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SYSTEMATIC REVIEW

Assessment of Accuracy in Scanning Intracoronal Preparations with Different Intraoral Scanners : A Systematic Review

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ABSTRACT

Background: There are no systematic reviews on assessing the accuracy of intraoral scanners in scanning the intracoronal preparations, so this systematic review aims to assess the accurate intraoral scanner in scanning intracoronal preparations aiming to assist Dental professionals in producing improved fit of inlays, onlays and endocrowns.

Aim: The objective of this Systematic Review is to assess the Accuracy of different intraoral scanners in capturing images of intracoronal preparations like inlays, onlays, and endocrowns.

Materials and Method: Literature searches were performed up to April 2024 in Cochrane, PubMed, web of science, Google scholar, Embase, Scopus, databases. Article selection was determined by adherence to inclusion criteria being 1) in vitro studies 2) Randomized controlled clinical Trials 3) studies using single or multiple intraoral scanners 4) articles published in english and exclusion criteria being 1) all animal studies 2) narrative reviews and expert opinion 3) letters to the editors 4) conference abstracts 5) systematic review and meta analysis. QUADAS-2 tool was employed for in vivo studies and QUIN Tool employed for in vitro studies.

Results: 20 studies out of 10,666 Potentially pertinent records were incorporated into the qualitative synthesis. Eleven in vitro studies and one in vivo study account Trios has better Trueness and Precision where as Six in vitro studies interpret trueness and precision of CEREC® Primescan and five studies infer that Carestream CS3500 has improved trueness and precision.

Conclusion: This systematic review indicates that the Trios (3Shape) intraoral scanner demonstrates superior accuracy compared to other intraoral scanners, with CEREC® Primescan intraoral scanner following closely behind, particularly in terms of trueness and accuracy. Various additional factors should be taken into account, such as the size of the preparation, tooth location, presence of saliva, and operator's experience, all of which exert a significant influence on the accuracy of intraoral scanners. Further research and development of these intraoral scanners must be conducted for further clinical settings.

Keywords: Intraoral scanners, Trueness, Precision, Intracoronal preparations, Systematic Review.

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INTRODUCTION

Success of any indirect restoration depends on a precise impression. The predictability of the fit of indirect restorations through conventional means of physical impressions has been proved to be highly

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successful accurate and documented well in literature.[1,2] In the contemporary digital age, traditional techniques are being supplemented by intraoral scanners. The adoption of intraoral scanners ensures commendable clinical accuracy, diminishes variability dependent on operators, shortens treatment duration, and enhances patient compliance.[3] Digital impressions are gaining increasing popularity and acceptance among clinicians compared to conventional impressions. The advantages of digital impressions include a three-dimensional previsualization of the preparation and a reduction in working time. Additionally, digital impressions electronically store information, allowing for data retrieval without any distortion. [4]

Marginal fit and accuracy are the crucial factors for extracoronal restorations. Studies have proved that the indirect restorations (extracoronal preparations [5] & intracoronal[6]) fabricated using intraoral scanning and Computer Aided Design /Computer Aided Manufacturing technology have proved to have accurate fit within the clinically acceptable marginal and internal fit when compared to conventional technique of fabrication.

The occurrence of discrepancies in intraoral scanning may be associated with factors such as the digitizing environment, scanning strategies, and data processing.[7] A range of technologies has been employed to generate virtual images, and their application varies depending on the scanned tissue, the specific device used, and its clinical application. Studies reveal that extracoronal preparations showed statistically significant trueness & precision when compared to intracoronal preparations.[8] Hence, the outcomes remain contentious, and the true clinical accuracy offered by these technologies may not be reliably replicated in a single study.

Considerable research has been undertaken on digital prosthetic workflows, with a particular focus on intracoronal preparations. He accuracy and precision of IOS in intracoronal preparation designs varies due to factors such as depth, width, and divergence of the cavity preparation.

Trueness represents the deviation of the measured value from the actual value, whereas precision describes the deviation among repeatedly measured values. Both of them together termed as Accuracy[9].

There is no literature evidence as to which intraoral scanner is accurate in scanning the intracoronal preparations is available. An accurate intraoral scanner in scanning intracoronal preparations should be appraised aiming to assist Dental professionals in producing improved fit of inlays, onlays and endocrowns. Compiled factors affecting the scanning of intracoronal preparations using intraoral scanners is necessary.

The aim of this systematic review was to assess the accuracy of intraoral scanners specifically in the context of intracoronal preparations like inlay, onlay and endocrowns. Secondary objective being, to assess the most accurate intraoral scanner in reproducing details of the intracoronal preparations.

MATERIAL AND METHODS

1.1. Search strategy

The design of this systematic review adhered to the recommendations outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [10]. A protocol was determined before the literature search and registered on the Open Science Framework (OSF) available at available at 10.17605/OSF.IO/DK9G5.

The population, intervention, comparison, and outcome (PICO) question was as follows (Table1):

The PubMed/MEDLINE, Web of Science, Cochrane, Google Scholar, Embase, and Scopus databases were utilized to identify potentially relevant studies up to April 2024 (last search update) The search strategy was independently executed by two of the authors, (H D, T S) And compromised specific medical subject headings

Table 1: PICO for this Systematic Review

P	Intracoronal preparations (inlays, onlays, endocrowns)
I	Intraoral scanners.
C	Lab scanners
O	Accuracy, trueness & precision of intraoral scanners.

