# Accuracy of In-Vivo Digital Impressions of Complete Arch with Intraoral Scanner Vs Conventional Impression - A Review

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## ABSTRACT

**BACKGROUND**

We intend to evaluate the accuracy of in vivo conventional and digital methods in generating complete-arch dental models for measuring tooth dimension.

**METHODS**

Search was conducted through an electronic database in Medline, Cochrane Library, ResearchGate, PubMed and Google Scholar using query terms such as intraoral scanning; digital impression; accuracy in vivo full arch digital impression; analog impression; accuracy conventional impression; in vivo intraoral scanning; alginate impression; accuracy of plaster models; digital models; and complete arch accuracy. The outcomes were the accuracy of teeth dimension measurements in plaster models in comparison to digitized and digital models in vivo.

**RESULTS**

Nine studies matched the inclusion criteria. Two papers compared teeth measurements through plaster models and direct digital models, four papers compared plaster models and digitized models, one paper compared plaster models, digitized and direct digital models, one paper compared four different methods of direct intraoral, plaster models, direct digital and digitized models and one study reported teeth measurements from directly measured intraoral, plaster models, and direct digital models. Neither digital nor plaster models could be considered to replicate exactly the dentition, however it was agreed by the authors that intraoral scanning could represent the intraoral situation more accurately on digital models due to the lesser procedural steps, hence fewer source of error.

**CONCLUSIONS**

According to the results of the present review, although there were slight differences in readings of the measurements made on all the methods, the differences were neither statistically nor clinically significant and it is acceptable in clinical application. This review was registered in PROSPERO at CRD42020208662.

**KEY WORDS**

Intraoral Scanning, Digital Impression, Analog Impression, Digitized Model, Digital Model, Digital Impression Accuracy, Stl files, Conventional Impression Accuracy, Tooth Dimension Accuracy, Digital Model Accuracy.

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## BACKGROUND

With the rise of many devices, gadgets, and applications which facilitates the function of our day-to-day life, the field of dentistry has also been stormed with the new digital advances to provide a better level of treatment outcome.

Although the concept of computer-aided design (CAD) and computer-aided manufacturing has been part of dentistry for many years, the integration of digital devices has gained popularity and attention from not only clinicians but also dental technologists. The first method and apparatus claim patent were developed in 1989 for a three-dimensional registration and display of prepared teeth[1] which then evolved as a powerful tool called the Chairside Economical Restoration of Esthetic Ceramics (CEREC).[2,3,4]

Among the most used digital tool that gained remarkable responses from clinicians is the intraoral scanner. Within a few years, the growth of many types of intraoral scanners proved to be profitable to the manufacturers, and beneficial to the clinicians' treatments. Evidence and studies have indicated that these devices may be more accurate[5] and efficient[6] compared to a conventional impression technique, but arch distortions remain the limitation for full arch intraoral scanning from being fully precise and accurate.[7] For both the digitally-inclined and the less-digitally-inclined clinicians, the important question that has been asked repeatedly is whether the virtual dental model can replace the conventional plaster model and match it in terms of precision and accuracy with regard to its function as a measurement tool and as the basis for treatment planning.

Impressions, whether analog or digital, is important in facilitating procedural steps of treatment. The imprints are used extensively, for example as a cast study model, teeth preparation for fixed and removable prosthodontics, as a tool in planning multidisciplinary treatment sequence, to aid in measuring teeth dimensions and spaces in restorative and orthodontics, and to record inter-occlusal relationships. Hence, it is critical that the impressions can produce precise replication of the recorded structure.

While analog impression accuracy is mainly dependent on the clinician's skill and the material properties, the quality of the digital impression is attributed to the accuracy of the optical impression captured during the scanning process. Accuracy in digital scanning is divided into *trueness* and *precision*. The term *trueness* refers to the ability of a measurement to match the actual value of the quantity to be measured and *precision* is the ability of a measurement to be consistently repeated,[8] and in the case of intraoral scanner, its ability to produce repeatable outcomes when the same object is being scanned.

