The Saudi Dental Journal (2023) 35, 891–904

King Saud University

The Saudi Dental Journal

www.ksu.edu.sa
www.sciencedirect.com

REVIEW ARTICLE

Accuracy of digitally coded healing abutments: A systematic review

Vaibhav Talesara [a], Vincent Bennani [a,*], John Aarts [a], Jithendra Ratnayake [b], Zohaib Khurshid [c], Paul Brunton [d]

[a] *Department of Oral Rehabilitation, Faculty of Dentistry, University of Otago, Dunedin 9016, New Zealand*
[b] *Department of Oral Science, Faculty of Dentistry, University of Otago, Dunedin 9016, New Zealand*
[c] *Department of Prosthodontics and Dental Implantology, College of Dentistry, King Faisal University, Saudi Arabia*
[d] *Curtin University, Bentley, WA 6102, Australia*

Received 6 March 2023; revised 10 August 2023; accepted 13 August 2023
Available online 18 August 2023

KEYWORDS

Healing abutment;
Digital impression;
Digitally coded healing abutments;
Dental implants

Abstract The aim of this systematic review was to evaluate the in vitro accuracy of dental implant impressions taken using digitally coded healing abutments (CHAs) compared with impressions taken with conventional techniques (CI) and/or within the CHA group at varying degrees of angulations for multiple implant units. Two independent reviewers conducted a systematic electronic search in the MedLine, PubMed, Google Scholar, Cochrane Library, Web of Science, and Scopus databases. Some of the employed key terms, combined with the help of Boolean operators, were: "digitally coded healing abutments", "encode healing abutment", "dental implants", "impression accuracy", "digital impression", and "conventional impression". Publication dates ranged from January 2010 to November 2022. A total of 7 articles fulfilled the inclusion criteria: 6 studies compared the accuracy of CHA with conventional pick-up impression techniques, and one study only used CHAs at different angulations and heights to compare accuracy within the group. The results were divided into Group A (elastomeric impression of CHA) and Group B (CHA + Intraoral scanner). According to the results of this systematic review, elastomeric impression of CHA performed poorly when compared to CI for multiple implants, although an intraoral scan of CHA appears to be more accurate. Within the CHA group, the angulation and visible height of CHA play a significant role in impression accuracy. However, more studies are needed before CHA can be recommended for all non-parallel multiple implant-supported restorations.

* Corresponding author at: Department of Oral Rehabilitation, Faculty of Dentistry, University of Otago, Dunedin 9016, New Zealand.
E-mail address: vincent.bennani@otago.ac.nz (V. Bennani).

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

https://doi.org/10.1016/j.sdentj.2023.08.006
1013-9052

Contents

1. Introduction

The Encode® impression system was first introduced by Zimmer Biomet Dental in 2004 (Abduo, Lee et al. 2021). Coded healing abutments (CHAs) are essentially a three-in-one system that combines a healing abutment, impression coping, and a scan body into one digitally coded healing abutment for digital implant impressions (Zimmer Biomet 2022).

According to the manufacturers, the CHA can be used in 2 ways. Specifically, a direct digital intraoral scan can be obtained by scanning over the coded healing abutment without removing it. Alternatively, an elastomeric impression of the CHA is obtained intraorally, and a definitive cast is then poured. The implant analog is subsequently placed in the master cast using Robocast^{TM}/best-fit alignment technology. The company provides a decoder algorithm to ascertain the exact position, length, and diameter of the implant (Jung, Kim et al. 2020).

The current impetus towards the digitalization of implant dentistry using CAD-CAM technologies and the history of the recent pandemic, the goal is to send impressions digitally to the laboratory without the risk of contamination and the added steps of disinfection. The merits of using a direct digital scan are potentially reducing clinical chair time, minimizing patient discomfort from gingival manipulation (Atsuta, Ayukawa et al. 2016), avoiding distortion of impressions (Christensen 2009), requiring less physical space through digital storage (Kattadiyil and AlHelal 2017), cutting costs (Alghazzawi 2016), and reducing apical migration of junctional epithelium and *peri*-implant marginal bone loss (Canullo, Bignozzi et al. 2010). The potential advantages of using a digitally coded healing abutment are improving patient comfort, reducing appointment times, and minimizing disturbance of the soft tissue (Atsuta, Ayukawa et al. 2016).

It is imperative the accuracy levels that can be obtained using these coded healing abutments and their potential limitations when using them for multiple implant units. This review focuses on studies that document the accuracy of implant impressions obtained using digitally coded healing abutments and the aim is to help determine the accuracy of implant impressions that use digitally coded healing abutments at different inclinations and positions and/or when compared with conventional impression techniques.

2. Materials and methods

2.1. Search strategy and the PICO question

This systematic review followed the 'Preferred reporting items for systematic review and *meta*-analysis protocols' (PRISMA-P) 2020 statement (Page, McKenzie et al. 2021) (Fig. 1).

The population, intervention, comparison, and outcomes (i.e., the "PICO" for this systematic review) were defined as follows:

- Population: Partially or completely edentulous patients in need of implant-supported prostheses;
- Intervention: Use of digitally coded healing abutments;
- Comparison: Conventional impressions;
- Outcomes: Accuracy of impressions.

2.2. Data collection

The databases of Medline (Ovid), PubMed, Google Scholar, Scopus, Web of Science, and the Cochrane Library were searched from January 2010 to November 2022. A manual/citation search was also performed. The Medical subject head-