Table 2: MeSH Terms

P	(“intracoronal*” OR “onlay*” OR “inlay*” OR “endocrown*” OR “overlay*” OR “table top*” OR “mesiodistal*” OR “mesio-disto-occlusal*”)
I	(“Trios*” OR “iTero*” OR “planscan*” OR “CS 600*” OR “CEREC Omnicam*” OR “True definition*” OR “DWIS*” OR “E4D*” OR “lava COS system*” OR “fastscan*” OR “CS 3500R*” OR “CEREC Bluecam*” OR “3D Progress*” OR “lythos*” OR “prime scan*”)
C	(“Confocal imaging*” OR “ultrafast optical sectioning*” OR “stripe light projection*” OR “active wavefront*” OR “parallel confocal microscopy*” OR “optical coherence tomography*” OR “confocal microscopy & moireé effect*” OR “confocal microscopy & active triangulation*” OR “active triangulation*” OR “confocal microscopy & ultrafast optical scanning*” OR “confocal microscopy*” OR “optical triangulation & confocal microscopy*” OR “confocal microscopy & optical coherence microscopy*” OR “confocal microscopy & optical triangulation*” OR “parallel confocal imaging*” OR “video scanning& triangulation*” OR “ultrafast optical sectioning*” OR “active wavefront sampling*” OR “interferometry*” OR “triangulation of light*” OR “accordion fringe interferometry*”
O	(“Accuracy*” OR “Trueness*” OR “Precision*” OR “marginal fit*”)

Table 3:Inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
In vitro and in vivo studies	All animal studies
Randomized clinical trials	Narrative reviews and expert opinions
Studies using single or multiple intraoral scanners	Letters to the editor
Articles published in English	Conference abstracts
	Systematic reviews and meta-analysis

Table 4: Data extraction of the included articles.

S. No	TITLE	AUTHOR	JOURNAL	YEAR	STUDY TYPE	SAMPLE SIZE+ GENDER	PARAMETER COMPARED	ARCH+ TYPE OF INTRACORONAL RESTORATION	SCANNER USED
1.	Impact of digital impression techniques on the adaptation of ceramic partial crowns [11]	Oliver Schaefer et al.	JOD	2014	. In vitro	-	Compared the marginal& internal fit of different IOS by superimposition	1.mandibular 1st molar (acrylic model). 2. Inlay.	1)I TERO 2)Cara TRIOS 3)CEREC AC 4) lava chairside oral scanner
2.	Comparative analysis on reproducibility among 5 intraoral scanners: sectional analysis according to restoration type & preparation outline form [12]	Ji-man Park	JAP	2016	invitro	Total 60 impressions 6 IOS (10 /Group)	Trueness Precision Reproducibility (superimposition)	Tooth no=17 MO Inlay	1)iTero 1st gen. 2)E4D dentist 3)Zfx intrascan 4)trios 2nd gen. 5) Fastscan 6) trios
3.	Evaluation of the accuracy & precision of four intraoral scanners with 70% reduced inlay & four-unit bridge models of international standard [13]	Soo-hyuk UHM et al	Dental material journal	2016	In vitro	30 scans per model	Accuracy Precision	--	1.Carestream dental 2.Trios 3. CEREC Bluecam 4. CEREC Omnicam
4.	Accuracy of three digitization methods for the dental arch with various tooth preparation designs: An in vitro study [14]	Kyung Chul oh et al	Journal of Prosthodontics	2018	In vitro	Total=30 impressions 1.DS=10 2.CS=10 3.IS=10	Trueness Precision (Both by superimposition)	1.17 tooth= DO inlay 2.15 tooth= full coverage crown prep. 3.27&25 FPD tooth prep.	1)Carestream dental 2)ATOS triple scan (industrial optical scanner)
5.	Comparing the accuracy (trueness & precision) of models of fixed dental prostheses fabricated by digital & conventional workflows[15]	Ji- young sim et al	Journal of prosthodontic research	2018	In vitro	24 models 1-stone model=8 2-digital model=8 3- 3D printed model=8	Trueness Precision (superimposition)	16- single crown 26- inlay 14 & 16- 3-unit bridge	Carestream dental
6	Trueness and Precision of Two Intraoral Scanners: A Comparative In Vitro Study [16]	Raul Nicolae Rotar et al	Wiley	2019	In vitro	10 scans	Trueness Precision (both by superimposition)	Tooth no.16 for ceramic onlay	1.Planmeca planscan 2.Cerec Omnicam
7.	Local accuracy of actual intraoral	Moritz Zimmermann et al	Jada	2019	In vitro	Total= 80 impressions (10/ group)	Accuracy (by superimposition) Trueness	1.Tooth no. 41 &46- full contour crowns. 2.tooth no. 44-MOD inlay	1.Carestream 2.iTero 3.Medit I 500 4.Cerec Omnicam

