An Evaluation of the Use of Digital Study Models in Orthodontic Diagnosis and Treatment Planning

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Abstract: The purpose of the present study was to determine the diagnostic and treatment planning value of digital models when compared with plaster study casts. In addition, the level of orthodontic experience of the examiner was assessed to determine whether this would have an influence on the decision-making process. Thirty randomly selected orthodontic patients from the Department of Orthodontics at the University of Alabama were selected for the study. From the 30 record sets, seven were selected attempting to mirror cases required for presentation to the American Board of Orthodontics. The seven evaluators were divided into two groups on the basis of their level of orthodontic experience. Initially, each evaluator assessed each patient record. Each evaluator was given a standardized questionnaire which recorded the evaluator's diagnosis based on use of the digital study models (T1). Regardless of whether the evaluator requested a review of the plaster study casts, the evaluator was given the plaster study casts. The evaluator then, using the plaster casts, filled out another identical questionnaire (T2). A chi-square test was used to determine any group differences in the frequency of changed diagnostic characteristics, treatment mechanical procedures, or proposed treatment plans after evaluating plaster study models. The statistical significance selected was $P = .05$ level of significance. The results showed that 12.8% of diagnostic characteristics, 12% of treatment mechanic procedures, and 6% of proposed treatment plans changed after T2. The results of the present study indicate that in the vast majority of situations digital models can be successfully used for orthodontic records. (*Angle Orthod* 2005;75:300–304.)

Key Words: Digital models; Orthodontics

INTRODUCTION

Digital radiographs and digital photography are becoming the norm in orthodontic records. Recent advances have now included electronic study casts. Because we had medical and dental histories, digital photographs, digital radiographs, and all treatment notes in digital format, the ability to obtain digital study casts has become most appealing. Plaster study casts have a long and proven history in orthodontics. They have been the "gold standard" in orthodontics, with advantages ranging from being a routine dental technique, ease of production, inexpensiveness, and ease in measurement to plaster casts being able to be mounted on an articulator for study in three-dimensions.

Alternatives to using plaster study casts have been suggested ranging from photocopies, photography, holograms to digitization of points from the plaster study cast. At present, plaster casts of the dentition remain a recognized tool for orthodontic diagnosis and treatment planning. Han[1] evaluated the consistency of orthodontic treatment decisions relative to diagnostic records. The latter study indicated how incremental information obtained from different types of diagnostic records contributed to the determination of orthodontic treatment decisions. Their results indicated that 55% of orthodontic treatment plans devised from study casts alone remained unchanged with the addition of other diagnostic records such as photographs and radiographs.[1]

Digital study models offer advantages that include ease of storage and retrieval, ease of interoffice transferability, and possibly equal or better diagnostic capabilities. Garino and Garino,[2] Caspersen et al,[3] and Zilberman et al[4] compared linear dental anatomic measures obtained from plaster and digital models whereas Tomassetti carried out Bolton analyses on plaster and digital models. The former investigators found a statistically significant difference between

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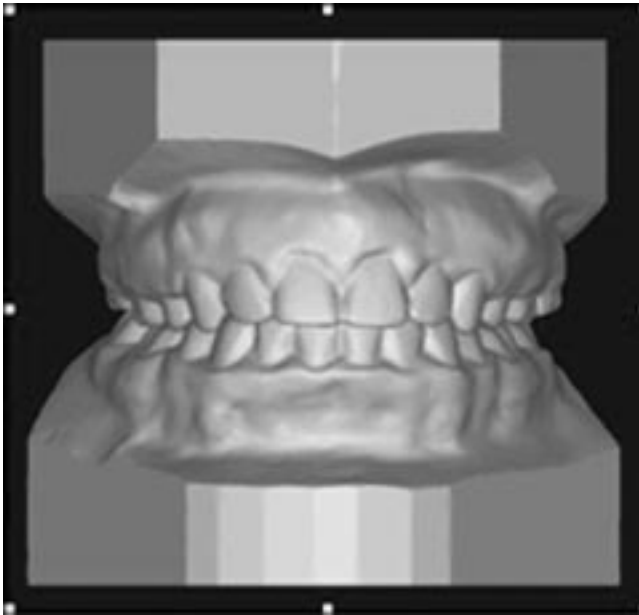
FIGURE 1. Anterior view of digital model (*e*model by Geodigm™ Corporation).

