

Intraoral scanner versus conventional impression techniques. Patient satisfaction and other patient-reported outcomes: a systematic review

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ABSTRACT

Objective: Intraoral scanner impressions are already present for many clinicians. The positive and pleasant patients experience takes special relevance in contemporary dentistry. The purpose of this systematic review was to analyze whether there are any differences in relation to comfort, satisfaction, and preference when patients at the dental office are receiving conventional impressions or digital impressions. **Methods:** a bibliographic search was carried out in Medline, Embase, Web of Science, Central, and Clinical Trials according to PICO strategy. The data screening was done by two authors. Risk of bias was evaluated using a Cochrane collaboration tool. The protocol was registered in PROSPERO. **Results:** Initial systematic search found 79 articles. After removing duplicated ones and those that did not meet inclusion criteria, there remained 10 studies. Seven of the included studies showed favorable results with digital impression in relation to comfort, satisfaction, and preference, while two of them showed

more favorable results for conventional ones. There was one study that did not show conclusive data between intervention and comparison. Two meta-analyses of subgroups were carried out with four of the articles, according to Brand of the scan and type of randomization. **Conclusions:** there is a high heterogeneity in methods used in available RCTs. Most of them do not contribute enough information to analyze and integrate statistics. Conclusions should be interpreted cautiously. Current scientific evidence suggests that the perception of patients in relation to comfort, preference, and satisfaction is in favor of intraoral scanners. It is necessary to carry out more RCTs that include patient reported outcome measurements.

KEYWORDS

Intraoral scanner. Digital impression. Patient-reported outcome measures. Satisfaction. Comfort.

INTRODUCTION

The technological aspects of dentistry have been undergoing changes for some time now.¹ Digitalization is being imposed, especially in restorative procedures with the well-known CAD-CAM systems.² Nowadays, dental offices and laboratories do not have full digitalization,³ but the number of steps dentists carry out digitally is gradually increasing. A good example of this are impression procedures. This is the main clinical change step affected with the appearance of intraoral scans and their commercialization.⁴

There are too many patients that suffer partial or full edentulism that need to recover aesthetics and function, as well as patients with attrition and erosion show severe malocclusions that need to be restored. These and several other situations require an impression to obtain a model of the patient's mouth as the first step to study the case and, subsequently, to establish a treatment plan, as well as in your own execution. These impres-

sions are indispensable and could be taken by conventional or digital means.

Intraoral scanners carry out a caption of the arches and the occlusal registration of the patient. The dentist introduces the head of the scanner into the mouth according to the instructions given by the manufacturer. Images from the caption appear on the screen in real time, and, with a specific software, can be worked on the system's own software or sent to the technician.

Conventional impression techniques are currently the most commonly used procedure for obtaining models of the dental arches⁵. This procedure consists of using a viscoelastic material, which after being prepared, is introduced into the mouth using a tray. When it is first inserted, the material in a gel state, after a few minutes the sun phase and gives a negative of the dental arches. This process is usually carried out in the upper and the lower jaw. The most frequently used materials are irreversible hydrocolloid, polyvinyl siloxane,

addition silicones, condensation silicones and polyethers, and your choice of the material depends on the purpose of the model. Moreover, the occlusion is registered by introducing warm wax or biting silicones. After that, the technician could pour the models and continue the prosthetic design in a conventional way, or it could also be possible to digitally scan the models and continue working in a digital manner.

Intraoral scanners have several advantages in comparison to conventional impression techniques, such as: avoiding the use of disposable materials, higher reliability, cleaner process etc. However, these advantages, mechanical aspects, and how it influences the final restoration are still being analyzed and studied in the scientific literature.⁶⁻⁹

MATERIALS AND METHODS

A systematic review of the literature has been carried out. PRISMA recommendations have been considered.¹⁷ The protocol was registered in the International Prospective Register of Systematic

Thus, it is very important to find out patients' perception of these techniques in relation to comfort and satisfaction, and even whether they prefer one or the other.^{10,11} These three aspects could be included in the measurement of results reported by patients (PROMS), and should be considered as the rest of measurements of results.^{12,13} The way to quantify these perceptions and to be able to measure changes with scales, such as visual analogue scale,¹⁴ is widely used to evaluate pain.^{15,16}

The objective of this review is to analyze whether there are any differences in perception according to comfort, satisfaction, or preference in dental office patients, when comparing conventional impression techniques and digital impressions.

Reviews (PROSPERO) with the following identification code: CRD42019127468.

PICO question was the following: Are there any differences in patient perception in relation to comfort, satisfaction,

or preference when comparing conventional impression techniques with digital impressions?

Inclusion criteria according to PICO model were the following:

1. Patients: patients that need a dental study or treatment planning.
2. Intervention: digital impression with intraoral scanners.
3. Comparison: conventional impressions with tray and physical materials.
4. Results: comfort, satisfaction and preference reported by the patients.
5. Study designs: randomized clinical trials (RCT).

A bibliographic search was carried out in the following databases: Pubmed (Medline), Ovid (Embase), Cochrane Library (Central), Clinical Trials, and Web of Science 6th May 2019. No limits were applied according to date or language.

Two authors of this review (JS and VG) read the abstracts of each reference

identified during the bibliographic search. According to inclusion criteria, full-text articles that could be relevant were obtained, read in detail, and analyzed each article independently. Disagreements were resolved by consensus between the authors. Articles were screened using Rayyan app (Mourad Ouzzani, Hossam Hammady, Zbys Fedorowicz, and Ahmed Elmagarmid). Rayyan — a web and mobile app for systematic reviews. *Systematic Reviews* (2016) 5:210, DOI: 10.1186/s13643-016-0384-4).

Information was extracted from the included RCTs independently, and the strength of agreement between reviewers was assessed using Cohen's kappa (K) statistic. Data extracted were: sample size, sex, number and experience of the professional/s, type of treatment, type of randomization, model of intraoral scan, use of powder during the scan process, type of material for conventional impression and for biting, duration of the procedure, questions and questionnaires for evaluation, and type of scale for answering.

The risk of bias was calculated according to Cochrane collaboration criteria: randomization, concealment of the assignation, losses in the following period, selective report of results, and other sources of bias.¹⁸ Blinding of participants and professionals was not possible due to the nature of the intervention, so it was removed from the evaluation of the risk of bias.

