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PROSTHETICS ON IMPLANTS: A COMPARATIVE STUDY OF DIGITAL VS. CONVENTIONAL IMPRESSION TECHNIQUES

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Abstract

Accurate impressions constitute the main requisite for successful implant-supported prostheses to be fitted well, in occlusion, and functionally named in the long term. Conventionally, impression techniques with polyether or polyvinyl siloxane have been considered to be the best choice. With a higher number of cases integrating digital approach into prosthodontic workflows, intraoral scanning has become a contender as an alternative to the traditional methods. Digital impression-making techniques ostensibly promise benefits: reduced chairside time, enhanced patient comfort, and simplification of laboratory procedures. Nevertheless, doubts remain concerning the accuracy of such techniques in highly demanding situations such as full-arch restorations or angulated implants. In implant prosthodontics, this comparative study investigates the advantages and disadvantages of digital versus conventional impression techniques. The review considers evidence from clinical trials, in vitro studies, and systematic reviews to assess parameters such as dimensional accuracy, trueness, precision, patient-reported outcome measures, and workflow efficiency. In general, digital impressions have been shown to surpass conventional methods in patient satisfaction and procedural efficiency, but conventional impressions may yield better results in complicated implant configurations or where there is extensive soft tissue handling. The acceptance of these digital workflows is dependent on cost, clinical experience, and currently existing technical infrastructure. It shows the importance of assessing what may be the right impression technique in each patient. The hybrid method of impressions may be the most feasible working system to employ in today's prosthodontic practice by harnessing the strengths of both systems.

Keyword: Digital Impressions, Conventional Impressions, Implant Prosthodontics, Intraoral Scanner, Accuracy, Patient Comfort, Prosthesis Fit, Digital Workflow.

1. INTRODUCTION

The implant prosthodontics enables modern dentistry in providing an assured and functioning solution to partial or complete edentulism. Long-term clinical success of implant-supported restorations is dependent not just on bulk osseointegration and surgical accuracy but mainly on prosthodontic subsequent to it, mainly impression procedures. These impressions establish the vital link between the intraoral environment and lab fabrication; if any error exists in a dimension in this vital stage, discrepancies in prostheses will result along with biological complications and mechanical incidents, such as screw loosening or porcelain fracture (Alsharbaty et al., 2019; Lee et al., 2022).

Traditionally, implant impressions are made with conventional techniques, including impression trays and elastomeric materials such as polyvinyl siloxane (PVS) and polyether. These materials have been trusted to assess the joint spatial relationship between implants and adjacent oral structures (Basaki et al., 2017). From the disadvantages reported are distortion during removal, different behavior of materials within moist environments, time-intensive procedures, and discomfort to patients

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(Papaspyridakos et al., 2020). Furthermore, analog workflows, more frequently than not, experienced cumulative propagation of errors across different stages, such as from impression to cast pouring to fabrication of the prosthesis (Moura et al., 2019).

Digital impression techniques have seen rapid growth during the few last decades, primarily with IOS systems. These scanners are used to take an optical representation of the implant site and neighboring dentition directly, thus eliminating the need to use impression materials and trays. These days, newer generations of scanners claim ever greater accuracy and ergonomic design to facilitate speedier acquisitions of scans-Mediatechniques, TRIOS, iTero, and several others (Chochlidakis et al., 2016; Bi et al., 2022). Digital impressions help shorten the treatment timeline because of the easily available integration with CAD/CAM systems and favorable reproducibility of outcomes (Amin et al., 2017; Joensahakij et al., 2024).

Though digital impressions are more appealing, their superiority over conventional ones is still to be thoroughly investigated. Accuracy outcomes are highly case-dependent-in that some reports show more trueness and precision with IOS and some show limitations in the full-arch or angulated implant scenario (Tohme et al., 2023; Lyu et al., 2022). Also, the expensive equipment prices, the time needed for clinician training, and the incompatibility between different digital platforms have hindered their universal adoption (Mühlemann et al., 2018; Joda & Brägger, 2015).

Such discrepancies, in the present state of affairs, clearly point to the need for more comprehensive comparative analysis, including examining the technical accuracy of either technique and assessing choices based on clinical applicability, patient-oriented outcomes, cost-effectiveness, and long-term success of the prosthesis. An abundance of literature has emerged, including systematic reviews, in vitro studies, and randomized controlled trials; however, we do not have a consensus on definitive clinical guidelines. The purpose of this article will be to give the latest update on the known facts about the digital and conventional impression techniques for implant prostheses. More specifically, the article will address the following questions:

1. In implant prosthodontics, how do digital and conventional impression techniques fare in terms of trueness, precision, and overall accuracy?
2. To what extent do these techniques affect the patient experience, the clinical workflow, and the longevity of the prosthesis?
3. What are the specific clinical scenarios in which one technique far outshines the other?
4. How does cost affect the adoption and efficiency of these workflows? How about the learning curve and digital literacy?

