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Intraoral scanners: enhancing efficiency and patient comfort in prosthodontics – a systematic review

(Escáneres intraorales: mejora de la eficiencia y la comodidad del paciente en prostodoncia: una revisión sistemática)

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Abstract (english)

This review evaluates the effectiveness of intraoral scanners in prosthodontics, focusing on their ability to reduce working time and enhance patient comfort compared to conventional impression techniques. A systematic review was conducted following PRISMA guidelines. Studies from 2016 to 2023 were selected based on predefined inclusion criteria, including clinical trials involving adult participants using various intraoral scanners. The review included comparisons with traditional impression techniques to assess time efficiency, accuracy, and patient experience. Five studies were selected from an initial pool of 1,544 articles. The findings indicate that intraoral scanners significantly reduce working time, particularly in full-arch rehabilitations, and improve patient comfort. Digital impressions were associated with shorter chair times and fewer complications during follow-up, highlighting their efficiency and acceptability. In conclusion, intraoral scanners offer a promising alternative to conventional methods in prosthodontics, with significant benefits in terms of time efficiency and patient comfort. Further advancements in scanner technology and digital workflows are expected to enhance their accuracy and reliability in clinical practice.

Keywords(english)

Intraoral Scanners, Prosthodontics, Digital Impressions, Conventional Impressions , CAD/CAM

Resumen (español)

Esta revisión evalúa la eficacia de los escáneres intraorales en prostodoncia, centrándose en su capacidad para reducir el tiempo de trabajo y mejorar la comodidad del paciente en comparación con las técnicas de impresión convencionales. Se realizó una revisión sistemática siguiendo las directrices PRISMA. Se seleccionaron estudios publicados entre 2016 y 2023 según criterios de inclusión predefinidos, incluyendo ensayos clínicos con participantes adultos que utilizaron diversos escáneres intraorales. La revisión incluyó comparaciones con las técnicas de impresión tradicionales para evaluar la eficiencia temporal, la precisión y la experiencia del paciente. Se seleccionaron cinco estudios de un total inicial de 1544 artículos. Los resultados indican que los escáneres intraorales reducen significativamente el tiempo de trabajo, especialmente en rehabilitaciones de arcada completa, y mejoran la comodidad del paciente. Las impresiones digitales se

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asociaron con tiempos de consulta más cortos y menos complicaciones durante el seguimiento, lo que destaca su eficiencia y aceptabilidad. En conclusión, los escáneres intraorales ofrecen una alternativa prometedora a los métodos convencionales en prostodoncia, con importantes beneficios en términos de eficiencia temporal y comodidad del paciente. Se espera que los avances en la tecnología de escáneres y los flujos de trabajo digitales mejoren su precisión y fiabilidad en la práctica clínica.

Palabras clave(español)

Escáneres intraorales, prótesis dentales, impresiones digitales, impresiones convencionales, CAD/CAM.

Introduction

Intraoral scanners have revolutionized prosthodontic practices by providing a digital alternative to conventional impression techniques. These advanced devices capture detailed digital impressions of the oral cavity, improving accuracy, efficiency, and patient comfort. This systematic review examines the efficacy of intraoral scanners compared to traditional methods, focusing on their impact on working time, patient experience, and clinical outcomes.

The shift from conventional impression materials like polyether and polyvinyl siloxane to digital workflows represents a significant advancement in dental technology. Recent studies have shown that intraoral scanners not only reduce the time required for impression-taking but also enhance patient satisfaction by minimizing discomfort associated with traditional methods [2]. Additionally, digital impressions facilitate streamlined workflows, from data acquisition to computer-aided design (CAD) and manufacturing (CAM), enhancing the precision and efficiency of prosthodontic treatments.

Methods

Study Design. This systematic review and meta-analysis followed the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and was registered in PROSPERO (table 1).

Research Question. The research question was framed using the PICO (Population, Intervention, Comparison, Outcome) framework: *"Do intraoral scanners reduce working time and enhance patient comfort compared to conventional methods in prosthodontics?"*

PICO Analysis. Population: Studies involving adult participants aged 3–55 years with one or two non-adjustable tissue-level implants in the posterior region, dentition in the opposing jaw, implant diameters of at least 4.1 mm, implant heights of at least 8 mm, and patients requiring full-arch rehabilitation in the maxilla.