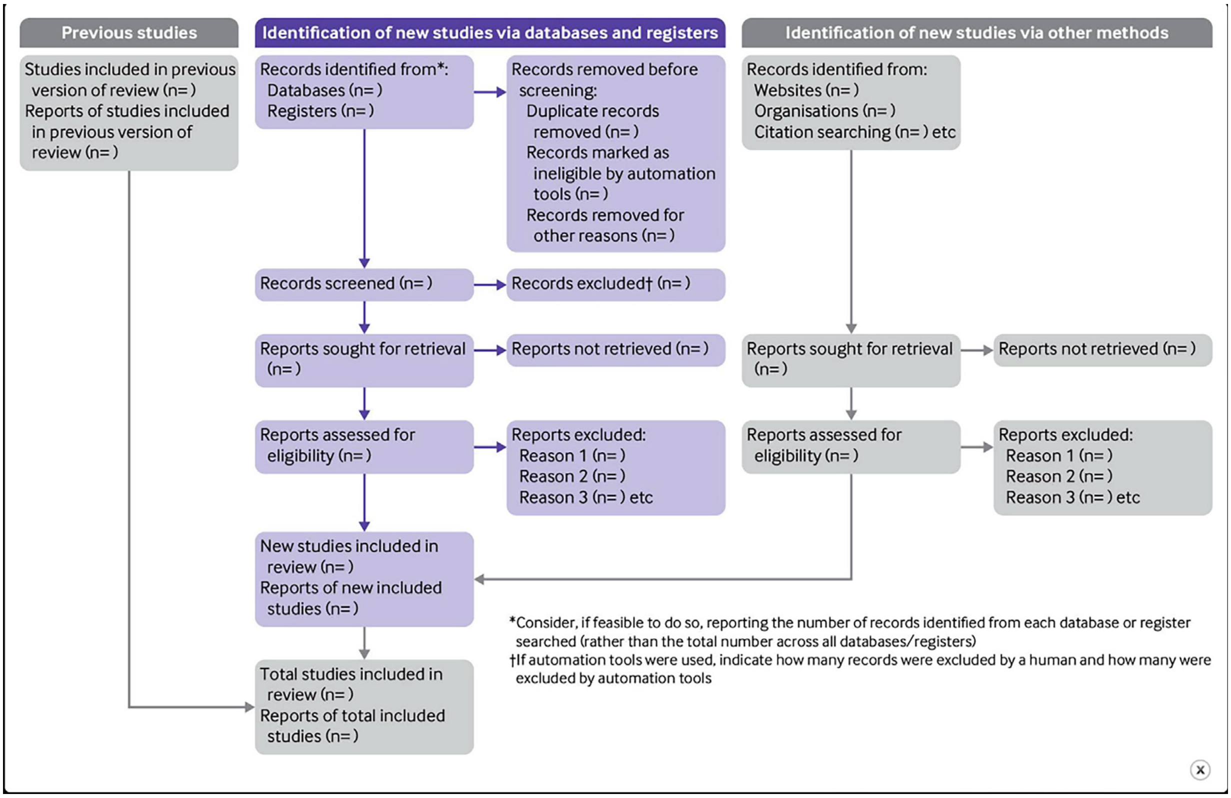

Fig. 1 PRISMA flow chart diagram.

Table 1 Results of grading of the included studies using the Modified CONSORT table.

Author	Abstract	Introduction		Methods			Results	Discussion	Other		Result
	1	2a	2b	3	4	5	6	7	8	9	10/10
Eliasson and Örtorp 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
Howell et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
Al-Abdullah et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9/10
Ng et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
Ahn and Lee 2020	Y	Y	Y	Y	Y	Y	Y	Y	N	N	8/10
Batak et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9/10
Jung et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	N	N	8/10

ings (MeSH) terms were used, and the search strategy according to the focused PICO question was conducted and modified depending on the electronic database being searched (Table 1) (Khurshid, Tariq et al. 2021). The year limit was set to January 2010–November 2022. The inclusion and exclusion criteria were as follows.

2.3. Inclusion criteria

1. Studies that assessed the accuracy of implant impressions obtained using digitally coded healing abutments and compared them with those obtained using conventional impression techniques.
2. Studies that compared accuracy within digitally coded healing abutment groups at different angulations/inclinations/positions.
3. Studies that included single and/or multiple fixed implant impressions and/or restorations.
4. Studies published in English.
5. Studies and reviews conducted between January 2010 and November 2022.

2.4. Exclusion criteria

1. Publications describing a technique or a clinical case.
2. Multiple publications on the same patient cohorts.
3. Studies where the accuracy of impression(s) using digitally coded healing abutment(s) was not assessed.
4. Outcomes not related to fixed implant prosthodontic treatment.
5. Studies not related to digitally coded healing abutments.

2.5. Data extraction and quality assessment

All studies involving the accuracy assessment of implant impressions using digitally coded healing abutment(s) for multiple units were included.

The initial search was conducted in Ovid, followed by searches in other relevant databases to identify additional articles. A hand search was performed to identify the studies that met the inclusion criteria. Articles that contained any of the exclusion criteria were removed. The flow chart in Fig. 1 describes the distribution of the number of studies that were selected among the different databases used.

This review comprises only in vitro studies, therefore, a Modified CONSORT (Consolidated Standards of Reporting Trials) checklist was adapted by Faggion et al. was utilized (Faggion 2012). Thus, articles 5 to 9 were eliminated because they presented a low risk of bias and irrelevance of randomization, and the sample size was not a critical factor (Table 1). Only studies with a score of 80% and above were included in this review.

3. Results

3.1. Study selection

After removing duplicates, a total of 115 unique studies were identified. A reviewer verified all potentially relevant articles. These studies and abstracts were independently screened prior to full-text reading. In cases where abstracts provided insufficient information, full texts were obtained. Studies meeting all inclusion criteria were discussed with the second reviewer (AA). If no consensus could be reached, a third reviewer (JL) was consulted. Only studies meeting the specific inclusion criteria were then selected. Finally, to supplement the electronic search, a manual search was conducted by considering entries in the reference lists of the selected studies, and any relevant studies not yet included were added.

Based on the title alone, 115 studies from the electronic search and 4 studies from hand citation were considered. After the first round of screening, 22 studies were selected, of which only 7 fulfilled the inclusion and exclusion criteria. These 7 studies were all in vitro and are part of this systematic review. The results of grading these studies using the Modified CONSORT table are illustrated in Table 1. The grading was verified by two independent examiners: JL and AA. Owing to the heterogeneity of the study designs and different assessment tools used, a *meta*-analysis could not be performed.

3.2. Study characteristics

All seven studies included in this review were in vitro studies that analyzed the accuracy of digitally coded healing abutments based on multiple implant units. After initial analysis of the study designs and methodologies, studies were divided into Group A and B.

Group A comprised studies that used elastomeric impressions of CHA to fabricate casts, and Group B included studies that used direct intraoral scanning technology with CHA.

For Group A, the casts obtained from elastomeric impressions of CHA were scanned via either Robocast™ technology (Biomet3i, Florida, USA) or a "best-fit" algorithm for the placement of implant analogues on the definitive casts. Group B used an IOS for direct scans of the CHA, which were then sent to the manufacturers or authorized dental laboratories as STL files to digitally place the implant analogue. Only one study (Anadioti, Gates et al.) used both elastomeric impression and IOS of the CHA for comparison with conventional impression techniques. Therefore, this study was included in both Groups A and B. The results were analyzed individually for both Groups A and B in the following sections.

3.3. Group A analysis

The study design of group A is described in Table 2.

3.4. Group A results

The summary of the findings for Group A is depicted in Table 3. Eliasson and Örtorp concluded that definitive casts fabricated using an elastomeric impression of digitally coded healing abutments combined with Robocast™ analogue placement were less accurate than those fabricated using conventional pick-up impression techniques. Howell et al. (Howell, McGlumphy et al. 2013) concluded that the accuracy of elastomeric impression of CHA was comparable to that of closed-tray conventional impression on non-parallel implant sites ($p < 0.05$); however, it was less accurate than conventional open-tray impression. Jung et al. (Jung, Kim et al. 2020) concluded that the mean total interarch deviation (at maximum intercuspation) in all experimental groups was < 100 μm.