For continuous results, difference between the mean values were calculated. A statistically significant value $P < .05$ was considered. When it was possible, a meta-analysis was carried out to integrate results of different studies, using aleatory models. Studies that did not provide the information required to do the statistical analysis and to be included in the meta-analysis were subjected to a narrative description.

Meta-analysis was performed with RCTs with similar comparisons for the same measurements of results. Different comparison and intervention measurements were used. Data were confined us-

ing an aleatory effects model. An analysis of the heterogeneity of results between the different studies was also performed by visual analysis of meta-analysis graphics and statistical heterogeneity (I^2). The high levels of heterogeneity and the possibility of a carry-over effect made it impossible to carry out a global meta-analysis between studies with parallel randomization and studies with cross-over randomization. In the other hand, it was possible to realize meta-analysis of the following variables: Brand of the scanner and type of randomization.

The number of participants for each comparison in cross-over studies will be divided equally between scanner group and conventional impression group. Calculations and graphics of meta-analysis were performed using Review Manager (RevMan) [Computer program]. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014. (<http://community.cochrane.org/tools/review-production-tools/revman-5>).

RESULTS

Initial electronic search gave 79 results, of which 30 were duplicated. After the reading of titles and abstracts, 28 of the remaining 49 articles were excluded. The remaining 21 articles were read at full-text, and 11 were excluded.

Of the 10 included studies,¹⁹⁻²⁸ four could be meta-analyzed^{20,21,23,28} (Fig 1). The strength of agreement between the inter-reviewer regarding final study selection was $\kappa = 0.8$.

The characteristics and variables of the included RCTs can be consulted in tables 1 and 2. The total number of patients in-

cluded in this systematic review was 268. It varies from 10 to 50 patients, with a mean of 27 participants. Treatments carried out in these patients were restorative procedures, such as crowns and fixed multiple prostheses; the article by Grünheid included patients under orthodontic treatment.²⁴ Three studies do not include any data about the dentist,^{25,27,28} five of them specify that intervention and comparison is carried out by an experienced dentist,^{19,21,22,24,26} and the studies of both Sailer and Benic were conducted by three experienced dentists.^{20,23}

“Intraoral scanners have several advantages in comparison to conventional impression techniques, such as: avoiding the use of disposable materials, higher reliability, cleaner process”.

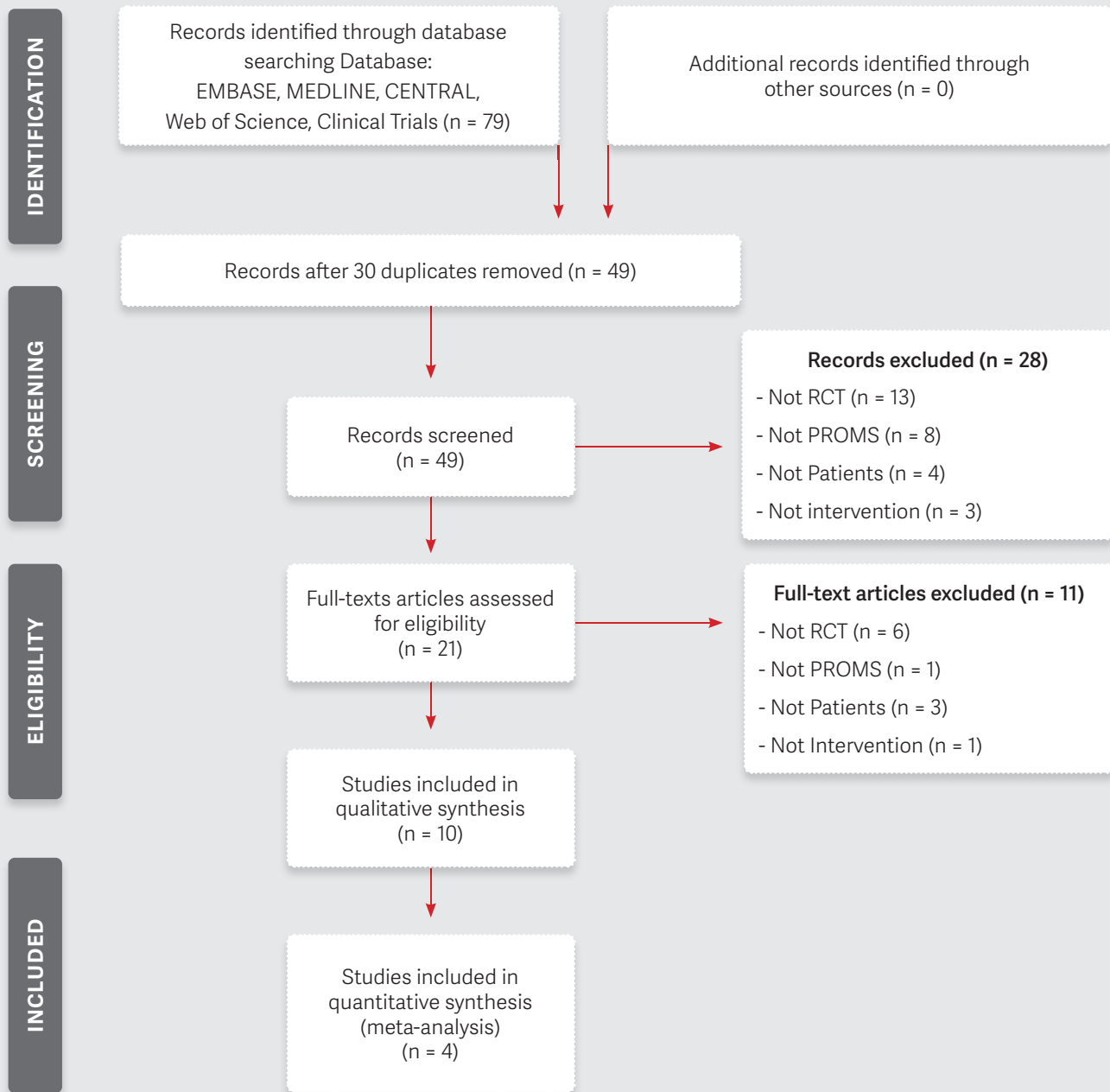


Figure 1: Flow Chart.

Table 1: Characteristics of the included studies.

