Original Article

Digital models vs plaster models using alginate and alginate substitute materials

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ABSTRACT

Objective: To compare the dimensional stability of four impression materials over time and to compare OraMetrix digital models vs traditional plaster models.

Materials and Methods: Two traditional alginates (Identic and imprEssix) and two alginate substitutes (Alginot FS and Position PentaQuick) were used to take multiple impressions of a maxillary typodont. Fifteen impressions for each material were taken and poured with plaster at three time points: 72 hours, 120 hours, and 1 week. Five impressions for each material were taken and were sent to OrthoProof for digital model reproduction at 72 hours. Digital models were then integrated with OraMetrix software. Plaster and digital models were measured in the anterior-posterior, transverse, and vertical dimensions. The control typodont and plaster models were measured using a digital caliper, and digital models were measured using OraMetrix software.

Results: Statistically significant changes were found for models replicated from Identic impression material in all three dimensions by 72 hours. Statistically significant changes were seen in imprEssix impressions in the vertical and intercanine dimensions. Digital models were significantly smaller in all dimensions compared with plaster models and the control.

Conclusions: Identic impression material showed a statistically and clinically significant change in all dimensions within 72 hours and therefore should not be used if impressions are not going to be poured immediately. Alginate substitutes were dimensionally stable over an extended period. Digital models produced by OraMetrix were not clinically acceptable compared with plaster models. (*Angle Orthod.* 2010;80:662–669.)

KEY WORDS: Digital models; Impression materials

INTRODUCTION

Diagnosis, the single most important phase of orthodontic treatment, is dependent on accurate and reliable orthodontic records. The vital information required to diagnose a malocclusion and develop an orthodontic treatment plan consists of models, photographs, panoramic and lateral cephalometric radiographs, and a clinical examination.[1] Digital technology has made significant changes in orthodontics. Digital photography and radiographs are rapidly replacing traditional methods. The progression to a completely ''paperless office'' has incorporated the use of digital models, records, consents, and financial agreements. Digital models have eliminated the need for storage space and have made retrieval and transfer of models easier. These three-dimensional models can be easily manipulated to gather measurements to facilitate diagnosis and treatment planning. With the numerous advantages of digital models and the progression to a

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"paperless office," digital models will replace traditional plaster models.[2–5]

Currently, three companies offer computer-based three-dimensional models: SureSmile (OraMetrix Inc, Dallas, Tex), OrthoCAD (Cadent Inc, Carlstadt, NJ), and E-Models (GeoDigm Corporation Inc, Chanhassen, Minn). Diagnostic impressions of the patient's dentition are mailed to the company, and the impressions are scanned using various technologies unique to the company. These scanned images are uploaded to the company software, allowing viewing of the three-dimensional models. The clinician, using the company's software program, can access these images. The program also allows the orthodontist to perform measurements and manipulate the models to achieve proper diagnosis.

The accuracy of the digital models depends initially on the accuracy of the impression. Typically, an irreversible hydrocolloid or alginate material is used for orthodontic diagnostic models because of inexpensiveness, ease of use, and relative accuracy. However, alginate does have a short-term dimensional stability. Impression materials such as polyether and polyvinyl siloxane (PVS) have been used for their accuracy and extended dimensional stability, but these materials are significantly more expensive. With advances in dental materials, manufacturers have created alginate substitutes that incorporate the longer dimensional stability of polyether and PVS without a significant price difference.

As digital models become more common, and as advances in dental materials introduce new impression products, more research needs to be done. This study will examine the three-dimensional accuracy of measurements made on digital models using OraMetrix and traditional plaster models using four different impression materials. The materials will also be evaluated for their dimensional stability over three time periods.

Clinical Application

With the increased use of digital diagnostic models, the purpose of this study was to compare digital and plaster models using various alginate and alginate-alternative impression materials. Clinicians can use the findings to determine whether digital or plaster models are comparable in diagnostic accuracy and which impression material will provide a diagnostically accurate model.

