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A systematic review about randomized clinical trials on digital impressions on sound teeth

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ABSTRACT

Aim In the dental literature there are a number of studies about digital impressions. They mainly are focused on the reproducibility of the measurements or on the validity, accuracy, trueness and precision of the scans compared with conventional materials, or on the reaction of patients to these new methods. The purpose of this study was to systematically review existing clinical trials reporting about intra oral scanning procedures on sound teeth.
Materials and methods PubMed, Cochrane Library and Web of Science databases were electronically searched and enriched by hand searches. The query terms "randomized clinical trials", "in vivo study", "sound teeth", "intraoral scanner", "digital dentistry" combined with the Boolean operators "OR" and "AND" have been used. No language or time limitation was applied. Selection criteria: oly randomized in vivo studies where sound teeth had been scanned intraorally were considered.
Results Twenty-four out of more than three hundred studies were selected for the review.
Conclusion In literature there are enough randomized clinical trials about sound teeth. They report about many clinical aspects.

KEYWORDS Digital dentistry, Digital impressions, Intraoral scanner.

INTRODUCTION

In the last years the use of digital impressions in dentistry has increased because of the progress of scanning systems (1,2,3,4,5).

In everyday life dentists use chairside devices to create digital models instead of using conventional impressions and gypsum casts, with all the advantages that they involves: minimal invasiveness or comfort for the patient, immediate verification of the impression, digital process simplification, instant feedback, easy communication with the patient, colleagues and technicians, reduced impression storage, possibility of a chairside fabrication of custom made removable and fixed appliances, etc. (6).
Digital models are used to study cases and make correct treatment plans, or to project prosthesis in a complete digital workflow, which permits the use of new materials that cannot be used with a conventional workflow.
In literature there are a number of studies about precision of different scanners, or about validity, reproducibility and reliability of the scans compared with traditional impression materials. But once these themes are scientifically proved and accepted, scanners will be considered valid and useful for daily dentistry; the learning curve that practitioner might need to achieve a good quality level impression made by intraoral scanner has to be studied.
The present review wants to analyze randomized clinical trials about sound teeth in literature to check which topics have already been analyzed enough and which topics need to be further explored.
In keeping with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews, the research question was then formulated with reference to participants (patients with sound teeth), intervention (full arch or partial digital impressions), and study design (*in vivo* study) parameters of the participants, interventions, comparators, outcomes, and study design (PICOS) method (7).

MATERIALS AND METHODS

An electronic search of the literature was conducted through PubMed, Cochrane Library and Web of Science, entering the query terms "randomized clinical trials", OR "*in vivo* study", OR "sound teeth", AND "intraoral scanner", AND "digital dentistry".
No language or time limitation was applied, in order not

