Measurements of plaster casts: from callipers to digital systems

Medição de modelos de gesso: do paquímetro ao sistema digital

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Abstract

Objective – Evaluate accuracy and reproducibility of linear dental measures in original and duplicated gypsum models using digital caliper and in digital models measured by O^{3d} software. **Methods** – 34 pairs of dental models were selected following the inclusion requirements: presence of all the permanent teeth from 1st molar to 1st molar; normal occlusion; with no prosthetic crowns; no previous orthodontic treatment; 2 millimeters or less crowdings or smaller spacings. The original and the duplicated models were measured with digital caliper. The duplicated dental models were laser scanned and measured by O^{3d} software (Widialabs™). The repetition of the measures were done by the same examiner and evaluated by **Pearson's** correlation **coefficient and paired Student's t test**. The same was done to compare the measurements between the original and the duplicated gypsum models and between the duplicated and the digital models **Results** – The repetition evaluation showed high correlation between the measurements. Statistically significant differences were found between duplicated and original models, but were more frequent in the comparison between the duplicated and the digital models. **Conclusion** – The accuracy of the measures of original, duplicated and digital models presented high correlation and no systematic error. The reproducibility in the comparison between the original and duplicated models and between the duplicated and digital models showed high correlation between the measures. Statistical differences were found using not only digital caliper, but also O^{3d} software; however they can be clinically acceptable, except from overbite in digital models.

Descriptors: Orthodontics; Dental models; Three-dimensional

Resumo

Objetivo – Avaliar precisão e reprodutibilidade de medidas dentárias lineares em modelos de gesso originais e duplicados utilizando paquímetro digital e em modelos digitais medidos com o Sistema O^{3d}. **Métodos** – 34 pares de modelos de gesso foram selecionados, preenchendo os seguintes requisitos de inclusão: presença de todos os dentes permanentes de 1.° molar a 1.° molar; oclusão normal; sem coroas protéticas; nenhum tratamento ortodôntico prévio; apinhamentos ou espaçamentos menores ou iguais a 2 milímetros. Modelos originais e duplicados foram medidos com paquímetro. Modelos de gesso duplicados foram escaneados a laser e medidos pelo Sistema O^{3d} (Widialabs®). A repetição das medições executadas pelo mesmo examinador foi avaliada pelo coeficiente de **Pearson** e pelo **teste *t* de Student pareado**. Esse procedimento foi empregado na comparação entre medições obtidas nos modelos duplicados em relação às dos modelos originais e na comparação entre medições obtidas nos modelos digitais em relação às dos modelos duplicados. **Resultados** – A avaliação da repetibilidade mostrou correlação alta entre as medidas. Diferenças estatisticamente significantes foram encontradas na comparação entre modelos duplicados e originais, no entanto foram mais frequentes na comparação entre duplicados e digitais. **Conclusão** – A precisão na repetição das medidas nos modelos originais, duplicados e digitais apresentou alta correlação e ausência de erro sistemático. A reprodutibilidade, na comparação entre modelos originais e duplicados e na comparação entre duplicados e digitais, apresentou alta correlação. Diferenças estatísticas foram encontradas com o paquímetro e o Sistema O^{3d}; no entanto aceitáveis clinicamente, exceto no caso da sobremordida em modelos digitais.

Descritores: Ortodontia; Modelos dentários; Imagem tridimensional

Introduction

The use of dental plaster casts for diagnosis and planning of clinical cases is of crucial importance in dentistry, orthodontics and facial orthopedics. With the technological advances, a variety of new methods have emerged for model-based measurement such as holograms,[1] mechanical callipers, digital callipers and video cameras,[2] computerised two-dimensional digitisers,[3,4] three-dimensional scanning digitisers,[2,5,6] three-dimensional digitisers,[7] and laser scanning systems.[8-10]

The technology of virtual models has several advantages such as easy storage, possibility of sharing images with patients and professionals involved in the treatment, less risk of physical damage and good reproducibility.[4,11] Many software have been developed worldwide, but the cost to convert plaster casts into digital models is high, a fact that stimulates professionals to create and research a national alternative. The replacement of plaster casts for digital models depends on scientific evidence and certification before any clinical use.

Another important fact is the plaster casts are at risk of loss or damage when being sent for digitalisation, whose objective is to obtain three-dimensional images of them. For a better security, it is interesting to duplicate the original plaster casts in order to preserve these against any risk, mainly when they come from other professionals or institutions to organise the research samples.