MATERIALS AND METHODS

Eighty single-arch impressions were taken of a standard maxillary typodont (Kilgore International Inc, Coldwater, Mich). The control used was the standard maxillary typodont, and measurements were made using the digital caliper directly from the typodont. Anterior-posterior, transverse, and vertical measurements were taken five times on the typodont and were averaged.

Four different impression materials were used, ranging from traditional alginates to alginate-alternative materials:

1. Material 1—Identic Alginate (Dux Dental, Oxnard, Calif), a traditional alginate
2. Material 2—imprEssix Color Change Alginate (Dentsply, York, Pa), a color change traditional alginate
3. Material 3—Alginot FS (Kerr USA, Romulus, Mich), an alginate-alternative material
4. Material 4—Position PentaQuick (3M ESPE Dental Products, Seefeld, Germany), an alginate-alternative material

Impressions were taken according to manufacturers' recommendations, including the recommended tray adhesives for each material. Identic and imprEssix Color Change Alginates were mixed with a mechanical mixer, the Alginator II (Dux Dental).

Three time intervals were used to evaluate the plaster models, as these are reasonable time intervals from the time impressions are taken until they can be reproduced as plaster or digital models:

1. T1—72 hours
2. T2—120 hours
3. T3—1 week

Digital models were evaluated only at T1, as material changes over time could be seen in plaster models.

Technique for Model Representation

Digital models (Twenty impressions were taken for digital models.)

- Five impressions per material
- Each impression was scanned three times; however, evaluated only at T1

Impressions were packaged according to OraMetrix (Richardson, Tex) guidelines and were shipped to OrthoProof USA (Albuquerque, NM) via 2-day shipping. Digital models were created using proprietary FlashCT cone beam computed tomography (CBCT) technology (Hytec Inc, Los Alamos, NM). This is a patented technology that requires the impressions to be scanned using CBCT technology based on the interaction of the radiation and the impression material. Digital files were

