Original Article

Evaluation of Digital Model Accuracy and Time-dependent Deformation of Alginate Impressions

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ABSTRACT

Objectives: The aim of this study was to evaluate the accuracy of digital models produced with the three-dimensional dental scanner, and to test the dimensional stability of alginate impressions for durations of immediately (T0), 1 day (T1), and 2 days (T2). **Materials and Methods:** A total of sixty impressions were taken from a master model with an alginate, and were poured into plaster models in three different storage periods. Twenty impressions were directly scanned (negative digital models), after which plaster models were poured and scanned (positive digital models) immediately. The remaining 40 impressions were poured after 1 and 2 days. In total, 9 points and 11 linear measurements were used to analyze the plaster models, and negative and positive digital models. Time-dependent deformation of the alginate impressions and the accuracy of the conventional plaster models and digital models were evaluated separately. **Results:** Plaster models, negative and positive digital models showed significant differences in nearly all measurements at T (0), T (1), and T (2) times ($P < 0.01$, $P < 0.05$, and $P < 0.001$). Arch perimeter measurements did not differ at T (0) and T (1) times ($P > 0.05$), but they demonstrated statistically significant differences at T (2) time ($P < 0.05$) between the models. **Conclusions:** This study showed that measurements on negative digital models offer a high degree of validity when compared to measurements on positive digital models and plaster models; differences between the techniques are clinically acceptable. Direct scanning of the impressions is practicable method for orthodontists.

Keywords: *Alginate impression, digital model, plaster model, storage time*

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Introduction

Study models are invaluable tools for orthodontic diagnosis and treatment planning,[1-3] as they provide three-dimensional (3D) assessments of the patient's dentition and malocclusion situation.[2,4]

Plaster study models have some disadvantages, such as the required laboratory processing time, space for storage, and risk of damage.[2-5] These difficulties indicate the need to develop a new technique.[5]

3D digital models were introduced in 1999 by OrthoCad, and in 2001 by Emodels.[3] The invention of digital models offered the orthodontist an alternative to plaster study models for some diagnostic measurements, including the Bolton ratio, mesiodistal tooth size, arch width, arch length, overjet, and overbite.[6-8] Advantages of digital models include reduced storage requirements, ease of data searching and transfer, the possibility of more accurate analysis, and reduced chances of loss or damage.[3,7,9] In the future, digital models may replace plaster models because they show the high validity and clinically acceptable differences from plaster models for intra- and inter-arch measurements.[3,10]

There are currently three techniques in producing digital models by different companies: (1) Laser scanning of

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plaster models; (2) cone-beam computed tomography imaging of orthodontic impressions or plaster models; and (3) intra-oral laser scanning of the dental arches or plaster models in-clinic.[2] In addition to the digital model supply companies, some companies, such as Maestro 3D, supply 3D model scanners, and orthodontic software for clinical practice.

In impression materials, particularly, alginates are becoming more popular and are more frequently accepted and used among orthodontists.[11,12] Similar to hydrocolloids, alginates are prone to distortion caused by expansion associated with imbibition due to absorption of moisture, or contraction due to moisture loss. In addition, in 100% humidity, alginate impressions will contract because of polymerization and syneresis.[4,11,13] Consequently, alginate impressions are not dimensionally stable and dimensional accuracy decrease over time.[11] Thus, the best results are achieved when alginate impressions are poured between 10 min and 1 h.[4,11,13,14]

The purpose of this study was to evaluate the accuracy of digital models produced with the Maestro 3D Dental Scanner, and to test the dimensional stability of alginates for durations of immediately T (0), 1 day T (1), and 2 days T (2).

Materials and Methods

A maxillary dental model was used as a master model. Palgat Plus Quick (3M ESPE, Neuss, Germany) alginate impression material was used to produce plaster models of the master model. In total, sixty impressions were taken from the master model. All of the impressions were taken by the same researcher using plastic trays of the same size. Alginates were mixed manually in accordance with the manufacturer's protocol. Impressions were not rinsed with water, and no disinfecting solution was used. The sixty impressions were divided into three equal groups: An immediate group T (0) (n = 20), 1st day group T (1) (n = 20), and 2nd day group T (2) (n = 20). The impressions of the immediate group were poured into stone within 30 min after direct scanning. The impressions of the T (1) and T (2) groups were placed in sealed plastic bags. The impression bags were stored in a dark room at standard room temperature. T (1) and T (2) group impressions were poured after 24 h and 48 h, immediately after direct scanning. At the end of two different storage times, sixty plaster models were prepared.

