Systematic Review Article

Variation of orthodontic treatment decision-making based on dental model type: *A systematic review*

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ABSTRACT

Objective: To determine in which clinical scenarios digital models are valid as replacements for plaster models during orthodontic treatment decision-making process and treatment planning.

Materials and Methods: An attempt to identify all pertinent published information was made. Retained articles were those where a decision-making process leading to differential orthodontic treatment plans based on either method were compared. The search was tailored for PubMed and adapted for EMBASE, MEDLINE, the Cochrane Library, LILACS, and Web of Science. A partial grey literature search was conducted through Google Scholar. References lists of the included articles were screened for potential relevant studies. The methodology of selected studies was evaluated using the Quality Assessment Tool for Diagnostic Accuracy Studies (QUADAS).

Results: Only two studies were finally selected for the qualitative and quantitative synthesis. QUADAS results scores from selected studies ranged from 61% to 83% of 11 items evaluated. In one, the overall treatment plan regarding orthognathic surgery for Class II malocclusion changed in 13% to 22% of the cases. In the other one, 6% of the orthodontic treatment plans changed.

Conclusion: Digital models could be used to replace plaster models in Class II malocclusion treatment planning. (*Angle Orthod.* 2015;85:501–509.)

KEY WORDS: Plaster models; Digital models; Decision making; Orthodontics; Review

INTRODUCTION

In some areas of dentistry, there is a need to record and manipulate three-dimensional (3D) replicas of a patient's occlusion before making treatment decisions.[1] Plaster dental models have provided dentists with a diagnosis and treatment planning tool in addition to being a 3D record of a patient's original occlusion.[2] Moreover, in the education field, dental plaster models have been considered important for didactic purposes, case progress assessment, and research documentation.[3]

The dental plaster model is the current gold-standard reference for occlusal assessment in orthodontics[3,4] and is considered a cornerstone tool for diagnosis and treatment planning.[3] Its advantages range from being easy to manufacture to being inexpensive and accurate. Conversely, dental plaster models have disadvantages such as storage costs and the potential for breakage, loss, and wear.[5]

Digital models provide multiple advantages, such as durability,[6] possibility to share images with other dentists and patients through the Internet,[7] monitoring of treatment progress,[1] reduced laboratory fees and chairside costs,[1] electronic storage of models,[8] improved patient education,[9] and increased office efficiency and production.[10] In contrast, major obstacles to the general use of this technology are related to cost,[10] security or privacy,[10] time management,[10] turnaround

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Table 1. Databases and Search Terms

Database	Key Words
PubMed http://www.ncbi.nln.nih.gov/pubmed	(dental cast OR dental model OR plaster model OR study model) AND (emodel OR e-model OR computer model OR digital model) AND (treatment planning OR treatment decision OR differential diagnosis OR differential diagnosis) AND (orthodon*)
EMBASE http//embase.com/search	(exp Dental Models/ or dental model*.mp. OR study model*.mp. OR plaster model*.mp. OR dental cast*.mp.) AND (digital model*.mp. OR computer model*.mp. OR e-model*.mp. OR emodel*.mp.)
MEDLINE http://www.ncbi.nln.nih.gov/pubmed	(exp Dental Models/ or dental model*.mp. OR study model*.mp. OR plaster model*.mp. OR dental cast*.mp.) AND (digital model*.mp. OR computer model*.mp. OR e-model*.mp. OR emodel*.mp.). *Refined search: (differential diagnosis.mp. OR treatment decision.mp. OR treatment planning.mp. OR orthodon*.mp.)
The Cochrane Library http//cochrane.bvsalud.org/portal	(exp Dental Models/ or dental model*.mp. OR study model*.mp. OR plaster model*.mp. OR dental cast*.mp.) AND (digital model*.mp. OR computer model*.mp. OR e-model*.mp. OR emodel*.mp.).
LILACS lilacs.bvsalud.org	(''modelos dentarios'' OR ''modelo de yeso'' OR ''modelo dental'' OR ''modelos de gesso'' [Words] OR ''emodel'' OR ''e-modelo'' OR ''modelo de PC'' OR ''modelo digital'' OR ''emodelo'' OR ''emodelo'' OR ''modelo virtual'' OR ''modelo digital'' [Words]) AND (ortodontia OR ortodoncia [Words])
Grey Literature (Google Scholar) scholar.google.ca	Any idiom; Without patents and citations; Classified by relevance; Search; ''orthodontic'', ''model'' in anywhere in the article; At least one of following words: ''study model'' ''dental cast'' ''dental model'' ''digital model'' emodel ''e-model''; 100 most relevant articles.
Web of Science http://apps.webofknowledge.com	TOPIC: ((dental cast OR dental model OR plaster model OR study model) AND (emodel OR e-model OR computer model OR digital model) AND (treatment planning OR treatment decision OR differential diagnosis OR differential diagnosis) AND (orthodon*)) Refined by: Research areas: (Dentistry Oral Surgery Medicine) AND research domains: (Science Technology) AND languages: (English) AND Document types (Article) Timespan=All years

