Implant Impression Techniques: Conventional Versus Digital

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ABSTRACT
Implant impression accuracy is critical for passive fit and long-term success of implant-supported prostheses. This review compares conventional and digital techniques in terms of accuracy, clinical use, workflow efficiency, and patient comfort. Conventional open- and closed-tray methods remain reliable, especially for multiple-unit and full-arch cases, with splinted open-tray impressions offering higher accuracy. Digital impressions with intraoral scanners are accurate for single implants and short spans and improve efficiency and patient experience, but may be less reliable in full-arch cases due to stitching errors. Emerging technologies such as photogrammetry and AI-assisted scanning may address these limitations. No single method is universally superior; technique selection should depend on clinical and prosthetic factors, as well as required accuracy.
Keywords: CAD/CAM, Conventional impression, Digital impression, Implant impression, Implant supported prosthesis, Intraoral scanner, Photogrammetry, Precision, Scan body
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INTRODUCTION

This technology for the replacement of missing dentition has seen incredible development in the last 40 years, becoming the treatment of choice(1). Transfer of the position, angulation, and surrounding soft-tissue architecture of the implant from the oral environment to the laboratory is a key component to predictable prosthetic outcomes(2).The impression procedure, conventional or digital, and its precision is a key factor in the success of the definitive prosthesis and consequently the long-term success of implant-supported restorations(3). For decades, the gold standard in implant impression techniques has been conventional impression materials (such as elastomeric and polyether) used in combination with impression copings (1,3). Although very well documented and clinically proven, they have inherent limitations such as dimensional stability of the impression material, errors associated with the impression processing in the lab, and excessive chairside time, all of which compromise patient comfort and the efficiency of the workflow(4). With the introduction of intraoral scanners (IOS) and related CAD/CAM workflows, the process of taking physical impressions and stone models has been replaced by the immediate capture of the position of the implants in three dimensions with the aid of the scan bodies (5). Both modalities are critically reviewed with regards to accuracy profile, clinical applicability, patient-centered outcomes and the comparative performance in prosthetic situations.(6)

Conventional Implant Impression Techniques

Technique Design and Material Selection

There are two traditional types of implant impressions: open tray (pick-up) and closed tray (transfer)(7). For angulated or multiple implant configurations, the open-tray approach (coping is left in the impression, and only later connected to a laboratory analogue) is generally favored because it allows for a rigid positional transfer (8). Polyether materials, such as Impregum and 3M ESPE, show great hydrophilicity and dimensional stability, whereas polyvinyl siloxane (PVS) materials have excellent elastic recovery and long working times for longer spans(9). Acrylic resin splinting of the impression copings has been shown to decrease inter-coping rotations and greatly enhance the accuracy of a full-arch impression by reducing the shrinkage distortion (10).

Accuracy and Limitations

Although clinically proven, the traditional technique suffers from cumulative dimensional changes, with impression material shrinkage upon polymerisation, stone expansion during setting, and imprecision of seating the analogue(11).Although proven, the traditional technique has

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cumulative dimensional changes due to polymerisation shrinkage of the impression material, stone expansion during setting, and seating of the analogue(12). Linear deviations of 50-300µm have been reported in implant position stone model reproductions, and deviations have been found to increase in proportion to the distance between implants (10).A systematic review by Papaspyridakos et al. (2014) showed that open tray techniques with splinted copings were found to be statistically more true than non-splinted and closed tray. In the latter, it is recommended to use full-arch implant-supported fixed prostheses (ISFP)(13).

Digital Implant Impression Techniques

Scanner Technology and Scan Body Principles

This course provides an introduction to scanner technology and the principles of the scan body. Digital implant impressions involve IOS systems and implant-specific scan bodies, which are geometric landmark features attached to the implant or abutment that are recognised by software library programs in the scanner(14). Sophisticated IOS systems use a variety of optical principles: Confocal laser microscopy (iTero Element, Align Technology), optical coherence tomography (3Shape TRIOS), active wavefront sampling (CEREC Omnicam, Dentsply Sirona) and structured-light stereophotogrammetry (Medit i700). The different technologies have their own advantages and disadvantages in terms of acquisition time, colour capture

Figure 1. Workflow comparison- Conventional (left) versus digital (right) implant impression technique. The conventional path uses impression copings and elastomeric materials leading to a stone cast, while the digital path employs scan bodies and IOS technology to generate a 3D file for CAD/CAM fabrication