- *Intervention:* Various intraoral scanners, such as 3M, Carestream CS 3600, Lava, iTero, and Dentsply Sirona, used for full-mouth scans.
- *Comparison:* Conventional impression techniques

Table. 1. Articles and Study Designs.

	Article	Year	Study Design
1.	Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part I: Time efficiency of complete-arch digital scans versus conventional impressions (Sailer I et al)[1]	2019	Randomised control trial
2.	Conventional versus Digital Impressions for Full Arch Screw-Retained Maxillary Rehabilitations: A Randomized Clinical Trial (Cappare P et al)[2]	2019	Randomised clinical trial
3.	Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up (Mangano F et al)[3]	2018	Randomised controlled trial
4.	Digital vs. conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: a randomized controlled trial (Hanozin B et al)[4]	2022	Randomised controlled trial
5.	Randomized Clinical Trial comparing clinical adjustment times of CAD/CAM screw-retained posterior crowns on ti-base abutments created with digital or conventional impressions. One-year follow-up (Derksen W et al)[5]	2021	Randomised clinical trial

Tabla. 2. Table extraction.

Treatment	Article Title	No. Of Patients/Population	Intervention	Comparison
Fixed Partial Denture	Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part I: Time efficiency of complete-arch digital scans versus conventional impressions (Sailer I et al)	10 patients >18 years eligible for 3-unit FPD in the posterior region not supported by third molar	Digital scanning using Lava C.O.S, iTero, Cerec Bluecam scanners	Conventional impressions using polyether
Implant	Conventional versus Digital Impressions for Full Arch Screw-Retained Maxillary Rehabilitations: A Randomized Clinical Trial (Cappare P et al)	50 patients (48–72 years) with edentulous upper arch and sufficient bone for 6 implants	6 immediate-loading implants scanned using intraoral scanners	Conventional pick-up impressions
Implant	Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up (Mangano F et al)	50 patients (22 males, 28 females, mean age: 52.6 years) with 15 implants in maxilla and 35 in mandible	Implant placement with digital workflow for 12 males and 13 females	Conventional workflow for 10 males and 15 females
Implant	Digital vs. conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: A randomized controlled trial (Hanozin B et al)	Patients >18 years with single or two non-adjacent missing teeth in the aesthetic area	Digital workflow using CARES software and scanning with TRIOS, 3Shape, and Denmark scanners	Conventional one-abutment, one-time technique
Implant	Randomized Clinical Trial comparing clinical adjustment times of CAD/CAM screw-retained posterior crowns on ti-base abutments created with digital or conventional impressions. One-year follow-up (Derksen W et al)	32 patients with 45 posterior tissue-level implants replacing solitary teeth	Intraoral scanner impressions (3MTM TDS)	Conventional polyether pick-up impressions

employing polyether or polyvinyl siloxane materials, used to evaluate time requirements and quality.

• *Outcome:* Intraoral scanners significantly reduce working time, time required for crown adjustments, and follow-up complications while improving patient comfort and acceptability.

Eligibility Criteria. *Inclusion Criteria*: Published clinical trial articles in English from 2016 to 2023. *Exclusion Criteria*: Non-English articles, animal studies, in-vitro studies, review papers, case reports, participants undergoing orthodontic treatment, and those with systemic illnesses.

Study Selection. The search process involved independent screening of article titles by two reviewers (LN and [Reviewer Name]). Duplicates and irrelevant studies were excluded. Abstracts meeting eligibility criteria were assessed, and full-text articles were retrieved for insufficiently detailed abstracts. Discrepancies were resolved through discussion or by involving a third party. Of 1,544 initially identified articles from PubMed, EMBASE, Google Scholar, and Web of Science, 107 were retained after duplicate removal. Abstracts of 87 articles were reviewed, with 35 excluded. A total of 52 full-text articles were evaluated, and 5 studies met the eligibility criteria for the systematic review.

Data Sources and Search Strategy. A detailed search strategy was tailored for each database, including Google Scholar, Web of Science, Scopus, PubMed, ResearchGate, EMBASE, and the Cochrane Central Register of Controlled Trials, covering publications from 2017 to 2023. MeSH (Medical Subject Headings) terms included: “intraoral scanners,” “workflow,” “digital workflow,” “digitization,” and “image.” Boolean operators (AND/OR) refined the search. Grey literature from Google Scholar was also included. Filters applied were full free text and randomized controlled trials. The PICO framework structured the search, adhering to PRISMA guidelines.