time depending on the technology,[3] and the potential that electronically stored information could be permanently lost.[11]

Scientific evidence consistently supports the validity of measurements from digital dental arch models.[12] Studies assessing the accuracy of measurements regarding tooth size,[13] arch width and length,[14,15] space analysis,[15,16] reconstruction of the dental cast shape,[17] and relationship between arches[18,19] have shown that digital dental models are reliable and credible.

Although the validity of digital vs plaster models in terms of accuracy and reliability of specific dental arch measurements has been demonstrated in previous systematic reviews,[12,20] a similar critical assessment has not been conducted for overall treatment decisions about malocclusion. When assessing malocclusion, plaster models are used not only to quantify measurable occlusal features but also to observe and manipulate the patient's occlusion in three dimensions. A previous systematic review (SR)[21] did investigate the use of records for orthodontic treatment planning decisions, but with a more wide scope. The purpose of this systematic review is therefore to evaluate whether the decision-making process differs when the orthodontic treatment planning is based on either plaster or digital models when the remaining orthodontic records are similar.

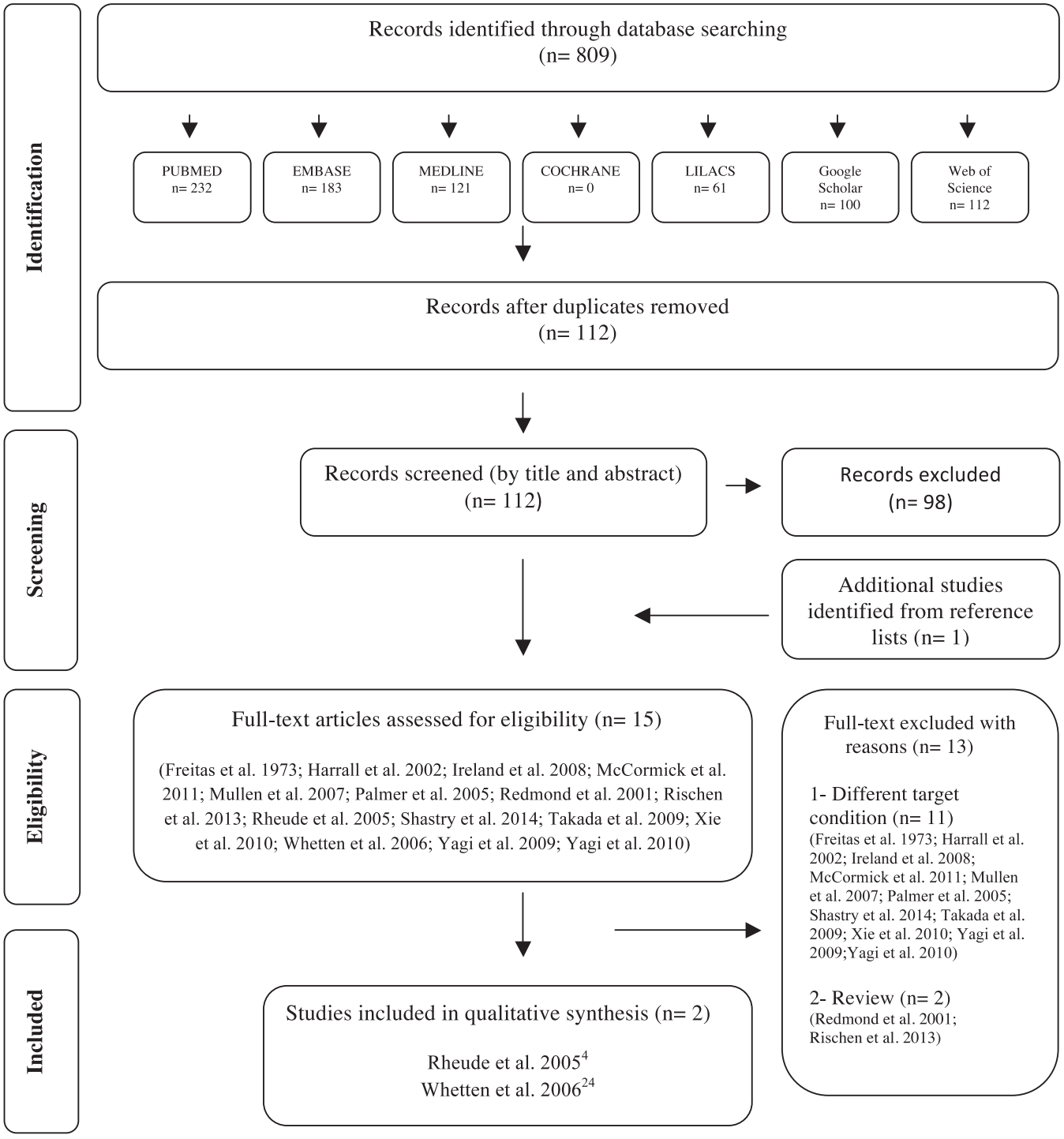
MATERIALS AND METHODS

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist.[22] A systematic review of studies that evaluated the orthodontic diagnosis and treatment planning decisions based on plaster dental models in contrast to digital dental models was undertaken. Study selection was based on the following inclusion criteria:

- An orthodontic decision-making diagnosis that led to differential treatment plans based on the same patient records except for use of either plaster dental cast or digital models;
- Digital models obtained from physical plaster models.

The search was tailored for PubMed and adapted for EMBASE, MEDLINE, the Cochrane Library, LILACS, and Web of Science. A partial grey literature search was conducted through Google Scholar. Searches were inclusive until June 4, 2014. Reference lists of the included articles were screened for potential relevant studies not identified through the electronic databases. Tailored truncation and word combinations were applied and adapted for each database search (Table 1).

