Clinical Oral Implants Research

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CLINICAL ORAL IMPLANTS RESEARCH

REVIEW ARTICLE OPEN ACCESS

Accuracy of Digital Impression Methods for Capturing the Peri-Implant Emergence Profile: A Systematic Review

Krisztina Mikulás[1,2] | Xinyi Qian[1,2] | Péter Tajti[1,2] | Gergely Agócs[2,3] | German O. Gallucci[4] | Ignacio Pedrinaci[4,5] | Péter Hermann[1]

[1]Department of Prosthodontics, Semmelweis University, Budapest, Hungary | [2]Centre for Translational Medicine, Semmelweis University, Budapest, Hungary | [3]Institute of Biophysics and Radiation Biology, Semmelweis University, Budapest, Hungary | [4]Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, Massachusetts, USA | [5]Section of Graduate Periodontology, Faculty of Odontology, Universidad Complutense de Madrid, Spain

Correspondence: Krisztina Mikulás (mikulas.krisztina1@semmelweis.hu)

Received: 10 May 2024 | **Revised:** 14 February 2025 | **Accepted:** 17 March 2025

Funding: This work was supported by the Faculty Priority Research Grant, Faculty of Dentistry, Semmelweis University (for KM, grant number: KKFOGKPO04) 2023, and Faculty Research Program Grant, Faculty of Dentistry, Semmelweis University (for XQ, grant number: KKFOGKPO01) 2023. Sponsors had no role in the design, data collection, analysis, interpretation, and manuscript preparation.

Keywords: computer-aided design | crowns | dental esthetics | dental impression technique | fixed partial denture | single-tooth dental implant

ABSTRACT

Background: Accurately replicating the emergence profile (EP) of conditioned soft tissue is pivotal for the success of implant-supported restorations. In the field of digital technology, various methods have emerged to capture EP. This review aims to critically assess current digital methodologies for capturing peri-implant EP.

Material and Methods: Prospective interventional or observational clinical studies focusing on digitally mapping the emergence profile (EP) around single implant-supported restorations were included. Systematic reviews, in vitro and animal studies, and those not emphasizing EP capture were excluded. A systematic search across four databases (MEDLINE, CENTRAL, Embase, Web of Science) was conducted on 7th August 2024 based on a previously registered protocol (PROSPERO registration number: CRD42023459484). Risk of bias was assessed with RoB 2, ROBINS-I, and JBI critical appraisal tools. Qualitative and quantitative analyses were carried out.

Results: Twenty-four eligible studies were identified, comprising 5 dental techniques, 12 case reports, 1 randomized controlled study, 2 cross-sectional studies, and 4 cross-over studies. The studies reported semi-digital pathways, direct scanning, indirect scanning, coded-healing abutments, and individualized use of scan bodies. Notably, the direct scanning technique showed considerable soft tissue collapse. Similar results can be achieved with indirect scanning and the conventional method.

Conclusions: Indirect EP scanning appears as the most promising method for capturing peri-implant EP. However, a confirmation of this finding requires a quantitative analysis through randomized clinical trials.

1 | Introduction

In recent decades, implant-supported restorations have evolved into a well-established therapeutic option for restoring a single tooth in the esthetic zone. However, these cases may be esthetically challenging, and success is determined by the presence of a well-contoured prosthesis blending seamlessly with adjacent natural teeth while ensuring the long-term health of both hard

The first two authors contributed equally to this study.

https://doi.org/10.1111/clr.14441

and soft tissues (Doliveux et al. 2020; Lewis and Klineberg 2011; Montero 2021; Ntounis and Petropoulou 2010; Polack 2002; Wittneben et al. 2013).

Achieving a natural peri-implant emergence profile (EP) during the provisional phase is of paramount importance in the esthetic zone (De Rouck et al. 2009; Morton et al. 2014; Wittneben et al. 2013). Diverse analog and digital techniques have been proposed to establish the most esthetic EP, all while promoting optimal peri-implant soft tissue development and architecture (Dhingra et al. 2020; Wittneben et al. 2016). The use of implant-supported provisional restorations (ISPR) and customized healing abutments can assist in obtaining the desired EP, thereby attaining satisfactory results for the definitive restoration (Breeding and Dixon 1996; Doliveux et al. 2020; Esguerra 2016; Finelle and Lee 2017; Lin et al. 2013; Liu et al. 2017; Liu et al. 2018; Oh et al. 2019; Proussaefs and AlHelal 2018; Yilmaz and Abou-Ayash 2020; Yiqing et al. 2018).

Accurately transferring implant positions plays a pivotal role in attaining long-term success in implant therapy while mitigating the risk of mechanical and biological complications (Kunavisarut et al. 2002; Sahin et al. 2002; Wang et al. 2002). However, the precise translation of soft tissue information onto the working cast to enable faithful reproduction of this preestablished EP is challenging (Azer 2010; Dhingra et al. 2020; Esguerra 2016; Liu et al. 2017; Monaco et al. 2019; Yilmaz and Abou-Ayash 2020; Yiqing et al. 2018). For capturing soft tissue information, both analog and digital methods are available. **Conventional methods (CM)** include the use of elastomeric impression materials with individualized open-tray impression copings, which, despite having been used for a long time, are associated with disadvantages such as patient discomfort and extended chairside time (Burhardt et al. 2016; Glisic et al. 2019) (Figure 1A–C). Digital methods, which replace CMs with intraoral scans (IOs) are gaining importance for single-unit restorations, with the potential for reducing the aforementioned disadvantages (Lee and Gallucci 2013; Wismeijer et al. 2018).