AUTHORS	SAMPLE	TREATMENT	CLINICIANS	ALETORIZATION
Mangano ²⁸ (2018)	50 patients	Implant-supported prostheses	-	Impression method
Gjelvold ²¹ (2014)	48 patients. 23 women, 25 men	Dental fixed prostheses	1 experienced clinician	Impression method
Sailer ²⁰ (2018)	10 patients. 6 women, 4 men	Dental fixed prostheses	3 experienced clinicians	4 impressions per patient
Benic ²³ (2016)	10 patients. 6 women, 4 men	Dental fixed prostheses	3 experienced clinicians	4 impressions per patient
Haddadi ²⁷ (2018)	19 patients. 9 women, 10 men	Dental fixed prostheses	-	2 impressions per patient
Wismeijer ²⁵ (2013)	30 patients	Implant-supported prostheses	-	2 impressions per patient
Grünheid ²⁴ (2014)	15 patients, 9 women, 6 men	Orthodontics	1 experienced clinician	2 impressions per patient
Sakornwimon ²² (2016)	16 patients	Dental fixed prostheses	1 experienced clinician	2 impressions per patient
Joda ²⁶ (2015)	20 patients	Implant-supported prostheses	1 experienced clinician	2 impressions per patient
Schepke ¹⁹ (2015)	50 patients	Implant-supported prostheses	1 experienced clinician	2 impressions per patient

AREA IMPRESSED	INTERVENTION	COMPARISION
Scan of quadrants and conventional impression for full arch registration	CS 3600 Carestream Dental	Polyvinyl siloxane and irreversible hydrocolloid
Both arches and occlusal registration	Trios 3Shape (TRIOS)	Polyether (IMPREGUM), irreversible hydrocolloid and wax
Both arches and occlusal registration	Lava COS 3M (LAVA) Powder Itero Align Technology Inc (ITERO) Cerec Blue-Cam Dentsply Sirona (CEREC) Powder	Light and Regular Polyether (PERMADYNE), silicone for occlusal registration and irreversible hydrocolloid
Scan of quadrants and unilateral conventional impression	Lava COS 3M (LAVA) Powder Itero Align Technology Inc (ITERO) Cerec Blue-Cam Dentsply Sirona (CEREC) Powder	Polyvinyl siloxane
Scan of quadrants and conventional impression for full arch registration	Trios 3Shape (TRIOS)	Polyvinyl siloxane, irreversible hydrocolloid and occlufast
Scan of quadrants and conventional impression for full arch registration	Itero Align Technology Inc (ITERO)	Polyether (IMPREGUM), irreversible hydrocolloid and wax
Both arches and occlusal registration	Lava COS 3M (LAVA) Powder	irreversible hydrocolloid and wax
Scan of quadrants and conventional impression for full arch registration	3M True Definition. Powder	Polyvinyl siloxane, irreversible hydrocolloid and silicone for occlusal registration
Scan of quadrants and conventional impression for full arch registration	Itero Align Technology Inc (ITERO)	Polyether (IMPREGUM), irreversible hydrocolloid and silicone for occlusal registration (blue mousse)
Both arches and occlusal registration	Cerec OmniCam Dentsply Sirona (CEREC)	Polyether (IMPREGUM), irreversible hydrocolloid and silicone for occlusal registration

Table 2: Tools for measurement and results. VAS (visual analogue scale)

AUTHORS	VARIABLE MEASURED	EVALUATION METHOD
Mangano ²⁸ (2018)	Comfort	VAS 100 mm
Gjelvold ²¹ (2014)	Comfort	VAS 100-mm
Sailer ²⁰ (2018)	Comfort	VAS 100-mm
	Preference	Choosing one intervention
Benic ²³ (2016)	Comfort	VAS 100-mm
Haddadi ²⁷ (2018)	Comfort	VAS 100-mm
	Preference	VAS 100-mm
Grünheid ²⁴ (2014)	Comfort	Likert 5 points
	Preference	Choosing one intervention
Sakornwimon ²² (2016)	Satisfaction	VAS 10
Joda ²⁶ (2015)	Satisfaction	VAS 100-mm
	Preference	VAS 100-mm
Wismeijer ²⁵ (2013)	Preference	VAS 10
Schepke ¹⁹ (2015)	Comfort	VAS 100-mm
	Preference	Choosing one intervention

QUESTION	BETTER RESULTS	STATISTICAL SIGNIFICANT DIFFERENCES
10 questions about treatment received. 1 question about comfort of the impression technique	Digital	Statistically significant (MD = 28.400; 95% confidence intervals [CI], 22.734 to 34.066; P < .0001)
1 question about general comfort	Digital	Statistically significant (MD = 38.360; 95% confidence intervals [CI], 27.255 to 49.465; P < .0001)
1 question about general comfort	Convencional	Statistically significant when comparing conventional versus Lava COS) (MD = 39.000; 95% confidence intervals [CI], 7.336 to 70.662; P < .002)
2 questions: what impression do you prefer? What impression do you not prefer?	No conclusive	
1 question about general comfort	No conclusive	
1 question about general comfort	Digital	Statistically significant (P=.0001)
1 question about general preference	Digital	Statistically significant (P=.003)
1 question about general comfort	Conventional	
1 question about general preference	Conventional	
6 questions for each intervention: time, taste, occlusal registration, size, queasiness and global sensation	Digital	Statistically significant (P<.05) every issue except occlusal registration .Global sensation (MD =1.500; 95% confidence intervals [CI], 0.344 to 2.656; P < .017)
6 questions for each intervention: time, convenience, anxiety, taste, queasiness and pain	Digital	Statistically significant (P<.05) in each question
3 questions: Convenience, speed, preference	Digital	Statistically significant P<.0001) in the 3 questions
7 questions for each intervention: global preference, preparation, time, taste, occlusal registration, size and queasiness	Digital in all aspects, except time	Statistically significant. Global preference (P=.026)
4 questions for each intervention: pain, drowning, anxiety, impotence	Digital	Statistically significant P<.001) in all the questions
1 question about general preference	Digital	-