3.5. Group B analysis

Group B (Tables 4 and 5) used an IOS for direct scans of the CHA, which were then sent to the manufacturers or authorized dental laboratories as STL files to digitally place the implant analogue. This group was comprised of 3 studies (Ahn and Lee 2020, Batak, Yilmaz et al. 2020, Jung, Kim et al. 2020). All three studies were highly ranked, with scores between 8 and 9 out of a total of 10 on the Modified CONSORT table.

In terms of study design, two studies (Batak, Yilmaz et al. 2020, Jung, Kim et al. 2020) were carried out on a partially edentulous mandible replica, and one study (Ahn and Lee 2020) was performed on a completely edentulous ridge block. There is heterogeneity in terms of the brand of CHA used in all three studies. Batak et al. (Batak, Yilmaz et al. 2020) used the Encode System from Biomet 3i, Florida, USA; Ahn and Lee (Ahn and Lee 2020) used CHA from Niobiotech, Seoul, Korea, and Jung et al. (Jung, Kim et al. 2020) used CHA from Dentium Co., Seoul, Korea.

The heights of coded healing abutments used in these studies were different. Batak et al. (Batak, Yilmaz et al. 2020) used two different heights (3 and 8 mm) of CHAs at different positions, Jung et al. (Jung, Kim et al. 2020) used a 6 mm height, and Ahn and Lee (Ahn and Lee 2020) did not specify the height of the CHA used.

All studies in Group B measured the accuracy of implants that were placed parallel to each other. Additionally, Ahn

Table 2 Detailed study description and statistical analysis used for Group A.

		Experimental Groups								
Author and Year	**Reference Group Measurement**	**CI/ISB Group Measurement**	**CHA Group Measurement**	**Brand of CHA**	**Measurement Instrument**	**Method for Measuring Accuracy**	**Magnitude of Error Calculation**	**Planes Measured**	**Accuracy Measured**	**Statistical Test**
Al-Abdullah et al. 2013 (Al-Abdullah, Zandparsa et al. 2013)	Reference epoxy resin cast with CAD/CAM titanium reference framework. Left: 30° convergence Right: 10° convergence	Verifying the fit of pre-milled titanium frameworks on working casts fabricated from conventional pick-up impression using an open-tray (splint) technique	Verifying fit of pre-milled titanium framework on definitive casts fabricated from elastomeric impression of CHA using VPS + Robocast™ technology for analogue placement	Biomet 3i	Horizontal Optical Comparator System (Deltronic, Santa Ana, CA, USA)	Measuring vertical discrepancy (z plane) of the framework fit	Mean and standard deviations	Z and angular	Yes Using fit of prefabricated reference titanium frameworks.	Mann–Whitney U tests, Kruskal–Wallis test
Eliasson and Örtorp 2012	Reference model of edentulous maxilla with 3 reference spheres with 3 implants on each side	Definitive casts fabricated from conventional pick-up impression using VPS	Definitive casts fabricated from elastomeric impression of CHA using VPS + Robocast™ technology for analogue placement	Biomet 3i	Laser Measuring Machine (LMM)	Difference between reference values from master cast and values from working casts	Root sum square (RSS) $\sqrt{(x^2 + y^2 + z^2)}$	x, y and z + Mean angle error: angular inclination and hexagon position (rotation)	Yes	Conventional descriptive statistics
Howell et al. 2013	Reference model of partially edentulous mandible with 2 implants on each side. Left: Parallel Right: 30° Divergence	Definitive casts fabricated from conventional pick-up impression using custom closed and open-tray + MP VPS	Definitive casts fabricated from elastomeric impression of CHA using VPS + Robocast™ technology for analogue placement	Biomet 3i	Digital Scanner Trios to create STL files of all test and reference models	Best-fit alignment: Rapidform XOR CAD software (INUS technology)	NS	x, y and z + Angular distortion	Yes	Analysis of variance and Tukey tests
Jung et al. 2020	Master reference scan of a partially edentulous mandible and fully dentulous maxillary dentiform models using 3D model scanner (identica blue; Medit)	Digital scans made from: Group CI: Master cast from pick-up CI + VPS and then scanned by 3D model scanner. Group DS: ISB + IOS (Medit i-500) Group MS: CHA + VPS and then scanned by 3D model scanner	Group IS: CHA + IOS (Medit i-500)	Dentium Co.	3D analysis software (Geomagic Control X, 3D systems Inc., USA)	Best-fit alignment	3D distance = $\sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2)}$	x, y and z + Angulation error x-y plane + Interarch deviation	Yes	Shapiro–Wilk test, Kruskal–Wallis test and Bonferroni correction

(continued on next page)

Table 2 *(continued)*

Author and Year	Reference Group Measurement	Experimental Groups: CI/ISB Group Measurement	Experimental Groups: CHA Group Measurement	Brand of CHA	Measurement Instrument	Method for Measuring Accuracy	Magnitude of Error Calculation	Planes Measured	Accuracy Measured	Statistical Test
Ng et al. 2014	Seven sectional mandibular arch master models: one with parallel implants, three with M–D, and thee with B-L total divergence of 10°, 20°, and 30° each	Definitive casts fabricated from conventional pick-up impression using custom closed-tray and MP PEI	Definitive casts fabricated from elastomeric impression of CHA using VPS + Robocast™ technology for analogue placement	Biomet 3i	Coordinate Measuring Machine (CMM)	Difference between coordinate values of master cast and test casts	3D distance R $R = \sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2)}$	x, y and z + Angular distortion (xz and yz)	Working/Test cast	Two-way analysis of variance (ANOVA) test, One-way ANOVA and Student–Newman–Keuls post hoc test

Abbreviations: CE: Completely edentulous; CHA: Coded healing abutment; CI: Conventional impression; FPD: Fixed partial denture; HB: Heavy body; IOS: Intraoral scanner; ISB: Intraoral scan body; LB: Light body; MP: Monophase viscosity; NP: Non-parallel; NS: Not specified; P: Parallel; PE: Partially edentulous; PEI: Poly ether impression material; VPS: Vinyl poly siloxane.

and Lee (Ahn and Lee 2020) used non-parallel implants in their investigation. Implants in this study were placed into the model with 0°, 10°, and 20° mesial angulations.

The IOS system used in these studies differed as well. In two studies (Ahn and Lee 2020, Batak, Yilmaz et al. 2020), Trios 3 Shape (3Shape Trios A/S, Copenhagen, Denmark) was used, while Jung et al. (Jung, Kim et al. 2020) used Medit i500 (Medit Corp. Seoul, South Korea).