Two reviewers (CP and GL) independently screened the titles and abstracts identified from the electronic database results. Next, full articles were retrieved to confirm their eligibility. Researchers were not blinded to the authors and results of the study. Two investigators (CP and GL) selected articles for inclusion in the review and performed quality assessment independently. Disagreements were discussed verbally, and a third investigator (CF) was involved when necessary.



[1] Adapted from PRISMA.

Figure 1. Flow diagram of literature search and selection criteria.

Table 2. Summary of Descriptive Characteristics of Included Articles

Author and Year	Country	Sample Size	Included Malocclusions	Objectives	Dental Cast Parameter
Rheude et al. 2005[4]	United States	7 sets of pretreatment records	Adults and early treatments of Class I malocclusion treated with extractions of permanent teeth; deep overbite; Class II division I malocclusion; anteroposterior skeletal discrepancy and transverse discrepancy	To determine the diagnostic and treatment-planning value of digital models compared with plaster study models To determine whether the digital or plaster models influence the decision-making process in different levels of orthodontist experience	Plaster dental model from impressions
Whetten et al. 2006[24]	Canada	10 sets of pretreatment orthodontics records	Class II molar in at least one side; ANB between 4° and 9°; overjet ≥4 mm; at least 13 years of age	To determine whether there is a difference in intrarater agreement in measurements for surgery, extractions, and auxiliary appliances based on the study model format	Plaster dental model from impressions

Thereafter one author (CP) performed data extraction and a second author (GL) crosschecked all the collected information. Disagreements were again discussed verbally until consensus was achieved. A third investigator was involved when necessary.

Any type of outcome measurement was considered (categoric and continuous variables). When required, authors were contacted to identify unpublished or unclear pertinent information.

Methodologic quality of selected studies was assessed through the Quality Assessment Tool of Diagnostic Accuracy Studies (QUADAS)[23] checklist. Two reviewers scored the QUADAS items and assessed, independently, the quality of each included study. A third reviewer (PWM) solved potential disagreements between the two reviewers. A meta-analysis was planned if the data from different studies were relatively homogeneous and appropriate to statistical clustering.