The **direct digital EP** scanning procedure for a definitive single-unit restoration involves three distinct scans: (1) The initial scan encompassing the ISPR along with the surrounding soft tissue; (2) the direct EP scanning of the peri-implant soft tissue taken immediately after ISPR removal; and (3) a

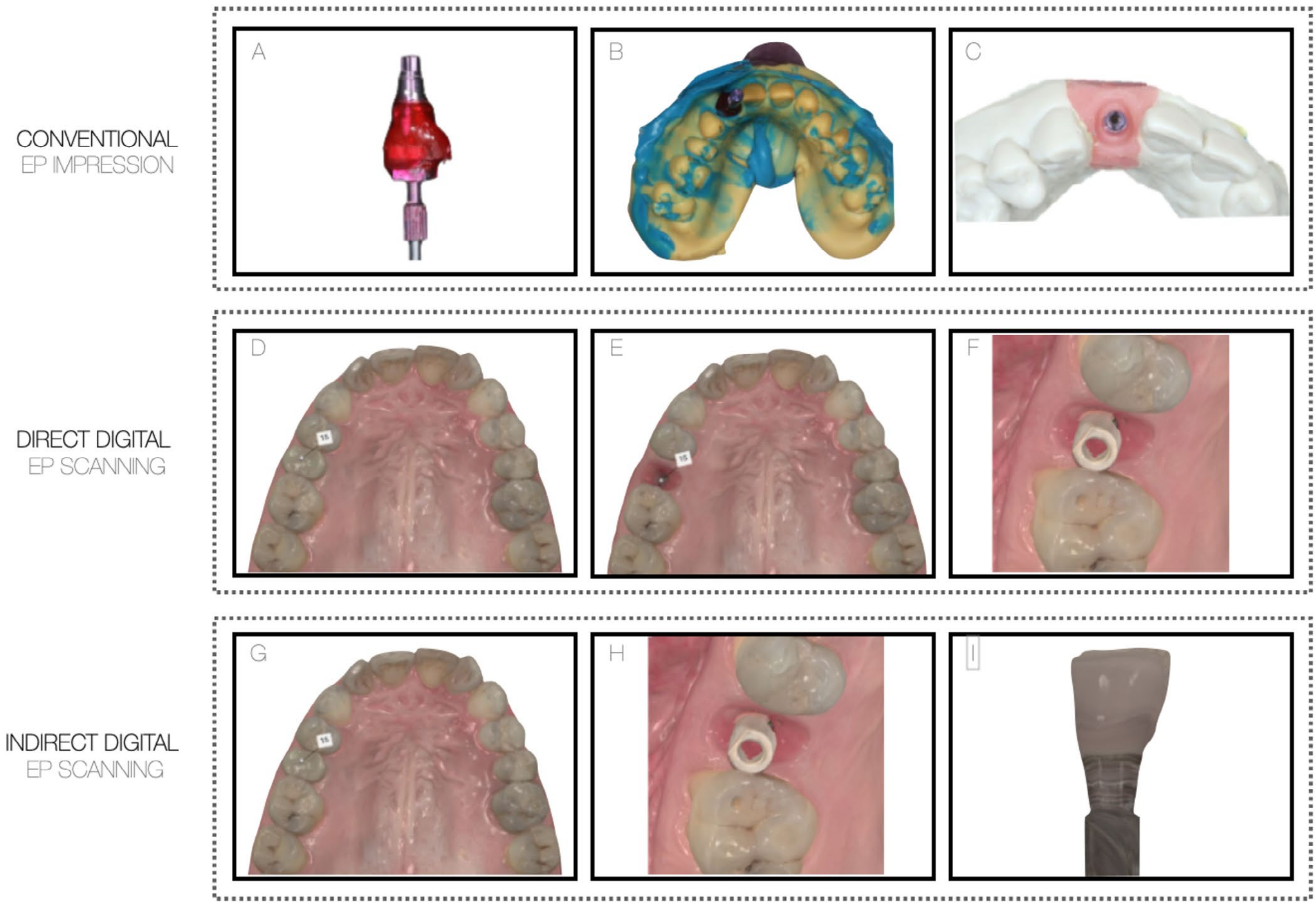

FIGURE 1 | Steps of conventional (A, B, and C), direct digital (D, E, and F), and indirect digital (G, H, I) workflows of peri-implant emergence profile (EP) replication. (A) Customized open-tray impression coping replicating the EP of the provisional restoration (ISPR); (B) Open-tray elastomeric impression with the technical analog attached to the impression coping; (C) Epoxy-resin cast with resilient gingival mask; (D, G) Intraoral full-arch scan with the ISPR in situ, to support the computer-aided design (CAD) phase; (E) Direct EP scan immediately after ISPR removal; the EP of the final restoration will follow the peri-implant soft tissue profile captured at this stage; (F, H) Registering implant position with a scan body; (I) Extraoral indirect EP scan of the ISPR, which will be overlapped with the scan with the ISPR in situ, to obtain the subgingival EP at the CAD phase.

scanbody screwed to the implant, enabling the precise 3D localization of the latter (Monaco et al. 2019) (Figure 1D–F). However, contradictory data exist regarding the digital scanning accuracy of the soft-tissue profile subsequent to the removal of the ISPR. Conflicting findings have emerged from other studies, indicating that ISPR removal can induce a considerable, time-dependent alteration in the submucosal contour due to the rapid peri-implant soft tissue collapse (Duran et al. 2018; Joda 2015; Li et al. 2019). Recently, **an indirect scanning protocol**, which involves an additional extraoral scanning of the ISPR, has been proposed, with the aim of eliminating the inaccuracies of direct scanning (Monaco et al. 2016; Xiong et al. 2022) (Figure 1G–I).

Due to the variability in the potential impact of ISPR removal on the accuracy of peri-implant mucosa replication, the primary objective of this review was to assess the precision of direct and indirect digital impression methods in capturing peri-implant EP compared to the conventional impression around single implant-supported crowns, based on the available evidence.