3.6. Group B results

Table 5 summarizes the results of group B. Jung et al concluded that the accuracy of implant impressions using IOS + CHA was comparable to that obtained using a pick-up CI technique ($p < 0.05$). The mean total linear inter-arch deviation ranged from 84 to 97 µm for both CHA + IOS and CI groups, with no significant difference between the groups (p greater than 0.05). (Table 5).

Batak et al. *(*Batak, Yilmaz et al. 2020*)*, compared the accuracy of CHA at different positions and heights (3 mm and 8 mm). The researchers reported that the CHA position had a significant effect on distance deviation ($p < 0.001$). Additionally, they found that the angular deviation increased as the height of CHA was increased and moved more posteriorly ($p = 0.41$). (Table 5).

Ahn and Lee *(*Ahn and Lee 2020*)* reported that the mean and standard deviations for CHA groups were higher than those for the CI group: 38.29 ± 4.12 µm and 25.56 ± 2.53 µm, respectively, which was statistically significant ($p < 0.05$). The study also concluded that the implant angulation had a significant impact on the impression accuracy of the CHA group (Table 5).

4. Discussion

This review focused on studies that measured the accuracy of CHA with respect to multiple implant units, comparing it with conventional impression techniques and/or within the CHA group at varying degrees of angulations. The selected studies displayed heterogeneity in terms of design, implant components used, and methods of measuring accuracy. While most studies measured accuracy at the master cast level, one study (Al-Abdullah, Zandparsa et al. 2013) used prefabricated CAM/CAM titanium framework to measure the accuracy of fit of the prostheses. Study designs also varied, with some using multiple implants for single unit prostheses, while others used three implant units for a three-unit FPD. Furthermore, studies differed in how accuracy was measured, utilizing techniques such as CMM, LMM, or 3D Lab Scanners, making *meta*-analysis impossible because the results cannot be combined.

One of the limitations of this systematic review is that all included studies were in vitro studies because they were the only ones that fulfilled the inclusion and exclusion criteria. This systematic review found that accuracy was mostly measured at the impression/master cast level. These results must be interpreted with caution because the error in accuracy may vary when considering the continuation from the impression stage to design, manufacturing, and prosthetic fit stage.

From the seven studies selected for this review, Group A demonstrated a consistent trend of elastomeric impressions

Table 3 Summary of findings for Group A.

Author and Year	Method of Recording CHA	Brand of CHA	Mean Angular Deviation/ Implant Angle Error	Outcomes (Mean R Deviations)	Summary of Findings	Modified CONSORT Grade
Al-Abdullah et al. 2013	Elastomeric Impression	Biomet 3i	Angular Distortion CHA: 10° Convergence: 0.59° to 0.08° CHA: 30° Convergence: 0.95° to 0.37° CI: 10° Convergence: 0.008° CI: 30° Convergence: 0.028°	**Vertical discrepancy of framework in the z plane** CHA: 48.17–228.33 µm (10° convergence 48.17–228.33 µm 30° convergence 67–211.67 µm) CI (open-tray with splint technique) 13.83–24.83 µm (10° convergence 13.83–24.83 µm 30° convergences 18.33–20.50 µm)	Elastomeric impression of CHA was less accurate than conventional pick-up impression. Prefabricated CAD/CAM titanium framework demonstrated higher vertical discrepancy in the CHA group than that in the conventional pick-up impression group. The convergence angle variable and implant position variable did not significantly affect the accuracy when comparing control and test groups.	9/10
Eliasson and Örtorp 2012	Elastomeric Impression	Biomet 3i	CHA: 0.41° CI:0.14°	CHA + VPS: 79.5 µm CI pick-up: 31.2 µm	An elastomeric impression of CHA is less accurate than a conventional pick-up impression. The mean displacement of implant analogues in all 3 planes was larger in the CHA group than in the CI group. The mean angular deviation and the mean rotational error in the CHA group was also statistically significant.	10/10
Howell et al. 2013	Elastomeric Impression	Biomet 3i	–	CHA 35–242 µm CI Closed-tray 6.9–183.7 µm CI (open-tray) 2.4 to 161.9 µm	Accuracy of elastomeric impression of CHA was inferior to open-tray CI technique on NP implant sites ($p > 0.05$). Elastomeric impression of CHA was less accurate than closed-tray and open-tray conventional pick-up impression on P implant sites. Within the CHA group: NP sites were significantly less accurate than P sites.	10/10
Jung et al. 2020	Elastomeric Impression and IOS	Dentium Co.	Second premolar: Group MS (CHA + VPS): 2.34 ± 0.46 Group CI pick-up: 0.96 ± 0.44° First Molar: Group MS:2.49 ± 0.53 Group CI: 0.88 ± 0.43°	Interarch deviation: All groups < 100 µm (84–97 µm) Intra-arch deviation: Group CI, IS: < 100 µm Group MS(CHA + VPS): > 200 µm	Group MS (VPS + CHA) was the least accurate among all groups when comparing intra-arch deviations. The mean 3D angle deviations were: 0.88° to 2.49°; with Group MS performing the poorest. Group MS (Elastomeric impression of CHA) is the least accurate among all test groups.	9/10
Ng et al. 2014	Elastomeric Impression	Biomet 3i	CHA: 0.29–1.190° CI: 0.046–0.12°	CHA + VPS 65–107 µm CI: 13–20 µm	Elastomeric impression of CHA was less accurate than a conventional open-tray pick-up impression Interimplant angulation did not have a significant effect on the accuracy of CHA.	10/10

Abbreviations: CAD/CAM: Computer aided design/computer aided manufacturing; CHA: Coded healing abutment; CI: Conventional impression. IOS: Intraoral scanner; ISB: Intraoral scan body; MP: Monophase (Medium body); NS: Not specified; NP: Non-parallel; P: Parallel; VPS: Vinyl poly siloxane.

Table 4 Detailed study description and statistical analysis used for Group B.

