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Intraoral Scanner in Implantology for Full-Arch Rehabilitation - An Integrative Review

Elton Matias Dias

Dissertação conducente ao Grau de Mestre em

Medicina Dentária (Ciclo Integrado)

Gandra, 15 de junho de 2020

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Trabalho realizado sob a Orientação de Prof. Doutor Carlos Manuel Aroso Ribeiro

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Eu, Elton Matias Dias, estudante do Curso de Mestrado Integrado em Medicina Dentária do Instituto Universitário de Ciências da Saúde, declaro ter atuado com absoluta integridade na elaboração desta Dissertação.

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Eu, **Carlos Manuel Aroso Ribeiro**, com a categoria profissional de **Professor Auxiliar Convidado** do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador da Dissertação intitulada "***Intraoral Scanner in Implantology for Full-Arch Rehabilitation - An Integrative Review"***, do aluno do Mestrado Integrado em Medicina Dentária, **Elton Matias Dias**, declaro que sou de parecer favorável para que a Dissertação possa ser depositada para análise do Arguente do Júri nomeado para o efeito para Admissão a provas públicas conducentes à obtenção do Grau de Mestre.

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O orientador

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Resumo e Palavras Chave

A utilização de scanners intraorais (IOS) está a tornar-se estabelecida na implantologia, embora as impressões convencionais represente um procedimento usado rotineiramente na prática dentária geral. No entanto, com o desenvolvimento da impressão digital intraoral, muitos procedimentos tradicionais estão a evoluir. Objetivos: verificar a fiabilidade e a precisão do IOS na digitalização em edentulos completos em comparação com as impressões convencionais na reabilitação com implantes dentários. Método: uma pesquisa literária na base de dados online Medline (PubMed), foi realizada para estudos, incluindo a literatura dentária. Uma busca adicional para identificar casos relevantes através da triagem de artigos de referência com texto completo foi realizada. Resultados: 22 estudos foram elegíveis para a revisão que abordavam o uso de IOS em implantologia em arco completo e avaliaram as impressões digitais do implante. A maioria dos estudos (n=18) foram experiências *in vitro* e em 13 (59%) artigos foram realizados na maxila. A digitalização no arco completo com 4 implantes foi o mais frequente em 12 (46,15%) dos relatórios e 8 (36,36%) os casos foram realizados com implantes exclusivamente angulados. Doze scanners diferentes foram encontrados nas descrições do artigo com tecnologia confocal ou fotogrammétrica. Conclusão: a maioria dos estudos demonstrou que a precisão do IOS nas impressões digitais sobre implante em arco total está dentro do limiar aceitável e um fluxo de trabalho digital completo pode ser clinicamente viável. Os diferentes sistemas IOS parecem ter o potencial de fornecer um resultado de uma gama de fiabilidade semelhante, não indicada qualquer preferência por um determinado sistema.

Palavras chave: Scanner intraoral; fiabilidade; arco dentário completo; impressão digital; Scanner sobre implante dentário.

Abstract and Keywords

The digital scanning with intraoral optical scanners (IOS) is becoming established in implant dentistry, although the conventional impression represents a routinely used procedure in general dental practice. However, with the development of the intraoral digital impression many traditional procedures have been changed. Aim: verify the accuracy and precision of IOS in digitization in full dental arch compared with conventional impressions in rehabilitation with dental implants. Method: a literature search in the online database Medline (PubMed), was performed for studies, including dental literature. An additional step search was performed to identify relevant cases by screening the reference list of all obtained full-text articles. Results: these studies, 22 eligible studies scanned the complete intraoral arch and evaluated digital implant impressions. The majority the studies (n=18) were in vitro experiments. Predominantly, the most studies, in 13 (59%) cases were performed in the maxilla. This full-arch with 4 implants was the most frequent in 12 (46.15%) of the reports and 8 (36.36%) cases were performed with exclusively tilted implants. Twelve different scanners were noticed in the article descriptions with confocal or photogrammetric technology. Conclusion: most studies have shown that the IOS accuracy of full-arch digital implant impressions lies within acceptable threshold and a complete digital workflow may be clinically feasible. The different IOS systems appear to have the potential to provide an outcome of similar accuracy range, no preference for a particular system can be made.

Keywords: Digital implant scan; accuracy; full-arch; digital impression; Intraoral digitizer.

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LIST OF ABBREVIATIONS

IOS - Intraoral Optical Scanner.

CMM - Coordinate measure machine.

CVI - Conventional impressions.

STL – Stereolithography.

ROI - Ranges of Interest.

SB – Scan Body

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LIST OF FIGURES AND TABLES

1 – INTRODUCTION

An introduction of digital technologies in dentistry has diagnosed and manage dental patients by improving the accuracy of data acquisition, enhancing treatment planning and restoration design, and speeding up the manufacturing process (1, 2).

The digital scanning with intraoral optical scanners (IOS) is becoming established in implant dentistry, although the conventional impression represents a routinely used procedure in general dental practice. However, with the development of the intraoral digital impression many traditional procedures have been changed(3).

Conventional procedures can be substituted, or even improved upon, by adopting computer-aided impression-making technologies. In recent years, the application of computer-aided impression-making technologies has gained significant interest. Digital impressions were considered to be favourable because of the potential to correct the sheer impression without the need to rehearse the whole procedure and prevent the unpleasant taste of conventional impression materials(4). It has been suggested that IOS may obviate the need for impression trays, impression materials, and stone cast, and shipping to a laboratory will no longer be required(5).

Therefore, patients are more confident with the convenience of computer-aided impression-making procedures. It was also demonstrated that these procedures allow for a more efficient workflow than conventional impression procedures(6).

The advantages of digital scanning include the elimination of error during the procedure, dispensing and polymerization of impression materials, disinfection, shipping to the laboratory, and patient comfort. The digital file scans are sent and stored electronically, improving efficiency, saving time, cost, and space. These fascinating advantages are considered to be quite useful in implant dentistry(6, 7).

Another advantage of IOS represents its application in implantology. The digital implant impressions with IOS do not need impression trays and materials, but also impression copings, so that patients can avoid opening their mouths widely during the impression(7).

In Implantology, the first and most significant step is the impression procedure. A different implant impression techniques have been used to generate a definitive cast that will ensure the accurate clinical fit of implant-fixed complete dental prostheses(8). An accuracy of conventional implant impression-making procedures is one of the most critical factors that significantly impacts the quality and fit of implant restorations(1).

The fit between a superstructure and the implant that supports it is considered to remain a key factor in the success of implant-supported prostheses. A poor fit may result in tensile, compressive, and bending forces when the prosthesis is connected to the implants(9). However, a passive framework fit to the long-term success of dental implants remains a well-recognized principle. Recording and transferring the 3-dimensional position of dental implants through impression taking is the first prosthetic step in achieving the passive fitness(10).

Digital impressions can be achieved by optical acquisition for directly connected scan bodies instead of the screw tightening and loosening of impression copings. Naturally, a higher impression accuracy is needed for implant-supported prostheses(11).

The fundamental factor for the use of digital intraoral impression, full-arch edentulous patient, is their equivalent accuracy to traditional impression. However, in literature, regarding the digital intraoral impression for full-arch there are contradictory results. Some authors concluded that the intraoral digital impression for full-arch showed similar accuracy to of the conventional impression, However, others report inconsistent results(8). An accuracy of digital images is essential to the result of the treatment.

The aim of this integrative literary review is to verify the accuracy and precision of IOS in digitization in full dental arch compared with conventional impressions in rehabilitation with dental implants.

2 – METHOD

A literature search in the online database Medline (PubMed), was performed for studies, including articles published from January 1, 2015, up to March 31, in the Dental literature. The search was limited to the English language (Table 1). An additional step search was performed to identify relevant cases by screening the reference list of all obtained full-text articles. Search for grey literature was not attempted.

The IOS accuracy was determinate as the agreement between the experimental and the reference data set, explained by both the closest to the reference data set (trueness) as the agreement within repeated measurements (precision)(12).

The references cited in the articles included were verified. Inclusion criteria represent clinical studies implementing digital scanning for complete-arch implant-supported (conventional or immediate) restorations that reported the related outcomes. All studies were original articles published in English in a peer-reviewed journal. Experimental studies of digital scanning for complete-arch implant restorations on edentulous models were additionally included.

Table 1: Research Strategy

1	2	3	4	5	Total*
scanner OR scanners OR scan OR digital OR computerized AND intraoral OR intra-oral OR IOS	accuracy OR precision OR trueness	Implant OR dental implant OR scan body OR scan bodies OR scan post OR scan maker	full-arch OR total arch OR edentulous OR toothless	impression OR conventional OR tray OR open tray	
2,852	256,490	131,610	13,538	14,089	5

* #1 AND #2 AND #3 AND #4

A review letter, case reports, abstracts, and articles that described digital scanning for partially edentulous situations, photogrammetric only and orthodontic use were excluded. When all inclusion criteria items were described, articles were selected for full-text reading, and articles considered eligible for review were selected. Meta-analysis was considered inappropriate because of the significant degree of heterogeneity of studies in terms of design and methodologies.

3- RESULTS

The initial database screening 55 articles were retrieved (Figure: 1) to 49 studies remained after title screening. After studying selection, 45 articles were screened for full-text reading. After that, 23 studies were excluded because they reported digital scans of partial arch and dentate arches, jaws without implant, a conventional impression only, pilot study, meta-analyses, literature and systematic reviews. The ultimate analysis, 22 of these studies were considered eligible for this review.