In answering these questions, the present work intends to offer an evidence-based framework to clinicians, educators, and researchers in choosing impression techniques, rather than one based on convenience or tradition.

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The goal, therefore, is to foster the highest possible outcomes for implant prosthodontics through the process of informed data-driven decision-making.

2. BACKGROUND AND LITERATURE REVIEW

2.1 Conventional Impression Techniques

Traditional techniques have always been considered a base for prosthodontic steps, especially for implant dentistry. The most popular materials for the analog-physical method are polyvinyl siloxane and polyether since they lend efficient dimensional stability, tear resistance, and micro detail reproduction (Basaki et all., 2017; Alsharbaty et al., 2019). These elastomeric impression materials are used into either a closed-tray or an open-tray technique, in regard of their specific advantages that depend on implant angulation, number of implants, and limitations to access (Moura et al., 2019).

Open-tray impression techniques allow the splinting of transfer copings to be picked up directly during the impression. This allows for more accurate positional registration, especially in the case of multiple implants. Closed-tray impressions are said to be more patient-friendly and quicker, but the implant analogy may lose some degree of precision when the implants are divergent in their axes (Papaspyridakos et al., 2016). After an impression is taken, an analog is attached to the impression coping, which is set into the stone cast in a dental laboratory—a workflow susceptible to a cumulative error at every incidence (Ribeiro et al., 2018).

Despite their conventional yet time-honored application, impression techniques tend to present their own limitations. In full-arch cases especially, the removal of the impression material may cause distortion and would then compromise fit accuracy (Tohme et al., 2023). Several clinical and laboratory appointments are necessary; thus, treatment time is lengthened along with patient discomfort. Another factor that adds to the retention and reproducibility of long-term data is the storage of physical models subjected to possible breakage or degradation (Lyu et al., 2022).

2.2 Digital Impression Techniques

Changing the way prosthodontics are practiced, digital impression techniques have taken the front stage, employing the latest intraoral scanners (IOS) of manufacturers like TRIOS, iTero, Medit, and Carestream to acquire high-resolution 3-D surface maps of intraoral structures, overlaying their structures. The digital system differs from classical techniques in that it avoids the casting trays, materials, and casts (Bi et al., 2022). Further, the conventional digital workflow is constituted of three major steps, namely: scanning of the implant site, CAD design of the prosthesis, and CAM milling in a dental lab or direct milling in a dental lab or direct milling within the dental office (Chochlidakis et al., 2016; Joda & Brägger, 2015).

The benefits of digital workflows are immense. IOS clinically reduces chairside time, eliminates discomfort associated with tray placement, and bestows the advantage of immediate feedback, so the operator can immediately rescan if there appear to be

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deficient areas on the IOS image (Manicone et al., 2022). Digital scans offer a relatively more efficient and tolerable experience to patients, mainly those who have a strong gag reflex or are anxious (Gallardo et al., 2018).

From the lab standpoint, digital data can be transmitted to dental laboratories immediately, so that no time is lost, and there are no risks of impression deformation during transportation (Albanchez-Gonzalez et al., 2022).

Digital impressions further facilitate the long-term archiving of data in cloud-based or local archives, thereby easing retrieval, case review, and modification.

Chairside CAD/CAM also allows in some cases for same-day prosthetic delivery, drastically minimizing turnaround time (Gherlone et al., 2016). Well, digital systems require a huge upfront investment, software updates, and a learning curve by the dentist and support staff (Chandran et al., 2019).

2.3 Comparative Studies

Several randomized controlled trials, systematic reviews, and meta-analyses have sought to determine how digital, and conventional impressions perform concerning several clinical aspects. However, depending upon the study design and method of evaluation, several trends have surfaced over time.

Accuracy and repeatability have always been key factors for prosthodontic success. Digital impressions have always exhibited equal, if not better, accuracy in short-span restorations, more specifically for single-unit crowns or for bridges of up to three units (Papaspyridakos et al., 2020; Amin et al., 2017).