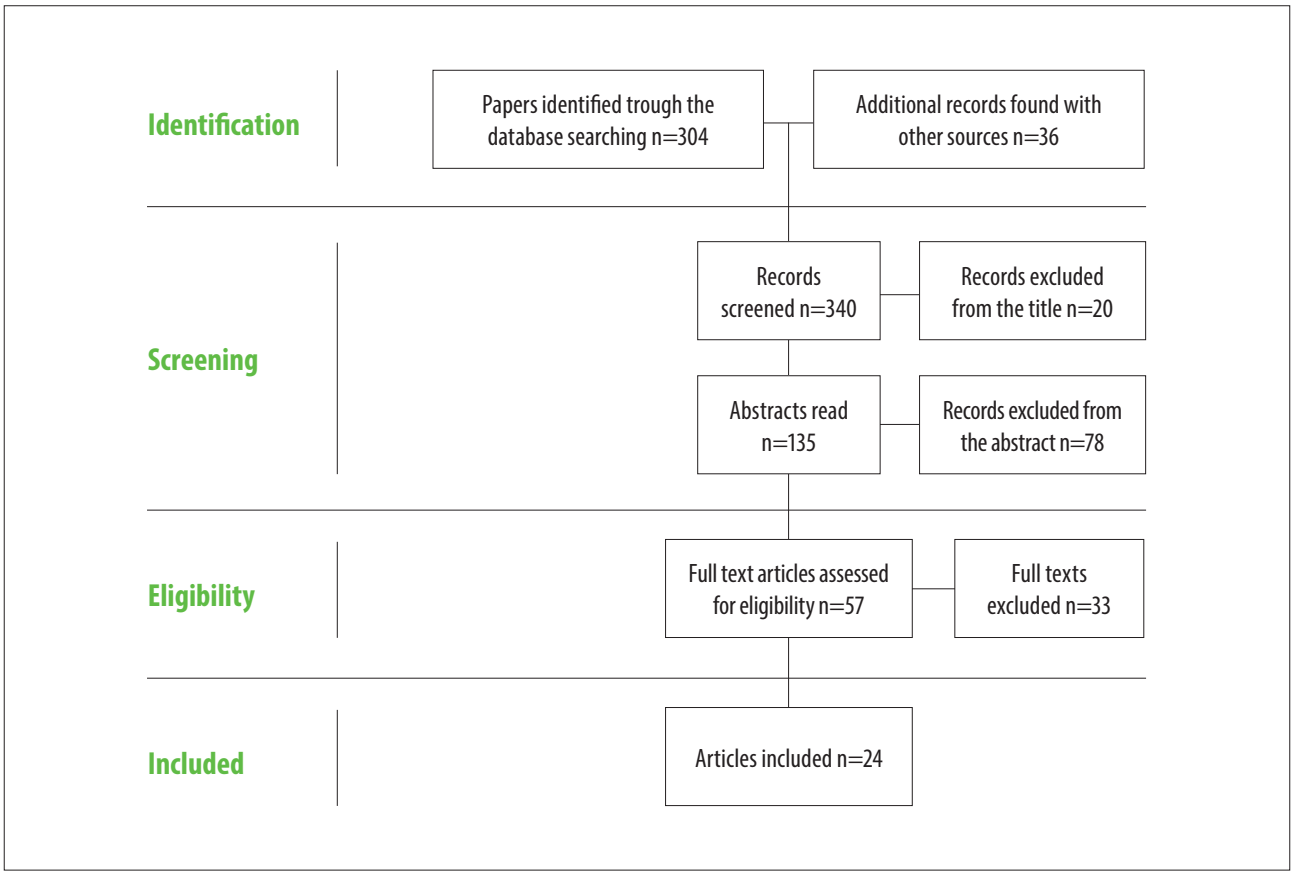

FIG. 1 Selection of articles.

to leave any study out.
Only randomized studies where sound teeth had been scanned intraorally were considered.
The papers were examined in different steps (Fig. 1).
Firstly, all the titles obtained from the research were read and titles that evidently did not refer to sound teeth impressions were excluded.
Then the abstracts of the selected titles were screened and all *in vitro* studies were excluded.
Then full-text articles were carefully read. Only the studies that were relevant to the objectives of the review and satisfied the requirements of the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) checklist (8, 9) were included in the review.
At the end, only randomized clinical studies on sound teeth digital impressions were included.
Papers referenced in the selected studies were added to the reviewed literature if pertinent.
The web was browsed by entering in the Google search box the same query terms as those used in the PubMed.

RESULTS

Around 300 articles were found from the research on the Pub-Med database and the other steps mentioned.

At first, the titles of these publications were read and those evidently referring to *in vitro* studies, implants or prepared teeth were discarded.
Secondly the abstract of the remaining articles was evaluated, and they were further selected. After an even more in-depth evaluation, and the selection of the studies mentioned as references in those already approved, only twenty-four studies met the criteria of the review (Table 1).
In the majority of cases, these studies were about accuracy, trueness or precision (10-23).
Other studies compared digital and conventional impressions (10-16, 19-27).
Five studies were about comfort, time perception and preferences of the patient (24, 25, 27, 28, 29).
Some of them were orthodontic studies (9, 14, 18, 24, 20, 29).
In many cases full arch impressions have been taken (11, 13-17, 30, 31), while in only two studies quadrant impressions have been considered (12, 19).
One study was inspired by a surgical application (31) and one had a gnathological implication (32).
Some papers took into consideration the experience of the operators (27, 29, 30, 33) and other mentioned learning curve (17, 30, 33).
Only two papers (20, 30) considered time as an important factor and only one (13) was about difficulties derived