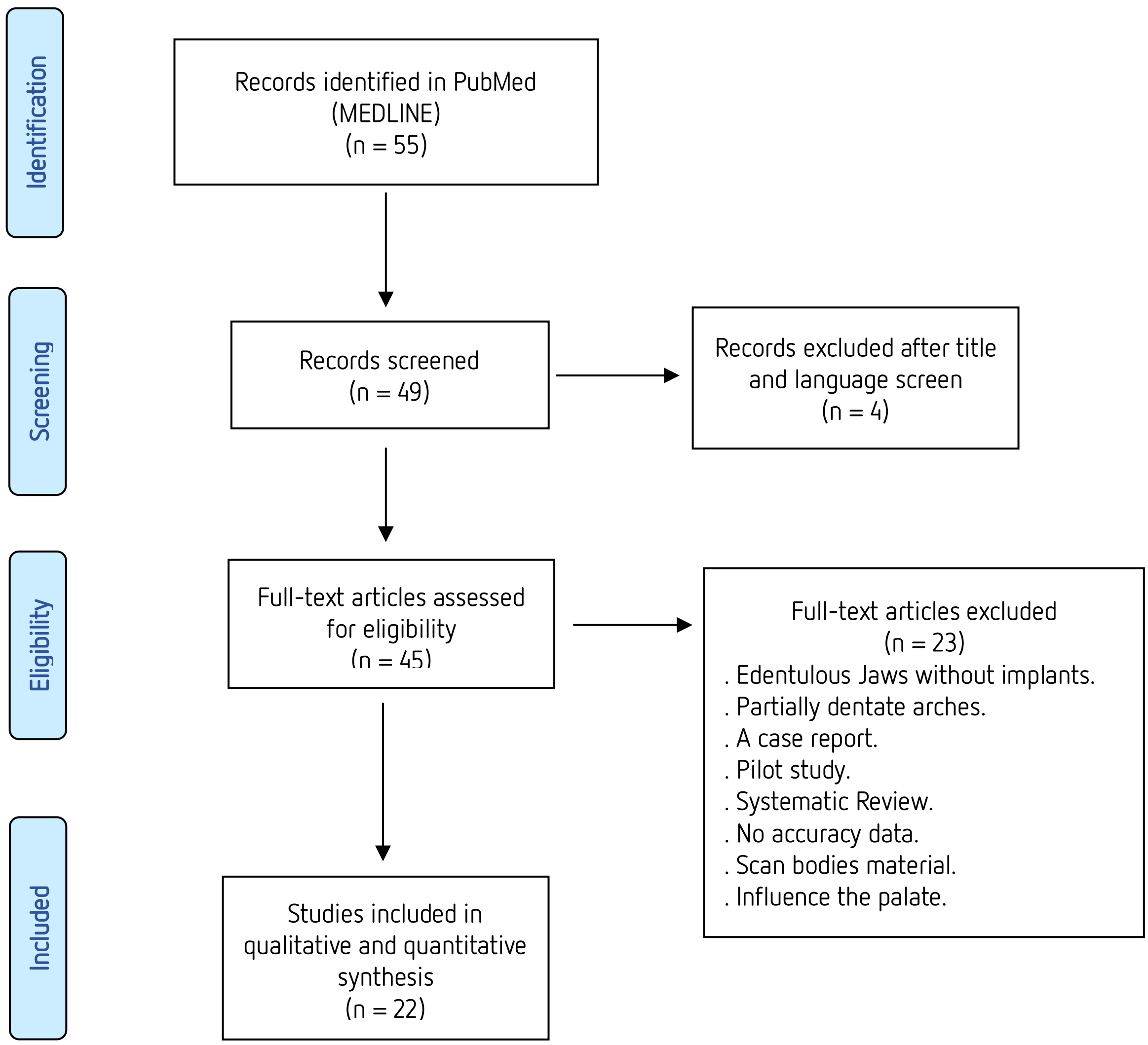

Figure 1: Screening strategy

The eligible studies were coordinated according to the evaluated structure and the information were collected and summarized in Table 2: author names, year of publication, sample number, IOS system(s), control impression(s), study set-up (in vivo or in vitro), evaluation method(s) and accuracy outcome. These studies, 22 eligible studies scanned the complete intraoral arch and evaluated digital implant impressions.

Table 2: Summary of articles eligible for this review.

Author (year)	Number of Implants	Set up	Max / Mand	Scanner	Methods	Results	Conclusion
Gimenez (9) (2015)	6	In vitro	Maxilla	3D Progess (MHT); Intrascan (Zimmer Dental); CMM	Scan bodies were placed at different angulations or depths apical to the gingiva. Five distances between implants (scan bodies) were measured, yielding 5 data points per impression and 100 per impression system. The CMM was used to measure the master model to obtain the authentic "true".	Accuracy in the first scanned quadrant was significantly better with 3D Progress, but ZFX Intrascan presented better accuracy in the full-arch.	Neither of the two systems tested would be suitable for digital impression of multiple implant prostheses. Because of the errors, further development of both systems is required.
Papaspyri-dakos (8) (2016)	5	In vitro	Mandible	TRIOS (3Shape); D103i (Imetric) – Extraoral;	Digital impressions (n = 10) were obtained with an IOS after connecting polymer scan bodies. For the conventional impressions, a splinted and a non-splinted technique were used for implant-level and abutment-level impressions (4 cast groups, n = 10 each). To compare the master cast with digital and conventional impressions at the implant level.	Significant 3D deviations (P < 0.001) were found between non-splinted, implant level and control. Implant angulation up to 15° did not affect the 3D accuracy of implant impressions.	Digital implant impressions are as accurate as conventional impressions. Splinted implant impression technique is more accurate than the non-splinted. Whereas there was no difference in the accuracy at the abutment level.
Gherlone (13) (2016)	4 (n=120)	In vivo	Maxilla or Mandible	TRIOS (3Shape); CDR Digital Radio-graph	Patients (n=25) at random selected for this study and were stratified into two groups: conventional and digital impressions. Patients underwent intraoral digital radiographs to check for the presence of voids at the bar-implant connection and evaluate an accuracy. The performed in 3, 6, and 12-month follow-up examinations.	At the 12-month evaluation in CIG, the crestal bone loss showed an average of 1.08 ± 0.77 mm for upright implants and 1.09 ± 0.32 mm for tilted implants. In DIG, a mean crestal bone loss of 1.13 ± 0.66 mm for upright implants and 1.06 + 0.91 mm for tilted implants was observed.	This clinical study has demonstrated it is possible to perform full-arch restorations with satisfactory accuracy following a digital impression technique based on active wave-front sampling. The digital impression procedure significantly required less time than the conventional procedure.
Vandewe-ghe (14)(2017)	6	In vitro	Mandible	COS (Lava); True Definition (3M)	PEEK scan bodies were scanned using four intra-oral scanners. Each model was scanned 10 times with every intra-oral scanner. The scans were imported into metrology software (Geomagic Qualify 12) for analyses. Accuracy was	The mean trueness was: for Lava COS = 0.112 mm, 3M TrueDef = 0.035 mm, Trios = 0.028 mm and Cerec = 0.061 mm and Trios (P = 0.005). The mean precision	The 3M True Definition and Trios scanner demonstrated the most superior accuracy. The Lava COS was found unsuitable for taking implant

				Cerec Omnicam (Sirona) TRIOS (3Shape); 104i (Imetric) - extraoral	measured in terms of trueness (comparing test and reference) and precision (determining the deviation between different test scans).	was: Lava COS = 0.066 m, 3M TrueDef = 0.030 mm, Trios = 0.033 and Cerec = 0.059 mm.	impressions for a cross-arch bridge in the edentulous jaw.
Amin (15) (2017)	5	In vitro	Mandible	True Definition (3M) Cerec Omnicam (Sirona) Activity 880 (Smart Optics) - extraoral	A stone master cast with 5 implant analogues was fabricated. The three implants were parallel to each other, the far left implant had 10°, and the far right had 15° distal angulation. A splinted open-tray technique was utilized for the conventional impressions. Master cast and conventional impression test casts were digitized with a high-resolution reference scanner.	Control group provided a mean value of 0.168 mm; Omnicam obtained a mean value of 0.046 mm; True Definition acquired a mean value of 0.0193 mm.	Full-arch digital implant impressions were significantly more accurate than the conventional impressions with the splinted open-tray technique.
Menini (16) (2018)	4	In vitro	Maxilla	True Definition (3M) CMM	Eight impression techniques were tested and digital impression (DI). A three-dimensional coordinate measurement machine (CMM) was used to measure implant angulation and inter-implant distances on TI casts. TI data and DI STL datasets were compared with a master cast. Gaps between framework implant analogues were measured through a stereomicroscope (×40 magnification).	Sheffield test revealed a mean gap of 0.022 ± 0.023 mm (the best TI), 0.063 ± 0.059 mm (the worst TI), 0.015 ± 0.011 mm (the best DI), and 0.019 ± 0.015 mm (the worst DI).	Within the limitations of this in vitro study, the use of an intraoral digitizer might represent a viable alternative to traditional impression materials for the fabrication of full-arch implant-supported prostheses provided with a satisfactory passive fit.
Gintaute (1) (2018)	2, 4 e 6	In vitro	Mandible	True Definition (3M) CMM	Four different edentulous mandibular reference models (RMs) were manufactured. Two straight (RM1); four straight (RM2); two straight and two tilted (RM3); and six straight (RM4) dental implants were placed, simulating four different clinical scenarios. The computer-aided impressions were obtained using an intraoral scanner (IOS). An industrial coordinate measuring machines (CMM) to obtain data of the 3D position.	The deviations obtained with both impression-making approaches did not exceed an inter-implant distance threshold of 100 µm and an inter-implant angle of 0.5 degree.	The accuracy of the computer-aided and conventional impression-making approaches for straight and tilted dental implants seems to be clinically acceptable and may therefore be considered for full-arch, multiple-implant restorations.
Pesce (17) (2018)	4	In vitro	Maxilla	True Definition (3M)	Five master casts reproducing different edentulous and four scan bodies were screwed onto	A mean gap of < 30 µm (range: 2 to 47 µm). A difference	Within this study, it appears that a digital impression may represent a