RESULTS

Once the selection process was completed only two articles[24] remained for the qualitative and quantitative synthesis. A flow diagram of the selection process is presented in Figure 1, and a list of excluded studies with reasons for the exclusion is outlined in Appendix 1.

Study Characteristics

The selected studies were conducted in the United States[4] and Canada.[24] Both assessment groups were based in dental schools and published in English. Sample size ranged from 7 to 10 sets of records. Age of the patients, as indicated pretreatment records, was at least 13 years in one study[24] but not specified in the other.[4] Plaster models were made from alginate impressions, and in both studies the digital models were produced by Geodigm Corporation (e-model, Falcon Heights, MN, USA). Two sets of impressions were made for each patient, one for the plaster model and the other for digital model production. Table 2 presents the data extracted from the included studies.

For the first study,[4] the assessed outcome was the influence of using plaster or digital models on diagnostic descriptions, treatment plans, and the absolute need for plaster casts to be able to complete a diagnostic decision. The seven cases represented different types of malocclusions, as defined by the American Board of Orthodontics, and encompassed an early treatment case, an adult treatment case, a Class I malocclusion to be treated with extractions, a deep overbite malocclusion, a Class II division 1 malocclusion, an anteroposterior skeletal discrepancy, and a transverse discrepancy.

In the second study,[24] a decision flowchart targeted agreements regarding the need for: surgery or not, extraction or not, and adoption of auxiliary appliance or not. They[24] blinded the examiners and the records to maintain evaluator blindness and prevent further identification of the case during the second evaluation. Ten sets of Class II malocclusion records were

Table 2. Extended

Method	Digital Model Production	Statistical Analysis	Findings	Outcome Measurements
7 examiners, orthodontists, divided into 2 groups according to experience level: Group 1: <15 years of experience Group 2: >15 years of experience	Geodigm Corporation	χ^2 test ($P = .05$)	Results showed that 12.8% of diagnostic characteristics, 12.0% of treatment mechanic procedures, and 6.0% of proposed treatment plans changed after analysis of records with plaster models.	In the vast majority of situations digital models can be used successfully for orthodontic records. Statistically significant differences were found between plaster and digital models, but the degree of record changes was minor and considered to be clinically insignificant for decision-making.
Orthodontists, divided in 2 groups (n=31): Group 1(experimental, models digital/plaster, and examiners who had never used digital models before): 20 orthodontists selected in 3 different cities (Edmonton and Calgary, Alberta, Canada, and Las Vegas, Nevada, United States Group 2 (control, models plaster/plaster): 11 orthodontists in Edmonton and Calgary	Geodigm Corporation	Mcnemar test	Good agreement was noted for surgery ($P = 1.00$, $\kappa = 0.549$), extractions ($P = .360$, $k = 0.570$), and auxiliary appliances ($P = 1.00$, $\kappa = 0.539$) for the digital/plaster group. Agreement in the plaster/plaster group for surgery ($P = 1.00$, $\kappa = 0.671$), extractions ($P = 1.00$, $\kappa = 0.626$), and auxiliary appliances ($P = .791$, $\kappa = 0.672$) was good. Overall proportions of agreement ranged from 0.777 to 0.870 for digital/plaster and from 0.818 to 0.873 for plaster/plaster.	There was no statistical difference in intrarater treatment-planning agreement for Class II malocclusions based on the use of digital models in place of traditional plaster models. Digital orthodontic study models (e-models) are a valid alternative to traditional plaster study models in treatment planning for patients with Class II malocclusion.

selected to represent a spectrum of severity based on ANB angle between 4° and 9°, overjet ≥4 mm, age 13 years and older, and at least a half-step Class II molar relation in one side.

Significant differences between the numbers of examiners included were detected. In the first study,[4] seven examiners were divided in two groups based on their level of clinical orthodontic experience. In the second study,[24] 31 examiners, divided in two groups, analyzed the records: an experimental group unfamiliar with digital models and a control group composed of 11 orthodontists who used digital models in treatment planning.