2 | Material and Methods

This study was conducted based on the Cochrane Handbook (Higgins et al. 2022), and reported following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines (Page et al. 2021). The study was registered in the International Prospective Register of Systematic Reviews (PROSPERO on 10th October 2023 registration number: CRD42023459484, https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=459484).

2.1 | Eligibility Criteria

The aim of this study was to answer the following PICO question: How accurate (outcome—O) are direct and indirect digital impression methods (interventions—I1, I2) for capturing peri-implant emergence profiles in patients with single implant-supported crowns (population—P) compared to the conventional impression (comparator—C)?

Studies matching the following criteria were included: clinical trials, case reports, and case series of patients in need of implant-supported single restorations(s), describing a method used for digital EP replication. Studies not meeting these inclusion criteria were excluded: questionnaires, in vitro and animal studies, systematic reviews, and conference abstracts.

2.2 | Search, Selection and Data Collection

A comprehensive search was conducted on August 7, 2024 in MEDLINE, EMBASE, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL) to select eligible studies with the following keywords: (dental implant) AND digital AND (impression OR replication OR capturing OR scan*) AND ((emergence profile) OR (soft tissue) OR (peri-implant mucosa)).

Following automatic and manual duplicate removal, two reviewers (KM and XQ) independently selected the articles based on titles, abstracts, and full texts. Disagreements were resolved by discussion between the two reviewers. The following parameters were extracted from eligible articles: first author, year of publication, study type, number of participants, implant type and position, phenotype, impression technique, type of cast, type of intraoral scanner applied, definitive prosthetic restoration, esthetic outcomes, and study results, including main findings and numerical data for measurement results regarding EP discrepancies between different impression methods. Qualitative and quantitative analyses were carried out. The methodology and results of the quantitative analyses can be found in Appendix S1.

No ethical approval was required for this review, as all data had already been published in peer-reviewed journals. The datasets used in this study can be found in the full-text articles included in the review. No patients were involved in the planning, conduct, or interpretation of our study.

3 | Results

After selection, 24 articles were deemed eligible for the analysis, including 5 dental techniques, 12 case reports, 1 pilot randomized controlled study, 2 cross-sectional studies, and 4 cross-over studies, among which 2 were pilot studies (Agnini et al. 2023; Canullo et al. 2018; Crockett et al. 2019; da Silva Marques et al. 2019; Dada et al. 2021; Dhingra et al. 2020; Doliveux et al. 2020; Duran et al. 2018; Galibourg et al. 2021; Joda 2015; Joda et al. 2014; Lee 2016; Li et al. 2019; Lin et al. 2013; Ling et al. 2023; Liu et al. 2017; Mesquida et al. 2024; Mino et al. 2019; Monaco et al. 2016; Monaco et al. 2019; Tanaka et al. 2023; Xiong et al. 2022; Yilmaz and Abou-Ayash 2020; Zimmermann et al. 2022) (Table 1). The selection flowchart is shown in Figure 2. The reasons for excluding retrieved articles at the full-text selection phase are listed in Table S1 (available online).

3.1 | Conventional EP Replication

In four comparative studies, a CM was employed as a control group, contrasted against their respective reported digital methods (Canullo et al. 2018; da Silva Marques et al. 2019; Duran et al. 2018; Xiong et al. 2022). Canullo et al. compared conventional and digital workflows in a case report, using traditional analog impressions with a customized implant impression coping (CIIC) and indirect EP scanning of the provisional crown to create full ceramic single crowns. Both methods resulted in minimal bone loss and esthetic success after 3 years (Canullo et al. 2018). The remaining studies involved scanning stone casts to establish a comparison with the digital models. Da Silva Marques et al. employed a customized stock impression coping, incorporating the impression of the patient's well-designed provisional crown to accurately replicate the EP (da Silva Marques et al. 2019). Duran et al. and Xiong et al. directly used the provisional restoration to take the impression and poured the stone cast immediately (Duran et al. 2018; Xiong et al. 2022). All of these stone casts were scanned to compare them to the digital models *in silico*.

TABLE 1 | Characteristics of the included studies.

Author, year	Study type	Number of patients	Number of implants	Implant type and position	Phenotype	Impression technique		Type of intraoral scanner	Type of cast	Definitive restoration	Esthetic outcomes of definitive restoration	Main findings
						Conventional	Digital					
Agnini et al. 2023	Case report	1	1	21, NR	NR	—	Provisional in situ + scanbody + indirect	NR	NR	Screw-retained zirconia crown	—	New technique for EP replication
Canullo et al. 2018	Comparative case report	2	2	11, PRAMA	NR	Customized impression coping	Provisional in situ + scanbody + indirect	Carestream, CS3600	Stone (case1); digital (case2)	Zirconia abutment + cemented lithium disilicate crown	PES: analog 8, digital 9	3-year success for both analog and digital pathway
Crockett et al. 2019	Dental technique	1	1	22, nr	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS	NR	NR	—	New technique for EP replication
da Silva Marques et al. 2019	Cross-over pilot study	6	6	maxillary esthetic zone, NR	NR	Customized impression coping	Direct EP scan	3Shape, TRIOS	Stone vs. digital	NR	—	EP from immediate direct scanning showed significant differences
Dada et al. 2021	Case report	1	1	21, Straumann	NR	—	Provisional in situ + indirect with repositionable analogue	3Shape, TRIOS	3D-printed	Zirconia abutment + ceramic veneering	—	New technique with repositionable analogue for EP replication
Dhingra et al. 2020	dental technique	1	1	21, Straumann	NR	—	Provisional in situ + direct + scanbody + indirect	3Shape, TRIOS3	Digital	Full-contour lithium disilicate crown	—	New technique for EP replication
Doliveux et al. 2020	dental technique	1	1	12, Straumann	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS	3D-printed	NR	—	New technique for EP gingival mask fabrication on 3D-printed cast