FIGURE 2. Three-dimensional view of digital model (*e*model by Geodigm™ Corporation).
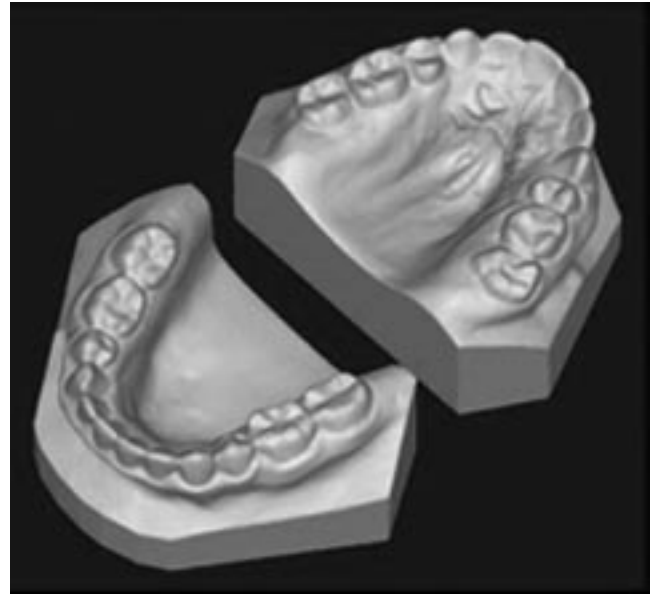
plaster and digital model linear measurements but concluded that the average difference was clinically insignificant. Tomassetti et al[5] carried out Bolton analyses on 21 conventional plaster study cast sets using a vernier caliper and found no statistically significant difference in measurement outcomes between the plaster and the digital study models.

However, up to the present, no studies have yet evaluated whether use of digital models would alter the diagnosis or treatment plan (or both) of orthodontic patients. The purpose of the present study was to determine the diagnostic and treatment planning value of digital models when compared with plaster study casts. In addition, the level of orthodontic experience of the examiner would be assessed to determine whether this would have an influence on the decision-making process.

MATERIALS AND METHODS

Thirty randomly selected orthodontic patients from the Department of Orthodontics at the University of Alabama were selected for the study. None of the subjects had orthodontic treatment previously. Two impressions were taken from each patient to produce a separate digital model and a plaster study cast. Plaster casts were made in house, whereas the digital model production was carried out by Geodigm™[6] (Figures 1 and 2).

From the 30 record sets, seven were selected, attempting to mirror cases required for presentation to the American Board of Orthodontics (ABO), excluding their optional case requirement. The seven case representations included early treatment malocclusion, adult malocclusion, Class I treated with extraction of permanent teeth, deep overbite malocclusion, Class II division 1 malocclusion, anteroposterior skeletal discrepancy, and transverse discrepancy.

Seven orthodontic faculty members were used as evaluators to assess the influence of using digital models vs plaster casts on the treatment plans, diagnostic descriptions, and treatment mechanics. The seven evaluators were divided into two groups on the basis of their level of orthodontic experience. Group 1 comprised orthodontists who had less than 15 years of clinical orthodontic experience, whereas group 2 comprised orthodontists who had 15 years or more clinical experience.

Initially, each evaluator assessed each patient record including the medical history, dental history, panoramic radiograph, cephalometric radiograph, extraoral and intraoral photographs, and digital models. The first author, who was very familiar with use of digital models, provided directions on computer viewing and manipulation of the digital models and then remained with the records evaluator throughout their evaluation for any assistance needed relative to but limited to digital models. Each evaluator was given a standardized questionnaire. Once completed (T1), the questionnaire recorded the evaluator's diagnosis based on use of the digital study models. The evaluators were then asked to write a brief description of their treatment plans and the treatment mechanic procedures that they would use based on their digital model evaluation at T1. In the questionnaire, the evaluators also answered the following question: "Would you like to see plaster study models?" If the answer was "yes," the evaluators were asked to list the reason(s), why they wanted to assess plaster study casts.