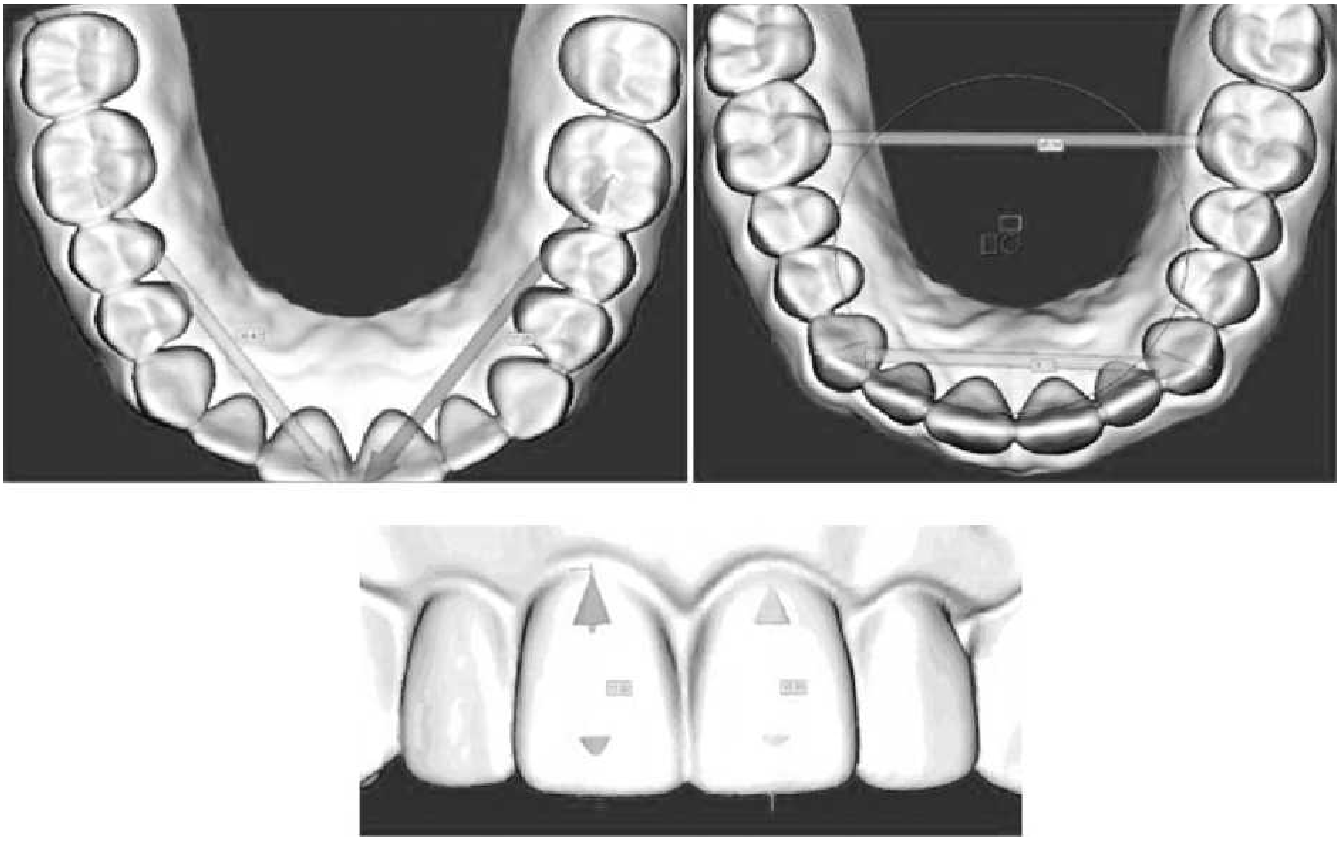

Figure 1. Digital measurements.

sent to OraMetrix, and digital models were viewed and measured using SureSmile v5.6 software. Measurements were made in all three dimensions: anterior-posterior, transverse, and vertical.

Plaster Models

Sixty impressions were taken for plaster models.

- 5 impressions for each material for each time interval
- Impressions were poured at the appropriate time intervals with 0–67 Snow White plaster (Heraeus Kulzer Inc, South Bend, Ind) using the manufacturer's recommendations of 100 g plaster to 26 mL water, vacuum mixed for 15 seconds.

Plaster models were measured using digital calipers (accuracy ± 0.03 mm). Measurements were taken in all three dimensions: anterior-posterior, transverse, and vertical.

Dimensions Evaluated

Anterior-posterior.

- The typodont, digital, and plaster models were measured from the central pit of the first molar to the MF line angle of the respective central incisor (Figure 1a).

Transverse.

- The typodont, digital, and plaster models were measured from the central pit of the first molar to the central pit of the contralateral first molar. The typodont and models were also measured from the cusp tip of the canine to the contralateral canine cusp tip (Figure 1b).

Vertical.

- The typodont, digital, and plaster models were measured from the incisal edge at the midline of the maxillary right and left central incisors to the gingival margin (Figure 1c).

Parameters Measured

The following parameters were evaluated:

- Quality of plaster models produced from different impression materials compared with control measurements
- Effects of time on the dimensional stability of the impression material used

- Comparison of control typodont measured with digital calipers, plaster models measured with digital calipers, and digital models measured with OraMetrix software

All digital models were compared with the control model, and all digital models were compared with the plaster models.

Statistical Evaluations

Differences in impression material over time were evaluated for plaster models compared with the control using a multilevel mixed-effect linear regression. The vertical, transverse, and anterior-posterior dimensions were evaluated for each material for each time point. Materials that showed a significant change ($P < .05$) in any dimension compared with the control were evaluated at T1 and T3 using a paired *t*-test. Technique differences were compared at T1 to determine whether significant differences existed between plaster and digital models. The control was compared vs digital models for each material and dimension at T1. The plaster and digital models were compared for each material and dimension at T1.

Comparisons were done using Kruskal-Wallis equality of populations rank test and one-way analysis of variance. All analyses were performed with STATA 10.0 (StatCorp, College Station, Tex).