(Continues)

TABLE 1 | (Continued)

Author, year	Study type	Number of patients	Number of implants	Implant type and position	Phenotype	Impression technique: Conventional	Impression technique: Digital	Type of intraoral scanner	Type of cast	Definitive restoration	Esthetic outcomes of definitive restoration	Main findings
Duran et al. 2018	Cross-over study	10	10	Maxillary esthetic zone, Biohorizons	NR	Provisional served as impression coping	Direct EP scan	Cerec Omnicam	Stone vs. digital	NR	—	EP from immediate direct scanning showed significant differences
Galibourg et al. 2021	Cross-sectional study	16	16	Maxillary esthetic zone, NR	NR	—	Direct EP scan at 0 s, 30 s, 2 m, 5 m	Planmeca	—	—	—	Significant EP collapse after 30 s compared to immediate direct EP scan
Joda et al. 2014	case report	1	1	22, Straumann	NR	—	Customized scanbody with conventional customization technique	iTero	NR	Zirconia abutment + ceramic veneering	PES: 9	New technique for mucosal margin replication, but submucosal part of EP can't be captured
Joda 2015	Cross-sectional study	5	5	Maxillary esthetic zone, Straumann	NR	—	Direct EP scan at 0 s, 5 m, 10 m	iTero	—	—	—	Slight EP change after 5 min, more significant after 10 min compared to immediate direct EP scan
Lee 2016	Case report	1	1	36, NR	NR	—	Provisional in situ then continued indirect scanning extraoral + scanbody	3Shape, TRIOSColor Pod	Digital	Customized titanium abutment + zirconia crown	—	New technique for EP replication

(Continues)

TABLE 1 | (Continued)

Author, year	Study type	Number of patients	Number of implants	Implant type and position	Phenotype	Impression technique: Conventional	Impression technique: Digital	Type of intraoral scanner	Type of cast	Definitive restoration	Esthetic outcomes of definitive restoration	Main findings
Li et al. 2019	cross-sectional study	10	12	Maxillary esthetic zone, NR	NR	—	[provisional in situ + indirect] vs. [direct EP scan at 0 s, 30 s, 1 m, 2 m, 3 m, 4 m, 6 m, 8 m, 10 m, 20 m]	3Shape, TRIOSColor Pod	—	—	—	Slight EP change at immediate direct EP scan that increased gradually compared to indirect EP scan
Lin et al. 2013	Dental technique	1	4	14,13,23,24, Straumann	NR	Diagnostic impression with provisional in situ	Scanbody	iTero	Milled polyurethane	—	—	New technique for EP gingival mask fabrication on milled cast
Ling et al. 2023	Randomized controlled trial	15	22	Maxillary, esthetic zone, Straumann, Nobel Biocare	NR	—	[Direct EP scan] vs. [indirect EP scan] + provisional in situ + scanbody	3Shape, TRIOS3	3D-printed	Customized titanium abutment + zirconia crown with direct vs. indirect pathway	PES: direct 7.89 ± 1.52, indirect 8.09 ± 2.27	Indirect scanning accurately replicates soft tissue profiles, while there is a collapse with the direct technique
Liu et al. 2017	Case report	1	3	11, 21, 22, NR	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS	3D-printed	—	—	New technique for EP replication
Mesquida et al. 2024	Case report	1	1	11, Nobel Biocare	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS3	Digital	NR	NR	New technique for EP replication
Mino et al. 2019	Case report	1	1	47, Straumann	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS2	Digital	Customized titanium abutment + zirconia crown	—	New technique for EP replication

(Continues)

TABLE 1 | (Continued)

Author, year	Study type	Number of patients	Number of implants	Implant type and position	Phenotype	Impression technique: Conventional	Impression technique: Digital	Type of intraoral scanner	Type of cast	Definitive restoration	Esthetic outcomes of definitive restoration	Main findings
Monaco et al. 2016	Case report	1	1	11, Straumann	NR	—	Provisional in situ + scanbody + indirect	3M ESPE	3D-printed	Zirconia abutment + ceramic veneering	—	New technique for EP replication
Monaco et al. 2019	Dental technique	—	NR	Esthetic zone	NR	—	[Direct EP scan] vs. [provisional in situ + scanbody + indirect]	NR	—	—	—	Direct scanning requirements: no soft tissue collapse within 1 min, short, wide, and conical EP shape; proposed protocol for direct and indirect multiscan techniques
Tanaka et al. 2023	Case report	1	1	13, Straumann	NR	—	Provisional in situ + scanbody + indirect	3Shape, TRIOS3	Digital	Titanium-base + monolithic zirconia crown	—	Fully digital technique with no need for a physical cast
Xiong et al. 2022	Cross-over study	16	16	Maxillary esthetic zone, NR	NR	Provisional served as impression coping	[Provisional in situ + indirect] vs. [immediate direct EP scan]	3Shape, TRIOS	Stone vs. digital	—	—	Accurate EP replication with indirect multiscan technique; rapid EP collapse with immediate direct EP scan

(Continues)

TABLE 1 | (Continued)

Author, year	Study type	Number of patients	Number of implants	Implant type and position	Phenotype	Impression technique		Type of intraoral scanner	Type of cast	Definitive restoration	Esthetic outcomes of definitive restoration	Main findings
						Conventional	Digital					
Yilmaz and Abou-Ayash 2020	Case report	1	1	46, Neoss	NR	—	Stock anatomic healing abutment with connectable scanbody	3Shape, TRIOS	Digital	Customized titanium abutment + zirconia crown	—	New combined healing abutment-scanbody implant system
Zimmermann et al. 2022	Case report	1	1	14, S.I.N.	NR	Partial arch impression with provisional in situ	Provisional in situ + direct + scanbody + indirect with provisional in the conventional impression	3Shape, TRIOS 3	Digital	Lithium disilicate crown	—	New technique for EP replication

Abbreviations: EP, emergence profile; NR, not reported; PES, pink esthetic score.