Regardless of whether the evaluator requested a review of the plaster study casts, the evaluator was given the plaster study casts. The evaluator then, using the plaster casts,

TABLE 1. Group and Overall Diagnostic Changes (T2)[a]

	No. of Diagnostic Characteristics Rendered	No. of Diagnostic Characteristics Changes	With Plaster Models Requested	Without Plaster Models Requested
Group 1 (<15 y)	560	83	11	72
Group 2 (>15 y)	420	43	4	39
Combined	980	126	15	111

[a] T2: evaluation of plaster study casts.

TABLE 2. Group and Overall Treatment Planning and Treatment Mechanical Changes (T2)[a]

	No. of Exams	No. of Treatment Planning Changes	With Plaster Models Requested	Without Plaster Models Requested	No. of Treatment Mechanical Changes	With Plaster Models Requested	Without Plaster Models Requested
Group 1 (<15 y)	28	1	0	1	6	1	5
Group 2 (>15 y)	21	2	2	0	0	0	0
Combined	49	3	2	1	6	1	5

[a] T2: evaluation of plaster study casts.

filled out another identical questionnaire (T2). The time period between the digital model evaluation (T1) and the evaluation of plaster study casts (T2) did not exceed 30 minutes, to try to maintain the same thought process for the given malocclusion. Comparisons were made between the questionnaires completed by each evaluator at T1 and T2. If any changes were noted, the evaluator was asked to record why the change had been made between digital models assessment (T1) and plaster study cast assessment (T2) because this was the only record variable in the study. The last question asked was whether the evaluator considered that they obtained any additional information from the digital model when compared with the plaster cast.

Statistical analysis

Statistical analyses were carried out to assess significance of the results. A chi-square test was used to determine any group differences in the frequency of changed diagnostic descriptions, treatment mechanical procedures, or proposed treatment plans after evaluating plaster study models. The statistical significance selected was $P = .05$ level of significance.

RESULTS

The results included the following: (1) the total percentage of all evaluators' (group 1 plus group 2) diagnoses, treatment mechanical procedures, and proposed treatment plans that changed because of reviewing the plaster study models (T1) after the initial results obtained with the digital models only; (2) the number of times and reasons why all evaluators desired to evaluate the plaster study models (after their evaluation of the digital models); (3) intergroup comparisons (evaluators group 1 vs group 2) of the number of times of diagnoses, treatment mechanical procedures, or

proposed treatment plans changed after evaluating the plaster study models.

Combined group

Diagnosis. A statistically significant difference was found in 14 of 21 diagnostic characteristics between T1 and T2 at the $P = .05$ level of significance. The 14 diagnostic characteristics included molar classification, cuspid classification, arch asymmetry, overbite, overjet, maxillary crowding, mandibular crowding, anterior crossbite, posterior crossbite, angulations, tooth size, tooth morphology, maxillary curve of Spee, and midlines.

A total of 126 of 980 diagnostic characteristics changed after evaluators assessed the plaster study models after evaluation of the digital models only (Table 1). Molar and cuspid classifications changed the most with 18 and 17 changes, respectively. Overjet, overbite, and mandibular crowding showed 11, 12, and 13 characteristic changes, respectively.

Tooth angulations and posterior crossbites ranked next with both categories recording nine out of 49 diagnostic characteristic changes. Arch form and mandibular curve of Wilson were the only two diagnostic descriptions that did not change. The last 11 diagnostic characteristics ranged from one to five changes for all evaluators combined.