Therefore, this work is aimed at assessing both accuracy and repeatability of dental linear measurements of original and duplicated plaster casts by using calliper as well as the corresponding digital models by using the O^{3D} software.

Methods

Thirty-four pairs of plaster casts from Caucasian students aged 12-17 years old were selected for study. Inclusion criteria were the following: normal occlusion, presence of all permanent teeth from 1st molar to 1st molar, no previous orthodontic treatment, dental crowding or spacing up to 2mm, and no prosthetic crown.

When the original plaster casts were made, irreversible hydrocolloid material (alginate) was used for impression while wax bite records were obtained at centric occlusion. The resulting mouldings were filled with orthodontic plaster to produce the study models. The bases of the models were trimmed according to Balters (1969),12 that is, following the Camper's plane as reference.

In order to avoid permanent damages to the original plaster casts, duplicates of them were made by an experienced professional under supervision of the author of this study. An irreversible hydrocolloid (JeltrateDustless-Dentsply™) was the moulding material selected together with trays (Morelli™) number 7 or 8 depending on the size of original casts. The tray was positioned on each original plaster cast for copy, including the base in order to keep parallelism with the Camper's plane. A special stone-type V plaster (Durone V-Dentsply™) was used, being applied with a metal plaster spatula (Metal Vander™) in vacuum and then poured into the moulds, which were on a dental plaster vibrator (VH™) to reduce the probability of bubble formation. After curing, the mould was finished but without the need for further trimming, thus preserving the base reproduced from the original plaster cast.

With regard to the O3D software, the examiner had to sign in to the site http://novosite.widialabs.com/ before using the services available. The duplicated plaster casts were scanned by a laser-based digitising system for generating virtual 3D images, which were then measured by the tools of the O3D software (Widialabs™). Digitalisation was performed at precision of 0.005" and 400 dots per inch, with no direct contact with the samples, which were made available for download and documentation.

O3D software allowed measurement of all view planes of the digital models in occlusion or individually, with movements in all orientations and free zoom at pre-defined positions such as frontal, posterior, lateral and occlusal views. The distance between both points is automatically calculated in millimetres and then tabulated for different analyses made available by the software, whose data can be transferred to statistical analysis software. The O3D software allows various types of analysis for permanent dentition.

A digital calliper (Digimess™) with 0.01 mm precision was used to measure both original and duplicated plaster casts, and the measurement obtained from latter was compared to that from digital models.

The selected measurements were based in the study by Dalstra and Melsen (2009)[11] and teeth measurements on the left side and lower teeth were aded. Therefore, the linear measurements were the following:

1. Mesio-distal diameter of tooth 11 (md11)
2. Mesio-distal diameter of tooth 21 (md21)
3. Mesio-distal diameter of tooth 16 (md16)
4. Mesio-distal diameter of tooth 26 (md26)
5. Upper inter-canine distance between cuspid tips (intercs)
6. Width of upper arch between buccal surfaces of upper first molars (interms)
7. Maxillary length from central incisor contact point to plane passing through the most posterior portion of upper first molars (compmx)
8. Mesio-distal diameter of tooth 31 (md31)
9. Mesio-distal diameter of tooth 41 (md41)
10. Mesio-distal diameter of tooth 36 (md36)
11. Mesio-distal diameter of tooth 46 (md46)
12. Lower inter-canine distance between cuspid tips (interci)
13. Width of lower arch between buccal surfaces of lower first molars (intermi)
14. Mandibular length from central incisor contact point to plane passing through the most posterior portion of lower first molars (compmd)
15. Overbite measured on the greatest trespass perpendicular to occlusal plane (sm).
16. Overbite measured on the greatest trespass parallel to occlusal plane (ss). All original and duplicated plaster casts as well as digital models were measured twice by the same examiner at a 1-week interval. Statistical methodology for assessment of repeatability was performed by using the interclass correlation coefficient (ICC).

The measurements of the original plaster casts were compared to those of the duplicated ones, which in turn were compared to measurements of the digital models. By using ANOVA and Tukey test at 5% significance.

Results

Repeatability assessment of the measurements performed by the same examiner showed a high correlation between both procedures regarding original, duplicated and digital models. The ICC ranged from 0.89 to 0.99 in original plaster casts, 0.94 to 1.00 in duplicated plaster casts and 0.91 to 0.99 in digital models.