Author and Year	Reference Group Measurement	Experimental Groups: CI/isb Group measurement	Experimental Groups: CHA Group Measurement	Brand of CHA	Instrument of Measurement	Method of Measuring Accuracy	Calculation of Magnitude of Error	Planes measured	Accuracy Measured	Statistical Test
Ahn and Lee 2020 (Ahn and Lee 2020)	Reference 40-mm-long edentulous ridge block with 3 implants	i. Group P: Working cast from pick-up impression (open-tray) + VPS ii. Group S: ISB + IOS	CHA + IOS: Trios 3Shape	Neo biotech	3D analysis software (Geomagic Control X, 3D systems Inc., USA)	Best-fit alignment method by superimposing STL files	Root Mean Square (RMS) $\sqrt{(x^2 + y^2 + z^2/3}$	x, y and z + Angulation error	Yes	Kolmogorov-Smirnov, One-way ANOWA test, Dunnett T3 test and The Jonckheere-Terpstra test
Batak et al. 2020 (Batak, Yilmaz et al. 2020)	Reference scan of a partially edentulous mandible using a laboratory-grade scanner (COMETL3D 8 M 150 Precision Structured Blue Light Scanner; ZEISS)	–	CHA + IOS: Trios 3Shape 4 groups 3 and 8 mm CHA at #36 and #37 positions	Biomet 3i	Digital (NS)	Best-fit alignment (PolyWorks Inspector)	3D distance = $\sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2}$	x, y and z + Angulation error x-y plane	Yes	Two-way repeated and ANOVA test Tukey-Kramer test
Jung et al. 2020 (Jung, Kim et al. 2020)	Master reference scan of a partially edentulous mandible and fully dentulous maxillary dentiform models using a 3D model scanner (identica blue; Medit)	Digital scans made from: Group CI: Master cast from pick-up CI + VPS and then scanned by a 3D model scanner. Group DS: ISB + IOS (Medit i-500) Group MS: CHA + VPS and then scanned by a 3D model scanner	Group IS: CHA + IOS (Medit i-500)	Dentium Co.	3D analysis software (Geomagic Control X, 3D systems Inc., USA)	Best-fit alignment	3D distance = $\sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2}$	x, y and z + Angulation error x-y plane + Interarch deviation	Yes	Shapiro-Wilk test, Kruskal–Wallis test and Bonferroni correction

Abbreviations: CHA: Coded healing abutment CI: Conventional impression. IOS: Intraoral scanner ISB: Intraoral scan body NS: Not specified STL: Stereolithography VPS: Vinyl poly siloxane.

Table 5 Summary of findings for Group B.

Author and Year	Method of Recording CHA	Brand of CHA	Mean Angular Deviation/ Implant Angle Error	Outcomes (Mean R Deviations)	Summary of Findings	Modified CONSORT Grade
Ahn and Lee 2020 (Ahn and Lee 2020)	IOS	Niobiotech	Std. Jonckheere–Terpstra statistic CHA:1.989 CI: 1.718 ISB:1.822	CHA + IOS: 35–50 µm CI pick-up: 18–32 µm ISB + IOS: 35.27 ± 2.56	Accuracy of implant impressions using CHA + IOS was inferior to that obtained using a pick-up CI technique. Increasing implant inclination/angulation negatively affected the accuracy of IOS capturing CHA details. No statistically significant difference between ISB and CHA group using IOS.	8/10
Batak et al. 2020 (Batak, Yilmaz et al. 2020)	IOS	Biomet3i	CHA + IOS 3 mm: Anterior: 0.42° Posterior: 0.40° CHA + IOS 8 mm: Anterior: 0.53° Posterior:0.7°	CHA + IOS 3 mm 325 µm–425 µm 8 mm: 250 µm-400 µm	CHA position had a significant effect on distance deviation (CHAs in the anterior region had lower distance deviations) CHAs performed similarly at 3 and 8 mm heights when placed more anteriorly. Increasing CHA height had a negative impact on the angular deviation when moved more posteriorly.	9/10
Jung et al. 2020 (Jung, Kim et al. 2020)	IOS and Elastomeric Impression	Dentium Co.	Second premolar: Group IS (CHA + IOS): 1.38 ± 0.35° Group CI pick-up: 0.96 ± 0.44° First Molar: Group IS: 1.41 ± 0.48° Group CI: 0.88 ± 0.43°	Interarch deviation: All groups: 84–97 µm Intra-arch deviation: Group CI, IS: < 100 µm	CHA + IOS is comparable to CI pick-up impression in terms of intra-arch, interarch, and 3D mean angular deviations Groups MS (Elastomeric impression of CHA) is the least accurate among all test groups.	9/10

Abbreviations: CHA: Coded healing abutment CI: Conventional impression IOS: Intraoral scanner ISB: Intraoral scan body; NS: Not specified STL: Stereolithography VPS: Vinyl poly siloxane.

of CHA being less accurate than the CI technique using open-tray, which is considered the gold standard for multiple units (Lee, So et al. 2008, Moreira, Rodrigues et al. 2015). This observation was consistent across different CHA systems used in the studies.

Group B (Ahn and Lee 2020, Batak, Yilmaz et al. 2020, Jung, Kim et al. 2020) used IOS to compare the accuracy of CHA, and their final conclusions varied. Ahn and Lee (Ahn and Lee 2020) agreed with the findings of Group A. However, Jung et al. (Jung, Kim et al. 2020) found that the IOS + CHA group had comparable impression accuracy to the CI group. Batak et al. (Batak, Yilmaz et al. 2020) had a different study design and concluded that the position of CHA in the mouth had a significant impact on the distance deviation of implant impressions. They also found that increasing the CHA height (from 3 to 8 mm) had a negative impact on impression accuracy and angular deviations as the CHA was moved more posteriorly. The heterogeneity in results can be partly attributed to the fact that the studies used different components and IOS systems.

The studies differed in their conclusions regarding impression accuracy with implants of varying angulations. Al-Abdullah et al and Ng et al reported that there were no significant errors in the CHA group with increasing implant angulations. However, Ahn and Lee and Howell et al found that increasing implant angulations resulted in significant differences in implant accuracy between the CHA and CI groups ($p < 0.05$). Additionally, Batak et al. reported a correlation with taller (8 mm) CHAs displaying larger angular deviations in the posterior region compared to the anterior region (Batak, Yilmaz et al. 2020). An interesting point raised by Al-Abdullah et al. is that according to the manufactures, at least 1 mm of the CHA should be exposed supragingivally for visibility and ease of recording and scanning (Al-Abdullah, Zandparsa et al. 2013).

An important factor influencing impression accuracy in multiple implant unit cases is the proximity of adjacent teeth/implants and the resulting impression thickness (Burns, Palmer et al. 2003). Howell et al. observed that in their study, there was minimal space for the impression material in the right second premolar site (Howell, McGlumphy et al. 2013). According to the authors, the right second premolar area of the impression may rebound differently upon removal, potentially resulting in inaccuracies. To address this concern, Burns et al. recommended modifying the impression coping when the interimplant distance is < 3 mm.

The abovementioned results are to be interpreted with some caution because four of the Group A studies (Eliasson and Ortorp 2012, Al-Abdullah, Zandparsa et al. 2013, Howell, McGlumphy et al. 2013, Ng, Tan et al. 2014) used elastomeric impressions of CHA in combination with Robocast™ technology to fabricate the definitive casts. The fixation of implant analogues to master casts in this technique is achieved using a monophase industrial resin adhesive (Howell, McGlumphy et al. 2013). It was reported that the variability of drill hole, resin thickness, and associated polymerization shrinkage may have had a bearing on CHAs poor accuracy when compared with the CI technique (Howell, McGlumphy et al. 2013).