3.2 | Semi-Digital EP Replication

In the semi-digital method, a CM was also applied at some point in the workflow. In some cases, impressions were made digitally, but for esthetical reasons, the crowns were hand-veneered on 3D-printed or milled casts. Meanwhile, Zimmerman et al. took an impression containing the ISPR and scanned this assembly to replicate the submucosal EP contour of the crown (Zimmermann et al. 2022). Lin et al. took an impression with the ISPR in situ, then used this impression as an index for creating a removable, resilient gingival mask on the milled cast (Lin et al. 2013). Doliveux et al. applied a very similar technique but perfected it by 3D printing an ISPR replica for the same purpose, avoiding the need to hold on to the patient's ISPR (Doliveux et al. 2020).

3.3 | Direct EP Scanning

Ten studies reported on direct EP scanning, involving the immediate intraoral scanning of soft tissue following ISPR removal (da Silva Marques et al. 2019; Dhingra et al. 2020; Duran et al. 2018; Galibourg et al. 2021; Joda 2015; Li et al. 2019; Ling et al. 2023; Monaco et al. 2019; Xiong et al. 2022; Zimmermann et al. 2022).

3.3.1 | Soft Tissue Collapses in Direct Scanning

All clinical studies reported significant soft tissue collapses immediately after removing the ISPRs, although to different extents as the degree of collapse depends on various factors such as 3D implant position, the amount of vertical and horizontal soft tissue, phenotype, and implant diameter (da Silva Marques et al. 2019; Duran et al. 2018; Galibourg et al. 2021; Joda 2015; Li et al. 2019; Ling et al. 2023; Xiong et al. 2022).

Li et al. used the virtual model based on the indirect EP scanning, whereas da Silva et al. and Xiong et al. applied digital scans of the conventional casts as control groups. Approximately 244 μm was detected by Da Silva Marques et al. and 415 μm by Xiong et al., while Li et al. reported on a smaller, yet still significant collapse both immediately (approximately 200 μm) and up to 20 min (up to 1 mm) after ISPR removal when compared to the indirect EP scanning (da Silva Marques et al. 2019; Li et al. 2019; Xiong et al. 2022).

As reported by Li et al., a discrepancy in peri-implant soft tissue was observed in non-keratinized, less rigid and stable peri-implant mucosa (Ivanovski and Lee 2018; Li et al. 2019) This slight dimensional change increased gradually over time, and there was a statistically significant discrepancy (range of 0.08 mm to 0.18 mm) immediately after the removal of the ISPR, suggesting some inaccuracy in direct scanning (Li et al. 2019).

Galibourg et al. and Joda compared the soft tissue collapse at different time points (30 s, 2 min, 5 min), (0 s, 5 min, 10 min) to the immediate direct scanning, where further significant soft tissue collapse was also observed as time passed (Galibourg et al. 2021; Joda 2015). Duran et al. also reported dimensional changes in peri-implant soft tissues immediately after ISPR removal compared to the conventional cast made with a pick-up impression with the patient's ISPR. These changes occurred primarily at