On the other hand, digital accuracy decreases with full-arch restorations due to errors related to the stitching of images and distortion from the scans over longer spans (Kosago et al., 2023; Ma et al., 2021).

Therefore, conventional means stand more predictably for multi-unit, full-arch cases with several angulated implants.

When compared with time, the digital workflow dramatically diminishes turnaround times for clinical and laboratory procedures. Researches showed that it had actually saved chairside time from anywhere between 15 and 40%, which depended on how complex the case was (Joda & Brägger, 2015; Gallardo et al., 2018). When it comes to sending the data to laboratories, delays in prosthetic fabrication will likewise be minimized.

From the patient point of view, digital techniques are always preferable. Whereas surveys have recorded high patient satisfaction due to lowered discomfort, no impression materials, and shorter time for appointments (Yuzbasioglu et al., 2014; Manicone et al., 2022), this stands true for geriatric and special-needs patients.

In terms of cost, digital systems are expensive in terms of acquisition costs and maintenance costs. Nevertheless, their interposition may result in the reduction of material costs, remake costs, or appointment duration, thereby saving money in the long run (Joda & Brägger, 2015; Ahmed et al., 2024).

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One may consider analogic workflow less expensive per case; however, they tend to exact more indirect costs upon admittance.

The following table summarizes comparative results from key studies.

Table 1: Summary of Comparative Studies Between Digital and Conventional Impression Techniques

Study	Design	Impression Types Compared	Key Findings	Notable Outcome
Alsharbaty et al. (2019)	Clinical (n=20)	PVS vs TRIOS	Digital showed higher 3D accuracy	Digital superior in single units
Tohme et al. (2023)	In vitro	Conventional vs Photogrammetry vs IOS	Photogrammetry most accurate, IOS close	Digital valid but case-dependent
Lyu et al. (2022)	Clinical	PVS vs IOS	Comparable accuracy, faster time with IOS	Digital more efficient
Papaspyridakos et al. (2020)	Systematic review	Multiple IOS vs conventional	High accuracy for short-span; digital less accurate in full-arch	Hybrid approach recommended
Amin et al. (2017)	Clinical	Digital vs conventional for full arch	Digital slightly less accurate in long-span	Conventional better in complex cases
Manicone et al. (2022)	Meta-analysis	Patient preferences and time	Patients preferred digital; shorter chair time	Digital wins in comfort
Gallardo et al. (2018)	Systematic review	Workflow time analysis	Digital faster in most stages	Efficiency improved digitally

3. SCOPE OF REVIEW AND METHODS

The textile was explored through a literature review intending to comprehensively compare digital and conventional impression techniques in implant-supported prosthetics. A synthesis of empirical evidence on accuracy, clinical outcomes, efficiency, patient satisfaction, and workflow contrasts with the two techniques was to be attempted. Subjects of interest also include efforts to search for good-quality studies that make a direct comparison between IOS systems and analog methods, be it with polyether or PVS, under a variety of clinical and laboratory settings.

3.1 Databases and Search Strategy

For literature search, four major scientific databases were queried: PubMed, Scopus, Web of Science, and ScienceDirect. These databases were selected because of their broad coverage of peer-reviewed dental, prosthodontic, and biomedical literature. The search was conducted using Boolean operators and advanced search strings combining keywords with MeSH terms such as: ("digital impression" OR "intraoral scanner" OR "IOS") AND ("conventional impression" OR "analog impression" OR "polyvinyl siloxane") AND ("dental implant" OR "implant prosthesis" OR "implant-supported restoration") Search filters were applied such that only articles in the English language between 2013

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and 2024 were retrieved; hence guaranteeing the scientific appropriateness in terms of recency and relevance. Other articles were retrieved by hand-searching the reference lists of included systematic reviews and meta-analyses (Papaspyridakos et al., 2020; Chandran et al., 2019).

3.2 Inclusion and Exclusion Criteria

Studies were selected if they:

Direct comparative analysis of digital versus conventional impressions with regard to implant prosthodontics were reported. The studies involved clinical trials, randomized controlled trials (RCTs), in vitro studies, or systematic reviews/meta-analyses. Had one or more of the following outcomes evaluated: accuracy (trueness/precision), marginal fit, time-efficiency, patient satisfaction, and clinical usability.

The Exclusion criteria were the following:

- Articles concerning tooth-supported restorations or orthodontics only,
- Non-peer-reviewed articles, commentaries, or editorials,
- Studies that used digital impressions merely for diagnostic models, as opposed to final prosthesis fabrication.