				Lab Simbiosi	the low-profile abutments, and a digital intraoral scanner was used to perform the master cast. Gaps between the frameworks and the implant analogues were measured with a stereomicroscope. To assess precision, three-dimensional (3D) point cloud processing software was used to measure the deviations.	was observed between the two groups by the 3D point cloud software, with higher frequencies of points in class 2 than in grouped classes 1 and 3 (P < .001).	reliable method for fabricating full-arch implant frameworks with good passive fit when tilted implants are present.
Alikhasi (18) (2018)	4	In vitro	Maxilla	TRIOS (3Shape) ATOS (Core 80) – Extraoral CMM	Ninety impressions were obtained using an intraoral scanner (Trios 3Shape) with scan bodies for digital impression. A custom opens trays and closed trays with additional silicone for the conventional impression. The CMM was used to measure linear and angular displacement for conventional specimens.	There were significant angular and linear distortion differences among three impression groups (P < 0.001), and between straight and tilted implants for either linear (P < 0.001) or angular (P=0.002) distortion.	Digital techniques demonstrated a superior outcome in comparison with conventional methods, and the direct technique was more efficient than the indirect conventional technique. When digital impression was applied, accuracy was unaffected by the type of connection and angulation.
Ribeiro (19) (2018)	4	In vitro	Maxilla	True Definition (3M) D104i (Imetric) - extraoral	Two different master models were created, one with parallel implants (model 1) and the other with non-parallel implants (model 2). Close and open tray conventional impression with and without splinting were performed and to compare with IOS. The master models were digitalized to compare them via an extraoral high-resolution scanner.	For model 1, the deviations of the digital impressions were slighter than those associated with the conventional techniques. This improvement was not observed when using model 2, however, where the conventional techniques yielded similar results.	Digital impressions of full-arch models were able to achieve the accuracy of conventional impressions in an in vitro model.
Tan (20) (2019)	6	In vitro	Maxilla	True Definition (3M) TRIOS (3Shape) Ceramill Map400 AG) inEos X5 (Sirona) D900(3Shape)	Six impression systems comprising one conventional impression material, two intraoral scanners, and three dental laboratory scanners were evaluated on two completely edentulous maxillary arch master models (A and B) with six and eight implants. Comparison of centroid positions between master and test models defined linear distortions, global linear distortions (dR), and 3D reference distance	True Definition exhibits the most limited accuracy. Independent samples t tests for dR, between homologous implant location pairs in Model A versus B, revealed the presence of two to four significant pairings for the intraoral scanner systems, in which instances dR was	True Definition exhibited the most limited accuracy for all linear distortions. There was no significant difference among the remaining five impression systems for linear distortion parameters in both Models A and B. Reducing inter-implant distance may

				CMM	distortions between implants (ΔR).	larger in Model A by 110 to 150 µm.	decrease global linear distortions (dR) for intra-oral scanner systems.
Iturrate (21) (2019)	4	In vitro	Maxilla	True Definition (3M) TRIOS (3Shape) iTero (Align) ATOS (5M/300) - Extraoral	A stainless-steel model of the maxilla model was scanned using a reference industrial scanner as the control and using 3 intraoral scanners. Accuracy in terms of trueness and precision was established by comparing five reference distances with or without the AGD (auxiliary geometric device) in place.	Without the AGD in place, trueness ranged from 21 ±16 µm in the shortest reference distance to 125 ±80 µm in the largest reference distance. With the AGD in place, trueness ranged from 11 ±8 µm in the shortest reference distance to 64 ±51 µm in the largest reference distance.	Complete-arch digital scans of edentulous jaws are more accurate when an AGD is used to resolve the lack of anatomic landmarks. An additional advantage is the use of the AGD allows for a more fluent scanning process.
Cappare (22) (2019)	6 (n=300)	In vivo	Maxilla	CS 3600 (Care-stream) NeWay (Faro) - extraoral	Patients have been scheduled randomly into control and test groups respectively for a fully conventional workflow and a completely digital workflow. In both groups, within 24 h, temporary prostheses were delivered. Patients underwent intraoral digital radiographs to evaluate the accuracy of the framework-implant connection, check for the presence of voids at the bar-implant connection and measure bone level.	All digital X-ray examinations revealed a bar-implant connection accuracy and no voids. Significantly less time was employed to perform digital impression procedure ($p < 0.05$).	This study showed a satisfactory accuracy and predictability of the IOS to represent a reliable alternative in clinical practice to the conventional workflow for implant full-arch rehabilitations. On equal terms of the two approaches, the digital workflow seems to remain a valid choice for full-arch rehabilitations due to the less invasive option for patients and its time saving.
Kim (23) (2019)	6	In vitro	Maxilla	TRIOS (3Shape) CMM	A master model was fabricated using epoxy resin for a conventional impression (CI) with open-tray, splinted-coping impression technique and an intraoral scan (DI) were performed. A CMM was used to deter mine the 3D spatial orientation of the implant replicas and an inspection software program was used to measure the implant replicas. To compare the accuracies of different impression techniques, a 3D	Group CI gave more accurate trueness values than group IOS for overall. Furthermore, group CI had more accurate precision values. Group IOS exhibited a statistically more significant angular displacement in the ZX plane, but the difference was only 0.24 degree. No differences were	The intraoral digital scan resulted in less accurate trueness than the conventional open-tray impression technique in terms of overall. The conventional impression technique resulted in more accurate precision than the

					part coordinate system was set to compute the centroid and projection angles of each implant replica.	detected between the 2 groups for the angular displacement in the XY plane.	intraoral digital scan for all the implant replica locations.
Di Fiori (3) (2019)	6	In vitro	Mandible	True Definition (3M) TRIOS (3Shape) Cerec Omnicam (Sirona) 3D progress CS 3600 (Care-stream) CS 3500 (Carestream) Emerald (Plan-meca) VirtuoVivo (DW) CMM	A polymethyl methacrylate acrylic model of an edentulous mandible with six scan-abutment was used as a master model and its dimensions measured with a coordinate measuring machine. Eight different IOS were used to generate digital impression. A software called, "Scan-abut" was developed to analyze and compare the digital impression with the master model, obtaining the scanning accuracy. The three-dimensional (3D) position and distance analysis were performed.	Mean value of the 3D position analysis showed: True Definition (31 μm±8 μm); Trios (32 μm ± 5 μm); Omnicam (71 μm ± 55 μm); CS3600 (61 μm ± 14 μm); CS3500 (107 μm ± 28 μm); Emelard (101 μm ± 38 μm); 3D (344 μm ± 121 μm); DWOS(148 μm ± 64 μm).	Not all scanners can be used for digital impressions in full-arch implant-supported fixed dental prosthesis, however new research in vivo investigating this topic are needed.
Iturrate (24) (2019)	4	In vitro	Maxilla	True Definition (3M) TRIOS (3Shape) iTero (Align) ATOS (5M/300) - Extraoral	A model was scanned with an industrial 3D scanner, and the measurements of three reference distances were established as reference values. Subsequently, the model was scanned in two alternative scenarios (with or without an auxiliary geometry part put in place and fixed to the model) using three intraoral scanners.	All measurements with the auxiliary geometry part gave significantly more accurate results ($p < .05$). Trueness improved in the three reference distances, reaching values between 8 and 35 μm. Precision also improved significantly with the use of the auxiliary geometry. The most exact precision was obtained with the True Definition.	The use of an auxiliary geometry piece improved the accuracy of complete-arch digital impressions of the edentulous maxilla, as well as facilitating the scanning process itself. Both trueness and precision measurements obtained by covering wide edentulous spaces with the auxiliary geometry piece showed remarkable improvement in digital impressions.
Arcuri (25) (2020)	6	In vitro	Maxilla	TRIOS (3Shape) iTero (Align) ATOS (5M/300) - Extraoral	An edentulous maxillary model was scanned with an extraoral optical scanner to achieve a reference file. Three ISBs made of different materials (polyetheretherketone (Pk), titanium (T) and Pk with a titanium base (Pkt)) were	There was a significant influence of material ($p<0.0001$) and position ($p=0.0009$). Were considered as response variable, material and	Implant angulation significantly affected the linear deviations while the implant position the angular deviation. No significant

					scanned with IOS by 3 operators.	position significantly influenced the expected (p=0.0232 and p<0.0001).	operator effect on the IOS accuracy was detected. The investigated IOS device showed a consistent linear accuracy for complete-arch implant impression, although extreme deviations up to 0.52mm were experienced.
Myoshi (26) (2020)	6	In vitro	Maxilla	True Definition (3M) TRIOS (3Shape) Cerec Omnicam (Sirona) CS 3600 (Care-stream) D810(3Shape) - Extra-oral	Edentulous maxilla model was scanned with four intraoral scanners (IOSs) and a dental laboratory scanner, and stereolithography (STL) data were generated. A conventional silicone impression was made, Nine different ranges of interest (ROIs) were defined, and the average discrepancies of the measurement points between each pair of STL images out of five for each ROI were calculated.	The effects of "impression methods" and "ROI" and their interactions were statistically significant. The discrepancies in the scanned datasets of the dental laboratory scanner were significantly lower than those in the other impression methods. The discrepancies of the IOSs were comparable with those of the laboratory scanner when the ROI was limited.	The precision of the digital impression deteriorated in association with the expansion of the scanned ranges. Therefore, digital impressions for implant treatment should be limited to small prostheses, such as in the 3-unit superstructure supported by two implants for the time being.
Papaspyri-dakos (27) (2020)	4	In vitro	Mandible	TRIOS (3Shape) Activity 880 (Smart Optics) - extraoral	An edentulous mandibular cast was used as the master cast. Digital scans were made by using a white light intraoral scanner (IOS). The printed casts and the mandibular cast were further digitized by using a laboratory reference scanner. These STL data sets were superimposed on the digitized master cast in a metrology software program for virtual analysis.	When compared with the master cast, the printed casts had a mean ±standard deviation RMS error of 59 ±16 μm (95% CI: 53, 66). The maximum RMS error reached 98 μm. The average offsets were all negative, with a significant difference compared with zero (P<.001).	The implant 3D deviations of the printed casts from complete-arch digital scans had statistically significant differences compared with those of the master cast but may still be within the acceptable range for clinical application.
Huang (28) (2020)	4	In vitro	Mandible	TRIOS (3Shape) D2000 (3Shape) - extraoral	A reference model containing implants was fabricated. Digital impressions were taken using an intraoral scanner with different scan bodies (DO - original scan body 4.1 mm; DC scan body without extensional structure 5.5	The median of trueness was 35.85, 38.50, 28.45, and 25.55 μm for Group I, II, III, and IV, respectively. CI was more accurate than DO (p = .015) and DC (p =.002). The	The design of the extensional structure could significantly improve scanning accuracy. Conventional splinted open-tray impressions