Material choice and viscosity may also potentially have an impact on accuracy. Eliasson and Örtorp used a combination of light body and heavy body viscosities for VPS impression material, whereas other studies mainly used monophasic VPS (Eliasson and Ortorp 2012). Ng et al. used monophasic polyether impression material (Ng, Tan et al. 2014). This disparity needs to be accounted for when interpreting results because monophasic polyether exhibits the best torque resistance and dimensional stability (Wee 2000).

The effect of interimplant angulation on impression accuracy has been extensively studied in the literature. It has been reported that even conventional pick-up implant impressions in multiple units are negatively affected by increasing implant angulations (Assuncao, Filho et al. 2004, Vigolo, Fonzi et al. 2004, Cabral and Guedes 2007). The CHA group performed poorly possibly because the coded area of CHA collar exposed supragingivally was less visible for the Robocast™ (Al-Abdullah, Zandparsa et al. 2013). Their study reported that this was the case for the distal portion of anterior and mesial of posterior implant replicas.

Al-Abdullah et al. (Al-Abdullah, Zandparsa et al. 2013) also observed undercuts of more than 1 mm under 10° and 30° implant angulations. They hypothesized that the cumulative effect of deformation of elastomeric impression materials from these undercuts (Jorgensen 1976) and the way Robocast™ stabilizes the implant analogues may have caused errors in the 3D spatial relationship, contributing to larger vertical discrepancies in the CHA group.

The results of Group B were heterogeneous in nature. This could be due to the fact that all three studies used different brands of CHA and IOS systems. Recent studies (Michelinakis, Apostolakis et al. 2020, Amornvit, Rokaya et al. 2021) have demonstrated that Trios 3 has superior precision than Medit i500. One of the studies (Michelinakis, Apostolakis et al. 2020) also pointed out that Medit i500 significantly underestimated the reproduction of reference scanners' files. This may explain the possible reduced deviation between the CHA + IOS and CI group in the Jung et al. study (Jung, Kim et al. 2020).

Group B results also highlight two important factors. First, there are limited in vitro studies conducted using IOS with CHA in the past decade. However, despite a lack of in vitro studies, there have been a few similar systems recently introduced to the market (e.g., Niobiotech, Seoul Korea and Dentium Co., Seoul, Korea). Therefore, more CHAs are likely to be at our disposal to conduct more intensive studies in the future. Second, the results may vary owing to differences in IOS systems used and the surface characteristics and shape of a scan body. Several studies and reviews have focused on factors affecting the accuracy of IOS, examining different brands and other scan bodies (Rutkunas, Geciauskaite et al. 2017, Flugge, van der Meer et al. 2018, Michelinakis, Apostolakis et al. 2021, Zhang, Shi et al. 2021). Surface topography and material can influence IOS accuracy. The refractory and reflective indices of all-PEEK scan bodies can have a positive influence on the accuracy of complete arch digital impressions (Mangano, Hauschild et al. 2019, Arcuri et al., 2020). However, the poor mechanical properties of PEEK compared to those of titanium have been questioned in the past (Najeeb, Zafar et al. 2016, Skirbutis, Dzingute et al. 2017).

When considering digital implant impressions for multiple units, the splinting technique has been consistently shown to significantly improve overall accuracy, particularly in minimizing linear and angular deviations (Pozzi, Arcuri et al. 2022). This occurs because the IOS has a continuous point of reference and can stitch images together, avoiding scrambling of data (Rhee, Huh et al. 2015, Imburgia, Kois et al. 2020). However, all studies in Group B fail to specify if this was carried out, which may have negatively affected CHA's accuracy.

Another important factor is the use of powder for scanning. A previous study reported that the thickness of powder applied can negatively influence the accuracy of IOS (Meyer, Mormann et al. 1990). Most studies in Group B used powder prior to scanning the CHA. However, a study by Ender and Mehl (2013) concluded that powder-free scanners provide more true and precise image qualities when compared to IOS systems needing powders (1 3 2). Additional factors influencing impression accuracy with IOS are operator experience (Canullo, Colombo et al. 2021, Pesce, Bagnasco et al. 2021) and scanning strategy (Zhang, Shi et al. 2021). Only one study (Batak, Yilmaz et al. 2020) clarifies that all intraoral scans were performed by one operator.

It is also reported that inaccuracies increase with the number of implants being scanned using IOS (two-implant versus full mouth scenarios) (Canullo, Colombo et al. 2021, Pesce, Bagnasco et al. 2021). A recent study reported that the height of scan bodies can also affect scan accuracy (Fluegge, Att et al. 2017). However, these findings can be challenged by the results of studies by Jung et al. (Jung, Kim et al. 2020) and Batak et al. (Batak, Yilmaz et al. 2020). Both these studies confirmed that there was no significant effect on distance deviation owing to the height of CHA. This is further supported by a recent narrative review (Michelinakis, Apostolakis et al. 2021) that pointed out that, as long as the exposed portion of a scan body can provide adequate reference points for the scanner, accuracy is not significantly affected. Batak et al. used CHAs of two different heights in their study, both of which performed similarly in the anterior region (Batak, Yilmaz et al. 2020). However, it is important to interpret the results carefully because the cumulative effect of deviation from the change in height and position of a CHA can be higher (Batak, Yilmaz et al. 2020).

Studies by Jung et al. (Jung, Kim et al. 2020) and Ahn and Lee (Ahn and Lee 2020) used ISBs and CHAs to compare accuracies. Both studies reported that the scan body and CHA performed similarly. However, CHAs offer an advantage over ISBs in terms of shorter height, making them suitable for restricted spaces. ISBs, on the other hand, are more complex in design and vary significantly in terms of their geometry, making it difficult for IOSs to accurately record their trueness and preciseness (Mizumoto, Yilmaz et al. 2020).

The effect of implant angulation on IOS accuracy has been extensively investigated in previous studies (Gimenez, Ozcan et al. 2015, Gimenez, Pradies et al. 2015, Papaspyridakos, Gallucci et al. 2016, Gimenez-Gonzalez, Hassan et al. 2017, Moslemion, Payaminia et al. 2020). In a recent systematic review comparing digital versus conventional impressions, it was reported that implant angulation of < 20° did not significantly affect impression accuracy (Papaspyridakos, Vazouras et al. 2020). However, this contrasts with the findings of one of the studies (Ahn and Lee 2020) included in this review, where implant angulation of up to 20° did have a significant impact on angular deviations. It is postulated that the coded portion of the CHA may be submerged in the gingiva in cases of angulated implants (Al-Abdullah, Zandparsa et al. 2013). According to the manufacturers, at least 1 mm of the Encode[R] CHA must be located supragingivally to increase visibility for recording and ease of scanning (Zimmer Biomet).

5. Conclusions

In this systematic review, the accuracy of digitally coded healing abutments was evaluated and compared with conventional impression techniques for multiple implant units at varying inclinations. Based on the findings within the limitations of this review, the following conclusions can be made.