S. No	TITLE	AUTHOR	JOURNAL	YEAR	STUDY TYPE	SAMPLE SIZE+ GENDER	PARAMETER COMPARED	ARCH+ TYPE OF INTRACORONAL RESTORATION	SCANNER USED
	scanning systems for single-tooth preparations in vitro [17]						Precision	3. tooth no. 36-MO inlay	5.Primescan 6.Trios 3(in same speed) 7.Trios (normal speed)
8.	Comparative reproducibility analysis of 6 intraoral scanners used on complex intracoronal preparations [18]	Ji-man Park et al	JPD	2019	In vitro	30 scans (5/ group)	Trueness Precision (by superimposition)	Tooth no. 14or24+ occlusal prep. Tooth no.=26or16=MO Tooth no. 17or27= MOD Tooth no. 3or 45=MOD with lingual reduction Tooth no.= 36 or 46= Bucco-occlusal prep	1.CEREC Omnicam 2.E4D 3.Fastscan 4.Itero 5.Trios 6.Zfx intrascan
9.	Accuracy of four different intraoral scanners according to different preparation geometries. [19]	Alexander Schmidt et at.	IJOP	2020	invitro		Trueness Precision (Both by superimposition)	Maxillary model 1.15- full crown with margin chamfer. 2.11- veneer with chamfer 3.24-inlay (MOD). 4.26-onlay with occlusal chamfer	1)trios 2 2) Omnicam 3) true definition 4)primescan
10.	Trueness of intraoral scanners in digitizing specific locations at the margin & intaglio surfaces of intracoronal preparations [20]	Ryan Jin-young et al	JPD	2020	In vitro	30 scans (5 scans/ IOS)	Trueness (superimposition)	5 posterior Teeth. 1-14= occlusal prep. 2-16/26+17/27=MO prep. 3- mandi 1st premolar=MOD + lingual prep. 4-Mandible. 1st molar= BO prep.	1.CEREC Omnicam 2.E4D 3.fastscan 4.itero 5.trios 6.zfx intrascan
11.	Influence of tooth preparation design and scan angulations on the accuracy of two intraoral digital scanners: an invitro study based on 3-Dimensional comparisons [21]	Rami Ammoun et al	Journal of prosthodontics	2020	In vitro	8 teeth preps. 1.partial coverage=4 2. full coverage=4	Accuracy (superimposition)	1)MOL ceramic onlay 2)MoD ceramic inlay 3)veneer	1.True definition 2. trios
12.	Influence of Preparation Type and Tooth Geometry on the Accuracy of Different Intraoral Scanners [8]	Yasmine Ashraf et al	Journal of prosthodontics	2020	In vitro	120 scans. -4 types of preparations Scanned 10 times with each IOS	Trueness & precision (superimposition)	4 mandi. 1st molars	1.CEREC AC Omnicam 2.Trios 3.Medit i500
13.	In vitro analysis of intraoral digital impression of inlay	Jae- Hoon Kim et al	Journal of Prosthodontic research.	2020	In vitro	80 scans. -4 types of preparations -Scanned 10 times with each IOS	Trueness & precision (superimposition)	16- MO- short, MO-long, DO-short, DO-long. 46- MO- short, MO-long, DO-short, DO-long.	1.CEREC Primescan AC.

S. No	TITLE	AUTHOR	JOURNAL	YEAR	STUDY TYPE	SAMPLE SIZE+ GENDER	PARAMETER COMPARED	ARCH+ TYPE OF INTRACORONAL RESTORATION	SCANNER USED
	preparation according to tooth location and cavity type. [22]								
14.	Influence of different inlay configurations & distance from the adjacent tooth on the accuracy of an Intraoral scan. [23]	Sung-ae son et al	JPD	2021	In vitro	4 teeth Total scans=40 (10/teeth)	Trueness Precision (by superimposition)	Tooth no.=46 DO Inlay	1.CEREC 2.primescan
15.	Influence of adjacent teeth on the accuracy of intraoral scanning system for class II inlay preparation [24]	Jae- Hoon Kim et al	Journal of aesthetic restorative dentistry	2021	In vitro	30 scans 1)Cerec primescan=10 2) trios 3 = 10 3) Medit I 500 = 10	Trueness of IOS & precision with/ without the adjacent teeth present (superimposition)	MOD inlay prep. On 16	1)CEREC primescan 2) TRIOS 3 3) Medit i500
16.	Impact of different complete coverage onlay preparation designs and the intraoral scanner on the accuracy of digital scans [25]	Guilherme Schmitt et al	JPD	2022	In vitro	90 scans 1.ELE=30 2. TRI=30 3. PRIMESCAN =30	Trueness & precision (superimposition)	Complete coverage onlay On right mandi. Hemi arch.	1)iTero 2) trios 3 3) primescan
17.	Effect of preparation type on the accuracy of different intraoral scanners: An in vitro study at different levels of accuracy evaluation [26]	Jaafar Abduo et al	Journal of Esthetic and Restorative Dentistry	2022	In vitro	120 scans; 3 designs 1. OC-3x10=30 2. MT-3x10=30 3. TS-3x10=30	Trueness & precision (superimposition)	On 16 – inlay, onlay, crown	1) CEREC Omnicam (OC) 2) Medit i500 (MT) 3) Trios 3 (TS)
18.	Scanning accuracy of an intraoral scanner according to different inlay preparation designs [27]	Yeri Park et al	BMC Oral health	2023	In vitro	40 scans; 4 designs 1. CEREC Prime scan AC	Trueness & precision (superimposition)	On 36- inlay MO- narrow shallow, narrow deep, wide shallow, wide deep.	1) CEREC Prime scan AC
19.	Application of 3D digital scanning and CAD/CAM systems for zirconia indirect restorations [28]	Mariela Tsanova et al	Journal of IMAB	2016	in vivo	10 restorations on 5 patients (2 on each) Age- between 18 & 65 years	Manufacturing CAD/CAM zirconia indirect restorations	--	Trios 3
20.	Evaluation of clinical success & marginal adaptations of	Can Metiner et al.	International journal of computerized dentistry	2021	In vivo	24 pt.-(F=13 & M=11)	1)Marginal adaptation of partial crowns.	33 onlays 15 overlays 12 inlay restoration	1.Trios 2.Cerec Omnicam

S. No	TITLE	AUTHOR	JOURNAL	YEAR	STUDY TYPE	SAMPLE SIZE+ GENDER	PARAMETER COMPARED	ARCH+ TYPE OF INTRACORONAL RESTORATION	SCANNER USED
	inlay & onlay restorations manufactured after conventional & digital impressions: a prospective randomized controlled clinical study [29]					Total 30 mandi teeth =30 maxi. Teeth.	2)Clinical performance (photograph)		

Table 4: Data extraction of the included articles.