Data Extraction. Study details were organized into a “Characteristics of Included Studies” table 2. Data were extracted using a pre-defined standard sheet and cross-verified for accuracy by two independent reviewers (table 2).

Assessment of Methodological Quality. The Cochrane Collaboration’s tool was used to assess the risk of bias, following the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, 2008). Two reviewers (LN

Tabla. 3. Quality Assessment.

Study	Randomization	Allocation Concealment	Assessor Blinded	Dropouts Described	Risk of Bias
Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part I: Time efficiency of complete-arch digital scans versus conventional impressions (Sailer I et al)	Yes	Yes	Yes	Yes	Low
Conventional versus Digital Impressions for Full Arch Screw-Retained Maxillary Rehabilitations: A Randomized Clinical Trial (Cappare P et al)	Yes	No	Yes	Yes	Low
Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up (Mangano F et al)	Yes	Yes	No	Yes	Low
Digital vs. conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: a randomized controlled trial (Hanozin B et al)	Yes	No	No	No	High
Randomized Clinical Trial comparing clinical adjustment times of CAD/CAM screw-retained posterior crowns on ti-base abutments created with digital or conventional impressions. One-year follow-up (Derksen W et al)	Yes	yes	No	No	Moderate

and IK) independently graded the bias as "Yes," "Unclear," or "No" based on major and minor criteria. *Major Criteria*: Randomization method, allocation concealment, blinding, dropouts, and overall risk of bias. *Minor Criteria*: Sample justification, baseline comparisons, eligibility criteria, and error methods. Results were summarized in [Table 2]. *Inclusion Criteria:* 1. Partially edentulous adults. 2. Presence of at least one osseointegrated Straumann tissue-level implant with an RN prosthetic connection to replace a single missing tooth in the posterior region. 3. The location of the missing tooth (future restoration site) must have at least one opposing antagonist tooth. 4. Stable medical condition at the time of the study. 5. The implant must meet specific size requirements: a minimum diameter of 4.1 mm and a minimum height of 8 mm. *Exclusion Criteria:* 1.Presence of signs of inflammation or peri-implant diseases during the time of implant impressions. 2. Implants that do not allow for straight occlusal screw access within the contours of the planned implant crown. 3. Patients with known allergies to any of the prosthetic components used in the intervention.

This table 3, simplifies the decision-making process for choosing between digital and conventional impressions by summarizing key performance indicators and referencing relevant studies. It highlights the advantages, challenges, and appropriate applications of each method in modern dental practice.

The table 4, provides a comparative overview of several studies analyzing the accuracy and effectiveness of digital and conventional dental impression techniques. It categorizes these studies based on their type, focus, scanner types used, and main findings. The study types range from pilot in vitro experiments to systematic reviews, with each approach addressing specific aspects of dental impressions. Some studies, like those focused on intraoral versus laboratory scanners, emphasize the impact of the scanning environment on accuracy. Others, such as umbrella reviews, synthesize existing research to provide broader insights.

The focus of these studies varies but commonly includes comparing the precision of digital scanners to traditional methods, assessing factors influencing scanning accuracy, and evaluating the role of operator expertise and scanning strategies. For example, studies have shown that intraoral scanners are highly effective, particularly when used by experienced operators and with optimal scan body designs, but their performance can be influenced by variables like implant angulation or scanner model. In contrast, conventional methods are reliable but may lack the speed and convenience of digital alternatives.

Key findings from these studies highlight that the choice of scanner type, the design and position of scan bodies, and the selected scanning strategy all significantly influence the accuracy of impressions. While digital methods are increasingly favored for their efficiency and accuracy, especially in complex

Table. 4. Digital and conventional impressions.