Digital model production

The twenty impressions of the T (0) group were transformed into digital format with a 3D model scanner (Maestro 3D MDS400; AGE Solutions, Pontedera, Italy), and direct scanning of the impression with the plastic trays was done by the same researcher. These digital models are referred to as negative digital models. After obtaining the plaster models from these impressions, they were transformed into digital format and referred to as positive digital models. The digital models were analyzed with the Maestro 3D Ortho Studio Software (version 2.9; AGE Solutions S.r.l., Pisa, Italy). The remaining negative and positive digital model groups of T (1) and T (2) were prepared in a similar manner. At the end of the two different storage times, sixty negative digital models and sixty positive digital models were prepared.

Parameters measured

In total, 9 points and 11 linear measurements were used to analyze the plaster models, and negative and positive digital models [Figures 1 and 2]. Reference points were the right first molar mesiobuccal cusp tip (RM), left first molar mesiobuccal cusp tip (LM), right canine cusp tip (RC), left canine cusp tip (LC), contact point of the right and left central incisors (S), deepest point of the right first molar buccal gingival curve (RMG), deepest point of the left first molar buccal gingival curve (LMG), deepest point of the right canine buccal gingival curve (RCG), and the deepest point of the left canine buccal gingival curve (LCG). Linear measurements were distance between the RC-RM, the distance between the LC-LM, the distance between the RC-LC, the distance between the RM-LM, the distance between the RC cusp tip and the contact point of the RC-S, the distance between the LC and the contact point of the right and LC-S, the arch perimeter (P), the distance between the RM-RMG, the distance between the RM-RMG, the distance between the LM-LMG, the distance between RC-RCG, and the distance between the LC-LCG. Plaster models were measured with digital calipers to an accuracy of 0.01 mm [Figure 3].

Statistical methods

The Kolmogorov–Smirnov test was used to assess the normality of numerical data. For those that were normally distributed, one-way analysis of variance was used for assessing comparisons between groups. Descriptive statistics are presented as means ± standard deviation. For numerical variables that were not normally distributed, the Kruskal–Wallis test was used. Descriptive statistics are presented as medians (25th–75th percentiles). $P < 0.05$ was considered statistically significant.

Results

When evaluating the plaster models, and negative and positive digital models at T (0), statistically significant differences were found in nearly all of the measurements ($P < 0.05$, $P < 0.01$, or $P < 0.001$). P and

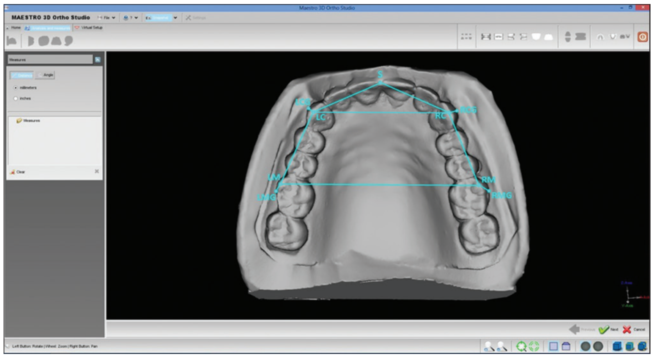

Figure 1: Reference points and linear measurements on the negative digital model

LC-S measurements did not show significant differences between the model groups at T (0) time [$P > 0.05$; Table 1].