Reference	Author	N of treated patients	Used IOS	Mean topic investigated
24	Burhardt	38	CEREC Omnicam, Lava C.O.S.	preferences of orthodontic patients
25	Burzynski	180	iTero, TRIOS	preferences of patients, comparison with traditional impressions
10	Camardella	28	TRIOS color	accuracy reproducibility of measurements on digital models
28	Chalmers	43	TRIOS	patient perception
11	Ender	5	Lava T-Def, Lava C.O.S., iTero, TRIOS, TRIOS color, CEREC bluecam 4.0, CEREC bluecam 4.2, CEREC omnicam	comparison between the scanners and traditional impressions
12	Ender	5	CEREC Bluecam, CEREC Omnicam, Cadent iTero, Lava COS, Lava T-Def, Trios, Trios Color	comparison between the scanners and traditional impressions
13	Flugge	1	iTero	precision
30	Garino	328	iTero	efficiency, scanning times
14	Grunheid	15	Lava COS	accuracy, scan time, patient acceptance
31	Hernández	6	Lava COS	interocclusal relationship
32	Jaschouz	15	CEREC bluecam	interocclusal relationship
15	Kamimura	12	Lava COS	inter-operator reproducibility
33	Kim	4	iTero, TRIOS	learning curve
16	Kuhr	50	CEREC Omnicam, Lava T-Def, TRIOS	comparison between the scanners and traditional impressions
26	Lee	32	iTero, TRIOS	comparison between the scanners and traditional impressions
17	Lim	1	iTero, TRIOS	trueness, reproducibility, experience
18	Naidu	30	iOC	Validity, reliability, reproducibility
19	Ning Gan	32	TRIOS	accuracy
29	Park	24	iTero, TRIOS	operator preferences
20	Wiranto	22	Lava COS	validity, reliability, reproducibility of linear measurements
21	Xie YL	5	Trios Ortho	comparison with conventional impressions
27	Yuzbasioglu	24	CEREC Omnicam	preferences of patients
22	Zhang	20	iTero	accuracy reproducibility of measurements on digital models
23	Zimmermann	5	Cerec Omnicam Ortho, Ormco Lythos	comparison with conventional impressions

TABLE 1 The works analyzed.

from intraoral conditions (saliva and limited spacing).

DISCUSSION

In most of the considered studies it is concluded that intraoral scanners have a clinically acceptable accuracy and excellent reliability and reproducibility (18, 19). Comparing digital intraoral impressions with the conventional ones, Ender concludes that "Digital impression systems had higher local deviations within the complete arch cast; however, they achieve equal and higher precision than some conventional impression materials" as irreversible hydrocolloid material. And that "no advantage in accuracy is gained by digitizing a conventional impression" (11). In another study with the same protocol but on quadrant impression he stated: "The clinical precision of digital quadrant impression model is sufficient to cover a broad variety of restoratives indications".

Conventional materials used to make comparisons were alginate, polyether or polyvinyl siloxane.

In some papers the conventional workflow was used to make a comparison between the reproducibility of the measurements made on digital models with a specific software (as orthocad), and the measurements made on physical models with a digital caliper (10, 18, 20). In Naidu's study measurements of tooth widths are applied to the calculation of Bolton index (18). A similar study is conducted by Wiranto that compares the conventional workflow with the indirect digitization with a CBCT of the model and with a totally digital workflow concluding that both are valid, reliable and reproducible methods (20).

Other studies use conventional materials to compare the patient's preference for conventional impressions or digital ones. Grunheid (14) evaluates time and patient acceptance of full arch scans and finds out that "73.3% of the patients preferred impressions because they were "easier" or "faster"." On the contrary in Burhardt's and Yuzbasioglu's studies patients prefer digital impressions (24, 27).

The practical aspect is also evaluated by Park (29) but from the operator's point of view. He uses questionnaires asking about the difficulty of use, patient discomfort, awareness, preference, and clinical usefulness of two intraoral scanners (iTero and Trios) comparing them. This paper focused the attention on a singular point: appropriate training can change the operator's perceptions on the efficiency of intraoral scanners positively.

In other publications the importance of training is considered: Garino conducts a study in which operators have the same training and similar skills (30), Lim (17) and Kim study the changes of scanning accuracy and time respectively, with repeated scanning experience in operators with almost three years of working experience. Kim concludes that "scanning time was influenced by clinical experience", it decreased after repeated scanning, while scanning proficiency increases (33). A limitation of Kim's study is that operators did only ten digital impressions and this number of session was too short to reach a plateau: the learning curve presented is incomplete because scanning time decreased until ninth and tenth sessions, so that it can only be supposed that with continuous practice a plateau would be reached. All these studies were on hygienists not dentists or dentistry students.