In relation to the material used for the conventional impression in the main arch, five of the studies used polyether, four of which used Impregum,^{19,21,24,26} and the other Permadyne.²⁰ Four other studies used polyvinyl siloxane,^{22,23,27,28} and one of them used irreversible hydrocolloid.²⁴ For the antagonist arch, all of them used irreversible hydrocolloid except Benic,²³ where the material is not specified. In relation to the occlusion register, five studies used specific silicones,^{19,20,22,26,27} three used wax,^{21,24,25} and two studies do not specify the material used.^{23,28} Scanners used in the different studies were as follows: 3M Lava C.O.S. in three of them,^{20,23,24} iTero-Align Technology in three,^{20,23,25} CEREC Bluecam in two,^{20,23} 3Shape TRIOS in two,^{21,27} 3M True Definition in one,²² CEREC Omnicam in one,¹⁹ and Carestream CS 3600 in one.²⁸

Two studies are parallel studies carrying out just one technique (conventional or digital) on the patients.^{21,28} The rest of them are cross-over studies, so a conventional impression and at least

one digital impression is performed, in a randomized way, in each patient. The two articles in parallel show data about comfort; of the seven cross-over studies, five give information about comfort,^{19,20,23,24,27} two about satisfaction,^{22,26} and six about preference.^{19,20,22,24,25,27}

The most commonly used tool for quantifying the responses was 100-point Visual Analogue Scale (VAS),^{19,20,21,23,26,27,28} followed by dichotomous choice for preference between intervention and comparison in three of the studies.^{19,20,24} 10-point VAS was used in two studies,^{22,25} and 5-point Likert scale was used in one study.²⁴

In five of the included studies, the question about comfort, preference, and satisfaction was included in a questionnaire with different aspects related to taste, queasiness, size of the device, pain and duration of the procedure.^{19,22,25,26,28}

Nine studies include information about the duration of each technique. Periods measured are very variable; measurements are carried out at different

times during the process. The different authors start and finish the measurements at different times and some of them even include the time to fill the laboratory prescription.²⁵

Five RCTs compare data of hemi-arches scanned from a conventional impression of the arch.^{22,25-28} Another four studies performed all the interventions in full-arches.^{19-21,24} For its part, Benic's study performed conventional impression and digital impression in each hemi-arch.²³

In relation to the risk of bias (Fig 2 and 3), four studies do not include information about the mechanism to obtain randomization, so they are considered less reliable,^{19,24,25,27} in comparison with the remaining six studies, considered as low risk of bias.^{20-23,26,28} In relation to concealing the randomization, five studies do not include information about that, so they are considered less reliable.^{19,22,24,25,27} The remaining five studies are considered with low risk of bias.^{20,21,23,26,28}

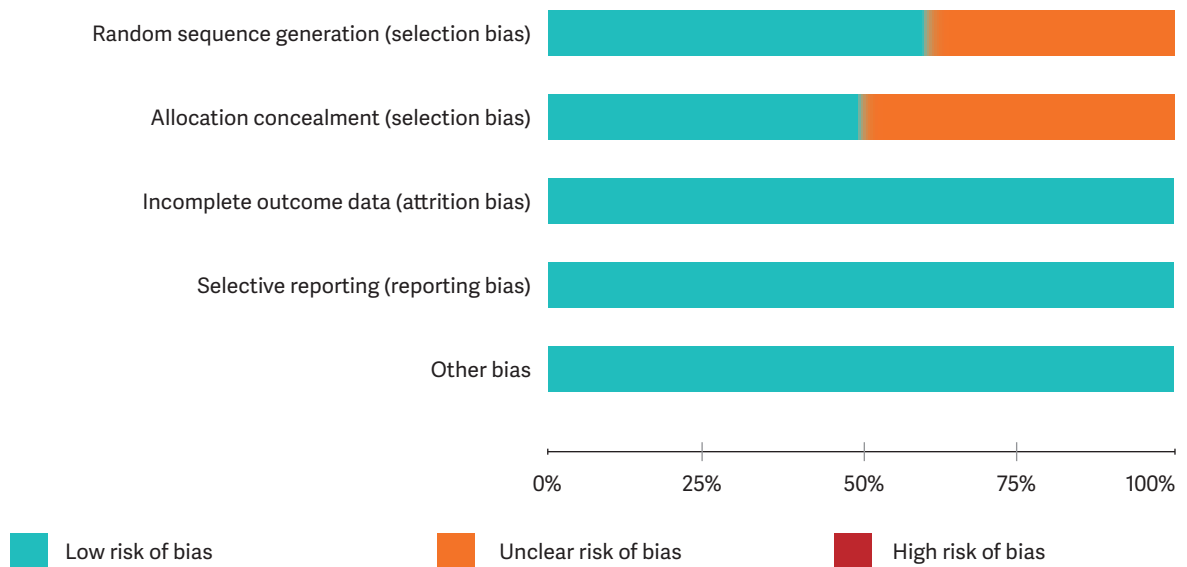


Figure 2: Risk of bias summary.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Benic 2016	+	+	+	+	+
Gjelvold 2016	+	+	+	+	+
Grünheid 2014	?	?	+	+	+
Haddadi 2018	?	?	+	+	+
Joda 2016	+	+	+	+	+
Mangano 2018	+	+	+	+	+
Sailer 2019	+	+	+	+	+
Sakornwimon 2017	+	?	+	+	+
Schepke 2015	?	?	+	+	+
Wismeijer 2014	?	?	+	+	+

Figure 3: Risk of bias graph. Low risk of bias (green), unclear risk of bias (orange), high risk of bias (red).

PARALLEL RCTS

Comfort

Gjelvold et al.²¹ showed a significant difference in favor of intraoral scan using the VAS 100-mm while asking about comfort, in comparison to conventional impression techniques (MD = 38.360; 95% confidence intervals [CI], 27.255 to 49.465; $P < .0001$).

Mangano et al.²⁸ reported statistical differences in favor of digital procedures when asking patients how comfortable the procedure of impression was (MD = 28.400; 95% confidence intervals [CI], 22.734 to 34,066; $P < .0001$).

CROSS-OVER RCTS

Comfort

Sailer et al.²⁰ concluded that conventional impressions are more comfortable than scanners. They only found significant differences when LAVA C.O.S. (MD = 39.000; 95% confidence intervals [CI], 7.336 to 70.662; $P < .002$) was compared with conventional impression. In another RCT in 2016, authors did not find

significant differences between the two procedures.²³

Grünheid et al.²⁴ used a Likert scale. They obtained 40% of patients comfortable with conventional impressions, while only 13.3% of patients were comfortable with the scan. However, authors do not explain whether data were statistically significant.