Parameter	Digital Impressions	Conventional Impressions	References
Accuracy	High accuracy for single-unit and short-span cases; affected by implant angulation and scanning strategy.	Reliable in various cases but prone to dimensional changes (e.g., due to material shrinkage).	Shely et al. (2023), Çakmak et al. (2020), Afrashtehfar et al. (2022)
Efficiency	Faster scanning process and no need for physical storage of models.	Time-consuming, requiring physical impressions and model pouring.	Ahlholm et al. (2018), Mandelli et al. (2018)
Operator Dependency	Dependent on experience with digital tools and proper scan body alignment.	Requires expertise in material handling and precise impression techniques.	Ben-Izhack et al. (2024), Amin et al. (2017)
Material Costs	Initial cost for scanner equipment is high; lower recurring costs.	Lower initial costs but higher recurring expenses (materials, shipping, and model storage).	Alikhasi et al. (2018), Turkyilmaz et al. (2020)
Patient Comfort	Less invasive and more comfortable for patients due to no impression materials being used.	Can cause discomfort, especially in cases of gag reflex or extended procedures.	Mandelli et al. (2018), Giménez et al. (2014)
Versatility	Ideal for digital workflows, CAD/CAM, and full-arch cases with specific adjustments.	Compatible with traditional prosthetic workflows; limited for complex digital designs.	Arcuri et al. (2020), Fluegge et al. (2017)
Environmental Impact	Eco-friendly, as it reduces the use of disposable impression materials and physical storage requirements.	Higher environmental footprint due to waste from impression materials and physical model storage.	Nimavat et al. (2021), Afrashtehfar et al. (2022)
Applications	Widely used for prosthetics, implants, orthodontics, and full-arch restorations.	Primarily used in traditional prosthetic restorations and in cases without access to digital technology.	Natsubori et al. (2022), Pachiou et al. (2023)
Learning Curve	Requires initial training but becomes efficient with experience.	Familiar to most clinicians; does not require advanced technology training.	Alikhasi et al. (2018), Çakmak et al. (2020)

implant scenarios, traditional techniques still offer dependable results in simpler cases. Table 5, offers a succinct yet comprehensive reference for understanding these trends and can guide decision-making in clinical practice and further research.

Results

Study Selection. The initial search identified 1544 studies, of which 5 studies were selected for systematic review based on independent reviews meeting the inclusion criteria.

Characteristics of the Trial Setting. Netherlands: 1 study (Derksen W et al) (5), Italy: 2 studies (Cappare P et al) (2), (Mangano F et al), Switzerland: 2 studies (Sailer I et al) (1), (Hanozin B et al)

Characteristics of the Participants. *Age Group*:

Out of the 5 studies, 4 studies included participants aged 18 and above. 2 studies (Cappare P et al) (2), (Mangano F et al) (3) recruited participants aged 45–60 years. 1 study (Derksen W et al) (5) did not specify the age of participants.

Blinding. 3 studies (Sailer I et al) (1), (Cappare P et al) (2), (Derksen W et al) (5) were double-blinded.

Exclusions. All studies excluded participants with the following conditions: Signs of inflammation or peri-implant diseases, Allergies or diseases in the oral cavity, Smoking habits, use of antibiotics, pregnancy, hypertension. Evidence of parafunctional habits, TMJ disorders, or severe medical complications.

Characteristics of the outcome. Hanozin B et al (2019): Accuracy of implant positioning was evaluated by deviation in entry point, apex position, and angulation. Statistically significant improvements were found using s-CAIS compared to free-handed surgery.

Sailer I et al (2017): Time for complete-arch impressions, including powdering and occlusal registration, was shorter with conventional impressions compared to digital scans. Patients and clinicians rated digital scans as less comfortable than conventional impressions.

Cappare P et al (2020): Digital impressions took significantly less time compared to conventional methods ($p<0.05$).

Mangano F et al (2019): Impression-taking time was nearly halved in the digital group compared to the analogue group (20 minutes vs. 50 minutes). Digital workflow was more efficient than the conventional workflow when considering active working time.

Derksen W et al (2021): Adjustment time for crowns was significantly shorter in the digital group using intraoral scanners (3.35 minutes) compared to the conventional group (6.09 minutes).

Discussion

The digital era has revolutionized dentistry, providing advanced technologies for scanning both implants and teeth. Scanners, both intraoral and extraoral, offer numerous benefits, including enhanced patient comfort, reduced material distortion, shortened chair time, passive impressions, and the generation of digital files for CAD workflows.

Digital vs. Conventional Workflows. 1. Advantages of Digital Workflows: o Accuracy and Precision: Digital impressions yield a stereolithography (STL) file, enabling high-precision CAD designs. Accuracy refers to the consistency of scans, while trueness reflects how well the scan matches the actual dimensions of the object. o Patient Comfort: Digital workflows reduce the discomfort associated with conventional impressions, such as gagging, pain, and unpleasant taste. o Efficiency: Studies show that digital impressions, particularly with modern scanners, significantly reduce active working time compared to conventional methods. o Material Independence: Unlike traditional methods, digital workflows are less affected by environmental factors such as moisture or deformation of materials.