S.NO	SCANNER DESIGN	POWDER/ POWDER FREE	CONTROL GROUP	STATISTICAL DATA	OUTCOME/ INFERENCE
1.	1) confocal imaging 2) ultrafast optical sectioning 3) stripe-light projection 4) active wavefront [11]	1) powder free 2) powder free 3) powdering 4)powdering	Optical reference scanner	Mean marginal fit - lowest for iTero =90 degrees. Internal fit lowest for Cerec with Bluecam. TEST: Shapiro-Wilk's test & Levene's test Significance: P< 0.05	Marginal &internal fit of iTero& trios> than CBC, COS. 2) confocal imaging& ultrafast optical sectioning>. 3) All the results were under clinically acceptable limits. 4) powdered free IOS has better reproducibility than the powdered
2.	1.parallel confocal microscopy 2.optical coherence tomography 3. confocal microscopy & Moireé effect 4.confocal microscopy& active triangulation 5. active triangulation 6. confocal microscopy & ultrafast optical scanning [12]	--	Reference scanner- Dental wings	Trueness of fast scan (45.1±28.5) > E4D (112.7±82.4) TEST: 2 sample t test & analysis of variance Sig: alpha = 0.05	1.fastscan>iTero>Fastscan (trueness &precision) 2) deviation was more E4D & Zfx 3)using powder displayed higher trueness & accuracy 3)iTero> E4D> Zfx 4) active triangulation has better trueness 5) optical coherence tomography has better resolution.
3.	1)Active triangulation 2)confocal microscopy & ultrafast optical scanning 3)Confocal microscopy 4. optical triangulation & confocal microscopy [13]	--	Lab scanner- Ceramil Map 400	Trueness of CS3500, trios (0.009)> Bluecam (0.017) Precision of CS3500& TRIOS (0.012)> Bluecam (0.021) TEST: 1 way ANOVA, post hoc- Scheffe's test. Sig: (P< 0.05)	1.CS3500&trios showed highest accuracy& precision 2.Highest angulation errors observed in Omnicam
4.	Active triangulation [14]	-	ATOS- triple scan	1.Cs>DS& IP 2.27 area had more deviation than first (138.76±38.19) quadrant side. 3. the more posterior scan is req. more deviation observed. 15 teeth had a trueness of (70.62± 13.620) TEST: Kruskal-Walli's test, Shapiro-wilk test Sig: alpha= 0.05	1.Carestream showed least trueness & precision 2. industrial scanner showed better trueness& precision.
5.	Active triangulation [15]	--	Reference model preparation & scanned with Comet L3D	Trueness of stone model (28.49±1.74)> 3D printing (55.16±2.70) Precision of stone model (22.79±5.76) > 3D printing (54.93±8.44) TEST: Shapiro wilk, Levene's test post hoc Tukey honest & 1	Conventional models>digital models

S.NO	SCANNER DESIGN	POWDER/ POWDER FREE	CONTROL GROUP	STATISTICAL DATA	OUTCOME/ INFERENCE
				way ANOVA Sig: alpha = 0.05	
6.	1.confocal microscopy& optical coherence microscopy. 2.confocal microscopy & optical triangulation [16]	1) powder free 2) powder free	Desktop scanner- D700 (3 Shape)	1.Mean trueness of planscan= 48.6±4.39 2.mean value of planscan is better (24.86±2.91) TEST: Kolmogorov-Smirnov test Sig: (P> 0.05)	1. Planmeca PlanScan was better than Omnicam in terms of trueness and precision 2)there was no significant difference in between both the scanners in terms of accuracy
7.	1. active triangulation 2.parallel confocal imaging 3.video scanning & triangulation 4.confocal microscopy& active triangulation 5. confocal microscopy 6.confocal microscopy & ultrafast optical scanning 7.confocal microscopy & ultra-fast optical scanning [17]	-	PVS impression	**Mean trueness** for PS=18.7> Trin= 22.6> Tri=23.6 **Mean precision** for PS=8.3> Medit=13.6> Trin=14.0 TEST: Kruskal-Walli's test Sig: P <0.05	1.Marginal preparation showed more deviation than surface preparation 2.IOS has higher accuracy for surface parameter 3. no significant difference in trueness & precision
8.	1. confocal microscopy & active triangulation 2.optical coherence tomography 3. active triangulation 4. parallel confocal imaging 5.confocal microscopy & active triangulation 6. confocal microscopy & Moireé effect [18]	--	Desktop scanner- Sensible S3; MEDIT	Trueness of trios= 24.4 micro met.)> E4D (44.1) Precision- trios (7.0 micrometre.)> E4D (37.7 micro met.) TEST: Kolmogorov-Smirnov test, Kruskal-Walli's test Sig: trueness- (P< 0.05) Precision – (P> 0.05)	1) optical coherence tomography has higher trueness. 2) active triangulation has lower trueness 3)Trios> Cerec Omnicam>iTero>fast scan>Zfx>E4D 4) no significant difference in precision values. 5)E4D has the highest deviation
9.	1) ultrafast optical sectioning 2)confocal microscopy & active triangulation 3) active wavefront sampling 4) confocal microscopy [19]	3) powdered	Industrial lab scanner: ATOS core GOM.	positive deviation of TR (4.6±0.7 micrometre)> OC (25.9±2.4 micrometre)	1) TR, PS> for accuracy (veneer &full crowns) 2) highest precision for all preparations by primescan 3)PS, TD> for precision.
10.	1.Confocal microscopy 2. optical coherence tomography 3. active triangulation 4. parallel confocal imaging 5.confocal microscopy 6. confocal microscopy with Moireé effect [20]	--	PVS impression	Mean trueness for trios (23.9 micro met.) > E4D (77.5 micro met.) TEST: Kruskal-Walli's test& multiple Mann- Whitney Sig: alpha= 0.05	Trios> than the other IOS
11.	1) active wavefront sampling 2) confocal microscopy & ultrafast optical scanning [21]	1.powdered 2. powder less	Desktop scanner- D900L, 3 Shape	Trueness of TRI= (15.5±2.7) micro met. Trueness of TRU =22.0±3.6 micro met.) TEST: 2-way ANOVA, post hoc- Tukey HSD. Sig: (P<0.001)	1.Complete coverage crowns>partial coverage 2.Trios> true def.
12.	1) Confocal microscopy 2) confocal microscopy with ultrafast optical scanning 3) video scanning & triangulation [8]	No powder used.	Reference scanner- INEOS X5	Trueness of Trios (35.70±14.12 micro met.) > Omnicam (57.83±22.14 micro met.) TEST: 1 way ANOVA & 3-way ANOVA Sig: (P<0.001)	Trios, Medit i500> Cerec
13.	1) confocal microscopy [22]	-	Reference scanner-E3 3shape.	Trueness for MO-short - 10.03 ± 0.25 > DO- long – 10.32± 0.23 for 16 Trueness for DO- long – 12.05±0.32 > DO-short – 12.28±0.54 for 46. Precision for MO- short – 2.78 ±0.38 > DO-short – 2.81±0.42 for 16.	1) trueness of 16 better compared to 46 2) precision is similar in both 16 and 46.