For their part, Haddadi et al.²⁷ found significant differences ($P = .0001$) in favor of the scan. However, there was high heterogeneity in data related to conventional technique, where interquartile rank went from 16 to 89 with a mean value of 59.8 and a median of 73, in comparison with an interquartile rank from 2 to 9 with a mean of 6.2 and a median of 6 in the scan, 0 being the minimum discomfort and 100 the maximum discomfort.

Schepke et al.¹⁹ used a questionnaire with the following four items: annoyance ($t[49] = 6.2$; $P < .001$; $d = .9$), feeling of drowning ($t[49] = 5.1$; $P < .001$; $d = .7$), anxiety in case the procedure has to be repeated ($T = 9$; $P < .001$; $r = .5$), and

feeling of impotency ($t[49] = 4.1$; $P < .001$; $d = .6$). A VAS was used for the answers. Significant differences were reported in favor of digital procedure.

Satisfaction

Sakornwimon et al.²² found statistically significant results in favor of the intraoral scan for global satisfaction, by using a scale of 10 points (MD = 1.500; 95% confidence intervals [CI], 0.344 to 2.656; $P < .017$). Moreover, authors reported statistically significant results in relation to time involved (MD = 1.000; 95% confidence intervals [CI], 0.157 to 1.843; $P < .021$), taste (MD = 1.600; 95% confidence intervals [CI], 0.452 to 2.748; $P < .007$), size of the device (MD = 1.300; 95% confidence intervals [CI], 0.035 to 2.565; $P < .044$), and queasiness (MD = 2.300; 95% confidence intervals [CI], 0.787 to 3.813; $P < .003$), except for the occlusal registration, where data were in favor of scan, but without significant differences (MD = 0.600; 95% confidence intervals [CI], -0.625 to 1.825;

$P < .306$).

Joda et al.²⁶ obtained similar results. They used VAS 100-mm and asked six questions for each intervention. Authors obtained statistically significant results for scans in all the aspects evaluated: duration (MD = 21.600; 95% confidence intervals [CI], 9.364 to 33.836; $P < .05$), convenience (MD = 25.000; 95% confidence intervals [CI], 12.101 to 37.899; $P < .05$),

anxiety (MD = 21.700; 95% confidence intervals [CI], 2.765 to 40.635; $P < .05$), taste (MD = 60.900; 95% confidence intervals [CI], 49.526 to 72.274; $P < .05$), queasiness (MD = 56.200; 95% confidence intervals [CI], 42.994 to 69.406; $P < .05$) and pain (MD = 30.700; 95% confidence intervals [CI], 16.370 to 45.030; $P < .05$).

PREFERENCE

Sailer et al.²⁰ reported not only results about comfort but also the preference of the patients. Patients were asked questions such as: what impression technique do you prefer? And what impression technique do you not prefer? The authors did not find any of the procedures as preferred or not preferred. Results were similar for the three different scans and the conventional impression technique. For the first question, three patients preferred Lava, two preferred iTero, two preferred CEREC, and three preferred conven-

tional impression techniques. For the second question, three did not prefer Lava, three did not prefer CEREC, and four did not prefer the conventional procedure. Similar conclusions were obtained by Grünheid et al.²⁴ The authors reported that 73.3% patients preferred conventional impression techniques while 26.7% preferred scan.

However, the remaining authors found preference for intraoral scans. In this regard, Haddadi et al.²⁷ showed a statistically higher preference for intraoral ($P = .003$). Of 19 patients, 16 pre-

ferred the scan. Results were measured with a 100 mm VAS, 50 being no preference, less than 50 preference for conventional impressions, and more than 50 preference for digital impressions. Mean value was 83.5 with an interquartile rank from 72 to 97 and a median of 89.

The study of Joda et al.²⁶ showed statistically significant differences ($P < .0001$) in relation to patients' preference for scanners according to different factors: convenience (MD = 78; 95% confidence intervals [CI], 72.083 to 83.916; $P < .0001$), speed (MD = 72.5; 95% confidence intervals [CI], 65.05 to 79.95; $P < .0001$) and global assessment (MD = 77.3; 95% confidence intervals [CI], 70.638 to 83.961; $P < .0001$) using VAS 100-mm, 0 being preferable conventional, 100 preferable digital, and 50 no preference for either intervention.

In a similar study, Wismeijer et al.²⁵ used a questionnaire of seven items for each intervention, with 10-point VAS. They obtained statistically significant

results for scanners in relation to preparation ($P = .021$) and taste ($P = .0001$), while satisfaction in relation to the duration ($P = .021$) was statistically significant for conventional impression. Values for occlusion registration ($P = .247$), impression system ($P = .593$) and queasiness ($P = .773$) did not show statistical differences; however, the tendency was in favor of scanners. The authors also asked for the global preference; the patient had to choose one of the two interventions. In this case, results were statistically significant for scanners ($P = .026$).

Schepke et al.¹⁹ asked patients to choose one technique as preferred. Of 50 participants, 41 (82%) chose digital technique, 5 (10%) did not show any preference, and 4 (8%) preferred the conventional procedure. No statistical significance was reported.

Four of the included articles had data of mean values and deviations for the evaluation of comfort and could be used for meta-analysis^{20,21,23,28}. High het-

erogeneity (I^2 95.5% $P = .00001$) and the possibility of a carry-over effect prevent a global meta-analysis from combining data from parallel and cross-over studies.

However, after adjustment of the sample size of the studies of Sailer and Benic, a subgroup meta-analysis was performed in four articles.^{20,23} Moreover, Gjelvold included data of a VAS100-mm inverted,²¹ so an inverted interpretation was necessary to compare data from the four RCTs. Sub-group meta-analysis was performed according to: type of randomization, cross-over or parallel and brand of the scan.

In relation to type of randomization, the meta-analysis showed statistically

significant differences in favor of scanner of parallel subgroup, with a high heterogeneity (I^2 59%, $P = .12$). For cross-over subgroup (which included two studies with three comparisons each) data were not statistically significant; however, there was a tendency in favor of conventional impression and heterogeneity was acceptable (I^2 16%, $P = .31$) (Fig 4).