The quality of the analog impressions is affected by the skills of the operator, time taken before pouring into a plaster cast, the nature of alginate as the impression material which is prone to contraction due to moisture loss and imbibition due to absorption of moisture, the tendency of alginate impressions to undergo syneresis and polymerization[9,10,11] and the possibility of these impressions to decrease in accuracy and stability over time,[12] wear due to repeated measurements[13] and also distortion of shape when expose to various levels of temperatures and humidity.[14] The issues faced by analog impressions have highlighted the convenience of using intraoral scanners for example the ease of repeatability, real-time visualization, not having to disinfect the impressions and impression trays, no cast pouring, rapid communication and availability and the selective capture of the relevant areas.[15,16,17,18,19,20]

However, for IOS to be considered as the 'gold standard' it is important to establish its accuracy to be at par with that of analog methods. To the knowledge of the authors, there is a lack of a systematic review articles that focus on the accuracy of conventional and digital methods in generating complete-arch dental impressions in measuring tooth dimension clinically.

The purpose of the present review is therefore to evaluate the accuracy of conventional and digital methods in vivo, in generating complete-arch dental impressions for measuring tooth dimension.

## METHODS

### Search

The methodological approach for this systematic review was done after looking through protocols based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol (PRISMA-P) statement [12] which involved four steps as shown in Figure 1. These steps were done to collate all primary searches and empirical evidence available to answer the question on the accuracy comparison between conventional impressions and digital impressions obtained from intraoral scanning.

A PICO (Patient / Population, Intervention / Indicator, Compare / Control, Outcome) question was formulated to put forth the research being discussed. The question was: In a patient with a complete permanent dentition up to first molars, are measurements done on virtual models from intraoral scanning impressions as accurate as measurements done on study models taken with analog impressions in regard to tooth dimension?

The search was conducted through an electronic database as follows: Medline, Cochrane Library, Research Gate, PubMed, and Google Scholar. The search included articles written only in English from the year 1997 to 2020. Query terms used were intraoral scanning; digital impression; comparison accuracy of in vivo full arch digital impression; analog impression; accuracy conventional impression; in vivo intraoral scanning; alginate impression; accuracy of plaster models; digital models; and complete arch accuracy. (Table 1).

### Eligibility Criteria

These paper review studies which compare the accuracy of digital impressions to analog impressions using impression materials were recorded in vivo. The paper has to fulfil the criteria of an English paper, studies done in vivo, the impression of complete arch involving the first molar to the first molar, comparing the digital impressions and digitized models with clinical steps, and procedure explained. The exclusion criteria were established as follows: non-English papers, in vitro studies, impressions for partially edentulous and edentulous arches, papers that do not specify procedural steps, impression materials, and system of intraoral scanners are also excluded from the review.

## Study Selection

Study selection included in this review was done in detail adhering to the protocols by Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Protocol, PRISMA-P[21,22]

Step one was the search for the appropriate titles and identification from the databases. This resulted in 1,876 articles. Searches were also done from other sources for example Google Scholar, Web of Science and ResearchGate (1,221 articles). Titles that were not suitable for the review criteria were excluded.

Step two was to screen the abstract and determine through the abstract the suitability of the papers to the inclusion criteria and to identify review papers. Duplications were excluded, and review papers related to the topic and to be included in the qualitative analysis were screened.

In step three, papers for the selected abstracts were obtained, and the full text was analysed for its appropriateness to the scope within the research question and the correlation to the topic of review. Articles that were relevant and referenced in review papers were obtained and included in the qualitative data (Figure 1). The protocol of this systematic review recognized that in vivo studies were the most appropriate to address the focused question that supports the clinical effectiveness of intraoral scanner.

## Risk of Bias of Studies

For this review, QUADAS (Quality Assessment of Diagnostic Accuracy Studies) was used to assess the risk of bias of the selected studies.[23] This assessment consisted of 14 questions on the methodology to help estimate the risk of bias of the included studies (Table 2).

# RESULTS

Data were extracted from the selected papers; authors, reference publication dates, data collection time frame, setting, sample demographic and characteristics, study design and analytical approach, impressions used, methodology and results: prevalence of accuracy of impressions, related factors, operators, possible error, measurement bias, research gap, major achievement in the study and main areas of debate and outstanding research question.

## Risk of Bias within Studies

As question 12 of the QUADAS items did not relate to the study that was being reviewed, four studies satisfied 12 of the 13 QUADAS items, three studies satisfied 10 of the 13 QUADAS items and two studies satisfied 9 of the 13 QUADAS items were found. The selection of study participants gave rise to the highest risk of bias as those subjects were unlikely representative of patients with a variety of conditions in the clinical practice.