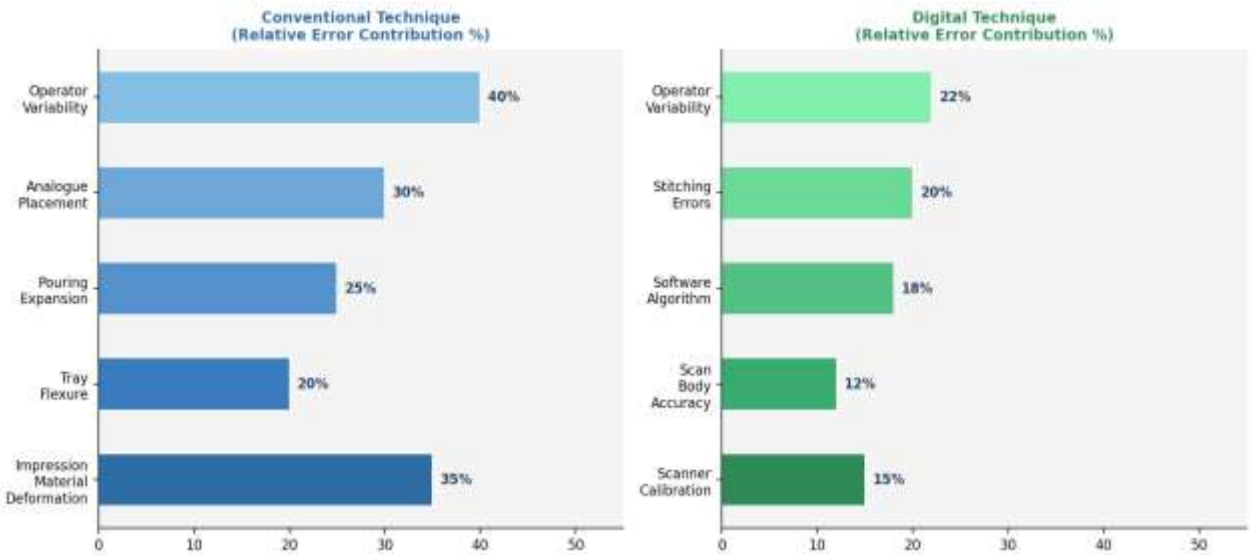

Figure 2. Relative error source contribution in conventional (left) versus digital (right) implant impression techniques. Conventional impressions accumulate error across material deformation, laboratory pouring, and operator variability; digital methods are primarily limited by scanner calibration and frame stitching artefacts

ability and sensitivity to specular reflectance from metallic surfaces on the scan body[14]

Accuracy — Trueness, Precision, and Span Dependency

In vitro studies show that modern IOS systems are able to provide clinically acceptable trueness in single implant cases, with mean deviations usually being below 20 µm, which is comparable to or better than conventional methods [15]. With greater complexity of the arches, however, there are more cumulative errors that range from 100 to 500 µm in full-arch edentulous scans, which are explained to be due to stitching artefacts from consecutive frames in long scan paths[16]. Menini et al. (2022) conducted a systematic review and meta-analysis of 47 studies that showed no significant difference in trueness for single-implant prostheses and short-span prostheses, and conventional impressions with splinted copings had superior trueness for full-arch prostheses. The conventional impressioning techniques were generally inferior to the digital impressioning techniques on the precision (repeatability) criterion, indicating good repeatability even if the absolute error is comparable[17].

Figure 3. Comparative performance radar- Conventional (blue) vs. digital (green) impression techniques across seven clinical dimensions. Digital impressions excel in trueness, precision, time efficiency, and patient comfort; conventional impressions retain advantages in cost-effectiveness and multi-unit full-arch reliability

CAD/CAM Integration and Workflow Benefits

The digital pathway seamlessly connects to CAD/CAM systems: the exported STL or proprietary file is imported into CAD/CAM design software (3Shape Dental System, exocad DentalCAD, CEREC SW), the virtual prosthetic design is milled from zirconia, titanium or lithium disilicate, or manufactured by direct metal laser sintering (DMLS) for a framework[18]. This closed-loop system eliminates several analogue transfer steps, thus minimizing the accumulation of fabrication error and significantly decreasing turnaround time. In a randomised controlled trial in favour of digital arm,a decrease of total treatment time of 38% and a significantly lower number of clinical appointments[19].

Comparative Analysis and Patient-Centred Outcomes

Case-Specific Performance

The use of digital impressions has successfully matched or surpassed the accuracy of traditional impression-making techniques in single implants and when used in short-span fixed prostheses (up to three units)[20]. A systematic review that found no significant difference in the marginal fit between CAD/CAM restorations made from a digital impression and those made using traditional methods, with marginal gaps remaining consistently below the 120 µm clinical threshold[13]. In the case of full arch implant-supported fixed prostheses, evidence remains in favour of traditional open tray methods and splinted copings[21]. The progressive stitching error accumulation observed during the extended arch scans, especially in edentulous patients has not yet been addressed in the current IOS generation[22].