Other aspects of intraoral digital impressions have been taken into consideration: Kamimura studies the interoperator reproducibility and asserts that "inter-operator reproducibility with a digital impression technique may be better than that of a conventional impression technique and is independent of the clinical experience of the operator" (15). This is one of the best advantages of intraoral scanners: make the operator's experience almost irrelevant on the quality of scans so that even a young inexperienced operator can be able to take a good quality impression.

Only in Yuzbasioglu's paper operators have no previous experience and times of scanning with Cerec (Omnicam, Sirona) are compared. "The mean overall treatment time of the digital impression technique was 248.48 ± 23.48 s (27). The mean time for entering patient information was 19.08 ± 3.57 s, and the mean time for entering the laboratory prescription time was 13.63 ± 1.98 s. The mean digital impression time for the upper and lower jaws was 98.94 ± 10.56 s and the mean bite scan time was 14.68 ± 3.82 s." (27).

Time is also considered by Garino (30) who notes that once experience has been gained, the time needed to make a full intraoral scan with itero is 10-11 minutes, and by Wiranto who focuses his analysis on the measurements on plaster and digital models mentions the use of powder and time and techniques needed to prepare teeth to the scan: "for making an intraoral scan, the tooth surfaces were first dried and coated with a thin layer of titanium oxide powder; the process of powder coating the dentition takes 1 minute. The maxillary and mandibular dentitions were scanned separately, and then a scan of the teeth in occlusion was made" (30).

Few studies look at clinical practice, Flugge considers specifically that "intraoral conditions (saliva and limited spacing) contribute to the inaccuracy of a scan" (13).

Other applications of intraoral scanners are also interesting, in particular two studies were different from the others selected for this review: Jaschouz studies how the habitual intercuspation of patients varies with the position of the patient and at different times (32). Meanwhile Hernandez shows how digital models can be used in combination with CBCT to create a virtual patient and to study the intermaxillary relationship "to obtain the intermediate splint by CAD-CAM technology (computer aided design, computer aided manufacturing) (31) this procedure eliminates the need for dental impressions, simplifies the necessary technical steps and computational work, and reduces the patient's exposure

to ionizing radiation" (31).
However, accordingly with a recent survey made by National Union of Italian Dental Industries (UNIDI), only 5% of European dentists already have an IOS in their practice. That might be in contrast with the RCT results already described. It is highly desirable to have available RCTs with more focus on learning curve to achieve satisfactory IOS impressions from practical and precision point of view.

CONCLUSIONS

In literature there are enough *in vivo* randomized clinical trials about sound teeth.
A large part of the literature about digital scanning is represented from *in vitro* studies. *In vivo* studies deal with implants or implant surgery applications and fixed prosthesis.
The majority of the reviewed articles concern preferences of patients, comparisons with conventional materials, precision and reliability of the scanners or define their possible applications in the orthodontic or other branches. No study gives the user indications about the learning process and needed time to reach a high standardized quality level of intra oral digital impressions.