## Descriptive Analysis

Out of 55 papers that went through the eligibility assessment, nine papers were eligible for this review. Only one paper reported on the accuracy of impressions through all the four methods, which are obtained from direct intraoral measurement, from the study model obtained from alginate impression, intraoral digital impression, and scanned image of the plaster study model.[24]

Five papers reported on comparison of plaster models and digitized plaster models.[25,26,27,28,29] Two of the papers reported on the comparison of plaster study models and digital models[30,31] and one paper reported on the comparisons of three methods of plaster study models, direct digital scanning into digital models and the direct measurements of tooth dimension intraorally.[32]

To assess the comparison of measurement accuracy from the digital models and digitized models, scans from direct intraoral scanning of the patient was transformed into digital models which then stored as digital file into stereolithography (STL) file format. These are considered the standard measurement for reference which was going to be compared with the digitized models. Digitized models are digital impressions taken from plaster models of patients and converted into STL files.

The analog impression was taken using the alginate and plaster models will be produced from this impression. Intraoral scanner was then used to scan the plaster models into STL files. Teeth width and heights from both direct scanning and digitized files are measured using an online software and compared.

*1. Teeth dimension and measurements from plaster models vs direct digital models.*

Two of the selected studies followed approximately the same method of comparing the dimensions and measurements of teeth but comparisons were from the plaster models to digital models, where analog impressions were poured into plaster models then measurements were done on the plaster models, and the same group of subjects were scanned using an intraoral scanner into stereolithography (STL) files, and then measurements were done on the scanned models using Ortho Analyzer software. Yilmaz reported the measurements of the plaster models using a Munchner Design Dental Vernier which measured the mesiodistal width of incisors, canines, premolars and first molars. The measurements were recorded to 1% (0.01) of a millimetre. In this study, Yilmaz et al. reported that the measurements for the space analysis and the Bolton analysis were not statistically significant for both groups measuring through the conventional or digital method ($p>0.05$). These measurements were done by the same researcher and repeated five times to increase the reliability. Bolton analysis is a measurement calculated by dividing the total of the widths of the maxillary teeth by the total of the widths of the mandibular teeth.[33] They found the similarities in both methods in measuring teeth dimensions to substantiate the reliability and effectiveness of digital analysis clinically.

Camardella reported on the same method but with two examiners doing the measuring, recorded that a clinically relevant measurement error was likely to be presented in digital models compared to measurements done on plaster models. The study also found that errors related to crown height of central incisors were the largest clinically among the two examiners and suggested it may be caused by the measurement method or due to the differences of the actual models. The reproducibility of some of the parameters measured was also a concern between the two examiners. Despite having the differences, the paper agreed that it was not clinically significant and intraoral scanning may be used to replace the plaster model.

*2. Teeth dimension and measurements from plaster models vs digitized models.*

Out of the nine papers evaluated, four papers reported on the same method of measuring teeth dimensions, comparing plaster models to digitized models. The digitized model's measurements were done on a computer with the Orthoanalyzer 2013 software programme and magnified at greater proximity to the desired area of the model. Paired t-test was used in comparing the plaster models and intraoral scans measurements for all these papers. Most of these studies have found that the measurements taken from both plaster models and digital models were not significantly different. Even so, a significant difference was reported by Leifert where the measurements of the tooth width and tooth height of the maxillary teeth were significantly different at $p < 0.05$ which showed greater variability in the maxillary results although this study was discussing on space analysis and the method used in the analog measurement was the brass wire over the contact points and the incisal edges from the first molar to first molar contralaterally. The mean values of measurements in the plaster models were recorded to be slightly higher than the measurements on the digital models. It continued to suggest the greater variability of the inclination of the anterior teeth in the maxillary arch as opposed to the mandibular arch being the main reasons for the differences found in the maxillary measurements.

A study by Mullen et al. agreed with findings by Leifert that showed there was no significant difference between the Bolton ratios calculated using plaster models and the digital models and concluded that the traditional method of using callipers to measure the plaster models was just as accurate as measurements done on digital models.