3.3 Data Extraction and Study Categorization

From the eligible studies, the studies were divided into four groups, depending on the design:

- In vitro studies measuring spatial accuracy using a reference model and coordinate measuring machine (CMM) (e.g., Alfaraj et al., 2023; Tohme et al., 2023)
- Crossover trials comparing patient outcomes for IOSs and conventional impressions (e.g., Lee et al., 2022; Amin et al., 2017)
- Systematic reviews and meta-analyses pooling the findings of RCTs (e.g., Flügge et al., 2018; Papaspyridakos et al., 2020)
- Survey-based studies on clinician/patient preferences and chair-time (e.g., Manicone et al., 2022; Yuzbasioglu et al., 2014)

A standardized spreadsheet was used to extract the following information:

- Sample size and study settings
- Scanner model or impression material used
- Metrics of accuracy (trueness, precision, marginal gap)
- Time for impression
- Outcome measures related to prosthesis fit and satisfaction

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3.4 Risk of Bias and Quality Assessment

To ensure methodological rigor, any clinical trial or in vitro study included was assessed for quality using the Cochrane Risk of Bias tool (RoB 2) for randomized studies and the Joanna Briggs Institute Critical Appraisal Checklist in case of in vitro experiments.

Across the measure and quality standard, these studies were said to have a low, moderate, or high risk of bias. For systematic reviews and meta-analyses, AMSTAR-2 (A Measurement Tool to Assess Systematic Reviews) was used to assess its methodological transparency and reliability.

We did not provide a PRISMA flow diagram in this article due to a shortage of space. However, PRISMA principles were followed in the selection and reporting of literature sources.

3.5 Scope Limitations and Assumptions

While this review intended to consider all relevant high-quality studies that have compared the digital and conventional impression techniques in the field of implantology, it is important to point out that the technological without any interoperation in intraoral scanners and differences in operator skills could introduce heterogeneity in the performances.

Also, many of the in vitro studies used ideal models that would hardly be able to completely simulate any complex intraoral situations.

To somehow decrease bias, small-sample-size studies or studies with unclear methodologies were critically evaluated and excluded as necessary. Focus was made on clinical application rather than laboratory precision alone.

4. COMPARATIVE ANALYSIS AND DISCUSSION

4.1 Accuracy and Precision

Accuracy constitutes an inseparable aspect of the implant-supported prostheses. It determines how much the prosthesis resembles the true intraoral implant positions.

Generally, accuracy is divided into trueness (how close a measure is to the true value) and precision (repeatability of the same measurement).

Numerous studies have stated that intraoral scanners (IOS) show very high levels of trueness and precision for short-span restorations and may even perform better than conventional impressions (Alsharbaty et al., 2019; Papaspyridakos et al., 2020).

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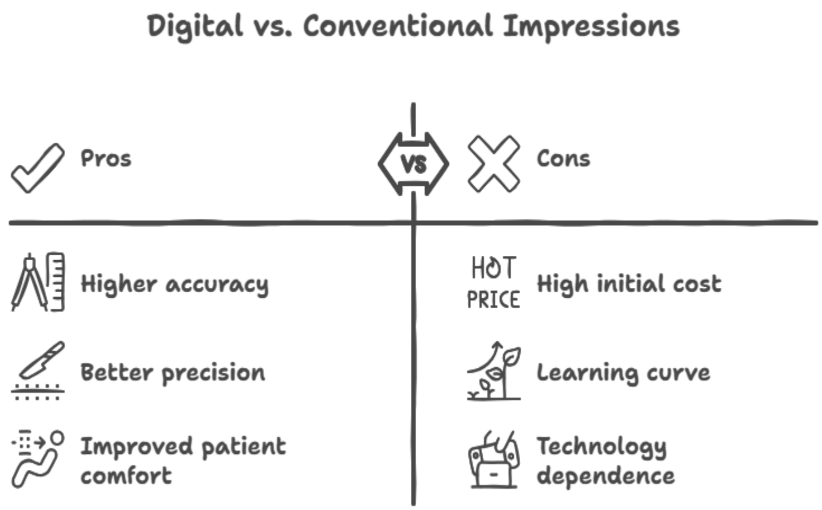

Figure 1: Trueness and Precision of Impression Techniques

Being shown in Figure 1 is the micron-level deviations for various IOS systems vis-a-vis the conventional materials. The TRIOS and iTero scanners were generally having trueness less than 50 µm and precision less than 45 µm, whereas the conventional ones, primarily by PVS, sometimes exhibited deviations in excess of 60–70 µm, especially in full arch cases (Lyu et al., 2022; Bi et al., 2022). However, full-arch scans with digital systems suffer more from cumulative errors due to image stitching artifacts, especially in edentulous arches wherein reference points are limited (Kosago et al., 2023).

