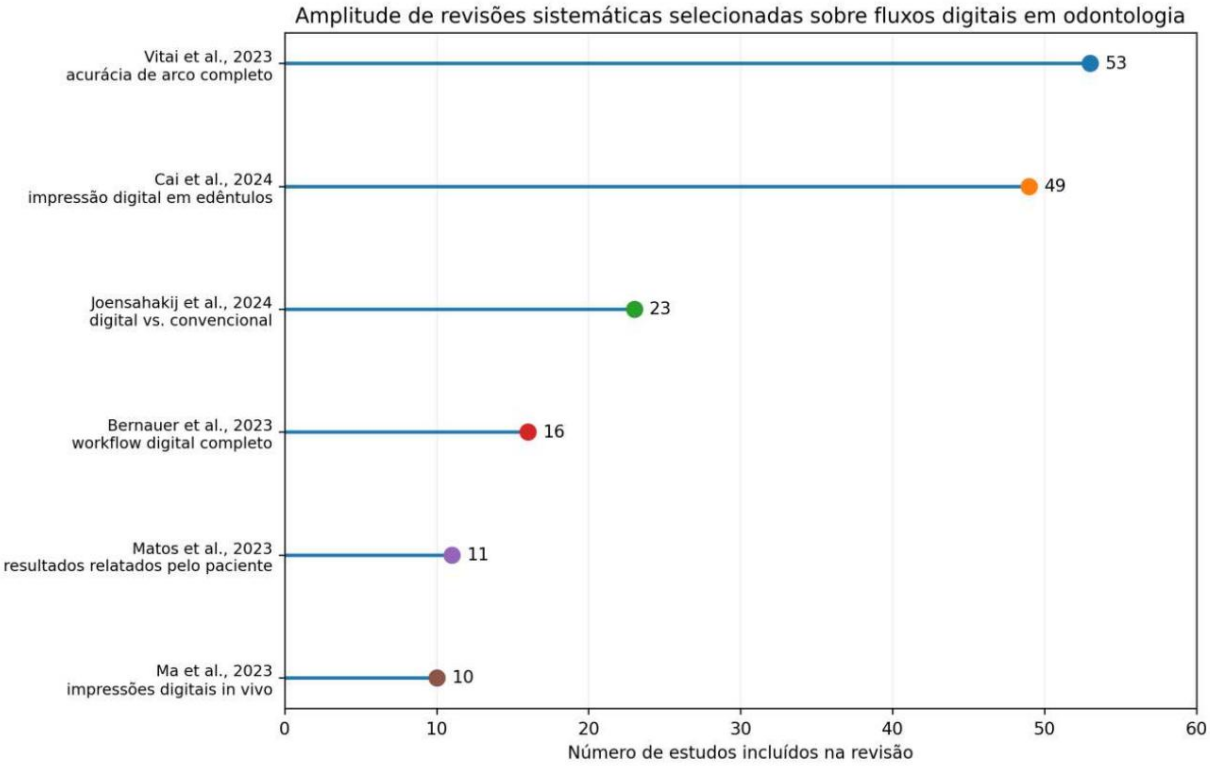

Figure 1. Number of studies included in selected systematic reviews that support the Discussion about digital workflows, accuracy, and patient experience. Source: author's own elaboration with based on the reviews cited.

3.6 Photogrammetry: a different technology, not just a better scanner

Stereophotogrammetry uses different principles than conventional intraoral scanners to to record three-dimensional implant positions, reducing reliance on continuous stitching of surfaces along the arc.

Recent reviews indicate promising performance in full arches. A published meta-analysis In 2025, it was found that photogrammetry showed greater accuracy compared to intraoral scanners. Several laboratory outcomes were observed, although clinical evidence remains less extensive. The potential benefit is particularly relevant when small angular or linear errors are present. Distributed along an arc, they can interfere with the passivity of the structure.

This does not mean that photogrammetry replaces all other forms of record-keeping. It captures specific... Spatial relationships need to be integrated with information on tissue, occlusion, and prosthetic design.

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The incorporation of new technologies must consider cost, training, and file compatibility.
and indication. A more precise device for a specific task is not necessarily the flow.
most efficient for all treatments.
Photogrammetry exemplifies the necessary maturity in digital dentistry: understanding that
Different technologies solve different problems, and quality lies in making the right choice, not...
indiscriminate adoption.

3.7 Complete digital workflow: from archive to restoration

A complete workflow begins with acquisition, but doesn't end with the STL file. The final result
It depends on the design, library, software parameters, material, manufacturing strategy, and control.
of quality.
Bernauer, Zitzmann, and Joda (2023) identified 16 eligible clinical studies in their update.
on complete digital workflows in fixed prosthetics. Despite the growth in the literature, the authors
They highlighted that the absolute number of trials remained low, especially for restorations.
multiple.
The best data supported the use of fully digital workflows in selected situations, such as
Monolithic posterior crowns on implants. This specificity should be preserved when communicating.
the evidence.
Integration with CAD/CAM reduces physical steps, but creates new dependencies: the correct library,
Calibration, machining or printing strategy, sintering and finishing. The error shifts location;
It doesn't disappear.
Interoperability is also an important issue. Closed formats, proprietary libraries and
Software versions can influence the continuity of the workflow between the clinic and the laboratory.
Therefore, a mature digital workflow needs checkpoints. Checking preparedness, contacts,
The responsibility for occlusion, adaptation, and aesthetic outcome remains with the clinician.

3.8 Digital education and critical reading of innovation

The speed at which new scanners and software are released creates an epistemological problem: the
Equipment available today may not have been evaluated in the studies that formed the basis of a review.
published two years earlier.

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Vitai et al. (2023) compared 26 scanners and still concluded that performance depends on the clinical scenario. This data shows why universal rankings are aging rapidly and need to be interpreted with caution.

Professional training should include principles of clinical metrology, an understanding of trueness, and... Precision, sources of error, and reading confidence intervals. Without this foundation, digital dentistry... There is a risk that it will be taught as a sequence of buttons.

It is also necessary to acknowledge conflicts of interest and differences between independent study and... Promotional material. Product demonstrations can be useful for operational learning. but they are not a substitute for scientific comparison.

Continuing education gains value precisely at this point: translating complex studies into... clinical decisions without oversimplifying them to the point of distorting their conclusions.

The most advanced digital competence isn't about using all available technologies. It's about knowing how to choose. validate and, when necessary, revert to a conventional or hybrid method because of the evidence and the case. They indicate that it is safer.

Conclusion

Digital dentistry should be analyzed as a chain of decisions and data transformations. Reduce The concept of using a scanner impoverishes the scientific understanding of the process. Accuracy is not... Abstract ownership of a brand; depends on the extent of the brand's reach, its structure, and acquisition strategy. Operator, algorithm, and clinical purpose. The most consistent benefits of digital technology appear in Efficiency and patient experience in specific indications. These gains are important, but They do not allow for the inference of universal superiority. In extensive arcs, the literature remains heterogeneous. Recent reviews show improved results, but also differences between technologies and Experimental designs. Photogrammetry expands the possibilities in recording multiple implants. and demonstrates that digital innovation does not occur through a single technological route. CAD/CAM workflows They reduce physical steps and increase integration, while at the same time creating linked sources of error. Software, library, manufacturing, and interoperability. Clinical validation remains essential.

A digital file does not possess its own authority; it needs to be confronted with fabrics, function, Adaptation and restorative objective. It is concluded that true digital maturity is critical, not enthusiastic. The technologically advanced professional is one who understands the power of the tool, It recognizes its limitations and chooses the method based on the indication and the evidence.

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