In a study reported by Santoro et al. plaster models and digital models tooth measurements showed differences in measurements even if the differences were within a small range (0.16-0.38mm) of mean differences. An orthodontic-style Boley gauge was used to record the analog measurements to the nearest 0.1mm. The digital model's tooth measurements were done by analysis tools provided by the Ortho CAD. In this study it was reported there were statistically significant differences between the measurements made from the two methods and it was reported that the digital model measurements were smaller than the corresponding plaster models even though these differences were clinically acceptable. These findings were also similar to what was reported by Mullen et al. in their paper where they found that their measurements from the e-models (digital models) are smaller than the ones they found from the plaster models, but it was within the range of error within the study and other studies and so was considered clinically insignificant.

A paper highlighted in one of the studies that measured distances on plaster models gave rise to more intra- and inter-observer variability if it involved more than one examiner, than measuring the same distances on digital models using virtual measuring tools which could give rise to variation and differences. Intra-operator error was recorded by these papers that were dependent on the parameter measured such as determining the contact point between two teeth for the measurements. It was also reported from these papers that some cases may have an interproximal area between teeth which was defined sufficiently to ascertain that the greatest mesio-distal diameter was being measured.

*3. Teeth dimension and measurements from plaster models, direct digital models and digitized models.*

One paper reported on the validity of intraoral scans showed that in terms of the teeth height and width measurements, there were no significant differences between the two models, and the differences in means were less than 0.1 mm. They also agreed that the measurements of tooth heights and widths between the plaster models and the intraoral scans were within the limits of agreement.

*4. Teeth dimension and measurements from direct intraoral, plaster models, direct digital models and digitized models.*

Only one paper that we evaluated investigated the comparisons throughout all four methods, namely the direct intraoral, plaster models, digitized models and direct digital models. In the reviewed paper, the same method of comparison was done where the measurements were taken from the mesiodistal tooth width of central incisors, lateral incisors, canines and first premolars of both maxillary and mandibular arch at the contact points of the tooth, perpendicular to the tooth and parallel to the occlusal surface[34] on the digital models directly scanned from the intraoral, and then compared it to the measurements made from the digitized models. In this study, 3Shape Trios intraoral scanner was used for the direct intraoral scanning on 10 patients who were going for orthodontic treatment and subsequently the record of measurements was calculated using 3Shape Ortho Analyzer software.

The conventional impressions by alginate were cast using Orthocal (Type V gypsum product) within 10 mins of the impression being made. These models were then scanned using the same intraoral scanner 3Shape Trios into stereolithography (STL) files and the measurements were done using the 3Shape Ortho Analyzer software. The scanning of both intraoral and the model were done by a skilled technician. The measurements were done by the same clinician and in this paper, the results of the intraclass correlation coefficients test showed that although the measurements were decreased or increased in certain measurements, the values were not significantly different when compared to directly measured readings intraorally, on the plaster model, intraoral scan and plaster model scans on all teeth measured.

*5. Teeth dimension and measurements from direct intraoral, plaster models and direct digital models.*

From the studies evaluated, one study reported teeth measurements from directly measured intraoral, plaster models and direct digital models showed that measurements of the distances done directly from the subjects' intraoral were significantly shorter compared to the measurements on the plaster casts and on the digital models between the upper first molar and upper canine on the right side and the upper right and left canine From this study, the measurements recorded from the plaster models and the digital models were not significantly different which was also concluded in all the studies reviewed.

Out of these nine papers, only one paper reported for a single examiner that carried out measurements on both plaster and digital models and these measurements were taken five times to increase the reliability of the measurements, and the arithmetic average of these measurements was used in the evaluations. Other eight papers reported two examiners measuring the dimensions and space analysis.

## DISCUSSION

The use of direct impression method in obtaining dental models has been applied by all clinicians irrespective of the discipline. For example, in prosthodontics the fit of the definitive prosthesis and impression accuracy depend on every phase of the process. The dental CAD/CAM systems usually involve less steps in producing the prosthesis (i.e., digital impression, design, and milling) and this proved to produce lesser error when compared to the conventional method.[35] In conventional techniques however, more steps are needed and every step, including impression, stone casts, wax patterns, investment, and casting, must be carried out precisely to achieve the best fit. In orthodontics, obtaining impressions for the purpose of space analysis and teeth measurements have been practiced widely and conventional impressions have imposed a storage problem to almost every practice. This review aims to compare the accuracy of plaster models, digital models and digitized plaster models.

From the nine papers reviewed, almost all reported on the same methods but comparing either plaster with digitized plaster models, plaster models and direct intraoral scanning and/or direct measurements into patients' intraoral. This review indicates that regardless of the method of impression technique, the system and the material used, to some degree there is inevitable inaccuracy that still exists but is within the clinically acceptable range.