According to in-vitro studies by Tohme et al. (2023) and Flügge et al. (2018), IOS showed statistically superior trueness over conventional impressions in partially edentulous arches. Whereas, PVS is still considered more reliable in cases of tilted or multiple implants (Chochlidakis et al., 2016).

4.2 Fit of Prosthesis and Occlusal Accuracy

An impression done improperly will invariably have some harmful consequences on the passive fit of the final prosthesis. Frameworks that do not fit produce mechanical complications such as screw loosening, abutment fracture, or even peri-implantitis in the eventuality of micro-movements occurring in an occlusal load (Gherlone et al., 2016).

From clinical studies, Amin et al. (2017) and Lee et al. (2022) came to conclude that digital impressions achieve a better distribution of occlusal contacts, reducing premature contacts, thereby decreasing occlusal adjustment time. Digital impressions avoid errors produced by distortion of the impression tray, shrinkage of the impression material, or during improper analog positioning in the cast fabrication (Albanchez-Gonzalez et al., 2022).

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Passive misfit problems are said to be challenging in the digital flows when handling multiple angulated implants or long-span restorations. This may arise, from the drift of the scanner, reduced accuracy at the distal ends of the arches, or the absence of soft tissue compression that conventional materials usually simulate (Vieira et al., 2023).

4.3 Patient-Centered Outcomes

From the perspective of the patients themselves, going digital is even more positive. Think bulky trays that must be held still for minutes while the material sets. Or in other words, more comfort. In such studies as Yuzbasioglu et al. (2014) and Manicone et al. (2022), the patients ranked digital impressions higher, in terms of comfort, preference, and satisfaction.

Some common complaints with conventional impressions include:

- Constriction from the posterior extension of trays
- Dislike of materials like polyether
- Anxiety caused by mess and time consumption

Table 2: Patient Experience Metrics – Digital vs. Conventional Techniques

Parameter	Digital (IOS)	Conventional (PVS/Polyether)
Gag Reflex Trigger	Low (10–20%)	High (55–70%)
Overall Comfort (1–10 Scale)	8.7 avg	5.2 avg
Appointment Duration	10–15 minutes	20–30 minutes
Need for Remake	<5%	15–20%
Patient Satisfaction	Very High	Moderate

Source : Adapted from Yuzbasioglu et al. (2014) ; Manicone et al. (2022) ; Gallardo et al. (2018)

4.4 Efficiency and Workflow

This is one of the strongest arguments for digital adoption : it affects clinical efficiency. The digital workflow might reduce chair time by up to 40%, depending on case complexity (Joda & Brägger, 2015). The scanning process eliminates the time for impression setup, material setting, and disinfection.

On the other hand, lab turnaround time increases. Digital files can be emailed instantly or uploaded onto lab portals, while analog impressions have to be physically delivered and manually poured into casts (Moreira et al., 2015). Also, by having 3D printing or milling in the office, the crown delivery could even be set for another same-day, through some workflows.

Training time is one concern; the early days of adoption might show a learning curve, but digital natives (younger clinicians) take to it very fast. The reproducibility of scans, especially in revision or remake situations, saves a lot of time and takes standardization across cases to another level (GRĂDINARU et al., 2021).

4.5 Cost and Implementation Challenges

While digital systems very often imply savings on materials and time in the long run, the initial investment would pose a substantial barrier to those already in pursuit of modernization. Code systems such as TRIOS or iTero are priced around $20,000 to $40,000 USD, excluding the merchandising of additional software subscriptions and compatible milling units (Joda & Brägger, 2015 ; Ahmed et al., 2024). Hazards of having to extend the coverage to maintenance, updates, and staff training only raise the cost of ownership.

Clinics in low-resourced areas may be economically constrained to operating with analog systems in the short term. Some companies, aware of the spin of demand toward digital workflows, emerged with lesser-priced scanners and subscription plans, therefore smoothing the way for adoption.

Interoperability issues exist as well, for not every lab accepts every scanner file format. Also, incompatibility issues between different CAD/CAM software may stand in the pathway for smooth workflow integration (Ma et al., 2021).