REFERENCES

1. Joda T, Ferrari M. Chairside protocol for posterior single-unit implant restorations in a complete digital workflow. J Osseointegration 2018; 10(2): 33-36.
2. Sorrentino R, Nagasawa Y, Infelise M, Bonadeo G, Ferrari M. In vitro analysis of the fracture resistance of CAD-CAM monolithic lithium disilicate molar crowns with different occlusal thickness. J Osseointegration 2018;10(2):50-56.
3. Gastaldi G, Gherlone E, Manacorda M. A 3-D CAD/CAM technique in full-arch implant supported rehabilitations: the Virtual Implant-Prosthetic Procedure (VIPP Technique). A prospective longitudinal study. J Osseointegration 2018;10(1):2-10.
4. Venezia P, TorselloF, Cavalcanti R. E. Casiello, Chiapasco M. Digital registration of peri-implant transmucosal portion and pontic area in the esthetic zone. J Osseointegration 2017; 9 (4): 312-6.
5. Sorrentino R, Leone R, Leuci S. E CAD/CAM cobalt-chromium alloy single crowns in posterior regions: 4-year prospective clinical study. J Osseointegration 2017; (3): 282-8.
6. Goracci C, Franchi L, Vichi A, Ferrari M. Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: a systematic review of the clinical evidence. Eur J Orthod 2016 Aug;38(4):422-8.
7. Liberati A, Altman DG, Tetzlaff J. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol 2009;62: e1-34.
8. Whiting P, Rutjes AW, Reitsma JB. The development of QUADAS: a tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. BMC Med Res Methodol 2003; 3:25.
9. Whiting PF, Rutjes AW, Westwood ME. QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med 2011; 155:529-36.
10. Camardella LT, Breuning H, de Vasconcellos Vilella O. Accuracy and reproducibility of measurements on plaster models and digital models created using an intraoral scanner. J Orofac Orthop 2017;78(3):211-220.
11. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent 2016; 115:313-320.
12. Ender A, Zimmermann M, Attin T. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig 2016;20(7):1495-504.
13. Flügge TV, Schlager S, Nelson K. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop 2013; 144:471-8.
14. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of accuracy, time, and patient acceptance. J Orthod Dentofacial Orthop 2014; 146:673-82.
15. Kamimura E, Tanaka S, Takaba M. In vivo evaluation of inter-operator reproducibility of digital dental and conventional impression techniques. PLoS One 2017 Jun 21;12(6):e0179188.
16. Kuhr F, Schmidt A, Rehmann P, Wöstmann B. A new method for assessing the accuracy of full arch impressions in patients. J Dent 2016; 55:68-74.
17. Jung-Hwa Lim, Ji-Man Park, Minji Kim. Comparison of digital intraoral scanner reproducibility and image trueness considering repetitive experience. J Prosthet Dent 2018;119(2):225-232.
18. Naidu D, Freer TJ. Validity, reliability, and reproducibility of the iOC intraoral scanner: a comparison of tooth widths and Bolton ratios. Am J Orthod Dentofacial Orthop 2013; 144:304-10.
19. Ning Gan, Yaoyang Xiong, Ting Jiao. Accuracy of Intraoral Digital Impressions for Whole Upper Jaws, Including Full Dentitions and Palatal Soft Tissues. PLoS One 2016; 11(7): e0158800.
20. Wiranto MG, Engelbrecht WP, Tutein Nolthenius HE. Validity, reliability, and reproducibility of linear measurements on digital models obtained from intraoral and cone-beam computed tomography scans of alginate impressions. Am J Orthod Dentofacial Orthop 2013; 143:140-7.
21. Xie YL, Shen G. Accuracy and reproducibility of intraoral scanning in vivo. Shanghai Kou Qiang Yi Xue 2016;25(5):593-599.
22. Zhang, Suh, Lee. Validity of intraoral scans compared with plaster models: an in-vivo comparison of dental measurements and 3D surface analysis. PLoS One 2016; 11(6): e0157713.
23. Zimmermann M, Koller C, Rumetsch M. Precision of guided scanning procedures for full-arch digital impressions in vivo. J Orofac Orthop 2017;78(6):466-471.
24. Burhardt, Livas, Kerdijk. Treatment comfort, time perception, and preference for conventional and digital impression techniques: A comparative study in young patients. Am J Orthod Dentofacial Orthop 2016; 150:261-7
25. Burzynski JA, Firestone AR, Beck FM. Comparison of digital intraoral scanners and alginate impressions: Time and patient satisfaction. Clin Oral Investig 2016;20(7):1495-504.
26. Lee KM. Comparison of two intraoral scanners based on three-dimensional surface analysis. Prog Orthod 2018; 12;19(1):6.
27. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014; 14: 10.
28. Chalmers EV, McIntyre GT, Wang W. Intraoral 3D scanning or dental impressions for the assessment of dental arch relationships in cleft care: which is superior? Cleft Palate Craniofac J 2016; 53(5):568-77.
29. Park HR, Park JM, Chun YS. Changes in views on digital intraoral scanners among dental hygienists after training in digital impression taking. BMC Oral Health 2015; 15: 151.
30. Garino F, Garino B, Castroflorio T. The iTero intraoral scanner in Invisalign treatment: a two-year report. J Clin Orthod 2014; 48:98-106.
31. Hernández-Alfaro F , Guijarro-Martínez R. New protocol for three-dimensional surgical planning and CAD/CAM splint generation in orthognathic surgery: an in vitro and in vivo study. Int J Oral Maxillofac Surg 2013;42(12):1547-56.
32. Jaschouz S, Mehl A. Reproducibility of habitual intercuspation in vivo. J Dent 2014;42(2):210-8.
33. Kim J, Park HR, Kim M. Comparison of experience curves between two 3-dimensional intraoral scanners. A new method for assessing the accuracy of full arch impressions in patients. J Dent 2016; 55:68-74.