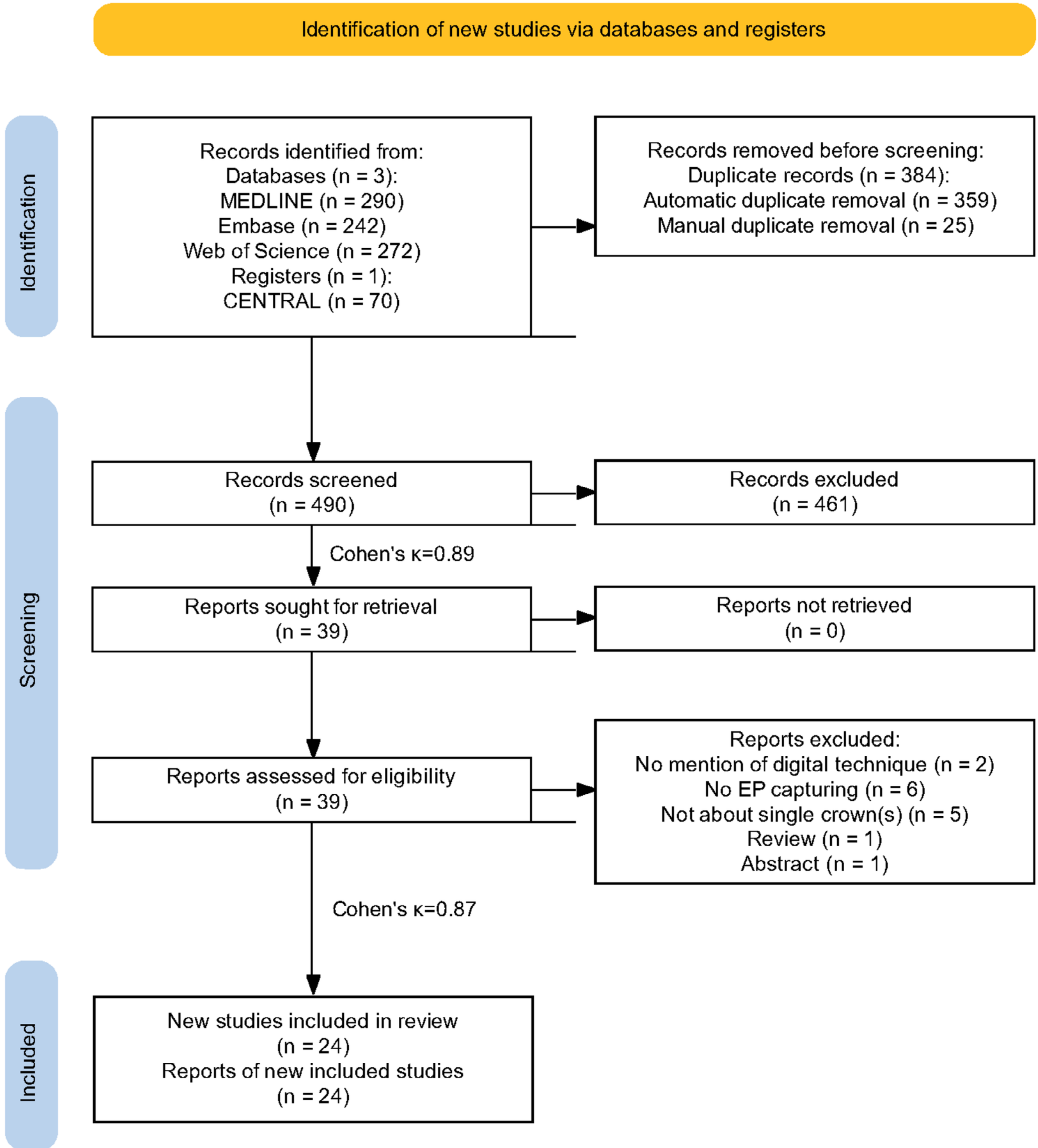

FIGURE 2 | Flowchart of the selection process.

the midlevel gingiva in the buccolingual (BL) dimension, and at both the coronal and midlevel gingiva thirds in the mesiodistal (MD) dimension. The changes ranged from 0.51 mm (coronal) to 1.35 mm (midlevel) (Duran et al. 2018).

Xiong et al. compared the accuracy of intraoral scanning for peri-implant soft-tissue profiling with and without the removal of the ISPR. They stated that the peri-implant mucosa collapsed by approximately 500 μm after 20 s of ISPR removal, regardless of the patient's phenotype, thus demonstrating that the ISPR plays a crucial role in preserving peri-implant soft-tissue architecture (Xiong et al. 2022). Li et al. observed that there was a statistically significant, but clinically minimal, displacement of the papilla and mucosal zenith levels, with up to 0.07 mm decrease immediately after ISPR removal, and up to 0.27 mm at 20 min (Li et al. 2019).

Galibourg et al. found that the volume of the EP decreased over time, with an average of 5% at 30 s, 10% at 2 min, and 14% at 5 min compared to the immediate direct scanning (Galibourg et al. 2021). Compared with the same reference, Joda 2015, only reported a 5.5% dimensional deviation at 5 min and a 21.7% deviation after 10 min of ISPR removal (Joda 2015). Following the conversion of the 5-min soft tissue collapse values measured by Galibourg et al. and Joda to percentage decrease of EP area, the results of both studies were coherent (Galibourg et al. 2021; Joda 2015). A standard for the clinically acceptable threshold should be decided according to the difference in accuracy of the indirect EP scanning and CM, as both are considered clinically accepted impression methods; however, the performance of this analysis was not possible due to the lack of data.

Ling et al. conducted a randomized controlled trial comparing the EP supported by definitive crowns fabricated with either direct or indirect EP scanning to the original EP supported by the provisional. They found a mean volumetric difference of $1.87\,mm^3$ vs. $0.75\,mm^3$ labially and $1.66\,mm^3$ vs. $0.65\,mm^3$ palatally with direct vs. indirect EP scanning, respectively. This would appear to indicate a more significant soft tissue collapse in direct scanning, albeit not statistically significant changes in both groups. The thickening of the mucosa was more prominent apically than coronally (Ling et al. 2023).

3.4 | Indirect EP Scanning

Seventeen studies reported on indirect EP scanning methods, which require multiple scans to be made and superimposed to obtain all necessary information for prosthetic fabrication (Agnini et al. 2023; Canullo et al. 2018; Crockett et al. 2019; Dada et al. 2021; Dhingra et al. 2020; Doliveux et al. 2020; Lee 2016; Li et al. 2019; Ling et al. 2023; Liu et al. 2017; Mesquida et al. 2024; Mino et al. 2019; Monaco et al. 2016; Monaco et al. 2019; Tanaka et al. 2023; Xiong et al. 2022; Zimmermann et al. 2022).

Dada et al. did not use a scanbody at all, but made an indirect scan with the ISPR screwed into a repositionable analog to design the final restoration (Dada et al. 2021). Lee et al. made an intraoral scan with the scanbody, then attempted to scan the ISPR in situ, and continued the same scan extraorally as the indirect scan. However, the software did not easily process such information, raising the risk of false data (Lee 2016). Dhingra et al. and Zimmermann et al. meanwhile, not only made the three basic scans mentioned earlier but performed a direct EP scan as well (Dhingra et al. 2020; Zimmermann et al. 2022). In a crossover study, Xiong et al. reported that indirect scanning was able to replicate the EP as accurately as the CM, with the ISPR serving as an impression coping (Xiong et al. 2022). Ling et al. concluded in their randomized controlled trial that while slight deviations occur, the indirect technique allows an acceptable replication of the provisional crown's submucosal contour (Ling et al. 2023). According to a comparative case report of two patients by Canullo et al., the 3-year outcomes of an anterior crown made digitally with indirect scanning are similar to those fabricated with a conventional workflow (Canullo et al. 2018). Zimmermann et al. performed a digital scan of the ISPR in situ and took an elastomeric impression with it. After removing the ISPR from the mouth, they performed a direct EP scan, then registered the 3D position of the implant with the help of a scanbody. Finally, they performed an indirect EP scanning with the ISPR seated in the elastomeric impression (Zimmermann et al. 2022).