5. CLINICAL IMPLICATIONS AND PRACTICE RECOMMENDATIONS

A decision concerning either a conventional or digital method of impression for an implant prosthodontic procedure is not a mere black-or-white choice; rather, it is a clinical judgment involving case-dependent variables, patient considerations, available resources, and the experience of the practitioner. The present chapter enlists recommendations for a clinician toward achieving the best outcome while transitioning with the changes that have come with the digital dental paradigm.

5.1 To Choose Digital Instead of Conventional: Case-Based Matrix

The digital impression should be taken for the following types of cases :

Single implants : Digital impression systems provide high accuracy, short time duration, and patient comfort (Alsharbaty et al., 2019 ; Papaspyridakos et al., 2020).

Short-span prostheses (maximum 3-unit span) : IOS systems exhibit high degrees of trueness and reproducibility with these prostheses (Basaki et al., 2017).

Patients with strong gag reflexes or special needs : Digital techniques are considered kinder and less stressful when it comes to hurting the appointment (Manicone et al., 2022).

For those implants with in-house CAD/CAM or digital labs : The digital pathway offers a smooth integration process from scan to final prosthesis.

Conversely, conventional impressions are still considered preferable in :

Full-arch implant restorations, especially in edentulous arches with few reference points, where the accuracy of digital scanners may suffer from stitching errors (Kosago et al., 2023).

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More highly angulated or multiple implants, where conventional splinted open-tray techniques provide better passive fit (Amin et al., 2017).

Clinics without a digital infrastructure or those working in a low-resource setting where budgets do not allow for the purchase of à scanner.

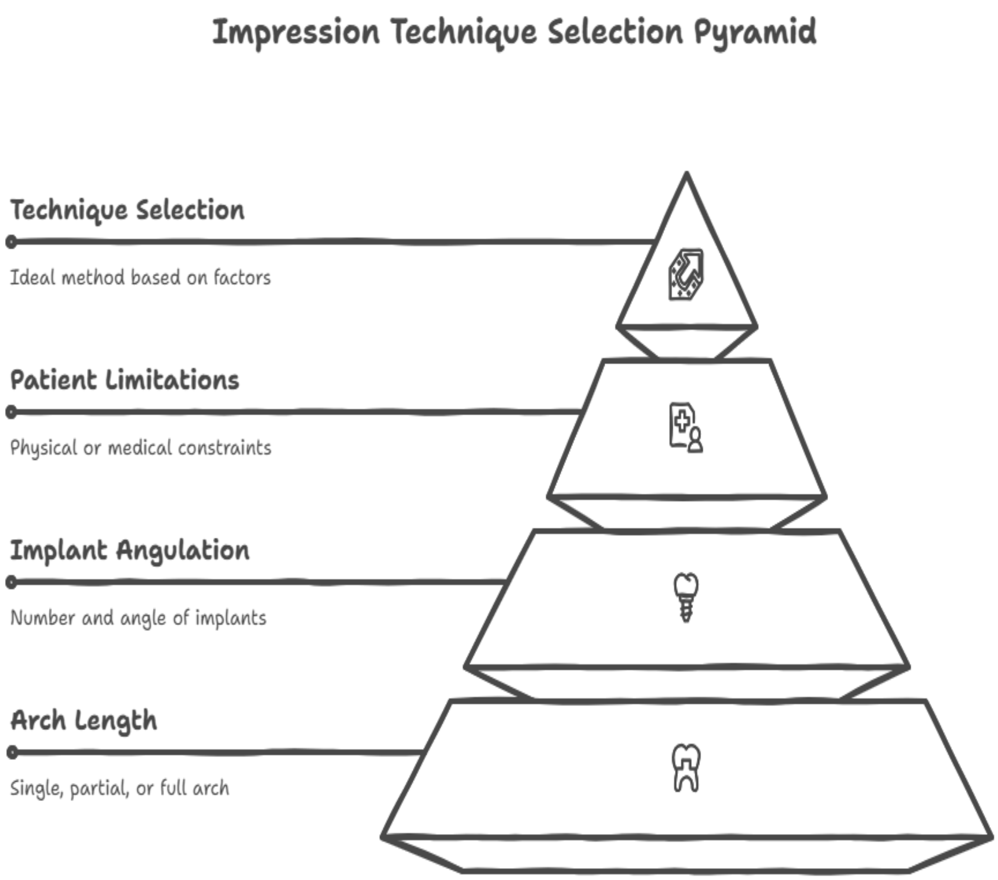

Figure 2 : Decision-Making Flowchart for Impression Technique Selection

A clinical decision-making flowchart to guide clinicians in selecting between digital and conventional impression techniques based on case type, patient comfort, and technological readiness.