RESULTS

Error studies were carried out on the various methods based on the repeated measures of one observer. The error was less than 0.5 mm and was found to be not statistically significant ($P < .05$). Measurements in the anterior-posterior, transverse, and vertical dimensions were obtained and described in accordance with the parameters described.

The Quality of Plaster Models Produced from Different Impression Materials Compared with Control Measurements

The mean of the five plaster models for each material for each time period was compared with the control measurements using a multilevel mixed-effect linear regression. Compared with the control measurement (Table 1a), Material 1 (Identic alginate) showed a statistically significant ($P < .05$) difference in all dimensions. Material 2 (imprEssix) showed a statistically significant change in intercanine width and vertical measurements as measurements decreased over time. Material 3 (Alginot FS) and Material 4 (PentaQuick) did not show any significant changes over time.

At T1, Material 1 showed the greatest decrease in measurements compared with the control in all dimensions. Although some increases in measurements were seen at T2 and T3, overall the measurements were significantly smaller for Material 1 (Figure 2a through 2c).

The Effect of Time on the Dimensional Stability of the Impression Material Used

The materials in each dimension that showed a significant change in Table 1a were compared in Table 1b at T1 and T3 using a paired *t*-test. This was done to see whether there was a significant change in measurements at the two extreme measurement points. As can be seen in Table 1b, there was no significant change for Material 1 in any of the dimensions between T1 and T3. Therefore it is evident that the significant dimensional change for Material 1 occurred from the control to T1. Material 2 showed a similar result, except for the change in the left vertical measurement, which had a significant change from T1 to T3.

Comparison of Control Typodont Measured with Digital Calipers, Plaster Models Measured with Digital Calipers, and Digital Models Measured with OraMetrix Software

The following results were obtained in the digital models compared with control and plaster vs digital models.

Digital models compared with control. Comparisons were done for each dimension at T1 for each material. Intercanine and intermolar dimensions showed a statistically significant difference, with digital models having a smaller dimension. Anterior-posterior dimension also showed a statistically significant difference, with digital models having a smaller dimension. However, the left anterior-posterior dimension for Material 2 and the right anterior-posterior measurement for Material 1 were not statistically significant. Right vertical measurements showed a statistically significant difference for all materials, with digital models having a smaller dimension compared with the control. Only Materials 1 and 2 showed a statistically significant difference in left vertical measurements, with digital models having a smaller dimension. Overall the control measurements in all dimensions were larger than the digital measurements.

Comparison of plaster and digital models at T1. Using a one-way analysis of variance and a Kruskal-