Means and standard deviations of the linear measures of original and duplicated plaster casts were calculated as well as the ANOVA as demonstrated in Table I. Statistically significant values ($p \leq 0.01$) were mostly found in the comparison between duplicated and digital models.

Table 1. Means and Standard Deviations (SD) of Linear Measures Obtained from Original. Duplicated and Digital Models. Correlation Coefficient r and paired t-test.

Measures	Original (0)		Duplicated (1)				Digital (2)			
	Mean	SD	Mean	SD	(a)	r_{01}	Mean	SD	(b)	r_{02}
md11	8.80	0.61	8.80	0.62		0.99	8.81	0.57		0.98
md21	8.82	0.61	8.83	0.60		0.99	8.82	0.58		0.97
md16	10.95	0.48	10.87	0.53	*	0.95	10.94	0.45		0.85
md26	10.77	0.47	10.73	0.50		0.93	10.74	0.48		0.91
intercs	34.91	2.21	34.94	2.23		0.99	34.78	2.22	**	0.99
interms	57.54	3.05	57.71	3.11	**	1.00	57.59	3.20		0.99
compmx	38.86	2.30	38.85	2.36		0.99	38.92	2.34		0.99
md31	5.42	0.30	5.37	0.32	*	0.93	5.44	0.32	**	0.94
md41	5.40	0.28	5.37	0.32		0.90	5.44	0.26	**	0.90
md36	11.10	0.53	11.07	0.53		0.95	11.07	0.57		0.97
md46	11.04	0.63	10.99	0.64	*	0.98	11.00	0.70		0.95
interci	26.20	1.54	26.03	1.70		0.96	26.13	1.70		0.96
intermi	54.91	3.04	55.13	3.06	**	1.00	55.22	3.07	*	1.00
compmd	33.53	2.12	33.58	2.22		0.99	33.84	2.33	**	0.97
sm	2.74	0.91	2.79	0.93		0.93	2.49	1.07	**	0.91
ss	1.49	0.57	1.51	0.50		0.95	1.58	0.58		0.91

(a) Comparison with original models using paired t-test (*) $0.01 < p \leq 0.05$ (**) $p \leq 0.01$.
(b) Comparison with duplicated models using paired t-test (*) $0.01 < p \leq 0.05$ (**) $p \leq 0.01$.
r = Pearson's correlation coeficient between models i and j (i,j = 0,1,2).

Discussion

The digital image resulting from O^{3D} software was obtained from a plaster caster. For security reasons, the original model can be duplicated and the copy sent to specialised company. In the present work, alginate was the material chosen for the moulding process because it is less likely to fracture during removal from the cast-model set.[13]

In order to avoid pouring the impression with plaster in the dental office, professionals have sent the alginate impression to get digital models. Some studies have evaluated whether alginate remained dimensionally stable during transport for digitalisation. Dalstra and Melsen (2009)[11] found stability within 3-5 days by wrapping the cast with moistened gauze and placing it inside sealed package, whereas Alcan *et al*. (2009)[14] and Torassian *et al*. (2010)[15] reported statistically significant dimensional alterations after 72 hours despite following the manufacturer's packaging instructions. For these reasons, one opted for pouring the plaster into the moulds and then send the resulting duplicated casts for digitalisation at Widialabs™.

The plaster used for duplication was that of type V, that is, a highly hard, micro-granulated material with low consistency and low rate of wear. However, despite being considered a high expansion plaster, Kenyon *et al*. (2005)[16] have shown that the expansion percentage is adequate for such a material. Because some measurements increased while others decreased, no expansion could be reported in the present study. As a result, the differences found in the measurement comparisons were not attributed to duplication.

The interest in investigating technologies capable of reproducing dental arches accurately and reliably into three-dimensional images is increasingly evident in the literature. The method for analysis of dental models by using MicroScribe 3DX digitiser (Immersion, San Hose, CA, USA) and TIGARO software was validated and can be applied for research.[7] However, using the same digitiser with Rhinoceros software (version 3.0 SR3c, Robert Mc Neel & Associates, Seattle, WA, USA), Chen *et al*. (2008)[17] reported that more complex anatomical characteristics such as fissures had not been precisely reproduced in the digital models.