In relation to the brand, the meta-analysis included six subgroup Trios and CS-3600 were the brands that obtained statistically significant data in favor of scanners. CEREC subgroup obtained a clear tendency in favor of conventional techniques. iTero subgroup did not obtain statistically significant data, but it showed the highest definition. CEREC

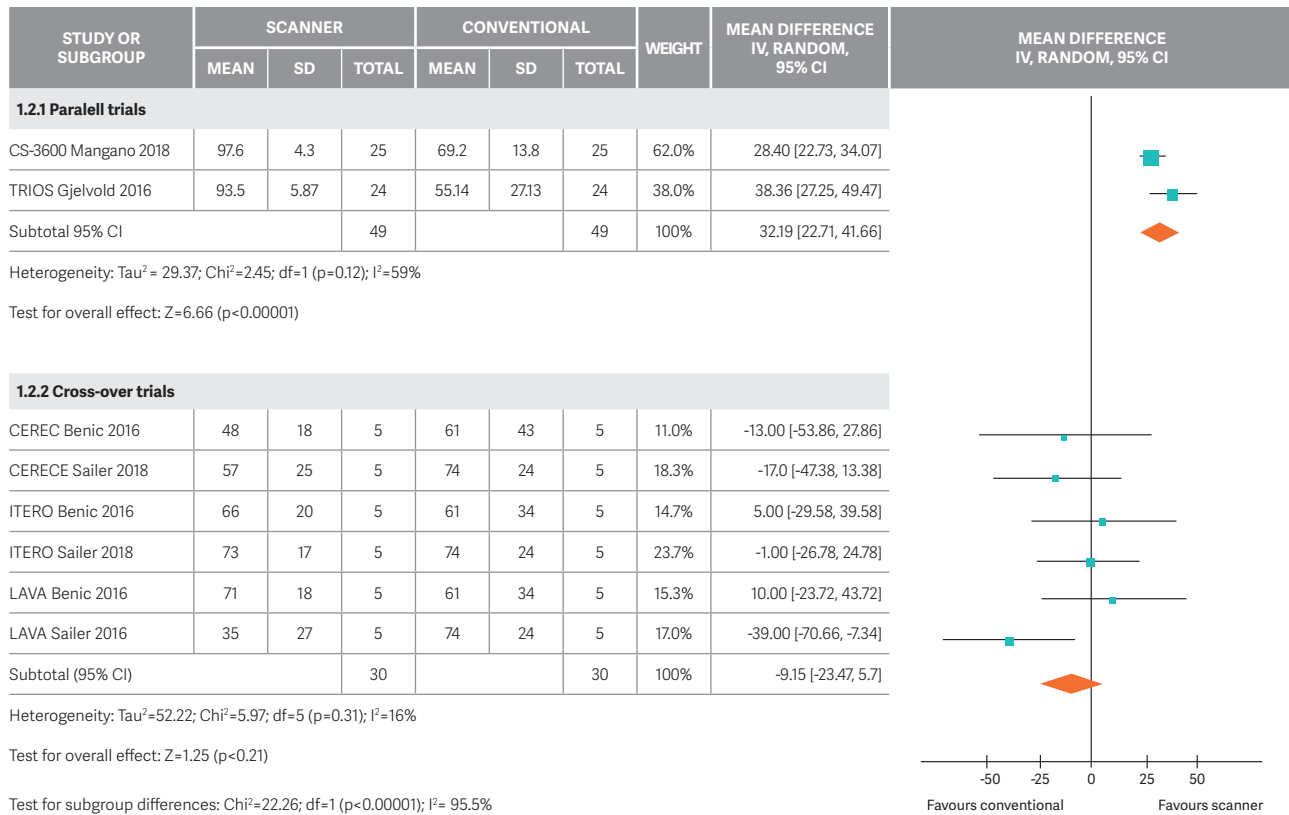


Figure 4: Meta-analysis sub-group. Type of randomization.