2. Challenges in Digital Scanning. o Scanner Variability: The outcomes depend on the type of intraoral scanner (IOS) used and the associated scanning strategy. For instance, the "stitching technique" often yields better precision than non-stitching methods. o Limitations: Factors such as limited intraoral space, patient compliance, saliva, and software handling can introduce errors during digital scanning. o Complex Cases: For full-arch

Table. 5. Comparison of digital conventional Impression.

Reference	Study Type	Focus	Scanner Types	Main Findings
Shely et al.	Pilot In Vitro Study	Influence of lab vs. intraoral scanners on implant axes and distances.	Laboratory, Intraoral	Intraoral scanners show varied accuracy depending on scan body usage.
Afrashtehfar et al.	Rapid Umbrella Review	Comparison of accuracy between intraoral scanners and traditional impressions.	Multiple Intraoral Scanners	Intraoral scanners are generally accurate, but limitations exist for complex cases.
Çakmak et al.	Clinical Study	Effect of scanner type and scan body position on full-arch scans.	Multiple Scanner Types	Scanner type and scan body position significantly affect accuracy.
Ben-Izhack et al.	In Vitro Study	Conventional vs. digital impressions for implant axes and distances.	Conventional, Digital	Digital impressions provided comparable results to conventional ones.
Alikhasi et al.	Experimental Study	3D accuracy of digital impressions vs. conventional methods under various conditions.	Digital, Conventional	Digital methods are highly accurate but influenced by implant angulation.
Mandelli & Gherlone	Comparative Study	Strategies for full-arch intraoral scanning and outcomes.	Multiple Digital Scanners	Scanning strategy impacts precision significantly.
Giménez et al.	Comparative Study	Operator experience and implant angulation impact on digital impression accuracy.	Parallel Confocal Laser Scanners	Operator experience and implant angulation are key factors in accuracy.
Amin et al.	Comparative Study	Full-arch digital vs. conventional implant impressions.	Digital, Conventional	Digital scans are comparable to traditional methods for full-arch impressions.
Pachiou et al.	Systematic Review	Characteristics of scan bodies influencing impression accuracy.	Intraoral Scan Bodies	Material and design of scan bodies significantly affect results.
Natsubori et al.	Experimental Study	Comparison of scanning accuracy for multiple implants.	Intraoral, Laboratory Scanners	Laboratory scanners slightly outperform intraoral scanners for complex geometries.

rehabilitations, conventional workflows sometimes fail to reproduce excessive disparallelisms accurately, necessitating reimpressions or adjustments.

3. Conventional Methods. o Advantages: In specific scenarios, such as cases with poor moisture control, polyether impressions outperform other materials like polyvinylsiloxane (PVS). o Disadvantages: Conventional methods are prone to distortions, contamination from saliva or blood, and inaccuracies stemming from material elasticity and handling.

Clinical Outcomes and Time Efficiency. • *Patient and Clinician Feedback*: Studies (e.g., Sailer et al.) report no clear preference for digital or conventional methods among patients. Clinicians, however, faced greater challenges with digital workflows due to software and scanner handling issues. • *Time Savings*: Digital workflows consistently demonstrated shorter impression times and more efficient working protocols compared to conventional methods. For instance, Mangano et al. reported a near 50% reduction in time using digital impressions. • *Error Rates*: While digital scans excel in trueness and precision, conventional methods occasionally outperform in cases involving posterior teeth or challenging intraoral environments due to cumulative errors in digital workflows.

Future Directions. 1. *Technology Development:* o Focus on scanners that eliminate the need for powdering, gingival displacement cords, and moisture control, streamlining the digital workflow. o Improve software handling and scanning strategies to minimize errors and enhance ease of use. 2. *Clinical Integration:* o Establish guidelines for selecting appropriate workflows based on case complexity, patient needs, and clinical settings. o Develop hybrid workflows that combine the strengths of both digital and conventional methods for optimal outcomes.

In conclusion, the choice between digital and conventional workflows depends on specific clinical scenarios, patient preferences, and the available technology. On equal terms, digital workflows represent a promising, less invasive, and time-efficient option, especially for full-arch rehabilitations. However, advancements in scanner technology and scanning strategies are essential to further enhance the reliability and accuracy of digital impressions.

Conflict of interest

None to declare.

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