Table 1a. Plaster Technique—Differences in Impression Materials Over Time

	Control		72 Hours		120 Hours		1 Week		
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	*P* Value[a]
Intercanine									
Control vs Material 1	36.93	(0.11)	36.21	(0.24)	36.44	(0.22)	36.40	(0.36)	<.001
Control vs Material 2	36.93	(0.11)	36.78	(0.25)	36.72	(0.15)	36.75	(0.18)	.013
Control vs Material 3	36.93	(0.11)	36.77	(0.16)	36.97	(0.06)	36.73	(0.04)	.131
Control vs Material 4	36.93	(0.11)	36.86	(0.05)	36.91	(0.10)	36.90	(0.05)	.549
Intermolar									
Control vs Material 1	48.19	(0.18)	47.80	(0.13)	47.97	(0.23)	47.76	(0.25)	.001
Control vs Material 2	48.19	(0.18)	48.23	(0.23)	47.97	(0.16)	48.10	(0.19)	.311
Control vs Material 3	48.19	(0.18)	48.15	(0.38)	48.08	(0.11)	48.13	(0.15)	.433
Control vs Material 4	48.19	(0.18)	48.03	(0.09)	48.11	(0.08)	48.04	(0.15)	.150
Left Anterior-Posterior Measurements									
Control vs Material 1	39.25	(0.07)	39.06	(0.31)	39.10	(0.22)	38.67	(0.16)	<.001
Control vs Material 2	39.25	(0.07)	39.10	(0.17)	39.08	(0.51)	39.34	(0.20)	.311
Control vs Material 3	39.25	(0.07)	39.40	(0.11)	39.32	(0.07)	39.15	(0.20)	.535
Control vs Material 4	39.25	(0.07)	39.17	(0.04)	39.29	(0.07)	39.18	(0.20)	.603
Right Anterior-Posterior Measurements									
Control vs Material 1	38.92	(0.12)	38.61	(0.03)	38.76	(0.14)	38.70	(0.08)	<.001
Control vs Material 2	38.92	(0.12)	38.97	(0.15)	38.76	(0.05)	38.87	(0.19)	.340
Control vs Material 3	38.92	(0.12)	38.79	(0.14)	38.76	(0.11)	39.02	(0.09)	.245
Control vs Material 4	38.92	(0.12)	38.89	(0.13)	38.80	(0.03)	39.11	(0.13)	.751
Left Central									
Control vs Material 1	11.01	(0.02)	10.67	(0.08)	10.55	(0.12)	10.66	(0.15)	<.001
Control vs Material 2	11.01	(0.02)	10.98	(0.08)	10.78	(0.07)	10.58	(0.13)	<.001
Control vs Material 3	11.01	(0.02)	10.91	(0.05)	10.96	(0.10)	11.08	(0.07)	.422
Control vs Material 4	11.01	(0.02)	11.05	(0.01)	11.03	(0.02)	11.09	(0.08)	.179
Right Central									
Control vs Material 1	11.21	(0.04)	10.83	(0.13)	10.67	(0.12)	10.81	(0.12)	<.001
Control vs Material 2	11.21	(0.04)	10.92	(0.10)	10.82	(0.07)	10.77	(0.15)	<.001
Control vs Material 3	11.21	(0.04)	11.18	(0.09)	11.20	(0.05)	11.22	(0.07)	.827
Control vs Material 4	11.21	(0.04)	11.18	(0.05)	11.21	(0.05)	11.18	(0.03)	.611

[a] Multilevel mixed-effects linear regression.

Wallis equality of populations rank test, plaster and digital techniques for the four materials were compared at T1. Significant findings were found for each dimension with various materials. Materials 2, 3, and 4 were significantly different in terms of intercanine and intermolar measurements. Materials 3 and 4 were significantly different for right and left anterior-posterior measurements. Materials 1 and 2 were significantly different for the left central measurement, and all materials were significantly different for the right central measurement. Plaster measurements were always larger than digital measurements (Figure 3a through 3c).

DISCUSSION

The results of this study show that material and time are crucial for the dimensional stability of impression materials, and the technique used can introduce variability among measurements. Many impression materials are dimensionally stable only

Table 1b. Plaster Technique—Mean Differences in Impression Materials Over Time

	72 Hours		1 Week		
	Mean	(SD)	Mean	(SD)	*P* Value[a]
Intercanine					
Material 1	36.21	(0.24)	36.40	(0.36)	.1864
Material 2	36.78	(0.25)	36.75	(0.18)	.8321
Intermolar					
Material 1	47.80	(0.13)	47.76	(0.25)	.7338
Left Anterior-Posterior Measurements					
Material 1	39.06	(0.31)	38.67	(0.16)	.0927
Right Anterior-Posterior Measurements					
Material 1	38.61	(0.03)	38.70	(0.08)	.0562
Left Central					
Material 1	10.67	(0.08)	10.66	(0.15)	.8993
Material 2	10.98	(0.08)	10.58	(0.13)	.0050
Right Central					
Material 1	10.83	(0.13)	10.81	(0.12)	.8807
Material 2	10.92	(0.10)	10.77	(0.15)	.1292

[a] Paired *t*-test.