### Plaster vs Digital vs Digitized Models

With digitized models being produced from plaster models, the fact that confounders such as expansion factor of the plaster models and the shrinkage level of the alginate impression material before being poured, do play an important role in determining the accuracy of any analysis to be done on these models.

Within this review, comparisons between these models however showed various results among the studies, and it was reported in all studies we evaluated that the differences were within the clinically acceptable range. Many previous studies have also compared the accuracy of the digitized model to direct digital model which was scanned straight from the patient's mouth[36,37] although the limitation of those studies was not similar to this review.

Some studies reported that the measurements done digitally on the digital models and digitized models gave smaller readings when compared to the measurements on plaster models[3,4]. This was also concluded by several other studies that did not fulfil the inclusion and exclusion criteria of this review.[38,39,40,41] These findings were found to be in contrast to the findings in one of the studies we reviewed where the digital measurements value was slightly bigger compared to the plaster models measurements[5]. Similar results were also found in an earlier study which was in agreement that bigger measurements were found from the digital models.[42] These can be caused by many factors and one possibility was the intrinsic difference between the 2 methods which involved a 3-dimensional visual pointing to interproximal contacts of an enlarged image. This step depended on the clinician's training, abilities and preferences. Measuring on computer screen can be more or less accurate compared to the traditional gauge-on-cast method[3] but this seemed to be in contrast with reports made by Mullen which found that the traditional measurement on plaster models was just as accurate as the digital measurements[4]. It has been suggested in the literature that intraoral situation can be represented more accurately on the digital models by the intraoral scanning due to the lesser source of error, and fewer processing steps could give rise to more accurate outcomes[6]. Although the differences have been discussed, it was highlighted by Profitt[43]that a difference of <1.50mm in the model analysis was not clinically significant. Within this review, based on this statement it could be confirmed that the differences found on the reviewed papers were not clinically significant.

One of the studies we reviewed highlighted the significant differences in the width and height of the maxillary teeth[7]. This was because finding the same landmarks in measuring the teeth was difficult to be repeated, especially in the maxillary arches where the axial inclinations of the anterior teeth is much greater than in the mandibular anterior teeth.[44] Another factor that may contribute to the differences of measurements would be the selected reference points for defining various measurements may differ between examiners especially when there are more than one examiner and even when the points are precisely described[5]. The inadequate reference point location was also reported to affect measurement reproducibility.[45] For all the evaluated studies in this review, the measurements were done at least twice to five times to reduce the measurement error and these remeasurements were repeated 2 weeks after the first measurement. It is important in determining the clinician's reliability when taking the measurements as data loss or deviation will occur due to learning curve of taking digital and plaster model measurement.

Although in most studies the accuracy of digital models acquired with intraoral scanning technology was assessed in comparison with those acquired from the alginate impressions, it is a known fact that neither method could be considered to exactly replicate the dentition. However, to the best of our knowledge, the intraoral situation can be represented more accurately on the digital models by the intraoral scanning because there are fewer sources of error.

| Database | Search Strategy | No. of Results |
|---|---|---|
| PubMed | Digital impression; intraoral digital impression; intraoral scanners; intraoral digital scanner; conventional impression; analogue impression; alginate impression and accuracy. | 1876 |
| Cochrane Library | Digital impression; conventional impression; accuracy | 2 |
| Science Direct | Digital impression; intraoral digital impression; intraoral scanner; intraoral digital scanner; conventional impression; analogue impression; and accuracy | 1,219 |