There were significant differences in RC-RM, RM-LM, RC-S, LM-LMG, RC-RCG, and LC-LCG measurements between the plaster model and digital model groups at T (1) time ($P < 0.001$). LC-LM measurements in the positive digital model group showed significant differences from the other model groups ($P < 0.001$). RM-RMG measurements were statistically different for each model group at T (1) time ($P < 0.001$). RC-LC, LC-S, and *P* measurements did not show

Table 1: Comparison between measurements made on plaster models, negative and positive digital models at T (0) time

	Plaster models	Negative digital models	Positive digital models	*P*
RC-RM	18.81 (18.70-19.02)[a]	19.33 (19.17-19.38)	19.28 (19.17-19.41)	<0.001
LC-LM	19.32 (19.23-19.43)	19.25 (19.16-19.32)[bc]	19.44 (19.37-19.57)[bc]	0.003
RC-LC	32.57±0.22	32.38±0.167[b]	32.54±0.17335	0.004
RM-LM	46.85 (46.75-47.04)	47 (46.85-47.08)	47.21 (47.10-47.29)[c]	<0.001
RC-S	18.11 (17.90-18.20)[a]	17.64 (17.55-17.71)	17.68 (17.64-17.72)	<0.001
LC-S	17.95±0.16	17.96±0.18	17.91±0.16	0.668
P	74.17±0.43	74.11±0.37	74.34±0.43	0.212
RM-RMG	8.25±0.16[d]	7.95±0.14[d]	8.09±0.16[d]	<0.001
LM-LMG	8.17±0.19[a]	8±0.11	8±0.21	0.004
RC-RCG	10.13 (9.95-10.26)[ab]	9.97 (9.91-10.05)[ab]	10.02 (9.97-10.01)	0.037
LC-LCG	10.12±0.11	9.96±0.17[b]	10.09±0.11	0.001

[a]Plaster model group was statistically different from other groups; [b]Negative digital model group was statistically different from other groups; [c]Positive digital model group was statistically different from other groups; [ab]Plaster model and negative digital model groups were statistically different from each other; [bc]Negative digital model and positive digital model groups were statistically different from each other; [d]All groups were statistically different from each other. RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

Table 2: Comparison between measurements made on plaster models, negative and positive digital models at T (1) time

	Plaster models	Negative digital models	Positive digital models	*P*
RC-RM	18.94±0.18[a]	19.35±0.13	19.31±0.08	<0.001
LC-LM	19.36±0.12	19.32±0.11	19.47±0.13[c]	<0.001
RC-LC	32.61 (32.48-32.68)	32.44 (32.34-32.60)	32.53 (32.41-32.67)	0.077
RM-LM	46.81±0.14[a]	47±0.11	47.10±0.15	<0.001
RC-S	17.94±0.1[a]	17.59±0.11	17.65±0.12	<0.001
LC-S	18.1±0.15	18.1±0.13	18.1±0.16	0.979
P	74.34±0.34	74.35±0.25	74.54±0.25	0.050
RM-RMG	8.33±0.08[d]	8.02±0.11[d]	8.10±0.1[d]	<0.001
LM-LMG	8.25 (8.18-8.37)[a]	8.01 (7.94-8.12)	8.11 (7.93-8.17)	<0.001
RC-RCG	10.23±0.12[a]	9.91±0.1	9.95±0.11	<0.001
LC-LCG	10.18 (10.11-10.23)[a]	10 (9.93-10.05)	10.04 (10-10.08)	<0.001

RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

Table 3: Comparison between measurements made on plaster models, negative and positive digital models at T (2) time

	Plaster models	Negative digital models	Positive digital models	*P*
RC-RM	19.07±0.08[a]	19.39±0.12	19.33±0.09	<0.001
LC-LM	19.29±0.1	19.27±0.1	19.32±0.09	0.272
RC-LC	32.44±0.16	32.4±0.12	32.44±0.11	0.586
RM-LM	46.55±0.11[a]	46.82±0.19	46.83±0.13	<0.001
RC-S	17.85 (17.78-17.93)[a]	17.39 (17.35-17.50)	17.55 (17.45-17.59)	<0.001
LC-S	17.97 (17.90-18.02)	17.86 (17.81-17.97)[b]	17.97 (17.92-18)	0.017
P	74.18±0.2[ab]	74±0.29[ab]	74.16±0.23	0.036
RM-RMG	8.14 (8-8.29)[a]	7.95 (7.77-8.02)	7.95 (7.86-8)	<0.001
LM-LMG	8.15 (8.05-8.32)[d]	7.9 (7.82-7.99)[d]	8.05 (7.91-8.1)[d]	<0.001
RC-RCG	10.02±0.15[a]	9.75±0.15	9.78±0.14	<0.001
LC-LCG	10±0.11[a]	9.71±0.17	9.76±0.1	<0.001

RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

Table 4: Changes in overall measurements of plaster models in different storage periods

	T (0)	T (1)	T (2)	*P*
RC-RM	18.85±0.24	18.94±0.18	19.07±0.09[b]	0.002
LC-LM	19.31±0.2	19.36±0.12	19.28±0.1	0.313
RC-LC	32.53 (32.41-32.75)	32.61 (32.48-32.70)[c]	32.39 (32.34-32.60)[c]	0.026
RM-LM	46.85±0.27	46.81±0.14	46.55±0.11[b]	<0.001
RC-S	18.06±0.17[d]	17.94±0.1[d]	17.85±0.1[d]	<0.001
LC-S	17.95±0.16	18.10±0.15[a]	17.97±0.1	0.002
P	74.17±0.43	74.34±0.34	74.18±0.2	0.194
RM-RMG	8.25±0.16	8.33±0.09[c]	8.13±0.16[c]	<0.001
LM-LMG	8.17±0.19	8.27±0.1	8.18±0.19	0.138
RC-RCG	10.12±0.18	10.23±0.12[a]	10.02±0.15	<0.001
LC-LCG	10.13±0.11	10.16±0.093	10±0.11[b]	<0.001

[a]T (1) time group was statistically different from other time groups; [b]T (2) time group was statistically different from other time groups; [c]T (1) and T (2) time groups were statistically different from each other; [d]All groups were statistically different from each other. RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

significant differences among the model groups at T (1) time [$P > 0.05$; Table 2].

Comparisons of measurements at T (2) showed that RC-RM, RM-LM, RC-S, RM-RMG, RC-RCG, and LC-LCG measurements in the plaster group were statistically significantly different from the other model groups ($P < 0.001$). LC-S measurements in the negative digital model group were statistically significantly different from the plaster model and positive digital model groups ($P < 0.05$). *P* measurements in the plaster models and the negative digital model groups were statistically significantly different from each other ($P < 0.05$). LM-LMG measurements were statistically significantly different in each model group ($P < 0.001$). LC-LM and RC-LC measurements did not show significant differences among the model groups [$P > 0.05$; Table 3].

Plaster model measurements in different storage periods showed that RC-RM, RM-LM, and LC-LCG measurements at T (2) time indicated significant differences from the other groups ($P < 0.01$, $P < 0.001$). There were significant differences in RC-LC and RM-RMG measurements between the T (1) and T (2) groups ($P < 0.05$, $P < 0.001$). RC-S measurements were statistically significantly different in each time group ($P < 0.001$). LC-S and RC-RCG measurements at T (1) were statistically significantly different from the other time groups ($P < 0.01$, $P < 0.001$). LC-LM, P,

Table 5: Changes in overall measurements of negative digital models in different storage periods

	T (0)	T (1)	T (2)	*P*
RC-RM	19.34 (19.18-19.38)	19.37 (19.28-19.42)	19.38 (19.32-19.45)	0.229
LC-LM	19.26 (19.17-19.32)	19.30 (19.25-19.38)	19.26 (19.18-19.34)	0.238
RC-LC	32.38±0.17	32.47±0.17	32.4±0.12	0.142
RM-LM	46.9764±0.17	47±0.11	46.82±0.19[b]	0.001
RC-S	17.64 (17.55-17.71)	17.60 (17.47-17.68)	17.39 (17.35-17.50)[b]	<0.001
LC-S	17.96±0.18	18.1±0.13[a]	17.87±0.11	<0.001
P	74.11±0.37	74.35±0.25[a]	73.1±0.29	0.002
RM-RMG	7.97 (7.87-8.05)	8.04 (7.92-8.10)[c]	7.95 (7.77-8.02)[c]	0.040
LM-LMG	8.02 (7.90-8.08)	8.01 (7.94-8.12)	7.89 (7.82-7.99)[b]	0.006
RC-RCG	9.98±0.16	9.91±0.1	9.75±0.15[b]	<0.001
LC-LCG	9.96±0.17	9.97±0.13	9.71±0.17[b]	<0.001

RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

Table 6: Changes in overall measurements of positive digital models in different storage periods

	T (0)	T (1)	T (2)	*P*
RC-RM	19.28±0.23	19.31±0.08	19.33±0.09	0.605
LC-LM	19.44±0.17	19.47±0.13	19.32±0.09[b]	0.002
RC-LC	32.54±0.17	32.52±0.16	32.44±0.11	0.088
RM-LM	47.21 (47.10-47.29)	47.07 (47-47.22)	46.81 (46.76-46.94)[b]	<0.001
RC-S	17.68 (17.64-17.72)	17.65 (17.60-17.74)	17.55 (17.45-17.59)[b]	<0.001
LC-S	17.95 (17.82-17.99)	18.11 (18-18.19)[a]	17.97 (17.92-18)	0.001
P	74.34±0.43	74.54±0.26[c]	74.16±0.23[c]	0.001
RM-RMG	8.09±0.16	8.1±0.09	7.92±0.12[b]	<0.001
LM-LMG	8 (7.91–8.07)	8.11 (7.93-8.17)	8.05 (7.91-8.09)	0.114
RC-RCG	10.02 (9.97-10.08)	9.99 (9.90-10.02)	9.78 (9.67-9.9)[b]	<0.001
LC-LCG	10.13 (10.04-10.16)	10.04 (10-10.09)	9.77 (9.69-9.82)[b]	<0.001

RC-RM=Right canine cusp tip and the molar mesiobuccal cusp tip; LC-LM=Left canine cusp tip and the molar mesiobuccal cusp tip; RC-LC=Right and left canine cusp tips; RM-LM=Right and left molar mesiobuccal cusp tips; RC-S=Right canine cusp tip and the contact point of the right and left central incisors; LC-S=Left canine cusp tip and the contact point of the right and left central incisors; P=Perimeter; RM-RMG=Right molar mesiobuccal cusp tip and the buccal gingival curve; LM-LMG=Left molar mesiobuccal cusp tip and the buccal gingival curve; RC-RCG=Right canine cusp tip and the buccal gingival curve; LC-LCG=Left canine cusp tip and the buccal gingival curve

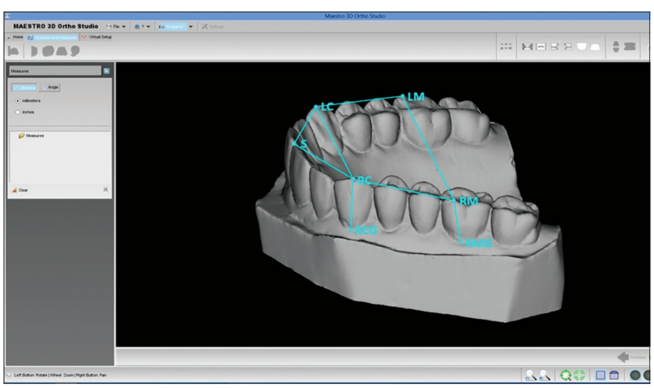

Figure 2: Reference points and linear measurements on the positive digital model

and LM-LMG measurements did not show significant differences between the time groups [$P > 0.05$; Table 4].

Comparisons of measurements in the negative digital models showed that RM-LM, RC-S, LM-LMG, RC-RCG, and LC-LCG measurements at T (2) were statistically different from the other time groups ($P < 0.01$, $P < 0.001$). LC-S and *P* measurements at T (1) were statistically significantly different from the other time groups ($P < 0.001$, $P < 0.01$). RM-RMG measurements in the T (1) and T (2) groups were statistically significantly different from each other ($P < 0.05$). RC-RM, LC-LM, and RC-LC measurements did not show significant differences between the time groups [$P > 0.05$; Table 5].

LC-LM, RM-LM, RC-S, RM-RMG, RC-RCG, and LC-LCG measurements at T (2) showed significant differences from the other time groups in the positive digital models ($P < 0.01$, $P < 0.001$). The LC-S measurement at T (1) was statistically significantly different from the other time groups ($P < 0.001$). The

Figure 3: Linear measurements with digital calipers on the plaster model

P measurements at T (1) and T (2) time groups were statistically significantly different from each other in the positive digital models ($P < 0.001$). RC-RM, RC-LC, and LM-LMG measurements did not show significant differences between the time groups [$P > 0.05$; Table 6].