- Elastomeric impression of CHA was not superior to conventional techniques for multiple implant units.
- CHA + IOS showed better impression accuracy for multiple implant units compared to elastomeric impressions of CHA.
- In cases of angulated implants, the visibility of CHA can be affected more on one side than on the other, potentially impacting its recording capability when using an IOS.
- CHA + IOS and ISB + IOS both reported similar impression accuracy for multiple units.
- CHAs have the advantage of being used in restricted spaces owing to their reduced size compared to ISBs, and there is no need to remove the healing abutment when making impressions.

6. Clinical significance

The accuracy of impression is essential for ensuring the passivity of implant-supported prostheses, especially in cases of multiple implant units with varying angulations. Based on the findings of this systematic review, it is recommended to use CHA with IOS instead of elastomeric impressions of CHA in multiple implant unit cases. The visibility of CHA, particularly in cases of angulated implants, should be carefully considered when using CHAs for multiple unit cases. Clinicians should also be aware of factors that can affect the accuracy of an IOS system when using digital impression techniques. Both CHAs and ISBs demonstrated similar accuracy when used with IOS. The use of ISBs and CHAs with IOS has increased in recent years, and it is important to recognize the evolving nature of digital implant prosthodontics.

CRediT authorship contribution statement

Vaibhav Talesara: Conceptualization, Methodology, Validation, Visualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Vincent Bennani:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Visualization, Supervision. **John Aarts:** Methodology, Validation, Writing – review & editing, Supervision. **Jithendra Ratnayake:** Methodology, Supervision, Validation, Writing – review & editing. **Zohaib Khurshid:** Formal analysis, Writing – review & editing, Supervision. **Paul Brunton:** Methodology, Validation, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors acknowledge the University of Otago Librarian Trish Leishman for her assistance. We also thank Falcon Scientific Editing for proofreading the English language in this paper."

References

Abduo, J., Lee, C.L., Sarfarazi, G., Xue, B., Judge, R., Darby, I., 2021. Encode protocol versus conventional protocol for single-implant restoration: A prospective 2-year follow-up randomized controlled trial. J. Oral Implantol. 47 (1), 36–43.

Ahn, G.-Z., Lee, J.-S., 2020. Comparison of the accuracy of implant digital impression coping. J. Dent. Rehabil. Appl. Sci. 36 (1), 29–40.

Al-Abdullah, K., Zandparsa, R., Finkelman, M., Hirayama, H., 2013. An in vitro comparison of the accuracy of implant impressions with coded healing abutments and different implant angulations. J. Prosthet. Dent. 110 (2), 90–100.

Alghazzawi, T.F., 2016. Advancements in CAD/CAM technology: Options for practical implementation. J. Prosthodont. Res. 60 (2), 72–84.

Amornvit, P., D. Rokaya and S. Sanohkan (2021) "Comparison of accuracy of current ten intraoral scanners." BioMed Res Int **2021**.

Anadioti, E., Gates 3rd, W.D., Elpers, J., De Kok, I.J., Cooper, L.F., 2019. Retrospective cohort analysis of maxillary overdentures retained by unsplinted implants. J. Prosthet. Dent. 122 (3), 301–308 e301.

Arcuri, L., Pozzi, A., Lio, F., Rompen, E., Zechner, W., Nardi, A., 2020. Influence of implant scanbody material, position and operator on the accuracy of digital impression for complete-arch: A randomized in vitro trial. J. Prosthodont. Res. 64 (2), 128–136.

Assuncao, W.G., Filho, H.G., Zaniquelli, O., 2004. Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent. 13 (4), 358–366.

Atsuta, I., Ayukawa, Y., Kondo, R., Oshiro, W., Matsuura, Y., Furuhashi, A., Tsukiyama, Y., Koyano, K., 2016. Soft tissue sealing around dental implants based on histological interpretation. J. Prosthodon. Res. 60 (1), 3–11.

Batak, B., Yilmaz, B., Shah, K., Rathi, R., Schimmel, M., Lang, L., 2020. Effect of coded healing abutment height and position on the trueness of digital intraoral implant scans. J. Prosthet. Dent. 123 (3), 466–472.

Burns, J., Palmer, R., Howe, L., Wilson, R., 2003. Accuracy of open tray implant impressions: an in vitro comparison of stock versus custom trays. J. Prosthet. Dent. 89 (3), 250–255.

Cabral, L.M., Guedes, C.G., 2007. Comparative analysis of 4 impression techniques for implants. Implant Dent. 16 (2), 187–194.

Canullo, L., Bignozzi, I., Cocchetto, R., Cristalli, M.P., Iannello, G., 2010. Immediate positioning of a definitive abutment versus repeated abutment replacements in post-extractive implants: 3-year follow-up of a randomised multicentre clinical trial. Eur. J. Oral Implantol. 3 (4), 285–296.

Canullo, L., Colombo, M., Menini, M., Sorge, P., Pesce, P., 2021. Trueness of intraoral scanners considering operator experience and three different implant scenarios: A preliminary report. Int. J. Prosthodont. 34 (2), 250–253.

Christensen, G.J., 2009. Impressions are changing: Deciding on conventional, digital or digital plus in-office milling. J. Amer. Den. Ass. 140 (10), 1301–1304.

Eliasson, A. and A. Ortorp (2012). "The accuracy of an implant impression technique using digitally coded healing abutments." Clin Implant Dent Relat Res **14 Suppl 1**(s1): e30-38.

Ender, A., Mehl, A., 2013. Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision. J. Prosthet. Dent. 109 (2), 121–128.

Faggion Jr., C.M., 2012. Guidelines for reporting pre-clinical in vitro studies on dental materials. J. Evid. Based Dent. Pract. 12 (4), 182–189.

Fluegge, T., Att, W., Metzger, M., Nelson, K., 2017. A novel method to evaluate precision of optical implant impressions with commercial scan bodies-An experimental approach. J. Prosthodont. 26 (1), 34–41.

Flugge, T., van der Meer, W.J., Gonzalez, B.G., Vach, K., Wismeijer, D., Wang, P., 2018. The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. Clin. Oral Implant Res. 29 (Suppl 16), 374–392.

Gimenez, B., Pradies, G., Martinez-Rus, F., Ozcan, M., 2015. Accuracy of two digital implant impression systems based on confocal microscopy with variations in customized software and clinical parameters. Int. J. Oral Maxillofac. Implants 30 (1), 56–64.

Gimenez, B., Ozcan, M., Martinez-Rus, F., Pradies, G., 2015. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. Clin. Implant Dent. Relat. Res. 17 (Suppl 1), e54–e64.

Gimenez-Gonzalez, B., Hassan, B., Ozcan, M., Pradies, G., 2017. An in vitro study of factors influencing the performance of digital intraoral impressions operating on active wavefront sampling technology with multiple implants in the edentulous maxilla. J. Prosthodont. 26 (8), 650–655.