Treatment plans. A statistically significant difference was found for the proposed treatment plan changes at the $P = .05$ level of significance. For all seven evaluators, three of 49 proposed treatment plans (Table 2) were changed after evaluators assessed the plaster study casts. All three proposed treatment plans changes occurred in the same patient. The proposed treatment plan changes included (1) surgical treatment with extraction of maxillary and mandibular first bicuspids to nonsurgical treatment with extraction of max-

illary second bicuspids and mandibular first bicuspids; (2) extraction of maxillary second bicuspids and mandibular first bicuspids to extraction of maxillary right first bicuspid and maxillary left second bicuspid and mandibular first bicuspids; and (3) surgical treatment with extraction of maxillary first bicuspids and mandibular second bicuspids to nonsurgical treatment with extraction of maxillary second bicuspids and mandibular first bicuspids. Plaster study models had been specifically requested at the time of digital model evaluations in two of the three proposed treatment plan changes listed above.

Treatment mechanical procedures. A statistically significant difference was detected for treatment mechanical procedure changes at the $P = .05$ level of significance. For all seven evaluators, six of 49 (Table 2) treatment mechanical procedures changed after evaluators also assessed the plaster study casts. Three of the seven evaluators accounted for the six changes reported. One evaluator accounted for four of the six changes reported. The changes in treatment mechanical procedures suggested by the single evaluator, after evaluating the plaster casts, included the addition of a Nance appliance, placement of a utility arch, and increased interproximal reduction. The other two of the three evaluators who suggested changes in mechanical procedures suggested placement of a lingual arch and earlier correction of posterior cross bite malocclusions in two patients. One of the seven evaluators who had suggested the most treatment mechanical changes after plaster model evaluation had requested a plaster cast during his original evaluation of the digital models.

Request for plaster casts at time of digital model evaluation. At the time of the initial examination, an evaluator requested the plaster study model of the patient while assessing the digital models in four instances out of the total of 49 record evaluation activities (seven evaluators each evaluating seven cases). The four requests occurred in two patient records. The four reasons for requesting plaster study models after viewing the digital models were (1) to see how much decompensation was needed for a surgical treatment; (2) to see how much transverse expansion was needed for a surgical treatment; (3) an unusual asymmetric extraction possibility; and (4) to see better detail of tooth morphology for interproximal recontouring.

Group differences

A statistically significant difference was found between group 1 ($\leq$15 years experience) and group 2 ($\geq$15 years experience) for seven diagnostic characteristic changes at the $P = .05$ level of significance. The seven diagnostic characteristics included molar classification, overjet, maxillary crowding, posterior crossbites, inclination, tooth size, and midline coincidence. A statistically significant difference was not found between group 1 and group 2 for the number of treatment planning procedure changes and pro-

posed treatment mechanical changes at the $P = .05$ level of significance.

DISCUSSION

The aim of the study was to assess whether the application of digital models instead of plaster study casts would affect diagnostic and treatment planning decisions. Ribarevski et al[7] reported that treatment planning by one orthodontist on the same set of records could have considerable variation. To minimize intra-examiner treatment planning variation, the time period between the digital model evaluation (T1) and the evaluation of plaster study casts (T2) did not exceed 30 minutes attempting to eliminate or reduce differences in treatment planning between T1 and T2 to be influenced by only the model type.

Seven of 30 record sets were selected attempting to mirror cases required for ABO certification. The selection of the seven orthodontic records for evaluation provided a variety of skeletal discrepancies, levels of crowding and transverse discrepancies. The younger orthodontists recorded more diagnostic changes. A possible explanation for this could be their limited experience in collecting data from limited records. A statistically significant difference was not found between group 1 and group 2 evaluators for either the number of treatment planning procedure changes or the proposed mechanical treatment changes at the $P = .05$ level of significance.

There was a statistically significant difference found in 14 of 20 diagnostic characteristics between T1 and T2 at the $P = .05$ level of significance. Molar and cuspid classifications had the most changes at 18 and 17, respectively. From T1 to T2, three of the 18 molar classification changes were $\geq$½ step (2 mm). The remaining molar classification changes did not exceed ¼ step (1 mm). Cuspid classification followed a similar pattern with only three of the 17 $\geq$ ½ step (2 mm). Mandibular crowding changes ranged from 1 to 4 mm, with an average of 1.5 mm more crowding recorded on plaster study models. Although many diagnostic characteristics were found to have statistically significant differences between T1 and T2, the degree of recorded changes were minor and considered clinically insignificant.