3.5 | Special Scanbodies

Two studies reported on the use of special scanbodies (Joda et al. 2014; Yilmaz and Abou-Ayash 2020). Joda et al. (2014) customized stock scanbodies (Joda et al. 2014). Yilmaz et al. reported on a special implant system that manufactured coded, anatomical, stock healing abutments, to which a special scanbody can be attached, but there were no measurements reported on the accuracy of this technique (Yilmaz and Abou-Ayash 2020).

3.6 | 3D-Printed and Milled Casts

Some studies fabricated the definitive prosthesis using only virtual models (Canullo et al. 2018; da Silva Marques et al. 2019; Dhingra et al. 2020; Duran et al. 2018; Lee 2016; Mino et al. 2019; Tanaka et al. 2023; Yilmaz and Abou-Ayash 2020; Zimmermann et al. 2022), whereas others 3D-printed or milled casts for checking and/or veneering the crowns (Dada et al. 2021; Doliveux et al. 2020; Lin et al. 2013; Ling et al. 2023; Liu et al. 2017; Monaco et al. 2016).

Doliveux et al. and Lin et al. used the provisional crown and an elastomeric impression as an index for creating a resilient gingival mask on the fabricated cast (Doliveux et al. 2020; Lin et al. 2013).

Monaco et al. 2016, Liu et al., and Dada et al. used 3D-printed casts to manufacture veneered crowns on zirconia abutments (Dada et al. 2021; Liu et al. 2017; Monaco et al. 2016). None mentioned any use of resilient gingival masks.

4 | Discussion

Once the desired soft tissue profile has been established, its accurate transfer is critical, but the question is whether the digital methods compete with the gold standard CM (Dhingra et al. 2020).

This is the first systematic review aimed at determining the best method for capturing peri-implant EP, summarizing the most recent evidence. Articles addressing the topic revealed a marked heterogeneity concerning the study types. The main findings by different methods of EP replication are outlined in Table 1.

4.1 | Systematic Review of the Collapse of the Peri-Implant Mucosa

Duran et al. found that a digital impression does not accurately capture the EP immediately after ISPR removal, reporting a 0.51–1.35 mm deviation (Duran et al. 2018). However, they measured the whole cross-sectional mesiodistal or buccolingual distances, including the mucosa on both sides and the space in between, instead of the inner surface dimensional changes, which may explain the larger deviations; therefore, their results cannot be compared to those of other trials. More rigorous methodologies should be applied in further studies. In comparison, Joda discovered a minor percentage change in the EP after 5 min and a more noticeable change after 10 min when compared to an immediate direct EP scan (Joda 2015; Li et al. 2019). The differences in the findings can be attributed to applying different measurement techniques. Joda used conventional impressions, in which the mucosa could have been compressed, while Li et al. directly scanned the peri-implant mucosa with IOS (Joda 2015; Li et al. 2019).

4.2 | Conventional vs. Digital EP Scanning Methods

Measuring the actual dimensions of the soft tissue in vivo can be challenging. Wei et al. evaluated the trueness of intraoral digital impressions by comparing them to the elastomeric impression (Wei et al. 2020). For the soft-tissue scan, Wei et al. reported a trueness level of approximately 80 μm labial to the natural dentition (Wei et al. 2020). Gan et al. reported a trueness level of 130.54 ± 33.95 μm and a precision level of 55.26 ± 11.21 μm for palatal soft tissue scans (Gan et al. 2016). Meanwhile, Deferm et al. reported a trueness level of 0.02 ± 0.07 mm and a precision level of 80 μm (Deferm et al. 2018). While IOS allows direct scanning of the intraoral soft tissue conditions without the need for conventional cast fabrication and the application of desktop or industrial scanners, the accuracy of this method, especially regarding 3D volumetric comparisons, still needs to be investigated (Wittneben et al. 2016).

Da Silva et al. evaluated two impression techniques in 6 patients: CM with CIIC and digital direct EP impression. The study found significant soft tissue differences with IOS use. This could be due to soft tissue collapse without ISPR support. CIIC prevented a 243.89 μm change in peri-implant soft tissue. However, differences were below the 1 mm detectable threshold, and the null hypothesis could not be rejected due to the small sample size (da Silva Marques et al. 2019).

The ISPR can also be used as an impression coping; however, elastomeric impression material must be used in this method as well. Moreover, the cast needs to be poured immediately to recover the ISPR for the patient, and this is only achievable if the technical equipment is in close proximity to the dental office. Xiong et al. found a greater dimensional discrepancy between the direct EP scanning (414.7 ± 116.0 μm) and conventional impression, as well as between IOS + ISPR (230.6 ± 85.5 μm) and conventional groups. This was attributed to the silicone gingival mask material used during casting, which might impact peri-implant mucosal accuracy. Inaccuracies during IOS procedures could also contribute to soft-tissue deviation (Xiong et al. 2022). It should be noted that this technique of creating an impression with the ISPR is not practical for everyday use.

4.3 | Indirect EP Scanning

By following the indirect scanning method, a virtual model can be established, which allows for a predictable and definitive restoration in the esthetic area, thereby shortening the duration of clinical procedures (Agnini et al. 2023; Canullo et al. 2018; Crockett et al. 2019; Doliveux et al. 2020; Lee 2016; Liu et al. 2017; Mesquida et al. 2024; Mino et al. 2019; Monaco et al. 2016; Monaco et al. 2019; Tanaka et al. 2023).

Monaco et al. suggested protocolizing this method; however, this is based on subjective experience, and currently, there is no conclusive evidence to support which technique is suitable and comparable to the gold standard for each phenotype (Monaco et al. 2019). According to Zimmerman et al., the advantage of the indirect technique is to provide a more efficient and rapid workflow to ensure a predictable and successful outcome (Zimmermann et al. 2022). Crockett posits in a dental technique report that the indirect EP scanning technique may be a valid option to capture the peri-implant soft-tissue configuration because the clinician is not under a time limit due to soft tissue collapse (Crockett et al. 2019).