S.NO	SCANNER DESIGN	POWDER/ POWDER FREE	CONTROL GROUP	STATISTICAL DATA	OUTCOME/ INFERENCE
				Precision for DO- long – 2.68±0.43> MO -long- 2.99±0.65 for 46	
14.	1. confocal microscopy 2. confocal microscopy [23]	-	Reference scanner- 3 Shape E3	Trueness of wide short (12.1 ±0.4)> narrow long (9.5 ±0.5) Precision of wide long (3.0 ±0.3)> narrow long (3.6 ±0.6) TEST: 2-way Anova & Bonferroni multiple comparison test. Sig: alpha = 0.05	1)As interproximal distance Increases the trueness increases As interproximal distance increase, the trueness decreases. 2.narrow, long group showed better trueness. 3. primescan had higher precision & trueness
15.	1) confocal microscopy 2) confocal microscopy with ultrafast optical scanning 3) video scanning & triangulation [24]	--	Lab scanner- 3Shape E3	Average deviation for precision for prime scan (3.74±0.60) > trios (4.95±0.30) TEST: 2 sample t test, 2-way ANOVA Tukey's HSD Sig: (P<0.05)	Performance of primescan was superior than TRIOS 3 & Medit i500
16.	1) confocal imaging. 2) confocal microscopy with ultrafast optical scanning 3) confocal microscopy [25]	--	Epoxy resin impression-> model poured-> scanned using desktop scanner- INEOS Blue	Trueness for trios (3.122 micro met.) > ELE (13.135 micro met.) Precision for trios (3.894 micro met.) > PRI (4.536 micro met) TEST: Shapiro- wilk's test, Kruskal Walli's test, Dunn test. Sig: (P< 0.001)	IOS's trios & prime scan had the best accuracy; however, all measured values were clinically acceptable
17.	1) Confocal imaging. 2) Video scanning & triangulation 3) Confocal microscopy with ultrafast optical scanning [26]	-	Reference (Identica) T300, Medit (Identica)	Trueness (inlay)- MT (3.2)>OC (6)> TS (9.5) (onlay) – TS (2.3)> MT (5.2)> OC (9.1) Precision (inlay)- TS (5.9)> OC (6.9)> MT (13.2) (onlay) – TS (2.8)> MT (13.3)> OC (16.8)	1) The smaller and less complex preparations have greater IOS accuracy than larger and more complex preparations. 2) Trios was better for inlay and onlay preparations.
18.	Confocal microscopy [27]	-	Reference scanner (3Shape E3; 3Shape)	Trueness- wide deep (18.56±1.48)> wide shallow (19.46±1.76) Precision- narrow shallow (4.24±0.79)> wide shallow (4.57±1.39)	Lowest deviation in the wide-deep group for trueness and for the precision, the narrow-shallow group showed the lowest average deviation.
19.	Confocal microscopy with ultrafast optical scanning [28]	--		--	CAD software requires excellent preparation of the tooth cavity & digital scanning
20.	1.Confocal microscopy with ultrafast optical scanning 2. confocal microscopy& active Triangulation [29]	--	PVS impression	Trios (90.16±2.04)> CEREC (90.22±1.82) TEST: paired sample t test, one way ANOVA. Sig: P <0.05	Digital impressions> conventional

Table 5: Principles of different intraoral scanners

S. No	INTRAORAL SCANNER	WORKING PRINCIPLE	DESCRIPTION	MANUFACTURING COMPANY	COUNTRY	RECENT PRODUCT	VERSION (YEAR)	AVAILABILITY IN INDIA
1.	Trios	Confocal microscopy.	Laser beam is used as the light source in confocal microscopy. Laser provides intense and focused illumination, typically at a single wavelength,	3 Shape	Copenhagen, Denmark.	Trios 5	2022	Yes