A majority of the diagnostic changes recorded from T1 to T2 occurred in the first few evaluations and decreased progressively as each evaluator continued through the cases. For example, most evaluators misdiagnosed crossbites during the first one or two evaluations but did not do so after this. This is likely because of inexperience with a new modality. Some evaluators stated there was a visual adjustment period when initially using the digital models. Of the seven evaluators participating in the study, only one evaluator used digital models in their private orthodontic practice. Observation and cognition of digital models becomes more accurate after the clinicians studied digital and plaster models for the same patient. Marcel[8] reported a sim-

ilar finding stating that experience is a factor when using digital models. It is recommended that when converting a plaster study cast practice to a digital office that includes digital models, it may be useful to evaluate both digital models and plaster study casts for each individual patient at the start of the transition.

A statistically significant difference was found for proposed treatment plan changes at the $P = .05$ level of significance. All three proposed treatment plan changes by the evaluators occurred in the same patient. The latter could be because of an error in one or more of the bite registrations for both the plaster and digital models for that patient, distortion occurring during shipping, or the possible difficulty in treatment planning for this patient in that there may have been a surgical treatment need. All evaluators who recommended treatment plan changes agreed that in this specific patient the digital model set was more Class-III dental with a more severe open bite as compared with the plaster study casts, suggesting that the error was more in the bite registration, rather than the inability of the evaluator to detect transverse or vertical discrepancies. It is advisable to record clinically the dental classification, overjet, and overbite characteristics in the patient's chart before sending out for digital models.

For all evaluators, six of 49 treatment mechanical procedures changed after evaluators had also assessed the plaster study casts. However, all the changes reported could easily have been decided upon during an early clinical orthodontic treatment appointment. The changes suggested were all of a minor clinical nature. Although calculated to be statistically significant treatment mechanical procedure changes, they were all clinically insignificant. This investigation did not include a clinical patient examination, which is the accepted procedure for comprehensive patient evaluation, but was done in this manner to eliminate all other bias. A possible follow-up study could compare differences of digital models vs plaster study casts, which included the clinical examinations.

Plaster study models were requested in four of the 49 evaluations. The four requests occurred in only two patient records. The four reasons for requesting plaster study models after viewing the digital models were to see how much decompensation was needed for a surgical treatment, to see how much transverse expansion was needed for a surgical treatment, an unusual asymmetric extraction possibility, and to see better detail of tooth morphology for interproximal recontouring.

On the basis of the findings of the present study, it is recommended that plaster study casts are likely advisable for all patients in whom surgery may be indicated as well as in patients who may require an unusual extraction pattern where a diagnostic set up may be indicated. The evaluation of variations in tooth morphology would likely be most reliable from a clinical dental examination.

Digital model production companies have anticipated some of the problems reported in this investigation and have begun to develop additional software to address these problems. These include the ability to carry out a digital diagnostic setup, automatic recognition of dental anatomic reference points, radiographic mensuration, simulation of proposed treatment planning, bracket positioning, and direct intraoral scanning without the need for dental impressions.

CONCLUSIONS

- Although many diagnostic characteristics were found to have statistically significant differences between the plaster and electronic models, the degree of recorded changes were minor and considered to be clinically insignificant.
- As the evaluators proceeded with the study and they looked at more digital models they recorded fewer variations between the plaster and electronic models.
- All recommended treatment mechanical changes suggested could have been detected easily in a patient's clinical examination.
- For those who wish to use digital models, it may be advantageous to use digital and plaster casts for an initial few patients. In addition, clinically recording the dental classification, overjet, and overbite would be useful. For proposed surgical patients or unusual extraction patterns, plaster casts, for the present, may be more accurate.
- The results of the present study indicate that in the vast majority of situations digital models can be used successfully for orthodontic records.

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