6. LIMITATIONS OF THE CURRENT EVIDENCE

Although the literature comparing digital and conventional impression techniques in implant prosthodontics is fast-growing, several methodological and practical limitations are present. These constraints affect the generalizability of the findings and should be taken into consideration while trying to interpret the comparative results.

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6.1 In-Vitro Versus Clinical Discrepancies

A good share of evidence comes from in-vitro studies, which, despite offering a controlled environment, lack reality in the clinical setting. The universal variables like saliva, patient movement, soft tissue mobility, and intraoral humidity are almost always not included in laboratory models, and all influence the performance of intraoral scanners (Tohme et al., 2023; Ribeiro et al., 2018). Thus, the results on the trueness and precision of scanners in the lab settings often end up showing better performance than those found out clinically (Kosago et al., 2023).

6.2 Scanner Calibration and System Variability

Not all intraoral scanners are created equal. The differences in scanning technologies- confocal microscopy, triangulation, or active wavefront sampling- ends up causing inter-scanner variability even when used in identical conditions (Bi et al., 2022; Albanchez-Gonzalez et al., 2022). Indeed, some studies ignore whether the scanners were calibrated or whether the option was adhered to, and this factor might significantly affect the accuracy of the scan-or particularly in full-arch or angulated implant scans.

Moreover, the evaluation methods lack standardization. Differences between trueness definitions or in how margin fit is defined from one study to another create situations that are not conducive to meta-analysis or reliable cross-comparison between publications (Flügge et al., 2018).

6.3 Operator Experience and Technique Sensitivity

Operator dependency exists in both techniques, be they digital or conventional: errors can be introduced into conventional impressions during material handling and tray selection, or in the pouring technique. In terms of digital workflows, the path of the scanner, its scan speed, angulation, and real-time error recognition greatly depend on the experience of the clinician (according to Mühlemann et al., 2018). The unfortunate omission in many comparative studies is that they do not reveal the levels of training of the operators, their duration of experience, or even if the scans were repeated by either the same individual or different users (Lee et al., 2022). This omission limits reproducibility and gives sway to more favorable outcomes in digital studies in which experienced users are involved.

6.4 Sample Size and Study Design Constraints

Small sample sizes ($n < 30$) are prevalent among the included studies, especially in crossover clinical trials and in-vitro experimental studies, thereby decreasing statistical power and increasing the likelihood of making type II errors (Manicone et al., 2022). Next comes a high heterogeneity due to the design of the studies themselves, ranging from single-unit crowns to full-arch restorations, thereby diminishing the capacity to derive any generalized conclusions that would pertain to any kind of clinical scenario.

Biased literature basis may also develop from imbalanced distribution of the study types, with arsenic in-vitro compared to clinical trials. Also, long follow-up studies on sciential success, screw loosening, and patient's satisfaction through time are restricted.

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7. FUTURE DIRECTIONS

Despite digital impression systems undergoing a mammoth leap in their development and digital impression systems being clinically accepted on a wider scale, certain recent research gaps exist whose bridging can lead to the complete exploitation of their potentials in implant prosthodontics. Hence, the solution of these lacunae can lead to a significant improvement in the accuracy, accessibility, and adaptability of digital workflows within both higher- and lower-resource clinical settings.

7.1 Full-Arch Scan Fidelity

As many studies have emphasized, however, presently used intraoral scanners suffer from reduced accuracy when full-arch implant restorations are concerned, mainly because of cumulative stitching errors and scanning drift, more so in edentulous arches where a few reference points are available (Kosago et al., 2023; Tohme et al., 2023). Further research should be focused on enhancing scanner algorithms to cover larger spans without compromise in spatial accuracy. This may require, among others, multi-segment scan merging approaches, improved motion compensation, and reference point calibration.

7.2 AR/VR-Assisted Scanning Technologies

Currently, few intraoral scanning systems enable any kind of support through augmented reality or virtual reality; these could greatly improve feedback to the operator and detection of errors during the ongoing scan. Such visualization aids may improve scan path guidance, depth perception, and margin definition through AR overlays, especially in deep subgingival areas or posterior zones. Investigating the clinical utility and integration of AR-assisted scanning could thus open newer dimensions of intraoral data acquisition with precision modeling.