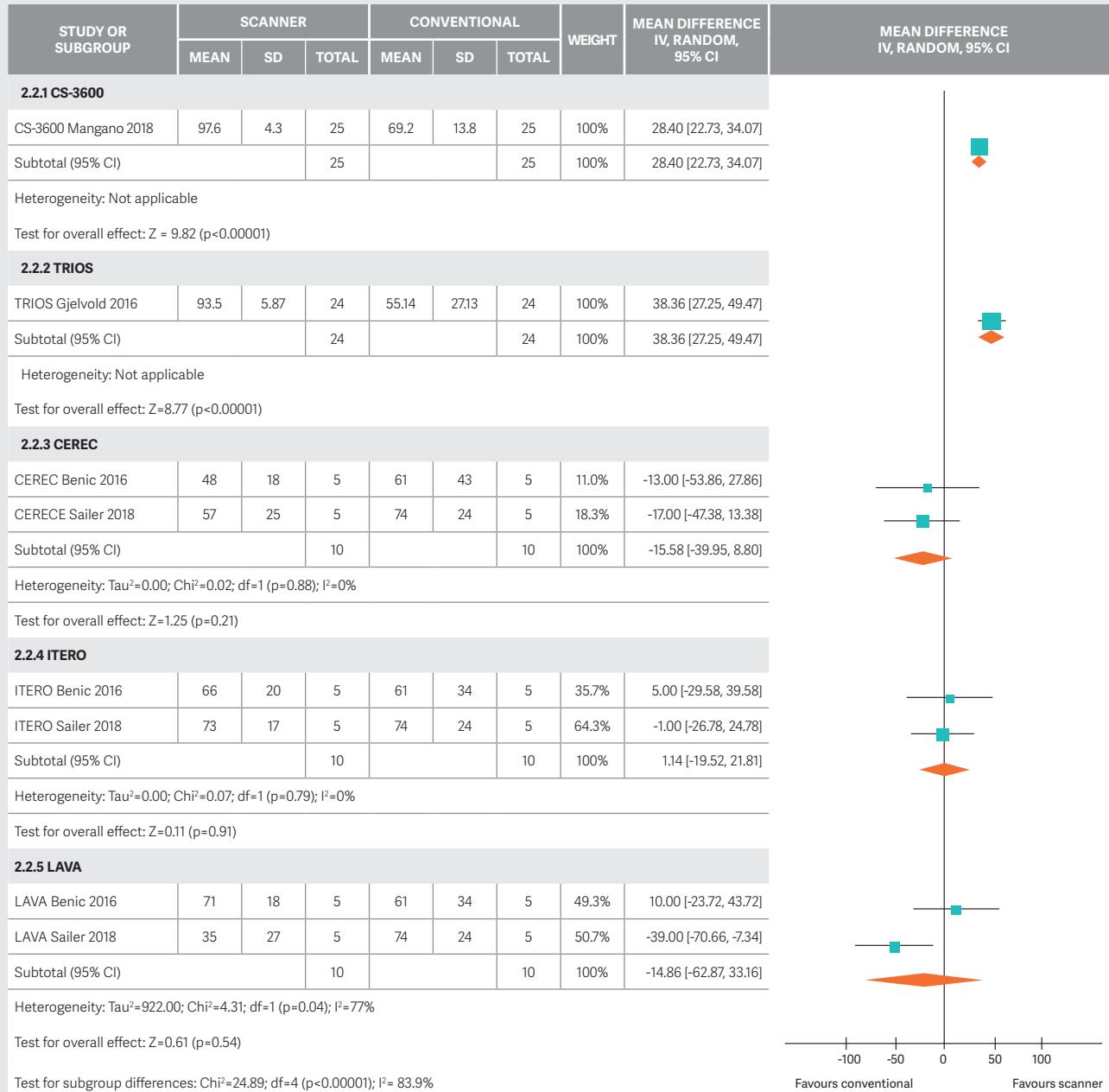


Figure 5: Meta-analysis sub-group. Brand of the scan.

and iTero had 0% heterogeneity. Lava subgroup did not show any statistically significant

DISCUSSION

From the 10 analyzed articles, seven found differences statistically significant in favor of intraoral scanners.^{19,21,22,25-28} Only two articles showed tendency in favor of conventional impression techniques.^{20,24} In this regard, Grünheid analyzed Lava C.O.S. scan used with powder in comparison with irreversible hydrocolloid.²⁴ Salier found statistically significant differences for conventional impressions when compared with scanner used with powder Lava C.O.S., but not in comparison with CEREC Bluecam and iTero scans.²⁰ Benic did not find conclusive data for any of the interventions.²³ These three studies showed a faster result for the conventional techniques and are three of the four studies included that use powder with the scan.

One of the problems of this review was terminology. Authors measured concepts such as comfort, satisfaction, and

and showed the highest heterogeneity (I^2 77%, $P=.04$) (Fig 5).

preference. These terms are similar but not exactly the same, so they cannot be analyzed altogether.

To standardize the method used for measurement is essential for obtaining solid conclusions. In this case, authors used different questionnaires, using questions with dichotomous answers, VAS etc. These differences made it impossible to meta-analyze most of the quantitative data, obliging us to carry out a qualitative analysis of them.

The technique of intraoral scanning is such a novel technique.¹⁴ Low experience of the clinician in comparison with conventional techniques, even if previous training has existed, could induce a bias to the detriment of scanners. Moreover, as is common in the field of research in dentistry, sample sizes are limited, seriously hindering the application of inferential statistics.

The duration of the impression and the scanning process is a determinant factor that could influence patients' perception. Seven articles include data about the duration of the process; however, periods measured are very heterogeneous, starting and finishing the measurement period at different moments of the procedure. It is not the objective of this study to determine which technique is faster, but instead to analyze how the duration influences the patients' perception of the procedure, so studies that consider periods outside of the mouth are not necessary. All the studies agree on the fact that the fastest technique was perceived as the most positive, except for Benic,²³ which was not conclusive about the perception in relation to the duration.

Moreover, the way of carrying out the intraoral impression is not the same in all the studies. Some authors do impression of full arch and others only of hemiarches. In this sense, four of the RCTs compared data obtained with scanner in hemiarches with data obtained in full arches by con-

ventional techniques, all of them being in favor of digital techniques.^{22,25-27} The digital technique used a smaller area, so it was faster, and, as seen before, there is a coincidence between less duration and more positive perception.

In relation to intraoral scanners, there are some differences in size of sensor introduced in the mouth, procedure for impression, need to apply powder over the surface of teeth. In the same way, the group of comparison (conventional techniques) also differs in the type of material (irreversible hydrocolloid, silicones, polyethers or wax). These differences between the intervention and comparison should be taken into account.

The application of powder to the surface of teeth should be considered an important factor that could interfere with patients' perception. The scanners that use powder are Lava C.O.S., CEREC Bluecam and True Definition. Data from the meta-analysis showed higher tendency in favor of conventional impression when scanners with powder were used, this ten-

dency being even more pronounced for CEREC Bluecam. Moreover, the qualitative review also showed tendency in favor of conventional impressions when scanners with powder were used. On the other hand, when scanners without powder were compared with conventional impressions, there was a tendency in favor of conventional techniques. Conversely, Sakornwimon was the only author that found positive data for True Definition scan, which uses powder, in comparison with conventional techniques.²² However, it is important to highlight that he compared partial digital impressions with full-arch conventional ones.

It is important to point out the impossibility of carrying out a blinding of the RCTs included. This lack of blinding of the patient, and also of the clinician, could induce positive connotations for scanners just because of the fact they are a modern technique, especially when patients receive both interventions and can compare them, as occurs in all the articles except the studies of Gjelveold and Mangano,^{21,28} respectively.

Only four of the 10 included studies could be meta-analyzed.^{20,21,23,28} The remaining studies did not use the same measuring scale, did not measure the same concept, or did not include mean values and standard deviations. A high heterogeneity was found, so it was impossible to obtain complete data of the meta-analysis. This heterogeneity could be explained by the differences between the scanners: use of powder, size of the sensor, and size of the area impressed. The type of RCT is also an important factor, there being two parallel studies and two cross-over studies that could not be meta-analyzed together. The division into subgroups allowed us to reduce heterogeneity in comparison with the heterogeneity that can be obtained when carrying out a complete meta-analysis of the four studies.

It has to be considered that VAS has been validated for the measurement of pain in dentistry.¹⁶ It should be necessary to validate a way to measure comfort, satisfaction and preference.

Several articles reported data that are statistically significant; however, they do not explain the minimally important difference (MID) of these scales to show clinical relevance. That is, it would be interesting to know the authors' opinion about what would be the minimum

CONCLUSIONS

- There is high heterogeneity in the methods used in several available RCTs. Most of them do not provide the information necessary for the statistical analysis, so interpretations with respect to different impression techniques should be cautious.