					mm; DCE scan body with extensional structure) and a conventional splinted open-tray impression (CI) were taken. The reference model and conventional stone casts were digitalized with a laboratory reference scanner.	median of precision was 48.40, 48.90, 27.30, and 19.00 for Group I, II, III, and IV, respectively. CI was more accurate than DO ($p < .001$), DC ($p < .001$), and DCE ($p = .007$). DCE was more accurate than DC ($p < .001$) and DO ($p < .001$).	were more accurate than digital impressions for full-arch implant rehabilitation.
Schmidt (29) (2020)	4	In vivo	Mandible	TRIOS 3Cart TRIOS 3Pod TRIOS 4Pod Primescan (Sirona) CMM	A metallic reference aid served as a reference dataset. Four digital impressions and one conventional (CVI) were investigated in five patients. Scan data were analysed using three-dimensional analysis software and conventional models using a CMM. The transfer accuracy between the reference aid and the impression methods were compared.	Overall, mean ± standard deviation (SD) transfer accuracy ranged from 24.6 ± 17.7 µm (CVI) to 204.5 ± 182.1 µm (Trios3Pod). The Primescan yielded the lowest deviation for digital impressions (33.8 ± 31.5 µm), followed by Trios4Pod (65.2 ± 52.9 µm), Trios3Cart (84.7 ± 120.3 µm), and Trios3Pod.	The current IOS equipped with the latest software versions demonstrated less deviation for short-span distances compared with the conventional impression technique. However, for long-span distances, the conventional impression technique provided the lowest deviation. Predominantly, the IOS systems demonstrated improvement regarding transfer accuracy of full-arch scans in patients.
Chochli-dakis (30) (2020)	4, 5 and 6	In vivo	Maxilla	True Definition (3M) Serie 7 (Dental Wings) - Extraoral	Sixteen patients received a supported fixed complete denture. The casts were scanned with a extraoral scanner. Intraoral full-arch digital scans were also obtained with scan bodies and STL files. Extraoral and intraoral scans were superimposed and analysed with reverse-engineering software. The primary outcome measure obtain the assessment of accuracy between scans of the verified conventional casts and digital full-arch impressions.	The 3D deviations between virtual casts from intraoral full-arch digital. In the 4-implant group, 5-implant group, and 6-implant group the 3D deviations were found to be 139 +/- 56 mum, 146 +/- 90 mum, and 185 +/- 81 mum, respectively. There was a positive correlation between increased implant number and 3D-deviations, but there was no statistically significant difference ($p = 0.1$)	The 3D accuracy of full-arch digital implant impressions lies within previously reported clinically acceptable threshold. Full-arch digital scans and a complete digital workflow in the fabrication of maxillary fixed complete dentures may be clinically feasible.

The majority the studies (n=18) were in vitro experiments (Table 3), which is justified by the fact that the image analysis comprised digital-based methods (1, 3, 8, 9, 14-21, 23-28). The in vitro studies have shown digital data acquisition could be a valid alternative to a conventional impression-making procedure (8).

Table 3: Model of clinical and laboratory studies.

		N	Percent
Set-up Studies	in vivo	4	18,18%
	in vitro	18	81,82%

Only 4 studies, in which the reference model was based on patient scanning, were performed clinically and used an intraoral scanner to scan the complete maxilla and mandible (13, 22, 29).

Predominantly, the most studies have been performed on the maxilla. In this study, 13 (59%) cases were performed in the maxilla and 8 (36%) cases in the mandibles. Nevertheless, 1 (5%) case, all jaws were considered for the study (figure 2).

Although historically most of the research for implant rehabilitation of edentulous patients was conducted in the mandible (31). The IOS performance in mandible would be more difficult than in the maxilla. Therefore, in mandible the reduced gingiva surface and additional tongue, cheek and muscle movements could the process more complex.

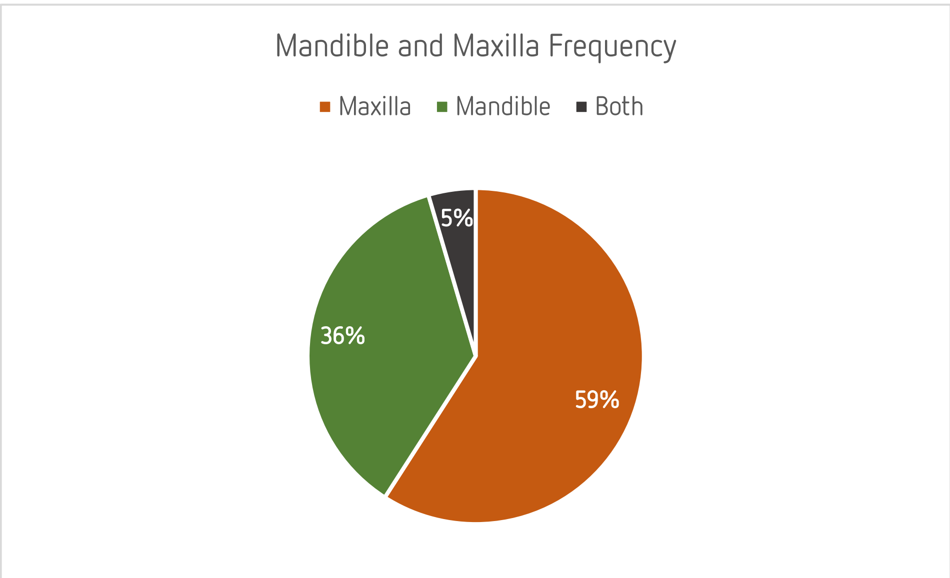

Figure 2: Frequency of maxilla, mandible and both in this study.

However, it is not yet known whether conventional procedures can be replaced, or even improved, by adopting computer-aided printing technologies. In recent years, the application of computer-aided printing technologies has gained significant interest. Nevertheless, some limitations can influence the information about the accuracy and precision of intraoral scanners. The number of implants per jaw can be one of them. This study showed the toothless arch with 4 implants was the most frequent in 12 (46.15%) of the reports. Among these, 8 (30.77%) were observed in the maxilla. Therefore, the review revealed that 10 (38.46%) articles with 6 implants were observed in the same arch and 7 (26.92%) these cases were performed in the maxilla, as summarized in Figure 3.

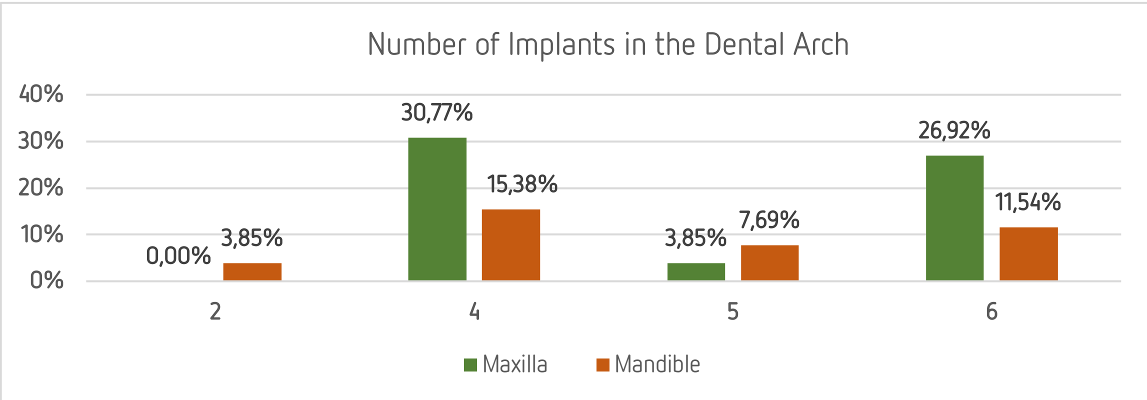

Figure 3: Number of implants detected in the maxilla or mandible.

Additionally, studies indicate the number of implants can influence the scanner's impression, hence if there are substantial distances between the implants in the total toothless arches, this can lead to inconsistent data during scanning.

Another possibility of limiting the utilization of intraoral scanners represents the angle of implants positioned in the jaws. The data can also be inconsistent. The an increase angled these implants are, the less accuracy there could be. However, the data are still inconclusive. This review showed that 8 (36.36%) cases were performed with exclusively angled implants. In Five (22.73%) articles were performed on angular and parallel implants. Even though, exclusive parallel implants were found in 7 (31.82%) of the cases. In finally, 2 (9.09%) cases in which their angulation was unrelated (Figure 4).

The surface area to be scanned increases the risk of angulation errors due to an accumulation of registration fails of the 3D surfaces, especially in the mandible. Moreover, because of the lacks of anatomic mucosal change during a scanner's performance in mandibular and also similar morphology of the scan bodies, turn complex a 3D individualization.