***Table 1. Search Strategy for Each Database and Corresponding Results***

| Study | Dalstra et al. | Yilmaz Hakan | Glisic Olja | Zhang et al. | Murugesan et al. | Camardella et al. | Leifert et al. | Santoro M et al. | Mullen et al. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Was the spectrum of patient's representative of the patients who will receive the test in practice? | N | Y | Y | U | Y | Y | Y | Y | Y |
| 2. Were selection criteria clearly described? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 3. Is the reference standard likely to correctly classify the target condition? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 4. Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests? | Y | Y | Y | Y | Y | Y | U | Y | Y |
| 5. Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 6. Did patients receive the same reference standard regardless of the index test result? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 7. Was the reference standard independent of the index test (i.e., the index test did not form part of the reference standard?) | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| **Study** | **Dalstra et al.** | **Yilmaz Hakan** | **Glisic Olja** | **Zhang et al.** | **Murugesan et al.** | **Camardella et al.** | **Leifert et al.** | **Santoro M et al.** | **Mullen et al.** |
| 8. Was the execution of the index test described in sufficient detail to permit replication of the test? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 9. Was the execution of the reference standard described sufficient detail to permit its replication? | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 10. Were the index test results interpreted without knowledge of the results of the reference standard? | U | Y | U | U | N | U | N | Y | Y |
| 11. Were the reference standard results interpreted without knowledge of the results of the index test? | Y | Y | U | U | Y | U | Y | Y | Y |
| 12. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice? | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 13. Were uninterpretable/ intermediate test results reported? | N | N | N | N | Y | N | N | N | N |
| 14. Were withdrawals from the study explained? | Y | Y | Y | Y | Y | Y | U | Y | Y |
| Score | 10 | 12 | 10 | 9 | 12 | 10 | 9 | 12 | 12 |

***Table 2. QUADAS Analysis for Each Included Study***

(Y: Yes, N: No, NA : Not Available )

| Paper | Dalstra et al. | Yilmaz Hakan | Glisic Olja | Zhang et al. | Murugesan et al. | Camardella et al. | Leifert et al. | Santoro M et al. | Mullen et al. |
|---|---|---|---|---|---|---|---|---|---|
| **Sample Size** | **12 Patients** | **30 Patients** | **59 Patients** | **20 Subjects** | **10 Patients** | **30 Patients** | **25 Patients** | **76 Patients** | **30 Patients** |
| Inclusion/ exclusion criteria | NA | Inclusion criteria:<br><br>1.No previous ortho treatment,<br>2. Presence of all permanent teeth from first right molar to first left molar<br>3. No absence of any region in the plaster and digital models. | Inclusion criteria:<br><br>Children and adolescents between 9-15 years.<br>No previous orthodontic or experience with digital intraoral scan or alginate impression.<br>Indication for orthodontic treatment.<br><br>Exclusion:<br>Patients with craniofacial syndromes or other general diseases | Inclusion criteria:<br><br>Full permanent dentition from second molar to contralateral second molar.<br>No missing teeth.<br>No prosthetic restorative teeth.<br><br>Exclusions<br>Severe crowding, dentofacial deformity<br>Inclusion | Inclusion criteria:<br>Individuals before undergoing orthodontic treatment,<br>individual with crowding ≤ 4mm, individuals with no missing first premolars, canines, lateral and central incisors in both arches, fully erupted permanent teeth from right first premolar to left first premolar on both upper and lower arch.<br><br>Exclusion criteria:<br>Morphological variations of the tooth that can compromise the measurements, grossly decayed teeth, root canal treated teeth, tooth with bulky restorations, proximal wear, proximal caries and fractures. | Inclusion criteria:<br><br>1. Fully erupted all permanent dentition including all upper and lower first permanent molars.<br><br>Exclusions:<br>Dental anomalies, severe gingival recessions, dental crown abrasions, attritions and erosions.<br>Fixed orthodontic retention | Inclusion criteria:<br><br>1.Permanenet dentition<br>2.Angle Class I molar relationship<br>3.Crowding<br>4.No orthodontic appliances or previous treatment | Inclusion criteria:<br>1.Plaster and digital models made from alginate impressions taken consecutively at the same visit<br>2.No appliances pre-treatment<br>3.No missing teeth from first molar to first molar<br>4.Stable centric occlusion with at least 3 occlusal contacts<br>5.No voids or blebs in the plaster or digital models<br>6.No fractures on the teeth on the plaster models | Inclusion criteria:<br><br>1. Complete adult dentition from first molar to first molar in both arches. |