However, the indirect EP scanning is characterized by the need for multiple scan files to be superimposed. One limitation found by Lee et al. was that the scanner's software may struggle to process complex information in the case of larger files, leading to potential inaccuracies (Lee 2016). Dada et al. also reduced the number of scans by eliminating the use of a scanbody and stated that the indirect EP scan with the digital analog is sufficient. However, this may cause inaccuracies in determining the correct implant position in prosthetic planning (Dada et al. 2021).

Ling et al. conducted a randomized controlled trial comparing definitive crowns fabricated based on either direct or indirect EP scanning. Crowns fabricated based on direct scanning could not support the peri-implant mucosa as the ISPRs, causing a significant deviation in the soft-tissue dimensions, with a decrease in vertical and an increase in horizontal aspects. This randomized study evaluates both the accuracy of digital EP replication and the following esthetic results that can be achieved with the prostheses fabricated with the two workflows (Ling et al. 2023).

Moreover, Mesquida et al. described the Boolean operation to merge the indirect EP scan onto the EP mapped around the scanbody, to create the mesh that allows the accurate replication of the definitive restoration based on the indirect EP scanning (Mesquida et al. 2024).

Finally, it should be noted that the accuracy of indirect scanning and the similarity of the definitive restoration's emergence profile to that of the interim restoration are still uncertain due to the low number of rather heterogeneous and low-evidence studies available.

4.4 | Special Scanbodies

Joda et al. customized the scanbody with the conventional customization technique, which only allowed replication of the outer contour and margin of the soft tissue but did not provide data on the actual submucosal EP, as it was not scanned indirectly (Joda et al. 2014).

Also available are coded healing abutments, which allow not only shaping of the EP but also impression-taking without the need for removing the healing abutment. This shortens the workflow, and after scanning, the data can immediately be transferred for the fabrication of the restoration (Abduo et al. 2017; Attar 2023). These scannable healing abutments also seem promising, but only limited data are available.

4.5 | 3D-Printed and Milled Casts

When fabricating dental prostheses using a hybrid workflow with a digital impression, a physical model is still required for the veneering. Lin et al. used a new technique for removable, resilient EP gingival mask fabrication on milled polyurethane casts with the patient's ISPR (Lin et al. 2013), while Doliveux et al. modified the technique by replacing the ISPR with its 3D-printed replica (Doliveux et al. 2020). These articles presented a new technique for the precise transfer of the EP with the help of a conventional gingival mask, which is an essential step in the semi-digital workflow when implementing the hand build-up technique. Tanaka et al. asserted that the application of multi-layered zirconium-dioxide crown materials precludes the need for veneering on a physical cast, and that staining is sufficient in this case even for restoring the esthetic region as well (Tanaka et al. 2023). Previously, monolithic zirconium-dioxide restorations could not compete with veneered zirconia restorations regarding esthetics, and 3D-printed casts were needed in digital pathways as well for hand veneering purposes (De Angelis et al. 2021). However, with the improvement in mechanical and esthetic properties of zirconia crowns, especially regarding multilayered zirconia, it might now be possible for monolithic restorations to achieve results comparable to those of veneered restorations, thus allowing fully digital workflows and decreasing additional workload (Zhang et al. 2022).

4.6 | Strengths and Limitations

The strengths of the present systematic review are the pre-established and published methodologies; moreover, to the author's knowledge, this study is the first review on this topic.

A limited number of well-designed studies were available in the literature for the analyses due to high heterogeneity in study characteristics and study types and the moderate to high risk of bias of most studies. Although the authors attempted to perform the quantitative analyses as planned in the pre-study protocol, the results were not interpretable due to the previously mentioned limitations. However, to ensure transparency and avoid publication bias, we published the materials related to this analysis in the Supporting Information.

The importance of this topic requires many more homogeneous studies in terms of phenotype, implant diameter, depth, distance to neighboring teeth and IOS accuracy, as well as the accuracy of the measurement programs in evaluating soft tissue parameters, and appropriate IOS protocols, especially those comparing the indirect scanning to the gold standard, with larger sample sizes to confirm that digital impression technologies can be used as an equally viable alternative to CM with strong evidence.

5 | Conclusion

Based on the available literature, indirect scanning may be indicated as an optimal digital technique for EP scanning, while direct scanning is less advised due to possible inaccuracies caused by soft tissue collapse when compared to the conventional method. This review suggests that future well-designed randomized clinical trials should be conducted focusing on the discussed parameters for higher level quantitative analyses.

Author Contributions

Krisztina Mikulás: conceptualization, project administration, methodology, formal analysis, writing – original draft, funding acquisition. **Xinyi Qian:** project administration, data curation, formal analysis, visualization, writing – original draft, methodology, funding acquisition. **Péter Tajti:** data curation, writing – original draft. **Gergely Agócs:** formal analysis, writing – original draft, software. **German O. Gallucci:** conceptualization, formal analysis, writing – review and editing, writing – original draft. **Ignacio Pedrinaci:** formal analysis, writing – original draft, writing – review and editing, data curation. **Péter Hermann:** writing – review and editing, supervision.

Acknowledgments

We extend our gratitude to Prof. Péter Hegyi, Director of the Centre for Translational Medicine at Semmelweis University, for his invaluable assistance. Special acknowledgment is given to Associate Professor Barbara Kispélyi, Ph.D., for generously sharing her expertise and providing consistent support across all phases of our study. We would also like to express our appreciation to Assistant Lecturer Kata Kelemen for her methodological guidance in the development of this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that supports the findings of this study are available in the Supporting Information of this article.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.