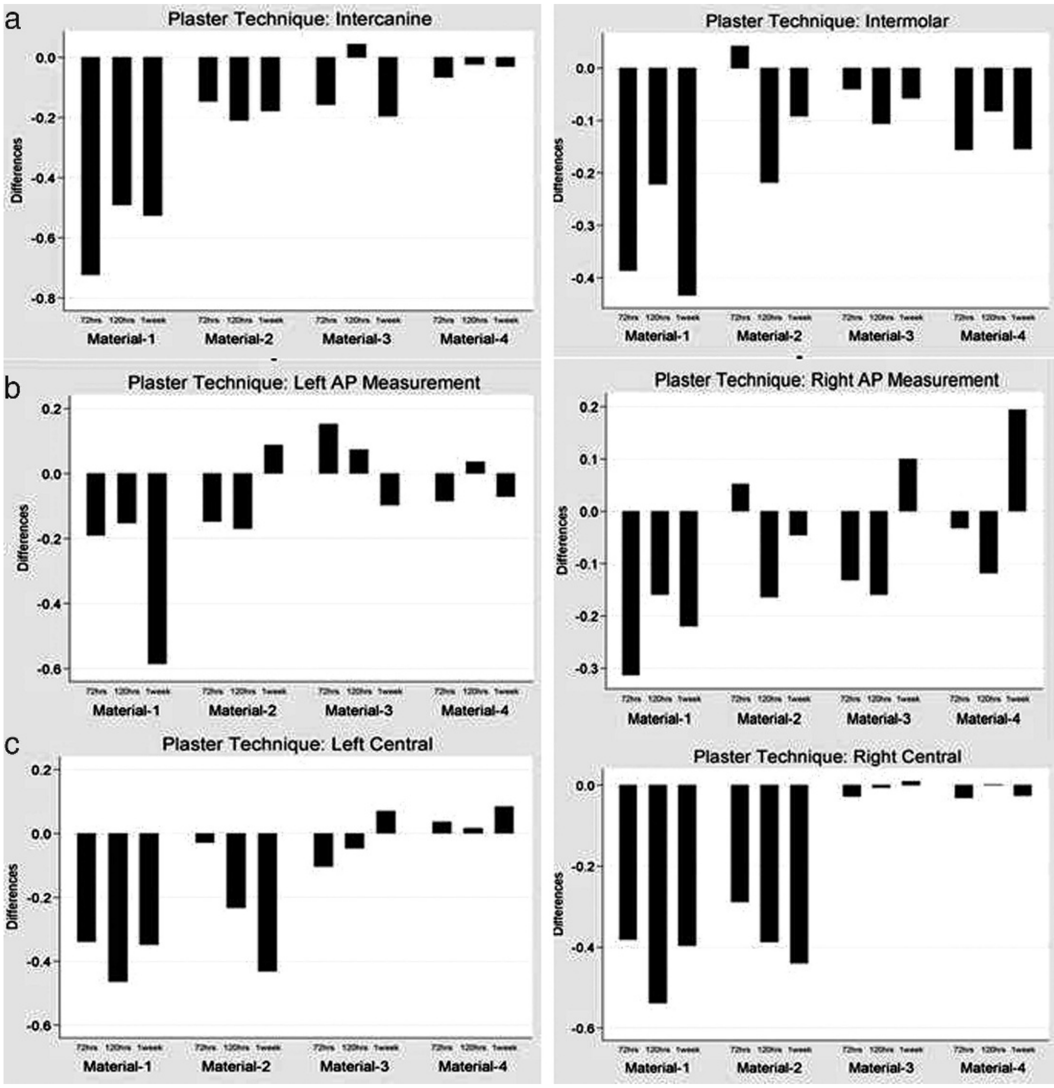

Figure 2. (a) Plaster technique: Differences in impression material over time in transverse dimension: Only Materials 1 and 2 showed a significant change in intercanine dimension, showing a decrease in measurement. Only Material 1 showed a significant decrease in intermolar measurements. (b) Plaster technique: Differences in impression material over time in anterior-posterior dimension: Only Material 1 showed a significant change compared with the control. In both left and right anterior-posterior dimensions, Material 1 showed a decrease in dimension. (c) Plaster technique: Differences in impression material over time in vertical dimension: Both Materials 1 and 2 showed a significant change in vertical dimension compared with the control. Both Materials 1 and 2 showed a decrease in vertical dimension.

for immediate use; however, with digital model services, turnaround time can be about 7 days. Therefore the dimensional stability of materials typically used for diagnostic models must be evaluated for a more extended period.