Risk of Bias Within Studies

The overall percentage of the QUADAS criteria for each study is shown in Appendix 2. The QUADAS score was 63% for one study[4] and 81% for the other.[24] The quality assessment score was based on 11 of the 14 items of the quality assessment. Specifically, 11 items, including patient spectrum, reference standard, verification bias, review bias, clinical review bias, incorporation bias, test execution, and indeterminate results, were analyzed by this systematic review and represent 100% of the score. The QUADAS items 4, 13, and 14 did not apply to this specific diagnostic setup. No study represented the whole spectrum of malocclusion cases properly. As in this case most of the diagnostic available information was similar, so full independence between tests could not be expected. Only 30 minutes passed between evaluations for one study,[4] and recall bias could occur in such a short time span.

Synthesis of Results

The study of Whetten et al.[24] presented decision agreement for surgery, indication of extractions, and adoption of auxiliary appliances when digital models were compared with plaster models and vice versa in a spectrum of Class II malocclusion cases. Overall agreement ranged from 78% to 87% for digital vs plaster and from 82% to 87% for plaster vs plaster.

Rheude et al.[4] found a statistically significant disagreement during diagnosis in 13% of the cases. In addition, disagreements were found during treatment of the same patient and during treatment mechanics selection in 6 of 49 mechanical procedures.

Both studies used e-models as digital models, and their examiners received specific training to view and manipulate the digital model's software.

Risk of Bias Across Studies

The selected studies[24] used similar diagnostic methods, which reduced the possibility of misdiagnosis. They could be considered homogeneous, but they presented the data in different way. Whetten et al.[24] reported only the proportion of agreement

whereas Rheude et al.[4] reported the number of diagnostic characteristics and treatment-planning changes. Therefore, it was not feasible to conduct a meta-analysis.

DISCUSSION

Orthodontic treatment planning is complex and requires the ability to simultaneously analyze multiple data obtained from different orthodontic diagnostic records. In this context, dental models are essential in providing a 3D record of a patient's occlusion.[5] The development of an interactive 3D digital model of a patient's occlusion has been proposed as a way to greatly improve the clinician's ability to determine different treatment options, monitor changes over time, predict and display final treatment results, and measure treatment outcomes more accurately.[7] Radiographs, photographs, and superimposition of images are tools that were initially nondigital but nowadays are largely optimized through the use of digital software. This systematic review found that digital dental casts could well replace conventional dental cast models for some clinical decision processes; however, complete equivalency has not been established.

Whetten et al.[24] attested that digital models do not affect the treatment-planning decision in Class II malocclusions. Although discrepancies were identified when borderline surgical cases were considered, neither the digital nor the plaster model skewed the frequency of recommendation for surgery. It is noteworthy that discrepancies were also present in treatment planning for borderline surgery cases based on two sessions with plaster models.

The results of the study of Rheude et al.[4] should be interpreted with caution. The sample size was small (seven cases) and represented a heterogeneous group of malocclusions. Only one case per malocclusion type was evaluated. The study design was appropriate to evaluate the degree of agreement regarding diagnosis. However, a study design without a spectrum of severity within a particular category of malocclusion does not provide enough information to evaluate equivalency of treatment plan decision-making. It was found that the frequency of variation in diagnosis between digital and plaster models decreased as the evaluator gained experience with digital models; thus, a transition phase is recommended when replacing plaster models with digital models as some software handling and understanding are required. In addition, a component of clinical experience, related to visual adjustment when using digital models and software tools, may initially affect the decision-making process.

The fact that orthodontists do not solely rely on dental models to diagnose patients and do treatment planning cannot be omitted. Therefore, the impact of changing one of the multiple diagnostic tools used during decision-making should not be overemphasized.

Two previous systematic reviews discussed the reliability of measurements from digital models compared with plaster models. Fleming et al.[12] and Luu et al.[20] concluded that measurements in digital models were reliable and valid. Our conclusions were different from those in the review by Rischen et al.[21] The current systematic review focuses exclusively on the diagnostic implications of using either plaster or digital models while keeping the remaining records similar. In contrast to their conclusions, we do not believe that, based on the available evidence of the two included studies, it can be concluded that digital models can be used to replace plaster casts. Digital models should only be used to replace plaster models in Class II malocclusion treatment planning. Unfortunately, the included articles did not provide sufficient evidence to conclude that digital models are a valid replacement for other malocclusion types. In addition, the review by Rischen et al.[21] did not analyze treatment-planning implications in depth.