- With the available data, there is a favorable tendency for digital impression in terms of comfort, patient satisfaction, and preference.

numerical data to determine clinical relevance.²⁹

The results of this systematic updated review are in accordance with those obtained by Gallardo et al.¹⁰ in 2016 after the analysis of five studies.

- This tendency does not appear in the case of scanners that use powder and when the conventional technique is faster than the digital one.

- It is necessary to develop more RCTs to obtain more specific conclusions.

REFERENCES

1. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. *Dent Mater J*. 2009 Jan;28(1):44-56.
2. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. *Br Dent J*. 2008 May;204(9):505-11.
3. Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. *J Prosthodont Res*. 2016 Apr;60(2):72-84.
4. Rutkūnas V, Gečiauskaitė A, Jegelevičius D, Vaitiekūnas M. Accuracy of digital implant impressions with intraoral scanners. A systematic review. *Eur J Oral Implantol*. 2017;10 Suppl 1:101-20.
5. Gallucci GO, Papaspyridakos P, Ashy LM, Kim GE, Brady NJ, Weber HP. Clinical accuracy outcomes of closed-tray and open-tray implant impression techniques for partially edentulous patients. *Int J Prosthodont*. Sep-Oct 2011;24(5):469-72.
6. Wismeijer D, Joda T, Flügge T, et al. Group 5 ITI Consensus Report: Digital technologies. *Clin Oral Implants Res*. 2018;29 Suppl 16:436-42.
7. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng LJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. *J Prosthet Dent*. 2016 Aug;116(2):184-90.
8. Flügge T, van der Meer WJ, Gonzalez BG, Vach K, Wismeijer D, Wang P. The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. *Clin Oral Implants Res*. 2018;29 Suppl 16:374-92.
9. Abduo J, Elseyoufi M. Accuracy of Intraoral Scanners: A Systematic Review of Influencing Factors. *Eur J Prosthodont Restor Dent*. 2018 Aug;26(3):101-21.
10. Gallardo YR, Bohner L, Tortamano P, Pigozzo MN, Lagana DC, Sesma N. Patient outcomes and procedure working time for digital versus conventional impressions: A systematic review. *J Prosthet Dent*. 2018 Feb;119(2):214-19.
11. Joda T, Derksen W, Wittneben JG, Kuehl S. Static computer-aided implant surgery (s-CAIS) analysing patient-reported outcome measures (PROMs), economics and surgical complications: A systematic review. *Clin Oral Implants Res*. 2018;29 Suppl 16:359-73.
12. Ishaque S, Karnon J, Chen G, Nair R, Salter AB. A systematic review of randomised controlled trials evaluating the use of patient-reported outcome measures (PROMs). *Qual Life Res*. 2019 Mar;28(3):567-92.
13. De Bruyn H, Raes S, Matthys C, Cosyn J. The current use of patient-centered/ reported outcomes in implant dentistry: a systematic review. *Clin Oral Implants Res*. 2015;26 Suppl 11:45-56.
14. Lee SJ, Macarthur RX 4th, Gallucci GO. An evaluation of student and clinician perception of digital and conventional implant impressions. *J Prosthet Dent*. 2013 Nov;110(5):420-3.
15. Monk AB, Harrison JE, Worthington HV, Teague A. Pharmacological interventions for pain relief during orthodontic treatment. *Cochrane Database Syst Rev*. 2017;11(11):CD003976.
16. Isacson G, Schumann M, Nohlert E, Meijersjö C, Tegelberg Å. Pain relief following a single-dose intra-articular injection of methylprednisolone in the temporomandibular joint arthralgia-A multicentre randomised controlled trial. *J Oral Rehabil*. 2019 Jan;46(1):5-13.
17. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med*. 2009 Jul;6(7):e1000100.
18. Higgins JPT, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011 Oct;343:d5928.
19. Schepke U, Meijer HJ, Kerdijk W, Cune MS. Digital versus analog complete-arch impressions for single-unit premolar implant crowns: Operating time and patient preference. *J Prosthet Dent*. 2015 Sep;114(3):403-6.
20. Sailer I, Mühlemann S, Fehmer V, Hämmerle CHF, Benic GI. Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part I: Time efficiency of complete-arch digital scans versus conventional impressions. *J Prosthet Dent*. 2019 Jan;121(1):69-75.
21. Gjølvd B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J. Intraoral digital impression technique compared to conventional impression technique. A randomized clinical trial. *J Prosthodont*. 2016 Jun;25(4):282-7.
22. Sakornwimon N, Leevailoj C. Clinical marginal fit of zirconia crowns and patients' preferences for impression techniques using intraoral digital scanner versus polyvinyl siloxane material. *J Prosthet Dent*. 2017 Sep;118(3):386-91.
23. Benic GI, Mühlemann S, Fehmer V, Hämmerle CH, Sailer I. Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part I: digital versus conventional unilateral impressions. *J Prosthet Dent*. 2016 Nov;116(5):777-82.
24. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of accuracy, time, and patient acceptance. *Am J Orthod Dentofacial Orthop*. 2014 Nov;146(5):673-82.
25. Wismeijer D, Mans R, van Genuchten M, Reijers HA. Patients' preferences when comparing analogue implant impressions using a polyether impression material versus digital impressions (Intraoral Scan) of dental implants. *Clin Oral Implants Res*. 2014 Oct;25(10):1113-8.
26. Joda T, Brägger U. Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. *Clin Oral Implants Res*. 2016 Dec;27(12):e185-e9.
27. Haddadi Y, Bahrami G, Isidor F. Evaluation of operating time and patient perception using conventional impression taking and intraoral scanning for crown manufacture: a split-mouth, randomized clinical study. *Int J Prosthodont*. January/February 2018;31(31):55-9.
28. Mangano F, Veronesi G. Digital versus analog procedures for the prosthetic restoration of single implants: a randomized controlled trial with 1 year of follow-up. *Biomed Res Int*. 2018 Jul;2018:5325032.
29. Tsakos G, Allen PF, Steele JG, Locker D. Interpreting oral health-related quality of life data. *Community Dent Oral Epidemiol*. 2012 Jun;40(3):193-200.