Tennison et al.[6] compared the dimensional stability of various alginates at 1 hour, 24 hours, 48 hours, 72 hours, and 120 hours. It was found that Identic exhibited shrinkage at all time points, ranging from 0.92% at 1 hour to 2.81% at 120 hours. In a study that compared traditional alginate (Kromopan N100, Kromopan USA, Inc, Des Plaines, Ill) vs alginate substitutes and PVS impression materials,[7] it was found that traditional alginates showed dimensional instability in the vertical dimension within 72 hours. Similar results are seen in this study, as Identic showed as much as 0.72 mm of dimensional change within 72 hours—a statistically significant change.

As was discussed in the Results, statistical tests were found to be significant if $P \leq .05$. However, in a clinical setting, according to the American Board of Orthodontics Objective Grading System (ABO OGS), discrepancies in the vertical, transverse, and anterior-posterior dimensions greater than 0.5 mm are considered to be significant.[6] When the impression materials used for plaster models were compared with the

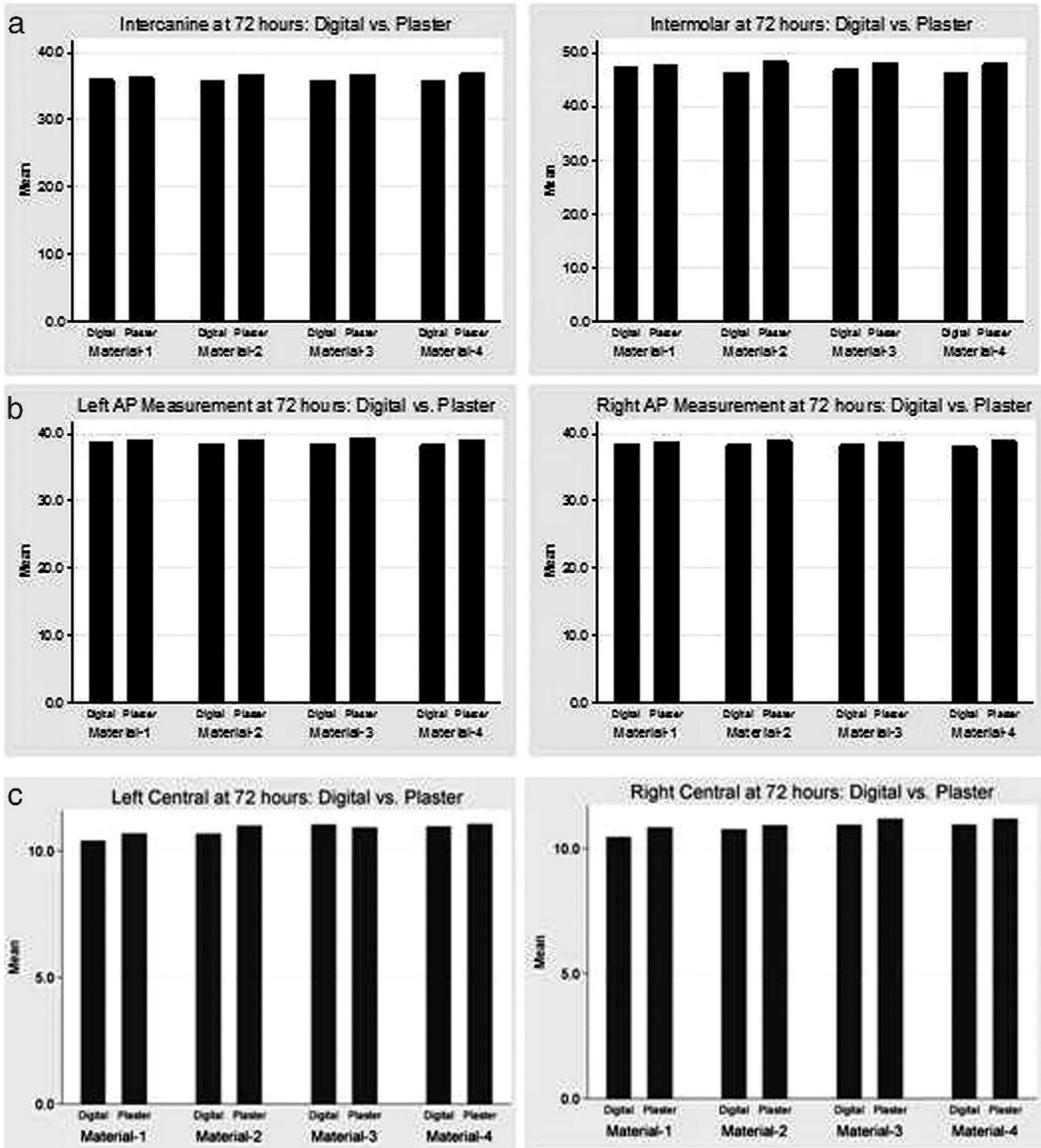

Figure 3. (a) Differences between plaster and digital techniques for all materials at T1 for transverse dimensions: Materials 2, 3, and 4 were significantly different, with digital model measurements being smaller. (b) Differences between plaster and digital techniques for all materials at T1 for anterior-posterior measurements: Only Materials 3 and 4 were significantly different for both right and left anterior-posterior dimensions when plaster models were compared with digital models. (c) Differences between plaster and digital techniques for all materials at T1 for vertical measurements: All materials were significantly different between plaster and digital models for the right vertical measurement. Only Materials 1 and 2 were significantly different for the left vertical measurement.

control measurements, only Material 1 (Identic) showed a statistically and clinically significant decrease in all dimensions measured. Material 1 showed a significant change at T1; therefore a significant dimensional change in Material 1 is seen within 72 hours. Although Material 2 did show statistically significant differences in the transverse and vertical dimensions, the differences were not clinically significant.