***Table 3a. Summary of the Major Data Extracted from the Selected Articles***

| Paper | Dalstra et al. | Yilmaz Hakan | Glisic Olja | Zhang et al. | Murugesan et al. | Camardella et al. | Leifert et al. | Santoro M et al. | Mullen et al. |
|---|---|---|---|---|---|---|---|---|---|
| Compared methods | Plaster models and digitized plaster models | 30 plaster models and 30 direct digital models | 59 patients - on the plaster and on digital models. | Plaster models, digital models, and digitized plaster models | Direct intraoral measurements on width of teeth as gold standard, direct digital impressions with 3Shape Trios, study model from conventional alginate impressions, conventional impressions with alginate poured into plaster and then scanned with the same intraoral scanner 3Shape Trios. | 28 plaster models and direct digital models | Plaster models and digitized plaster models | Plaster models and digitized plaster models | Plaster models and digitized plaster models |
| Recorded measurements | Mesio-distal width of teeth 11 and 16 | Mesiodistal width of 16 and 26 | 1.Distance between the cusp tips of permanent upper first canines<br>2.Distance between the mesiofacial cusp tips of the permanent upper first molars<br>3.Distance between the mesiofacial cusp tip of the permanent upper right first molar and cusp tip of upper right canine<br>4. Distance between mesiofacial cusp tip of permanent upper left first molar and cusp tip of permanent upper left canine. | 1.Transverse and anteroposterior dimensions of the intra-arch measurements<br>2.Tooth height<br>3.Tooth width | Mesiodistal tooth width measurements of central incisors, lateral incisors, canines and first premolar of both maxillary and mandibular arch | Mesiodistal of upper and lower teeth<br>Crown heights of upper and lower 1st molars, 1st premolars, canines and central incisors. | Mesiodistal width of teeth mesial to first molar arch length | Maximum mesiodistal widths of each tooth | Maximum mesiodistal widths from first molar to first molar |

***Table 3b. Summary of the Major Data Extracted from the Selected Articles***

| Paper | Dalstra et al. | Yilmaz Hakan | Glisic Olja | Zhang et al. | Murugesan et al. | Camardella et al. | Leifert et al. | Santoro M et al. | Mullen et al. |
|---|---|---|---|---|---|---|---|---|---|
| Assessed parameters | Comparing measurements of plaster models to digitised models – mesiodistal width of upper 11 and 16 | Mesiodistal width of upper and lower teeth | Dental arch distances | Dental arch distances and tooth width and heights measurements | Comparison of accuracy of mesiodistal tooth width measurements | Mesiodistal diameter, sum of 12 teeth, sum of lower 12 teeth, crown heights, upper intercanine distance, lower intercanine distance, overjet, overbite, interarch left and right sagittal relationship. | Arch length-contacts points of posterior teeth, canine tips and incisal edges of central and lateral incisors. | Mesiodistal teeth | Mesiodistal teeth and ball-bearing mounted models |
| Statistical tests | One-way ANOVA | T- test to analyse difference between measurement for normal distribution and Mann- Whitney U-test for not normal distribution. | Paired t-test for the arch differences. | Paired t-test for comparison of plaster models and digital models. Bland – Altman analysis to investigate agreement between plaster models and digital models. | One-way analysis of variance (ANOVA) and post-hoc test (Tukey and Bonferroni) | Paired t-test to compare measurements of digital and plaster models. | Paired t-test | 1.Paired t-test<br>2.Repeated measures ANOVA | Paired t-test |

***Table 3c. Summary of the Major Data Extracted from the Selected Articles***

| Paper | Dalstra et al. | Yilmaz Hakan | Glisic Olja | Zhang et al. | Murugesan et al. | Camardella et al. | Leifert et al. | Santoro M et al. | Mullen et al. |
|---|---|---|---|---|---|---|---|---|---|
| Conclusions | Digitized models proved to produce better reproducibility of measurement | The space analysis and Bolton analysis are not significantly different | Intraoral distances were significantly shorter compared with the measurements on the plaster casts and on digital models between the upper right and left canine, upper first molar and upper canine on the right side.<br>No significant differences were found between the plaster casts and the digital models. | No significant difference on tooth heights and widths for both plaster and digital models. | No significant differences in the measurements obtained from stone models and digital models obtained from intraoral scan and model scan. | Some measurements on digital models presented high chance for clinical relevance. Measurements of crown height of upper central incisors on digital models showed largest clinically relevant error for both examiners. | Space analysis measurements are similar for both plaster and digital models (good correlation of the data from digital and plaster models.) | No significant difference between any of the measurements of both plaster and digitized plaster models in different examiners. Statistically significant difference between tooth width made digitally and manually. Digital models' measurements are smaller than plaster models but not clinically relevant. | No significant difference between both e-models and plaster models. |