S. No	INTRAORAL SCANNER	WORKING PRINCIPLE	DESCRIPTION	MANUFACTURING COMPANY	COUNTRY	RECENT PRODUCT	VERSION (YEAR)	AVAILABILITY IN INDIA
			allowing precise excitation of fluorescent dyes or reflection from the sample.					
2.	Cerec primescan	Confocal microscopy and active triangulation	Active triangulation involves projecting a known light pattern (such as a laser dot or line) onto a surface, then measuring the reflected light from a different angle. This technique determines the distance or shape of an object based on geometric triangulation.	Dentsply Sirona	Charlotte, North Carolina	Primescan 2	2024	No
3.	Cerec Bluecam	LED with active triangulation	It works on the principle of electroluminescence, where light is produced by the recombination of electrons and holes in a semiconductor material.	Dentsply Sirona	Charlotte, North Carolina	CEREC Bluecam	2009	No
4.	Fastscan	Active triangulation with sheet of light projection	The scanner projects structured light patterns, such as grids or stripes, onto the surfaces of the teeth and surrounding oral structures. These light patterns can be emitted from a light source such as an LED or laser within the scanner.	Glidewell and Medit	Glidewell- New Port beach, California. Medit- Seoul, South Korea	Medit i900	2024	Yes
5.	E4D	Optical coherence tomography.	It is a non-invasive imaging technique that captures high-resolution, cross-sectional images of biological tissues. OCT works on the principle of low-coherence interferometry to produce detailed images of tissue microstructures, often at the micrometer scale.	Planmeca	Helsinki, Finland	E4D Nevo Scanner	2014	No
6.	iTero	Parallel confocal imaging.	Enables faster image acquisition by scanning multiple points simultaneously rather than scanning a single point at a time. It utilizes high-resolution optical sectioning and rejection of out-of-focus light, but significantly increases imaging speed.	Align Technology	San Jose, California, United States	iTero Lumina Scanner	2024	Yes

S. No	INTRAORAL SCANNER	WORKING PRINCIPLE	DESCRIPTION	MANUFACTURING COMPANY	COUNTRY	RECENT PRODUCT	VERSION (YEAR)	AVAILABILITY IN INDIA
7.	LAVA C.O. S	Active wavefront sampling	Optical imaging technique that captures high-resolution information about the wavefront of light reflected or emitted from an object. Involves sampling the light wavefront at multiple points to determine its structure, enabling correction of optical aberrations or distortions.	3 M	St. Paul, Minnesota, United States	LAVA C.O. S	2011	Yes
8.	True definition	Active wavefront sampling with structured light projection.	combines the principles of wavefront sensing and structured light projection to capture detailed 3D information about an object's surface while also compensating for optical aberrations. Has improved accuracy and depth resolution by dynamically sampling the wavefront and projecting patterned light onto the object.	3M	St. Paul, Minnesota, United States	True definition scanner	2014	Yes
9.	CS 3500 Carestream	Confocal laser scanner microscopy.	Employs a laser to scan across the sample, capturing information from specific focal planes, and eliminating out-of-focus light. The working principle of CLSM involves point-by-point scanning, confocal pinhole filtering, and optical sectioning.	Carestream Dental	Atlanta, Georgia, United states	CS 3800	2021	Yes
10.	Lythos	Accordion fringe interferometry.	This method is based on the principles of interferometry, where the interference patterns created by overlapping coherent light beams provide valuable information about the optical path length differences due to displacement or surface variations.	KaVo Dental	Biberach an der Riss, Germany	KaVo ProXam Intraoral scanner	2023	Yes
11.	3 D progress	Confocal scanning microscopy with Moiré pattern detector.	This method leverages the interference patterns created by overlapping grids (or patterns) to enhance the measurement of surface	3D Progress	Italy	3D Progress IOS	2015	No

S. No	INTRAORAL SCANNER	WORKING PRINCIPLE	DESCRIPTION	MANUFACTURING COMPANY	COUNTRY	RECENT PRODUCT	VERSION (YEAR)	AVAILABILITY IN INDIA
			topography and other fine details.					
12.	CEREC Omnicam	Combination of optical triangulation and confocal microscopy technology.	A coherent light source, typically a laser, is used to illuminate the sample. The laser provides a focused beam of light necessary for both triangulation and confocal imaging. The laser beam is directed onto the sample surface, creating a visible spot or line.	Dentsply Sirona	Charlotte, North Carolina	Cerec Omnicam	2013	Yes

(MeSH) & key words ("free-text words). The search strategy, described in (Table 2), was adapted and the results were cross-checked to eliminate duplicates.

All the articles that contained the search terms were collected and uploaded in Rayyan software.

Where the duplicates among them were deleted through the software and in the initial step, studies were chosen based on title and abstract analysis using the following inclusion criteria (Table 3): 1) in vivo and in vitro studies, 2) randomized clinical trials, 3) studies employing single or multiple intraoral scanners, and 4) articles published in English.

Exclusions were made based on the following criteria: 1) all animal studies, 2) narrative reviews and expert opinions, 3) letters to the editor, 4) conference abstracts, 5) systematic reviews and meta-analyses, and 6) articles published in foreign languages.

Any disagreements among the reviewers were resolved through discussion and the judgment of a third reviewer (L S). Final included articles were formulated after full text analysis. After the full text analysis, few articles were excluded with reasons. Final included articles were subjected to qualitative analysis.

Thorough data analyses were qualitatively conducted, providing a descriptive summary for each included study was conducted, as illustrated in (Table 4). Following this, an individual assessment of the risk of bias was performed for each article included in this study.

The assessment of the risk of bias (ROB) for the included studies was conducted in accordance with previous research [18, 30,27] and took into account the following parameters: sample size calculation, randomization of the specimens; specimen preparation described in a reproducible way; specimen preparation by single operator & adequate explanation of the test parameters utilized to assess the outcomes, encompassing both accuracy and precision.