Numerous studies have been done comparing plaster models measured by digital calipers vs digital models produced by OrthoCad or E-models (GeoDigm). When mesiodistal tooth width and intercanine and intermolar width were measured, digital models were found to be clinically acceptable. Studies done to compare plaster models graded by the ABO OGS vs OrthoCad digital models graded by the ABO OGS found significant differences in scores; therefore it was concluded that the OrthoCAD software was not adequate for scoring all parameters required by the ABO OGS. No studies could be found that used digital models by OrthoProof and OraMetrix software. Ortho-

Proof does not release detailed technical information regarding scanning and digitizing methods used. One has to assume that OrthoProof scanned the impressions as instructed based on the strict guidelines of the study.

When the plaster and digital models were compared, overall the digital model measurements were smaller compared with the plaster model measurements. Differences between the measurements were greater than 0.5 mm; therefore a clinically significant difference is seen between plaster and digital models. Because the control typodont was measured using digital calipers, similar to the plaster models, the control measurements were closely correlated with the plaster measurements. One possible reason for this dimensional discrepancy may be the method of image capture. Radiation sources have produced a burnout effect on the periphery that may have contributed to a smaller reading.

The control typodont was not scanned and digitized, and control measurements were not taken with OraMetrix software; this may have introduced the difference between digital and plaster models. The difference in plaster and digital measurements may be due to the ability to magnify the scanned image on the screen and the ability to cross-section the model to locate points. Also, digital models were scanned only at T1 and were compared with control and plaster models produced at T1. This was done to prevent dimensional changes in the impression materials that may introduce variations in measurements between digital and plaster models. Future trials can study digital models at various time points to determine whether time may have affected digital model measurements.

CONCLUSIONS

- Material choice and model replication technique are very important because they can introduce clinically relevant errors.
- A long-term dimensionally stable alginate is necessary if impressions are not going to be poured or scanned in a timely fashion.
- Digital models measured with OraMetrix software showed a clinically significant difference compared with traditional plaster models.

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