Cone beam computed tomography (CBCT) was found to be as precise as the OrthoCAD digital models for linear measurements of overbite, overjet, and crowding.[18] Nevertheless, Santoro *et al*. (2003)[5] and Leifert *et al*. (2009)[19] considered the use of OrhtoCAD to be clinically acceptable only. Version 2.2 and Version 2.66 were tested and did not meet the parameters required by the American Board of Orthodontics (ABO OGS – Objective grading system).[20,21] In another CBCT system (OraMetrix), it was observed statistically significant difference when digital models were compared to traditional plaster casts.[15]

Digital orthodontic models (scanner 3Shape D250, A/S and 3Shape Ortho analyzer) were as reliable as the traditional plaster casts, probably becoming the norm for clinical use.[14] It is recommended that occlusal view should be used to measure the mesio-distal diameter in digital models because of the better precision, repeatability and quick execution.[22]

In the present study, the repeatability of the measurements regarding all original, duplicated and digital models exhibited high correlation. Statistically significant differences was observed between original and duplicated plaster casts measured with calliper: md16, md31, md46 ($0.01 < p \leq 0.05$), interms, and intermi ($p \leq 0.01$). These differences found between the mean values were −0.08 mm for md16, −0.05 mm for md31 and md46, +0.17 mm for interms and +0.22 mm for intermi. Despite the statistically significant differences in interm ($0.01< p \leq 0.05$), intercs, md31, md41, compmd, and sm ($p \leq 0.01$), these differences were +0.09 mm for intermi, −0.16 mm for intercs, +0.07 mm for md31, and md41, +0.26 mm for compmd and −0.3 mm for sm. Hirogaki *et al*. (2001)[23] considered 0,30 mm differences clinically irrelevant.

For individual dental measurements, the greatest difference found was −0.08 mm for md16 in the comparison between original and duplicated plaster casts as well as +0.07 mm for md31 and md41 in the comparison between duplicated plaster casts and digital models. These differences between the mean values of mesio-distal diameters were not considered clinically significant at all.

With regard to the measurements of distances between canines and molars and of the arch length, the greatest difference between the mean values was +0.22 mm for intermi in the comparison between original and duplicated plaster casts and +0.26 mm for compmd in the comparison between the latter and digital models. These findings were not clinically significant as the distances were greater.

With regard to the overbite, the difference between mean values was −0.3 mm compared to both duplicated and digital models. Because the mean value for this measurement ranged from 2.49 to 2.79 mm, this difference can be clinically acceptable despite the relative difficulty regarding the methodology available in the O^{3D} System. The points were marked onto one of the planes of the virtual model, but when the view position was changed in order to check the demarcation, it was observed that the point did not correspond exactly to the desired position.

As reported earlier, statistically significant differences were found in the measurements obtained from both calliper and O^{3D} system, a finding possibly attributed to small random failures resulting from the methodology applied. The differences in the use of calliper, which is indicated for scientific works, can be attributed to the variation in the instrument angulation or even to the positioning of the instrument tips.[6] On the other hand, the O^{3D} system made demarcation of any local selected easier and without presenting the physical barrier relative to the adjustment of the instrument, mainly when the mesio-distal diameter of the teeth are measured.

The O^{3D} system had difficulty in measuring overbite, and even usage failure, which required technical support to solve it. Fleming *et al*. (2011)[24] in their systematic review recommended digital models as an alternative to conventional measurement on plaster models, although the evidence identified variable quality.

According to the Widialabs™ laboratory, the digital images of the dental casts are kept on file for five years, but it is strongly recommended a personal backup copy of them. In fact, the digital system has been improved over time towards its certification for scientific use respecting all pertinent legal requirements,[25] which will result in advantages such as less need of plaster model storage, better visualisation of the models, no contamination by bacteria or fungi, and no loss of plaster casts due to fractures, in addition to allowing communication between practitioners and patients.

The results of this study showed that digital models could be used at regular base in orthodontic clinic, as the measurement variation was clinically irrelevant. The cost of plaster casts and digital models are the same. Additionally the digital has the advantage to calculate all the angles, distances and analysis automatically by just identifying the clue points on the images. Nowadays almost all scanners demonstrated a level of accuracy so high that further improvement would not provide additional benefit for use in orthodontics.[26]

Conclusion

A high accuracy was observed in the repeatability of the measurements regarding original, duplicated, and digital models. However, statistical differences were found in the use of calliper and O^{3D} system as well, although such differences were clinically acceptable.

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