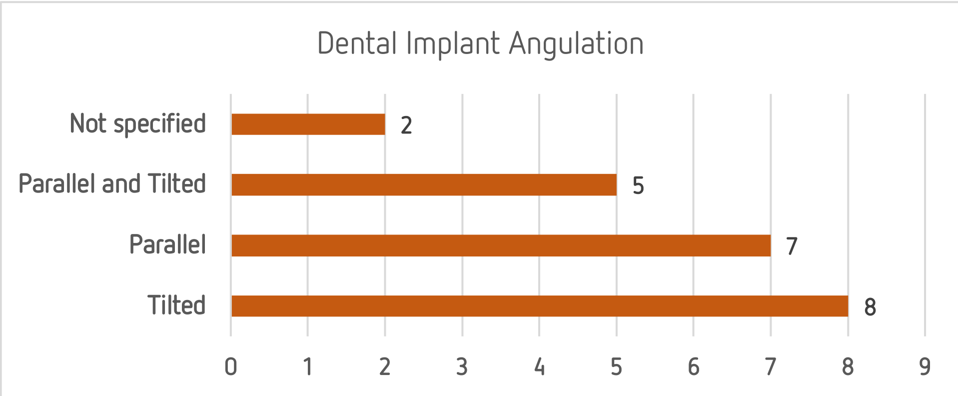

Figure 4: Numbers of angular and parallel implants.

Several technologies are available for digital scanning: confocal microscopy associated with 3D imaging technology (3, 8, 9, 13, 14, 18, 20, 21, 23-29) and photogrammetry. In that case, this technique a relies on images to record the geometrical properties of 3D objects and their interrelated spatial positions (1, 15-17, 19, 22, 30), as summarized in Table 4.

Table 4: Intraoral scanners described in eligible studies.

Impression system	Technology
Cerec Omnicam (Sirona)	Optical triangulation and confocal microscopy
CS 3500 (Carestream)	Optical triangulation and generated individual images
CS 3600 (Carestream)	Active speed 3D video
iTero (iTero)	Parallel confocal imaging technology
Lava Cos (3M)	Active wavefront sampling with structured light projection
Emerald (Planmeca)	Optical coherence tomography and confocal microscopy
TRIOS (3Shape)	Confocal microscopy and ultrafast optical scanning
True Definition (3M)	Active wavefront sampling 3D video technology
Zfx IntraScan (Zimmer)	Confocal microscopy and Moiré effect
3D Progess (MHT)	Confocal Microscopy combined with Moiré effect
Primescan (Sirona)	High-resolution sensors 3D and shortwave light.
VirtuoVivo (Dental Wings)	Multiscan Imaging captures data from many angles simultaneously.

Additionally, in this review 12 different scanners were noticed in the article descriptions. First, the TRIOS scanner (3Shape®) was the major reported, in 16 (34.78%) of the studies. Second, the True Definition (3M®) was performed in 12 (26.09%) cases. Others scanners were reported in Figure 5.

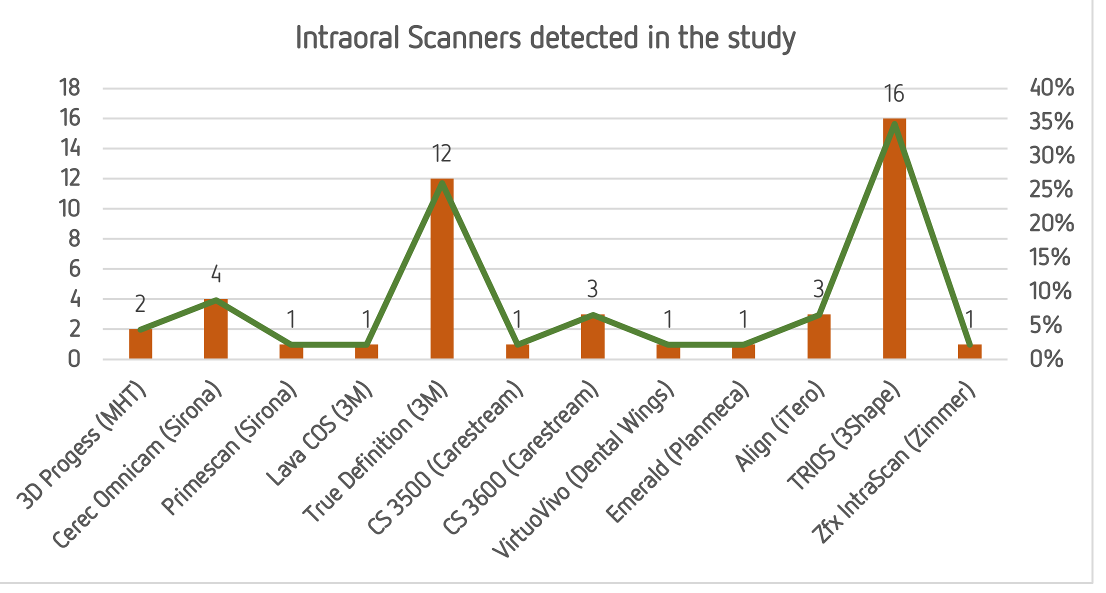

Figure 5: Intraoral scanners preformed in the articles.

In general, the studies aimed to evaluate the accuracy of digital scanners to compare them with conventional methods or extraoral and industrial scanners (8, 14, 15, 19, 21, 22, 25-28, 30), as summarized in Figure 6.

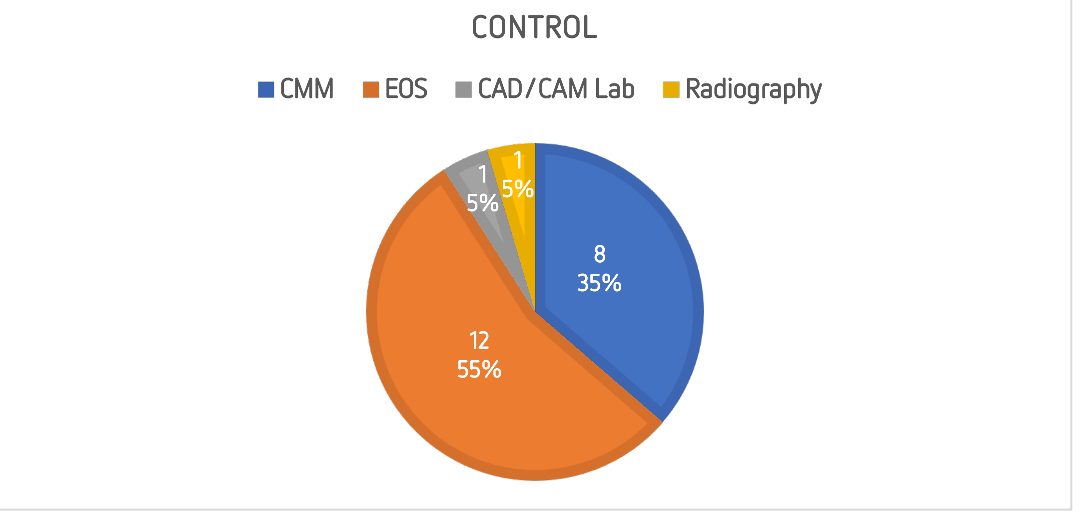

Figure 6: Intraoral scanners compared with others control methods.

Whereas, some in vitro studies focused on the intraoral scanner as compared with coordinate measure machine (CMM) (1, 3, 9, 16, 18, 20, 23, 29). The CMM are considered the gold standard, with an accuracy of 1 μm, whereas extraoral scanners reach 6 1 μm accuracy (8).

Nevertheless, in 1 case the IOS was assessed by radiographic control of marginal bone decrease in a time period (13). Prosper *et al.* (32) in 2010 reported that Implant success was represented by implanting survival plus marginal bone loss under 1.5 mm within 12 months after loading and the loss of 0.2 mm or less of the bone between subsequent follow-up appointments (32)

Finally, 1 article not specified properly, how to was evaluated the IOS to compared to control. The authors report the model was accomplished a specific dental laboratory (17).

Therefore, all data from the IOS and the corresponds to the control group (EOS and CMM) were imported with industrial reverse-engineering software that could read the STL files (Figure 7). The distances and angles between the centre points of the implants were used to evaluate the accuracy of the intraoral scanner. To locate the centre point of each implant for the IOS system, the STL file and the original design of the scan bodies were imported into the reverse-engineering software. The cylinders of the STL data captured by the scanner were isolated and matched one by one with the original CAD designs of the scan bodies (9).

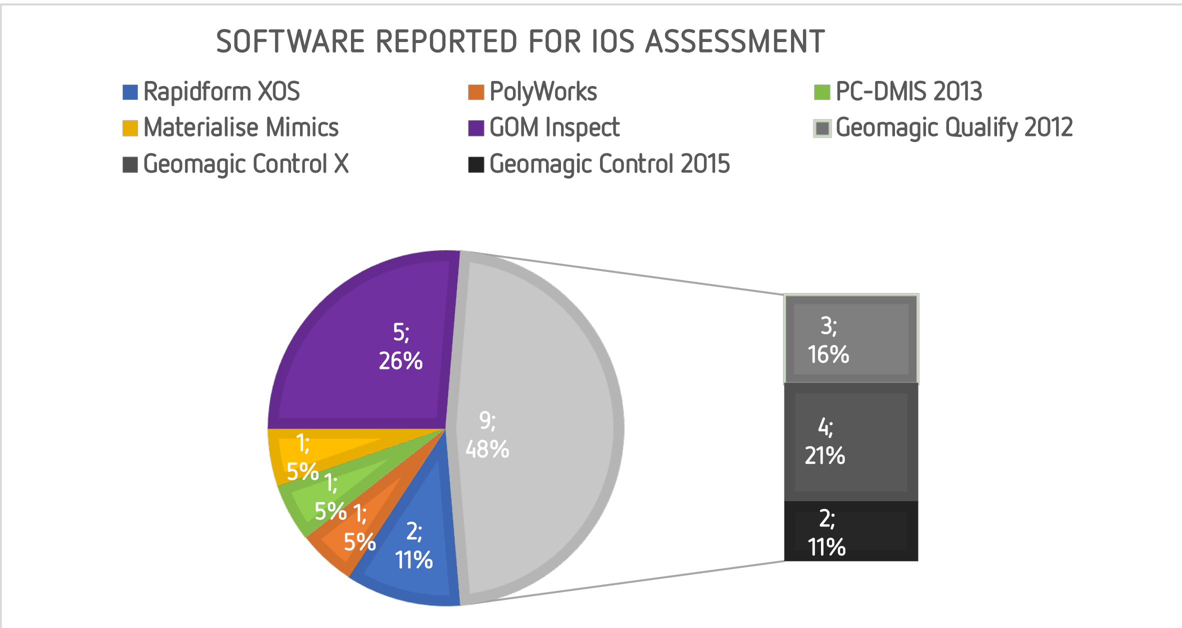

Figure 7: Industrial reverse engineering software observed in the studies.