***Table 3d. Summary of the Major Data Extracted from the Selected Articles***

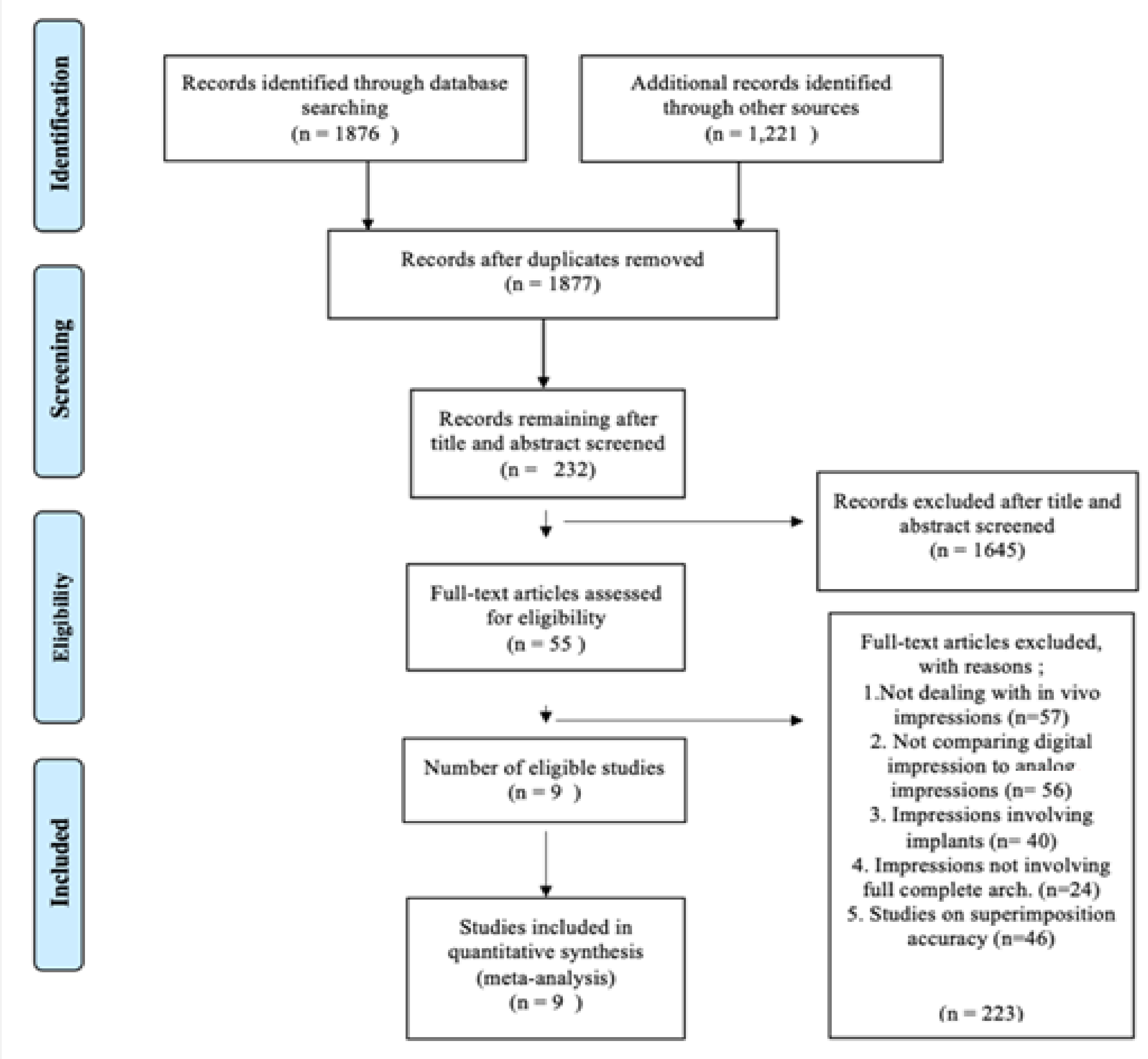


***Figure 1. Flow Diagram of Abstract Screening and Full Text Extraction Process***

## CONCLUSIONS

From this review it can be concluded that there were no significant differences among the measurements obtained from plaster models, digitized models obtained from the plaster models and direct intraoral scanning measurements. Although some studies showed slight variation in readings between methods, the differences were neither statistically nor clinically significant making it acceptable for clinical application.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.
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