Several authors have stated the benefits of accessing virtual images from patients' records. Among these benefits are easy data transmission during referral processes[3,10] and time savings during treatment planning and diagnosis compared with the time required for conventional model setup and reconstruction.[25] When considering the usefulness of digital models in addition to other digital orthodontic data, the decision process could be optimized by integrating 3D views of models, patient's photos, and cross-sectional anatomic images extracted from cone-beam computed tomography, thereby reducing the time spent to prepare surgical cases.[26,27] It has been argued that the high definition of 3D imaging software benefits the orthodontist's decision process.[28] It has not yet been proven, however. Finally, the useful application of digital technology to increase office efficiencies and reduce storage requirements is reported by orthodontists.[10] However, current clinicians should enhance their acceptance behavior by adapting to new technology.[29] It can be argued that this transition will not be faced by the future generation of orthodontists because they are already being trained with this technology. Several studies from the health sciences and education areas attested to the importance of using virtual patients to teach medical students.[29,30] Despite the high costs linked to the implementation of technology, virtual patients are considered an effective teaching methodology.[30,31] The benefits of this integrative learning approach range from education training to simulation of the consequences of clinical decision-making.

In summary, the results of this systematic review suggest that digital models are valid in treatment planning for Class II malocclusion. Additional research is needed to demonstrate the validity of digital models in treatment planning for other forms of malocclusion, such as Class III.

Some methodologic limitations of this review should be considered. First, there was no standardization regarding the methodology of the two included articles. Second, there was a significant sample-size difference. These studies do not represent the complete variation of the malocclusions faced by orthodontists. One article assessed seven sets of records[4] with different malocclusion types without showcasing the malocclusion spectrum for any of these malocclusion types. The other study[24] used 10 sets of records focused exclusively on a spectrum of Class II malocclusions. Future studies should include all types of molar relation and discrepancies. Issues regarding the capability of this technology to properly articulate the occlusion has been noted.[3] In one of the studies only 30 minutes passed between the evaluations.[4] It could be argued that the evaluators could have easily recalled their previous decision. Furthermore, digital models were assessed first followed by plaster models. The sequence of model analysis could produce a systematic bias. This study included only one case for each malocclusion category. Assessment of decision-making should evaluate multiple cases within each category. It is clear that additional research is needed to properly represent the whole malocclusion spectrum.

CONCLUSIONS

- Digital models could be used to replace plaster models in Class II malocclusion treatment planning.
- The included articles did not provide sufficient evidence to conclude that digital models could be used to replace plaster models in all other malocclusion types.

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APPENDIX 1
Articles Excluded and Reasons for Exclusion

Author(s)	Reason for Exclusion
de Freitas[1]	Different target condition
Harrell et al.[2]	Different target condition
Ireland et al.[3]	Different target condition
McCormick and Drew[4]	Different target condition
Mullen et al.[5]	Different target condition
Palmer et al.[6]	Different target condition
Redmond[7]	Review
Rischen et al.[8]	Review
Shastry and Park[9]	Different target condition
Takada et al.[10]	Different target condition
Xie et al.[11]	Different target condition
Yagi et al.[12]	Different target condition
Yagi et al.[13]	Different target condition

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APPENDIX 2
Quality Assessment of Included Studies[a]

Item	Whetten et al.[24]	Rheude et al.[4]
Was the spectrum of patients representative of the patients who will receive the test in practice?	No	No
Were selection criteria clearly described?	Yes	Yes
Is the reference standard likely to correctly classify the target condition?	Yes	Yes
Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis?	Yes	No
Did patients receive the same reference standard regardless of the index test result?	Yes	Yes
Was the reference standard independent of the index test (ie, the index test did not form part of the reference standard)?	No	No
Was the execution of the index test described in sufficient detail to permit replication of the test?	Yes	Yes
Was the execution of the reference standard described in sufficient detail to permit its replication?	Yes	Yes
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes	No
Were the reference standard results interpreted without knowledge of the results of the index test?	Yes	Yes
Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?	Yes	Yes
QUADAS criteria fulfilled (%)	81.8%	63.6%

[a] Adapted from Whiting P, Rutjes AWS, 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;3:25:1–13. Available from http:/.biomedicentral.com/1471-2288/3/25. Two questions from the Quality Assessment Tool for Diagnostic Accuracy Studies (QUADAS) were excluded as not applicable : n.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?) and n.13 (Were uninterpretable/ intermediate test results reported?).