Intraoral scanning demonstrated to be more accuracy and precision as compared to the conventional impression technique. Specifically, in this article, the studies have compared the accuracy and precision of different IOS and whether they can be employed in whole dental arch in implant dentistry. Notably, in 15 (68.18%) the papers demonstrated that is a feasible option (Figure 8) (1, 8, 13-19, 21, 22, 24, 27, 29, 30).

The measured deviations between the control data set and test data set determines the accuracy. Precision resulted from a comparison among different data sets obtained with the same scanner. However, some results were conveyed with different outcomes: including a trueness and precision, linear and angular deviation, root mean square error of superimposition and control and dimensional measurement error.

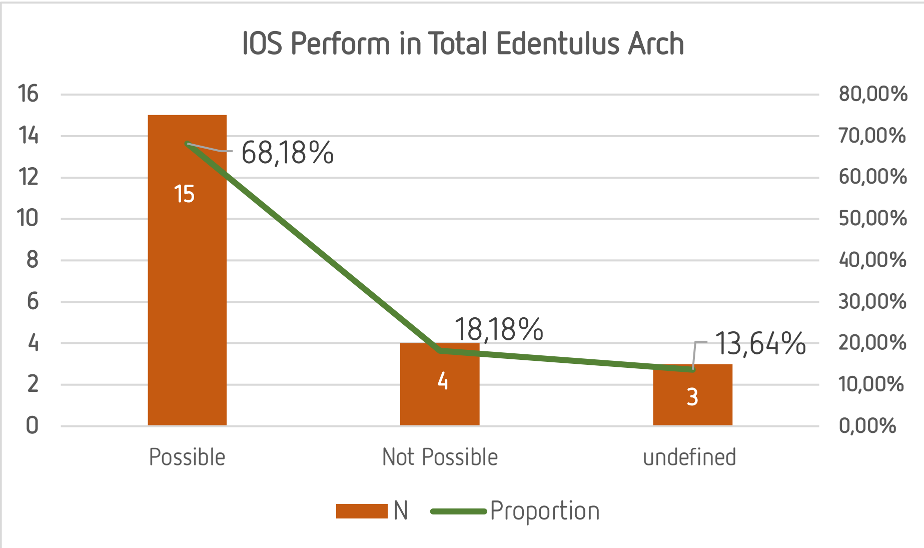

Figure 8: IOS Accuracy to perform whole arch in implantology

Intraoral scanning demonstrated to be more accuracy and precision as compared to the conventional impression technique. The IOS allowed simplifying the scan protocol by reducing the scan area to a clinically relevant extent like full-arch impression. In contrast, when taking a conventional impression, the implant transfer post generally interferes with the opposing jaw, thereby prohibiting a unilateral impression.

The differences in time efficiency for IOS among the included studies can be explained by (a) the study protocol (5), (b) the brand of IOS (32), (c) the software version, and (d) the level of user experience and skills (33). Moreover, IOS allows adding scans to an existing impression without the need for a complete retake, as necessary for a conventional impression (27).

4 – DISCUSSION

Recently, the IOS showed workflow totally digital is possible in dentistry. The concepts have spread broadly in the oral rehabilitation. Frequently, the IOS has been applied to in umpteen fields of dentistry. It has also contributed greatly, from treatment planning in several cases. The digital workflow is a field with high future growth potential. Therefore, are some aspects that need to be elucidated because the subject is still evolving.

Furthermore, the laboratory steps may add errors to this conventional workflow also. A lack of accuracy of the definitive cast results in misfit of the fixed prosthesis, which cannot be compensated by periodontal ligaments and may lead to implant or prosthetic complications, such as screw, ceramic, or implant fracture or peri-implant bone loss (33).

Ultimately, IOS accuracy has been improved for the measurement of full-arch dental, especially in the implantology. This method, it is possible employed digital impressions with a highly accurate become to possible a totally digital workflow. Moreover, several studies have attempted to assess the accuracy digital and conventional full-arch dental impressions.

Many parameters are defined by international scientific committees to describe the performances of a measuring system functioning according to a given measurement procedure (34).

Particularly, measurement accuracy: "*Closeness of agreement between a measured quantity value and a true quantity value of a measurand*" (35, 36). The term accuracy consists of two criteria, the precision and the trueness (Figure 9).

Therefore, measurement trueness: "*Closeness of agreement between the average of an infinite number of replicate measured quantity values and a reference quantity value*" (34, 35).

Thereby, measurement precision: "*Closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions*" (34, 35, 37).

Specially, the introduction the terms trueness and precision as different measures of accuracy. Trueness is defined as the comparison between a control STL data set and a test STL dataset. Precision is defined as a comparison between different dataset obtained using the same digital scanner (38).

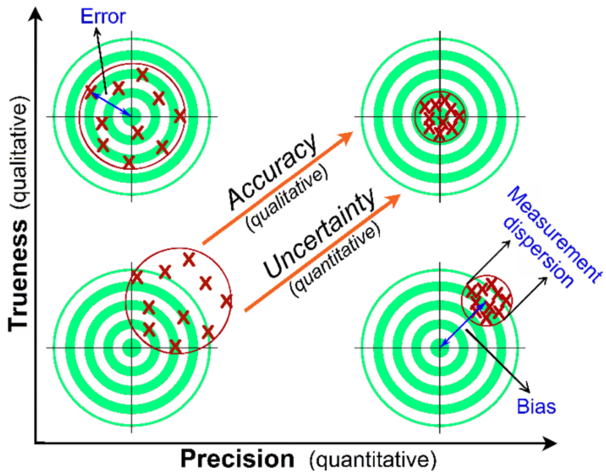

Figure 9: Target comparison to illustrate trueness, precision, accuracy, and uncertainty. Arrows indicate improving direction. Font: Villarraga-Gómez (37)

Provide that concept, the studies that related to compare the data set obtained with the same scanner in different samples, presumably, was evaluating the precision. However, the other studies that compared the data set obtained in between different digitization processes, after that, a superimposition of the STL files, probably was studying the trueness.

The precision of IOS can be measured easily by repetitive captures of the object and assessment of their reproducibility, whereas the calculation of trueness is slightly complex. An industrial scanner or a sophisticated device, like an industrial coordinate measuring machine (CMM), is needed to obtain a reliable reference model.

Specially, the IOS could obviate the need for a conventional trays and materials to impression and a plaster model. Therefore, shipping to a laboratory wouldn't be required. Particularly, in implantology, the IOS could possible to eliminate complex lab process, as impression copings. Moreover, the patients wouldn't need to open their mouths largely and protractedly during the conventional impression.

Certainly, a considerable advantage in using the digital method is practicality. The electronic files can be digitally sent and stored, saving time, cost, and space (39). These fascinating advantages are considered quite useful in implant dentistry. Digital impressions can be achieved by IOS, just connect scan bodies on implant head and onset a scan performs in implant placed.

A total of 22 studies evaluated the accuracy of IOS for full-arch scanning. Eighteen researches were laboratory originated (1, 3, 8, 9, 14-21, 23-28) and 4 studies were clinical investigation (Table 4) (13, 22, 29, 30). The IOS systems were reported in Table 4 and Figure 6.

Most studies (n = 15) eligible for the review concluded that the digitization was at least equal and sometimes better than conventional impressions, considering the methodological limitations employed (1, 8, 13-19, 21, 22, 24, 27, 29, 30). Among these studies (18,18%), all clinical trials (n = 4) did not report a significant difference in the measured data between IOS and virtual models generated from conventional impressions (13, 22, 29, 30).

The study of Gherlone *et al.* (13) in 2016, patients were selected (n=25) at random and were stratified into two groups: conventional and digital impressions. They underwent intraoral digital radiographs to check for the presence of voids at the bar-implant connection and evaluate an accuracy. They performed in 3, 6, and 12-month follow-up examinations. At the 12 month evaluation in a convention impression group (CIG), the crestal bone loss showed an average of 1.08 ± 0.77 mm for upright implants and 1.09 ± 0.32 mm for tilted implants. In digital group (DIG), a mean crestal bone loss of 1.13 ± 0.66 mm for upright implants and 1.06 + 0.91 mm for tilted implants was observed. Implant success was represented by implanting survival plus marginal bone loss under 1.5 mm within 12 months after loading and the loss of 0.2 mm or less of the bone between subsequent follow-up appointments (32). In concluding, on the basis of this study, the authors advocate the use of an intraoral scanner of dental implant full-arch rehabilitations and digitally create an accurate dental impression, which greatly increases efficacy. This will also facilitate patient satisfaction and the previsualization of the work undertaken, reduce the likelihood of impression size variations, and allow for acceptable marginal fit values of the restorations.

Cappare *et al.* (22) in 2019 reported in an article a satisfactory accuracy and predictability of the intraoral scanner (IOS) to be a reliable alternative in clinical practice to implant full-arch rehabilitations and suggested a realization of definitive restorations with a successful marginal fit precision.