Discussion

The preference for digital versus plaster models has increased among orthodontists, commensurate with technological advances in recent years. Currently, many orthodontists routinely use 3D digital models for diagnosis and treatment planning.[3,8,15] In general, digital models have shown a high degree of accuracy.[3,16] Some errors or problems have occurred during the digital model preparation process, which consists of two phases. The first phase involves taking an impression and pouring dental stone; the second phase consists of scanning the plaster model. In addition to evaluating the accuracy of digital scanning, the accuracy of impressions should be considered during the digital model preparation process.[4] In this study, the whole process of digital model preparation was investigated from taking impressions to 3D model analysis.

Direct scanning of impressions to prepare digital models is also possible, which eliminates the requirement for plaster models.[3] To date, there is no reported study about the accuracy, reliability, and efficacy of direct scanning from impressions. In this study, the accuracy of direct scanning from alginate impressions and plaster models was also compared using the Maestro 3D Dental Scanner and Ortho Studio software.

Plaster model, negative and positive digital model measurements at T (0), T (1), and T (2) times showed statistically significant differences. However, it was questionable whether these differences were clinically significant because they were <0.5 mm. In this study, a master model is used to represent maxillary arch, the same size plastic impression trays and one type of dental stone to reduce variables.

Most previous studies have reported that measurements obtained using digital models were lower than those obtained using plaster models.[6,8,16] Quimby *et al*.[17] found that measurements obtained using digital models were greater than those obtained using plaster models, but the differences were <1 mm. Santoro *et al*.[6] found statistically significant differences between measurements plaster and digital model measurements. Our study did not identify any consistent measurement bias with digital models, but the range of differences was similar to the results of Santoro *et al*.[6] in that they were clinically insignificant. Possible explanations for the differences between plaster and digital models include orthodontist skill and care when clicking the mouse pointer on tooth reference points. Depending on the researcher's training, ability, and careful selection of points, measurements on a computer screen can be more or less accurate than a traditional gauge on a plaster model. Once this was learned, it was easier to measure on the computer screen.[6,18] Furthermore, there is no physical barrier on the caliper dictating placement of measurement points on digital models. This allows someone to click the mouse printer either within or on the outside surface of the teeth.[18]

Previous studies have reported that transverse measurements obtained using digital and plaster models showed mean discrepancies between the approaches from 0.04 to 0.4 mm.[5,17,19,20] In general, these differences were small and unlikely to be of clinical significance.[3] In our study, the mean differences for RC-LC and RM-LM measurements were statistically significant but changed within a small range (0.03–0.36 mm).

The measurement of vertical crown height is likely to be imprecise with the identification of a cervical point being particularly unreliable.[3] Differences in the measurements of RC-RCG and LC-LCG varied from 0.03 mm to 0.32 mm, similar to the results reported by Keating *et al*.[21]

The effects of the time-dependent deformation of alginates on digital model accuracy were evaluated throughout the measurements on the plaster model, and negative and positive digital models. Most of our results showed significant differences among them at the 1st and 2nd day. However, these differences were small and did not exceed 0.4 mm, which can be accepted within clinical tolerance. Alginate impression shrinks because of different pouring times, which is most likely the explanation for the differences. Coleman *et al*.[22]

reported that significant dimensional changes between plaster models poured within 1 h of the alginate impression compared with pouring 24 h later. Obviously, this would be translated into the digital models. Alcan *et al*.[4] reported statistically significant changes after storing alginate impressions for up to 4 days, although no clinical relevance was noted.

Conclusions

This study showed that measurements on negative digital models offer a high degree of validity when compared to measurements on positive digital models and plaster models; differences between the techniques are clinically acceptable. Direct scanning of the impressions is practicable method for orthodontists. Furthermore, storing alginate impressions in plastic bags up to 2 days had no negative effect on the digital modeling.

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Conflicts of interest

There are no conflicts of interest.

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