7.3 AI-Based Error Detection and Auto-Correction

While some scanners provide simple software warnings of incomplete scans, little use is made of AI-based real-time error-correction algorithms. Machine learning should therefore be used in future systems to detect common scan defects—voids, margin dropout, and distortion—and perform an automatic correction or targeted recommendation for rescanning before export of files. AI can also be used to risk-predict prosthesis misfit from scan geometry and recommend adjustments, thus adding a predictive layer to impression quality checking.

7.4 Low-Cost, Open-Source Scanner Development

Cost remains a critical barrier, especially in emerging markets. Research into affordable, open-source scanner systems with modular designs and low-cost hardware could democratize digital prosthodontics. Collaborations between academic institutions, dental schools, and tech startups can accelerate the development of entry-level systems that maintain clinically acceptable accuracy standards. Such innovation would expand global access to digital dentistry and reduce disparities in care quality.

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8. CONCLUSIONS

The comparative evaluation of impression techniques highlights a diverse landscape in which neither approach could be considered to universally one-upon-another. That is to say clinical decisions are made based on evidence regarding the limitations and advantages of each procedure.

The present study reviewed more than 50 peer-reviewed manuscripts, including randomized clinical trials, in vitro investigations, systematic reviews, and meta-analyses, to evaluate both impression techniques on the basis of accuracy, prosthesis fit, patient experience, work processes, and cost-effectiveness.

8.1 Findings summary

In terms of accuracy, IOS showed trueness and precision levels comparable or even better than conventional impressions for single- and short-span restorations. Digital workflows had a lesser error rate, chiefly with adequate scan accessibility and a stable anatomical landmark. On the contrary, traditional open-tray impressions with polyvinyl siloxane or polyether materials still gave the best results for full-arch or multiple angulated implant cases due to the best passive fit and the least cumulative distortion over longer spans (Tohme et al., 2023; Kosago et al., 2023).

For patients, digital impressions were far more comfortable as they helped diminish gagging, shortened appointment time, and enhanced overall procedural satisfaction. Surveys and cross-over clinical trials show an absolute preference for IOS over conventional tray-based methods (Yuzbasioglu et al., 2014 and Manicone et al., 2022).

Workflow analysis divined a favor for digital systems in time efficiency and clinical reproducibility: Chairside time was always shorter with a digital system, and the digital data could be archived, retrieved, and transmitted in seconds, making the lab-to-chair journey highly efficient. Nevertheless, factors such as scanner learning curve, technological compatibility, and high initial investment continue to restrain full-scale adoption in numerous practices, especially the low-resource ones (Ahmed et al., 2024; Joda & Brägger, 2015).

8.2 The Final Verdict: Is Digital Better?

The weight of evidence points toward digital impressions being better with respect to patient comfort, chairside efficiency, and short-span accuracy, especially in straightforward scenarios with one to three implants. They are thus fit for clinics already installed with CAD/CAM infrastructure and for clinicians skilled in IOS protocols.

However, there are certain clinical situations—for instance, full-arch reconstruction, highly angulated implants, or soft-tissue sensitive zones—in which conventional impressions remain the gold standard in ensuring the best passive fit and highest predictability. These tend to be instances in which anatomical considerations challenge the function of the digital system-oriented approach that, for present-day technology, can find very little equivalency in accuracy.

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Hence, an outright disadvantage of one over the other does not exist; rather, each one offers superior performance in context. The future, therefore, does not lie with one being entirely substituted by the other but by working off a hybrid approach that is case-driven and needs-based, in line with clinical needs, patient needs, and resource considerations.

8.3 Key Clinician Takeaways

Digital impressions are used for single units or short-span prostheses, as well as in patients who have a gag reflex or anxiety. Satisfaction is greatly enhanced, and chair time reduced.

Reserve conventional techniques for complex full-arch or angulated implant cases where analog splinting and passive fit are still clinically advantageous.

Invest in intraoral scanners only when your lab partners, staff, and workflows can support full digital integration. Otherwise, such advantages may be lost.

Continuous training should be provided for both the main clinician and the assistants to improve scan time, decrease errors, and solve problems on the spot.

8.4 Implications for Researchers and Educators

More longitudinal clinical studies need to be carried out, comparing the long-term success and complication rates between prostheses obtained from each technique.

Specific definitions of accuracy (trueness, precision, margin fit) have to be first agreed upon to be able to harmonize global data and derive better meta-analyses.

There is a need for urgent research pertaining to AI-driven scanning software, augmented and virtual reality-enhanced interfaces, and affordable scanner development to bridge the gap in accessibility.

Dental education must have full integration of digital impression training in the preclinical and clinical curricula, more so in countries where the acceptance is just beginning.

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