Patients selected and have been scheduled randomly into control (conventional impression group, CIG) and test (digital impression group, DIG) groups respectively for a fully conventional workflow and a fully digital workflow. In both groups, within 24 h, temporary prostheses were delivered. Four months after the implant positioning, the two groups dealt with the fabrication of definitive restorations: conventional pick-up was performed in the control group, and definitive digital impressions were carried out in the test group. The time involved following these two procedures was recorded. Patients underwent intraoral digital radiographs to evaluate the accuracy of the framework-implant connection, check for the presence of voids at the bar-implant connection and measure bone level. A total of 50 patients received immediately loads prostheses supported by six implants (total 300 implants). All digital X-ray examinations revealed a bare-implant connection accuracy and no voids. Differences that were not statistically significant ($p > 0.05$) in marginal bone loss were found between control and test groups. Significantly less time was spent to performing a digital impression procedure ($p < 0.05$).

Notably, these studies with patients, an accuracy and precision have not been correctly evaluated. Subjective analysis was performed, with radiographic images and not standardized control of the data sets. Serious risk of bias and evaluation errors.

Several studies have attempted to define the misfit numerically, but there was no definite agreement to quantify the acceptable level of the misfit (40). Jemt (41) in 1991 stated that a misfit around 150 microns will be acceptable. Most investigators use the values between 50 and 200 μm are reported with the absence of an objectively accepted threshold (42). Thereupon, the impression data with a misfit larger than 150μm than control group should be advised a no computer-assisted impression employ.

Some devices can be created to minimize the risk of bias. Schmidt *et al.* (29) in 2020 created a metallic device as a reference data set to assist during scanning with IOS (Figure 10).

Figure 10. Metallic reference aid with four steel spheres. Font: Schmidt *et al.* 2020 (29)

Schmidt *et al.* (29) in 2020 have made four digital impressions (Trios3Cart, Trios3Pod, Trios4Pod, and Primescan) and one conventional impression (CVI). The CVI was investigated in five patients. Scan data were analysed using three-dimensional analysis software and conventional models using a coordinate measurement machine (CMM). The transfer accuracy between the reference aid and the impression methods were compared. Differences with $p < 0.05$ were considered to be statistically significant. Overall, mean ± standard deviation (SD) transfer accuracy ranged from 24.6 ± 17.7 μm (CVI) to 204.5 ± 182.1 μm (Trios3Pod). The Primescan yielded the lowest deviation for digital impressions (33.8 ± 31.5 μm), followed by Trios4Pod (65.2 ± 52.9 μm), Trios3Cart (84.7 ± 120.3 μm), and Trios3Pod. Within the limitations of this study, current IOS demonstrated less deviation for short-span distances compared with the conventional impression technique. The authors have concluded that, currently available IOS systems demonstrated improvement regarding transfer accuracy of full-arch scans in patients. Even though, the Trios3Pod scanner showed higher values than those recommended (41).

Finally, the clinical trials of Chochlidakis *et al.* (30) in 2020 report that the 3D accuracy of full-arch digital implant scans lies within clinically acceptable threshold. The full-arch digital scans and a complete digital workflow in the fabrication of maxillary fixed complete dentures may be clinically feasible. They conducted a prospective clinical study to compare the reliability of digital and conventional impression in completely edentulous patients rehabilitated with dental implants. Sixteen patients received maxillary implant supported fixed complete dentures. After the verification of the conventional final casts, these casts were scanned with a desktop (extraoral) scanner. Intraoral full-arch digital scans were also obtained with scan bodies and STL files. The extraoral and intraoral scans were superimposed and analysed with reverse engineering software. This study, the primary outcome measure was the assessment of accuracy between scans of the verified conventional casts and digital full-arch impressions. The secondary aim was the effect of the implant number on the 3D accuracy of impressions with Spearman's rank correlation coefficient. These 3D deviations between virtual casts from intraoral full-arch digital scans and digitized final stone casts generated from conventional implant impressions were found to be 162 ± 77 μm. In the 4-implant group, 5-implant group, and 6-implant group the 3D deviations were found to be 139 ± 56 μm, 146 ± 90 μm, and 185 ± 81 μm, respectively. There was a positive correlation between increased implant number and 3D-deviations, but there was no statistically significant difference ($p = 0.191$). However, the 6-implant group showed higher values than recommended by Jemt (41).

Significantly, most of the articles eligible for this integrative review were in upper jaw (13 or 59%) or maxilla models in the specifics of laboratory studies (9, 13, 16-26, 30) as reported in Figure 2.

In studies performed with maxilla (or model), 8 of these (61.53%) cases showed positive findings to the use of IOS in complete digital workflow for confection the total prosthesis on implant (13, 16-19, 21, 22, 24, 30). Moreover, in 3 studies on the upper jaw (or model), the results were unfavourable to the use of IOS in the confection of the prosthesis (9, 23, 26).

Particularly, in an article published in 2015 by Gimenez *et al.* (9), they confectioned a maxillary master model with six implants located in the second molar, second premolar, and lateral incisor positions were fitted with six cylindrical scan bodies. The scan bodies were placed at different angulations or depths apical to the gingiva. Two experienced and two inexperienced operators performed scans with either 3D Progress (MHT) or ZFX Intrascan (Zimmer Dental). Five different distances between implants (scan bodies) were measured, yielding five data points per impression and 100 per impression system. Measurements made with a high-accuracy three-dimensional coordinate measuring machine (CMM) of the master model acted as the true values. The values obtained from the digital impressions were subtracted from the CMM values to identify the deviations. The differences between experienced and inexperienced operators and implant angulation and depth were compared statistically. Neither of the two systems tested would be suitable for digital impression of multiple- implant prostheses. Because of the errors. When comparing

IOS with data obtained with CMM, all values were above the recommended values (41). They had concluded that further development of both IOS is required.

Another research that was unfavourable to the use of IOS in the total digital Workflow, was the research by Kim *et al.* (23) in 2019. They reported Conventional open-tray impressions produced significantly smaller linear displacements than the digital scan obtained using an intraoral scanner at the implant level in a complete-arch model. They had fabricated a master model by duplicating a maxillary edentulous cast that had 6 implant replicas in the right first molar, right first premolar, right lateral incisor, left lateral incisor, left first premolar, and left first molar positions. They used a conventional open-tray, splinted-coping impression technique to fabricate 10 definitive casts (group CI). Intraoral digital scans were performed, after which scan bodies were connected to each implant replica to fabricate 10 digital models (group IOS). For the master model and group CI, a computerized coordinate-measuring machine was used to determine the 3D spatial orientation of the implant replicas. For group IOS, the scan bodies were converted to implant replicas using a digital library, and an inspection software program was used to measure the implant replicas. To compare the accuracies of different impression techniques, a 3D part coordinate system was set to compute the centroid and projection angles of each implant replica. In result, they reported that the Group CI (control) gave more accurate trueness values than group IOS. The Group IOS exhibited a statistically greater angular displacement in the ZX plane (P=.002), but the difference was only 0.24 degrees. This article, no differences were found between the 2 groups for the angular displacement in the XY plane (P=.529).

Markedly, Miyoshi *et al.* (26) in 2020 has reported in your paper that the precision of the digital impression had deteriorated in association with the expansion of the scanned ranges. Therefore, digital impressions for implant treatment should be limited to small prostheses, such as in the 3-unit superstructure supported by two implants for the time being. They scanned an edentulous maxilla model with four intraoral scanners (IOS) and a dental laboratory scanner, and the stereolithography (STL) data were generated for to compare with the conventional impression was made. The authors had defined 9 different ranges of interest (ROIs), and the average discrepancies of the measurement points between each pair of STL images out of five for each ROI were calculated. In their article they found that the discrepancies in the scanned datasets of the dental laboratory scanner were significantly lower than those in the other impression methods. The discrepancies of the IOS were comparable with those of the laboratory scanner when the ROI was limited. The precision of the IOS investigated in this study for the edentulous maxillary with six implants was 29.0 ± 10.0 µm for "*TRIOS Scanner 2*" 16.0 ± 5.3 µm for "*3M True Definition Scanner*" 19.0 ± 1.4 µm for "*Cerec Omnicam scanner*" and 21.0 ± 6.1 µm for "*CS 3600 scanner*". Although, the author reporting these discrepancies, the values are among the recommended tolerance values (150µm) for the misfit of prosthetic components (41).

Overall, the trueness and precision of digital impressions are reported to be deteriorated with an increase in the scanned area (43) (8) (14), which is in agreement with the results of this study. It should be noted that the conventional impression also showed deterioration of precision as the ROI expanded. This finding was not unexpected and has been well acknowledged among clinicians, although, unfortunately, no study has investigated the relationship in a systematic and morphometrical manner (26).

Previously, it was shown in the results that the prevalence of studies in the mandible was 6 articles. Among these, only 1 case showed results not favourable to the use of IOS in total arches with dental implants.

Huang *et al.* (28) in 2020 has fabricated a mandible model to scanning using IOS with different scan bodies: DO - original scan body 4.1 mm; DC - scan body without extensional structure 5.5 mm; DCE - scan body with extensional structure and CI - a conventional splinted open-tray impression were taken (Figure 11).