The risk of bias was assessed for both in vitro and in vivo studies. For in vivo studies, the QUADAS-2 tool [32], developed by the University of Bristol, was employed which contains four domains. Domain1 indicates patient selection which comprises of set of questions as to how the patient was selected for their research in that particular study. Domain 2 indicates index test which includes set of questions regarding objective of the study, Domain 3 indicates reference standards and Domain 4 indicates flow and timing of the study. For invitro studies QUIN Tool [31] was used, QUIN tool consisted of a set of 12 criterions, like if the particular included study has clearly stated aims/objectives, if detailed explanation of sample size calculation was mentioned in the study, sampling technique, operator details, randomization, blinding, statistical analysis and presentation of results were appropriately mentioned in the study. Since Quin tool is modifiable, two additional criteria were added that is index test results & reference standard.

RESULTS

The search strategy initially identified 10,666 potentially relevant records. Following the removal of duplicates, 7,417 studies underwent title and abstract analysis. Among these, 7,371 studies did not meet the inclusion criteria, leaving 46 studies eligible for full-text analysis. Ultimately, 20 studies were included in the qualitative synthesis. Please refer to the PRISMA flowchart for a visual representation of the

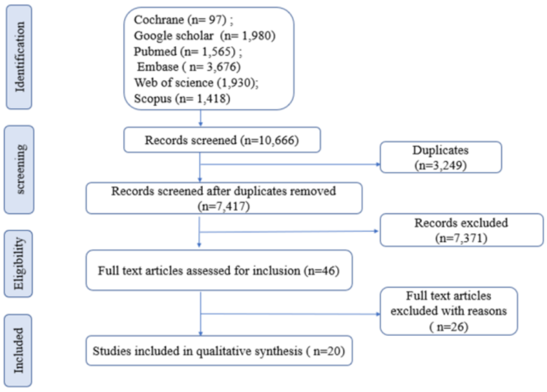

Figure 1: Prisma Flowchart.

In the case of in vivo studies, the QUADAS tool [32] was employed, which comprises four domains. Each domain addresses the risk of bias and concerns regarding applicability. The risk of bias within each domain is assessed using a set of signalling questions, the answers to which determine the final risk of bias for that specific domain. Among the four domains, INDEX TEST (domain 2) and REFERENCE STANDARD (domain 3) are crucial and cannot be omitted, while the remaining domains may be subject to modification. Results of Risk of Bias for invitro studies, QUIN tool is given in (Fig.2) & (Fig.3).

Results of Risk of Bias for in vivo studies, QUADAS tool given in (Fig.4) & (Fig.5).

selection process. (fig.1) Articles which assessed the accuracy by superimposition method were only included in the study.For invitro studies, QUIN tool consisted of 12 criteria, each criterion to be scored as follows, adequately specified = 2 points, inadequately specified = 1 point, not specified = 0 points, and not applicable = exclude from calculation. The scores acquired were employed to categorize the in vitro study into high, medium, or low risk. Scores greater than 70% were classified as low risk, those between 50% and 70% as medium risk, and scores below 50% as high risk [31]. Two questions were added into the criteria being, 13- INDEX TEST and 14- REFERENCE STANDARD.

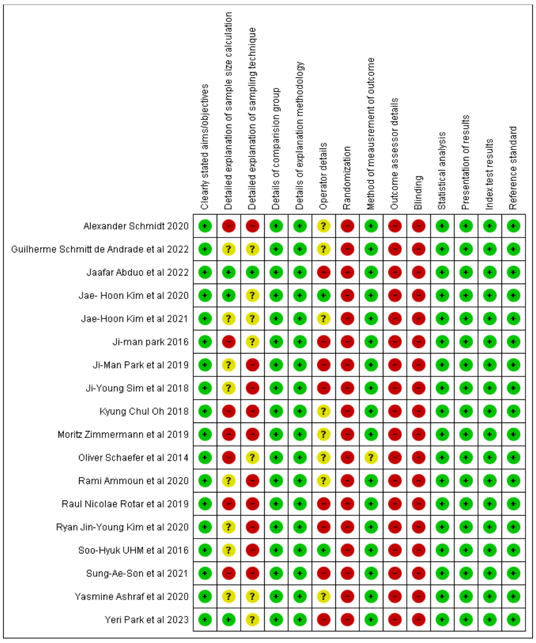

Figure 2: Summary of quality assessment using QUIN Tool.

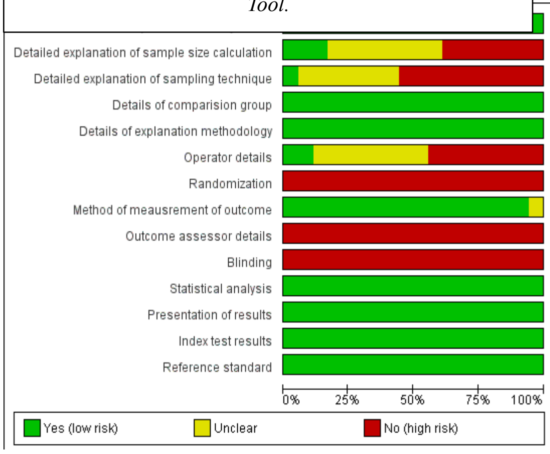

Figure 3: Rob of QUIN Tool.