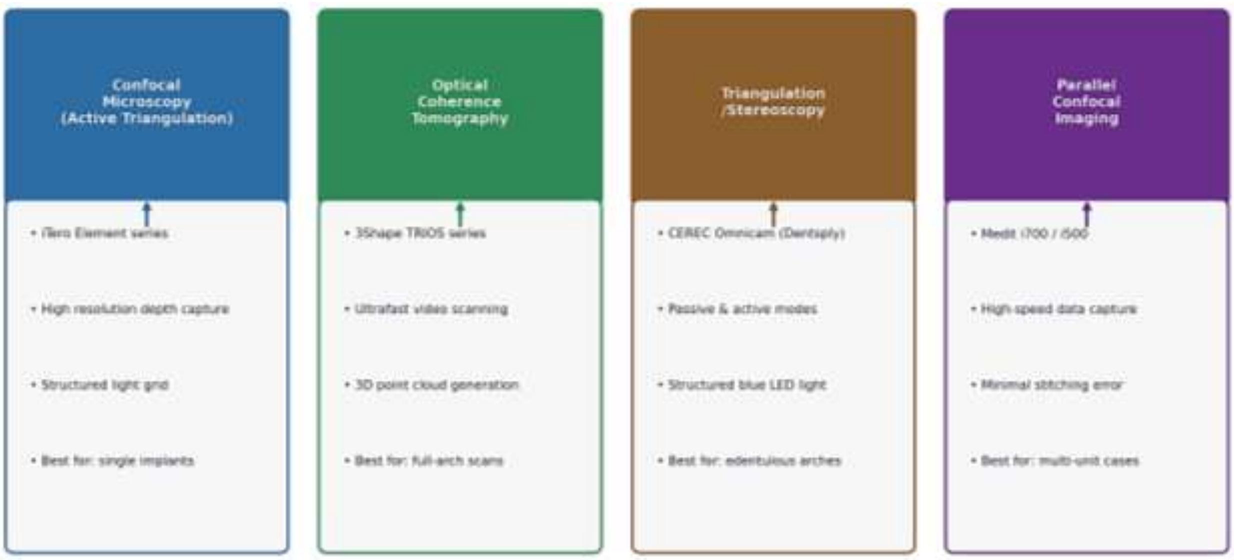

Figure 4. Principal intraoral scanner technologies used in digital implant impressions- Confocal microscopy (iTero), optical coherence tomography (TRIOS), optical triangulation/stereoscopy (CEREC Omnicam), and parallel confocal imaging (Medit) — with operating principles and optimal clinical indications

Photogrammetric systems like the PIC system (PIC Dental) have proven to be a solution that can capture implant positions without the need for mucosal reference points and, in prospective studies, have shown higher full-arch accuracy than IOS(20) .

Patient Comfort and Operator Learning Curve

Digital impressions are always linked to greater patient comfort with no viscous impression material, no unpleasant taste or smell, and no activation of the gag reflex — and are linked to significantly shorter chairside time[23]. Significantly greater patient satisfaction scores were obtained for the digital impression than for the conventional impression across all domains of comfort, procedure time and overall impression, especially for patients with a strong gag reflex, according to the study [24]. But there is an operator learning curve. Even when using the same scanner, novice operators make scans with significantly more stitching errors than experienced operators, and clinical conditions like limited mouth opening, blood or saliva contamination, and close proximity of the scan body to adjacent teeth further affect the quality of the scan [25]

EMERGING DEVELOPMENTS, FUTURE DIRECTIONS, AND CONCLUSION

Literature indicates that digital and conventional paradigms are converging by a combination of methods, with extraoral desktop scanning of conventional stone models enabling the clinicians to take advantage of the conventional accuracy for full-arch cases, while benefiting from the digital design and fabrication. AI-assisted scan optimisation is an emerging frontier: preliminary studies show up to 40% reduction in cumulative full-arch scan deviation with the use of machine learning algorithms for scan path guidance and automatic scan body detection. Mid-market scanners from manufacturers such as Medit, Shining3D and 3Disc are making scanning more accessible, resulting in competitive scanning accuracy at significantly reduced acquisition costs and enhancing the cost benefits for high-volume practices (HVPs) of implementing digital scanning. The comparative literature shows a rather complex picture in which no single modality is invariably superior. The conventional open-tray, splinted coping configuration is still the evidence-based standard for FAPs. Clinically comparable to, or better than, conventional impressions for single-implant and short-span fixed restorations, and highly favored by patients. There are credible solutions that could fill in the gaps on full-arch accuracy that are emerging in the field of photogrammetry and AI-guided scanning. The clinically sound option is still evidence-based case selection which is a combination of the impression modality choice, prosthetic span, patient factors, operator skill and the technology available, not using either of the two techniques indiscriminately.

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