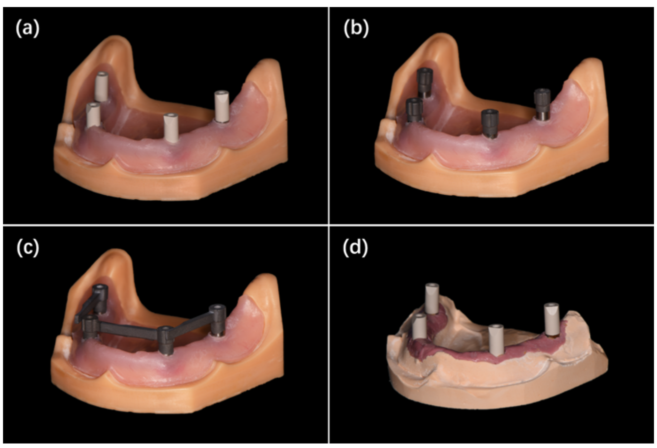

Figure 11. Group division. (a) Group I: Digital impressions using original scan bodies. (b) Group II: Digital impressions using CAD/CAM scan bodies without extensional structure. (c) Group III: Digital impressions using CAD/CAM scan bodies with extensional structure. (d) Group IV: Conventional splinted open-tray impressions. Font: Huang *et al.* 2020 (28)

The reference model and conventional stone casts were digitalized with a laboratory reference scanner. In conclusion, the conventional splinted open-tray impressions were more accurate than digital impressions for full-arch implant rehabilitation. However, the values found in the digitalization of the groups were: the median of trueness was 35.85, 38.50, 28.45, and 25.55 μm for group I, II, III, and IV, respectively. CI was more accurate than DO ($p = .015$) and DC ($p = .002$). The CI group was more accurate than DO ($p < .001$), DC ($p < .001$), and DCE ($p = .007$). DCE was more accurate than DC ($p < .001$) and DO ($p < .001$). Nonetheless, the research was showing these discrepancies, the values are among the recommended tolerance values (150μm) for the misfit of prosthetic components (41).

Patients with complete dentures have benefitted from the use of implants to improve masticatory efficiency. This review reported high implant and prosthesis survival rates for fixed rehabilitations and was supported by studies describing fixed dentures on 4 to 6 maxillary and mandibular implants.

When analysing the articles eligible for this review, papers that presented different methodologies had found. Regarding the amount of dental implants used for rehabilitation, ten (45.45%) articles were studied with 4 dental implants (13, 16-19, 21, 24, 27-29), two (9%) with 5 implants (8, 15), eight (36.36%) papers with 6 implants (3, 9, 14, 20, 22, 23, 25, 26). Nevertheless, other studies were formatted for different amounts of implants: one article with 2, 4 and 6 implants (1) and other research with 4, 5 and 6 implants (30).

However, among the 22 eligible papers, 8 studies with 4 maxillary implants (13, 16-19, 21, 24, 30), the scanned data, recommending the use of IOS in the total workflow because there were no significant data discrepancies between control groups (Table 5).

Conversely, studies that were performed with 6 implants ($n = 3$) in the maxilla presented data that were more inconsistent with the use of IOS in total edentulous arches and they would not advise the use of them (9, 23, 26).

However, these differences can be justified because the digital impression method cannot capture the whole dental image with a single scan, and scanned images of limited areas are connected and stitched to construct the whole image, the accumulation of errors increases as the range of the impression expands (14, 44). Otherwise, dental laboratory scanners show higher precision regardless of the range of the impression because they can capture the entire range of the model in a single laser scan (45).

Other factors that could influence the accuracy of impressions are implant angulation, although evidence is insufficient in this field (2, 18).

Notably, in this review, most articles were performed with tilted implants (n=8) (8, 9, 14, 15, 17, 23, 25, 29) and cases that had tilted and parallel implants (n=5) (1, 18, 19, 22, 30). In only 2 cases (9, 23), in research with tilted implants, the use of IOS did not present data that favoured the use of the scanner when compared with the control group. The other 2 cases, which did not have data to confirm the use of IOS in patients with total edentulism, occurred in a research on parallel implants (28) and another case in which the paper did not present details on the angulation of the implants (26).

Table 5: Recommendation to use of IOS in full-arch

Implants	Max or Man	Recommendation	Cases	Frequency
4	Max	Yes	8	29,63%
4	Mand	Yes	4	14,81%
6	Max	No	3	11,11%
5	Mand	Yes	2	7,41%
6	Max	Reservations	2	7,41%
6	Max	Yes	2	7,41%
6	Mand	Yes	2	7,41%
2	Mand	Yes	1	3,70%
4	Mand	No	1	3,70%
5	Max	Yes	1	3,70%
6	Mand	Reservations	1	3,70%

Studies have showed that when angulation was increased up to 45 degrees, accuracy was not affected in digital impression (18). Logically, accuracy of digital impression should not be affected by the angulation of implants as the concern of impression material deformation during removal, or displacement of impression coping. Tilted implants showed better accuracy than straight implants which can be explained by the fact that, in conventional impressions, the operator may remove the tray unexpectedly in direction of the tilted implant to prevent distortion.

In contrast, Lin *et al.* (46) in 2015 reported that the divergence between the two implants (0, 15, 30, and 45 degrees) did not affect the accuracy of the definitive cast created through traditional impression, but the divergence between the two implants significantly affected the accuracy of the milled cast through digital impression. They had reported that, at lower levels of divergence (0 to 15 degrees), conventional impression was more accurate than digital impressions. However, at a higher divergence (30 to 45 degrees), the differences in accuracy between conventional and digital impressions became less noticeable, with conventional impression still being slightly more accurate.

The use of digital scanning for completely edentulous arches has been questioned. The surface area to be scanned increases the risk of angulation errors due to an accumulation of registration errors of the patched 3D surfaces, especially in the mandible, as was shown with dentate arches (11, 47). Moreover, because of lack of anatomic relief (38, 48), mucosal changes during mandibular movements (19), and similarity of the morphology of the scan bodies, their individualization is complex (11, 33).

Certainly, if the technical procedures and contact with the oral mucosa have limited, optical scanning would be might improve patient comfort. These technologies rely on triangulation, confocal imaging, active wavefront sampling, or stereophotogrammetry to determine the distance to the object. Scan bodies, specific to optical technologies, need to be screwed or snapped on the implant or abutment to adequately transmit the 3D implant position. Hovering over the dental arch, the optical scanner produces a digital file (49).

Two main technologies for digital scanning have found in this review: confocal microscopy associated with 3D imaging technologies and photogrammetry (Table 4). Photogrammetry relies on photographic images to record the geometrical properties of 3D objects (optical targets) and their interrelated spatial positions.

Intraoral scanners use a video technique or still photo technique for the image scanning. Still, images are based on triangulation or parallel confocal laser scanning. Systems take several still images from which a 3D image can be formed. These are basic principles, and in addition to this each manufacturer uses its own techniques. IOS may also use multiple techniques for data collection. LAVA® C.O.S. (3M ESPE, St. Paul, MN) and Lava True Definition scanner (3M ESPE) use active wavefront sampling for data collection from which video image is formed. The CEREC® AC Omnicam (Sirona Dental System GmBH) system uses video for data collection. iTero® (Invisalign; Cadent Inc, Or-Yehuda, Israel) and 3Shape® Trios (Copenhagen, Denmark) use the parallel confocal method to produce digital data (49).

The IOS TRIOS® (3Shape), in this review, the most was used scanner (34.78%). Then, the IOS True Definition® (3M) was used in 26.09% of the papers and, subsequently, CEREC® AC Omnicam was performed in 8.70% of the cases (Figure 5).

Comparison of the performance of the confocal microscopy associated with 3D imaging technologies and photogrammetry with the conventional impressions had favoured the digital systems, or the systems were at least equivalent (1, 8, 13-19, 21, 22, 24, 27, 29, 30). The results for trueness for the full arch prosthesis were quite different.

Obviously, the reference models were different, and the acquisition software has been substantially improved, since the oldest article showed the worst accuracy. The accuracy is dependent not only on the optical scanning devices, but also the software used. Basically, the acquired surface data by IOS would be arranged in a common coordinate system, and then image reconstruction would be carried out (7). Due to the humid environment and the different materials and textures, such as a gingiva and the cheek in the oral cavity, as well as the mouth movements, direct intra oral scanning can be especially challenging. Furthermore, when imaging with no teeth, a higher resolution of acquisition is needed to make visible the gingival border and morphological variables among different individuals (50).

In despite this, in implantology, scan bodies (SB) have helped the IOS in scanning performed. Which are directly connected to the implants, were used as the scan object instead. It may be beneficial for digital implant impressions, because SB dimensions and unique features were input ahead of time into the software .

In addition, dull, smooth, and opaque surfaces of SB could contribute to easier scanning. Since digital implant impressions aim to capture not refined finish lines of the preparation but their position, IOS are suitable for implant impressions. Consequently, SB plays an important role in digital implant impressions (51).

Some reviews including literature and systematic reviews, as well as in vitro and clinical studies, have demonstrated that IOS use can, under certain conditions, significantly reduce impression time when compared with conventional approaches using impression materials and trays, although many studies included other clinical steps such as antagonist scans, occlusal bite record scans and data processing of IOS when investigating time efficiency (7).

Overall, the main limitations of the present study were the low number of clinical trials involving digital scanning for complete-arch implant-supported restorations. Results seemed promising, but longer follow-up is needed. However, the clinical validation of the framework fitting accuracy is difficult to ensure because radiographic evaluation and passivity sensation provide uncertain results.

The scientific evidence obtained through the present systematic review is limited to few clinical studies and in lab full-arch reconstructions. Different study protocols were applied during impression taking. Thus, heterogeneity among the included studies was distinct and data were difficult to compare.

Although randomized controlled clinical trials (RCT) are considered to provide the highest scientific evidence, an integrative review design might be considered more appropriate to evaluate efficiency and/or effectiveness of articles already published.

Finally, the use of digital scanning for rehabilitation in edentulous patients will reach maturity when digital scanning is included in a complete digital workflow.

5 – CONCLUSION

Within the limitations of this integrative review, the accuracy of IOS systems is comparable, in some cases, was better than the accuracy of conventional impressions.

Notably, most studies have shown that the IOS accuracy of full-arch digital implant impressions lies within acceptable threshold and a complete digital workflow may be clinically feasible.

Certainly, the different IOS systems appear to have the potential to provide an outcome of similar accuracy range, no preference for a particular system can be made.

There is evidence to show that IOS use can, significantly reduce impression time when compared with conventional approaches using less impression materials and trays and simplify the occlusal bite record.

Especially, there is still no clear consensus on influence of the implant scan body material, implant angulation and linear deviations and finally operator effect on the IOS accuracy wasn't well cleared.

Further studies on this subject need to be carried out so that some issues could be clarified in the future.

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