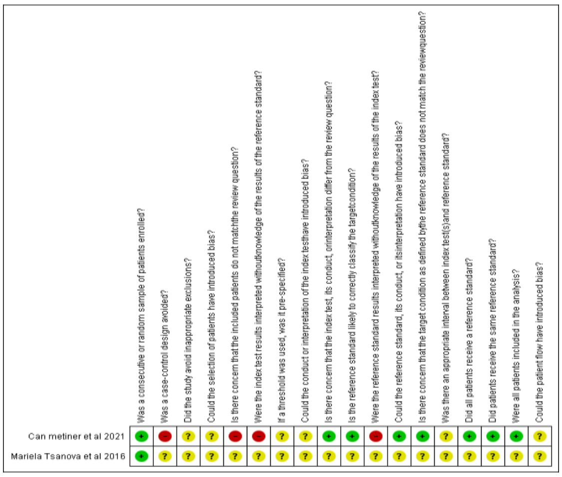

Figure 4: Summary of quality assessment using QUADAS Tool.

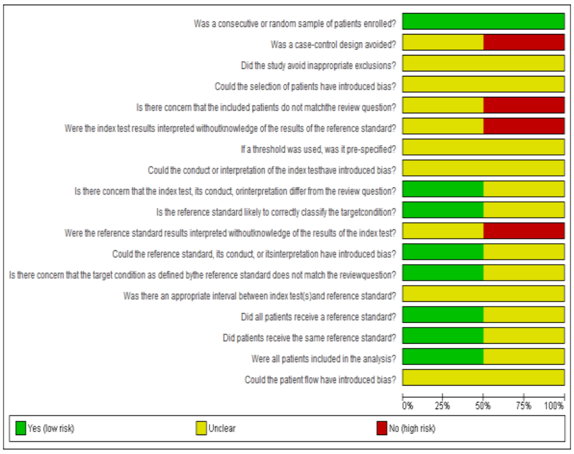

Figure 5: Rob of QUADAS Tool.

Discussion:

There are studies which evaluated the trueness and accuracy of intraoral scanners in scanning the surfaces of extracoronal preparations. These studies assessed that predictability of intraoral scanners in scanning the extracoronal preparations obtained better marginal and internal fit than crowns fabricated from conventional impression[33,34,29] However, there is a notable absence of similar investigations specifically focusing on intracoronal preparations. The trueness of intraoral scanners in scanning intracoronal preparations is uncertain and warrants further assessment. This systematic review provides insights into the trueness and precision of intraoral scanners when scanning intracoronal preparations.

Intraoral scanners are constructed with various principal designs, and the accuracy of a scanner is contingent upon the specific principles implemented in its construction. The different scanners and their scanning principles are as follows, (Table 5)

Few studies have demonstrated that intraoral scanners (IOS) can be considered reliable tools for creating impressions of intracoronal preparations .[35,36,37] In this present systematic review, a total of Eighteen in vitro and two in vivo articles were assessed. All eighteen in vitro studies specifically examined the trueness of digital impressions for intracoronal preparations. The assessment included a comparison of trueness, and precision by analyzing the acquired standard tessellation language (STL) files from scanned models against the true values of the master model. The master model was obtained using an industrial 3D coordinated measurement machine (lab scanner) certified for accuracy by the National Entity of Accreditation. Among the twenty studies, six studies investigated only trueness of intraoral scanners (IOS), three examined their trueness and accuracy, five examined trueness and precision and two studies evaluated the accuracy and precision and one study investigated only accuracy, precision respectively and only one study assessed the marginal and internal fit of restorations following the use of IOS for in vitro studies and two in vivo studies. In all the included studies, a total of nine intraoral scanners were employed namely, trios, prime scan, cs 3500, CEREC Omnicam, E4D, plan scan, I tero, True Definition (TRU), Medit i500.

Various authors emphasized that the design of the indirect restoration's preparation significantly influences the overall outcome when assessing the trueness and precision of intraoral scanners. Distinct factors that influence the outcome of different intraoral scanners are that the pulpal line angle in the occlusal cavity preparation and the axiogingival line angle in the box cavity were identified as the most challenging areas for obtaining accurate digital scans.[6,36] Inlay preparation for CAD/CAM should present 1.5-2mm of pulpal floor depth and box walls should diverge in an occlusal direction by more than 10 degrees to make optical capture easier and reduced the risk of excessive binding during seating [22,35.] Accuracy of scanning is influenced by the presence of adjacent teeth. As the interproximal distance increased, the trueness of the acquired digital image increased and the maximum positive deviation significantly decreased.[24,37] There should be a minimum of 1 mm interproximal space between the tooth of interest and its adjacent teeth for better capture of the scan without any deviation.

Accuracy was affected by the width and height of the box preparation, with wide and short designs proving more accurate than narrow and long ones.[24] Additionally, the presence of saliva impacts the accuracy of the intraoral scanner.[40]

A total of fourteen of the twenty studies have evaluated the trueness, accuracy and precision of Trios intraoral scanner and all the fourteen studies have concluded that trios were more superior in terms of accuracy compared to other intraoral scanners.

LIMITATION

All studies lacked appropriate randomization, outcome assessor details, and blinding procedures. The absence of detailed information on sample size calculation, sampling technique, and operator details in most of the included studies could undermine the validity of the conclusion regarding the better intraoral scanner.

FUTURE STUDIES

Further clinical studies are advocated with randomization and sampling technique to understand the influence of intraoral scanners in various intracoronal preparations.

CONCLUSION

The systematic review suggests that the Trios (3Shape) intraoral scanner leads in Accuracy, Precision, and Trueness, with the CEREC® Primescan as a close second, particularly excelling in Trueness and Precision for scanning the intracoronal preparations.

This systematic review also emphasizes significance of evaluating various aspects, such as dimensions of the preparation, tooth location, saliva, presence of adjacent teeth, and operator experience, as these are key to the accuracy of intraoral scanners.

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