Howell, K.J., McGlumphy, E.A., Drago, C., Knapik, G., 2013. Comparison of the accuracy of Biomet 3i Encode Robocast Technology and conventional implant impression techniques. Int. J. Oral Maxillofac. Implants 28 (1), 228–240.

Imburgia, M., Kois, J., Marino, E., Lerner, H., Mangano, F.G., 2020. Continuous Scan Strategy (CSS): A novel technique to improve the accuracy of intraoral digital impressions. Eur. J. Prosthodont. Restor. Dent. 28 (3), 128–141.

Jorgensen, K.D., 1976. A new method of recording the elastic recovery of dental impression materials. Scand. J. Dent. Res. 84 (3), 175–182.

Jung, H.-T., H.-Y. Kim, S.-Y. Song, J.-H. Park and J.-Y. Lee (2020). "Accuracy of implant impression techniques with a scannable healing abutment." J Prosthet Dent.

Jung, H.-T., H.-Y. Kim, S.-Y. Song, J.-H. Park and J.-Y. Lee (2020) "Accuracy of implant impression techniques with a scannable healing abutment." J Prosthet Dent DOI: .

Kattadiyil, M.T., AlHelal, A., 2017. An update on computer-engineered complete dentures: A systematic review on clinical outcomes. J. Prosthet. Dent. 117 (4), 478–485.

Khurshid, Z., Tariq, R., Asiri, F.Y., Abid, K., Zafar, M.S., 2021. Literature search strategies in dental education and research. J. Taibah Univ. Med. Sci. 16 (6), 799–806.

Lee, H., So, J.S., Hochstedler, J.L., Ercoli, C., 2008. The accuracy of implant impressions: a systematic review. J. Prosthet. Dent. 100 (4), 285–291.

Mangano, F.G., Hauschild, U., Veronesi, G., Imburgia, M., Mangano, C., Admakin, O., 2019. Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study. BMC Oral Health 19 (1), 101.

Meyer, B.J., Mormann, W.H., Lutz, F., 1990. Optimization of the powder application in the Cerec method with environment-friendly propellant systems. Schweiz. Monatsschr. Zahnmed. 100 (12), 1462–1468.

Michelinakis, G., Apostolakis, D., Tsagarakis, A., Kourakis, G., Pavlakis, E., 2020. A comparison of accuracy of 3 intraoral scanners: A single-blinded in vitro study. J. Prosthet. Dent. 124 (5), 581–588.

Michelinakis, G., Apostolakis, D., Kamposiora, P., Papavasiliou, G., Ozcan, M., 2021. The direct digital workflow in fixed implant prosthodontics: a narrative review. BMC Oral Health 21 (1), 37.

Mizumoto, R.M., Yilmaz, B., McGlumphy Jr., E.A., Seidt, J., Johnston, W.M., 2020. Accuracy of different digital scanning techniques and scan bodies for complete-arch implant-supported prostheses. J. Prosthet. Dent. 123 (1), 96–104.

Moreira, A.H., Rodrigues, N.F., Pinho, A.C., Fonseca, J.C., Vilaca, J. L., 2015. Accuracy comparison of implant impression techniques: A systematic review. Clin. Implant Dent. Relat. Res. 17 (Suppl 2), e751–e764.

Moslemion, M., Payaminia, L., Jalali, H., Alikhasi, M., 2020. Do type and shape of scan bodies affect accuracy and time of digital implant impressions? Eur. J. Prosthodont. Restor. Dent. 28 (1), 18–27.

Najeeb, S., Zafar, M.S., Khurshid, Z., Siddiqui, F., 2016. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J. Prosthodont. Res. 60 (1), 12–19.

Ng, S.D., Tan, K.B., Teoh, K.H., Cheng, A.C., Nicholls, J.I., 2014. Three-dimensional accuracy of a digitally coded healing abutment implant impression system. Int. J. Oral Maxillofac. Implants 29 (4), 927–936.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T. C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hrobjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372, n71.

Papaspyridakos, P., Gallucci, G.O., Chen, C.J., Hanssen, S., Naert, I., Vandenberghe, B., 2016. Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin. Oral Implant Res. 27 (4), 465–472.

Papaspyridakos, P., Vazouras, K., Chen, Y.W., Kotina, E., Natto, Z., Kang, K., Chochlidakis, K., 2020. Digital vs conventional implant impressions: A systematic review and meta-analysis. J. Prosthodont. 29 (8), 660–678.

Pesce, P., Bagnasco, F., Pancini, N., Colombo, M., Canullo, L., Pera, F., Bressan, E., Annunziata, M., Menini, M., 2021. Trueness of intraoral scanners in implant-supported rehabilitations: An in vitro analysis on the effect of operators' experience and implant number. J. Clin. Med. 10 (24).

Pozzi, A., Arcuri, L., Lio, F., Papa, A., Nardi, A., Londono, J., 2022. Accuracy of complete-arch digital implant impression with or without scanbody splinting: An in vitro study. J. Dent. 119, 104072.

Rhee, Y.K., Huh, Y.H., Cho, L.R., Park, C.J., 2015. Comparison of intraoral scanning and conventional impression techniques using 3-dimensional superimposition. J. Adv. Prosthodont. 7 (6), 460–467.

Rutkunas, V., A. Geciauskaite, D. Jegelevicius and M. Vaitiekunas (2017). "Accuracy of digital implant impressions with intraoral scanners. A systematic review." Eur J Oral Implantol **10 Suppl 1** (Suppl 1): 101-120.

Skirbutis, G., Dzingute, A., Masiliunaite, V., Sulcaite, G., Zilinskas, J., 2017. A review of PEEK polymer's properties and its use in prosthodontics. Stomatologija 19 (1), 19–23.

Vigolo, P., Fonzi, F., Majzoub, Z., Cordioli, G., 2004. An evaluation of impression techniques for multiple internal connection implant prostheses. J. Prosthet. Dent. 92 (5), 470–476.

Wee, A.G., 2000. Comparison of impression materials for direct multi-implant impressions. J. Prosthet. Dent. 83 (3), 323–331.

Zhang, Y.J., Shi, J.Y., Qian, S.J., Qiao, S.C., Lai, H.C., 2021. Accuracy of full-arch digital implant impressions taken using intraoral scanners and related variables: A systematic review. Int. J. Oral Implantol. (Berl.) 14 (2), 157–179.

Zimmer Biomet. (2019). ''Bellatek encode impression system.'' Retrieved 23 February, 2022, from https://www.zimvie.lat/content/dam/zimvie-corporate/en/products/manuals.

Zimmer Biomet. (2022). ''Encode emergence impression system.'' Retrieved 11 July, 2022, from https://www.zimvie.com/content/dam/zimvie-corporate/en/products/dental-products/encode-emergence-impression.