Comparison of Arch Widths Measurements Made on Digital and Plaster Models

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Abstract

Objectives: To compare arch widths measurements made on plaster models by using digital caliper, digital models from direct intraoral scanned and indirect scanned on plaster models.

Materials and Methods: Upper and lower impressions were taken from thirty volunteers with Class I normal occlusion or Class I malocclusion with mild crowding. The plaster models were made and digital vernier caliper was used to measure inter-canine width, anterior arch width and posterior arch width. Each volunteer and models were also scanned by intraoral scanner. Then, the 3Shape Ortho software was used to measure the arch widths. Intra-class correlation coefficient (ICCs) and One-way ANOVA (P<0.05) were used to assess intra-examiner reliability and validity of measurement between three groups.

Result: According to the high values of ICC (0.98-1.00), intra-examiner error could be neglected. Moreover, there were no statistical significantly different of inter-canine width, anterior arch width and posterior arch width between three methods of measurements. Although, scanning on lower arch intraorally was difficult due to the tongue but our result showed that there were no statistical significant different in digital models group compared with plaster models group.

Conclusion: The intraoral scanner can be used to measure arch widths with clinically acceptable accuracy and high reliability and reproducibility. In the future, it's possible to use digital models instead of conventional plaster models due to its advantages. Further study should compare tooth size by using these methods to prove the effective of intraoral scanner.

Keywords: intraoral scanner, arch width, digital model, plaster model, model analysis

Introduction

Nowadays Thai people are interested in and seeking for an orthodontic treatment in order to improve their facial and dental esthetics, followed by oral functions. Successful treatment planning in dentistry requires precise diagnostic information and extensive diagnosis. In orthodontic practices, collection of the patients' data is important for the subsequent diagnosis and treatment planning processes. One of the fundamental data can be gained from the models analysis. Model analysis is the method which used to evaluate tooth size, dental alignment, occlusion, space condition, symmetry of dental arch, and dental arch dimension in the patient.

From the past, researchers and clinicians have measured tooth size, arch widths and arch height by directly measurement from the teeth in the oral cavity or from diagnostic models by using Boley gauge vernier, a pair of dividers with millimeter ruler or sliding calipers. For directly measurement from the teeth in the oral cavity, it is difficult to perform because the size of caliper or instrument for measurement that is large and it also takes time for complete arch measurement. The alternative methods which have been used are standard photographs, photocopies, sophisticated occlusogram and laser holograms. However, Zilberman, Huggare, and Parikakis (2003) found the technique error in these methods. The most popular method and generally used is measurement on diagnostic models with calipers which widely used by many researchers (Akyalcin, 2011; Fleming, Marinho, & Johal, 2011;

Manopatanakul, Lertrid, Law, & Boonmegaew, 2011; Quimby, Vig, Rashid, & Firestone, 2004; Rheude, Sadowsky, Ferriera, & Jacobson, 2005; Schirmer & Wiltshire, 1997).

Although measurement on diagnostic models is used as a standard method but it still has some limitations such as difficulty of taking impression in the patients with pronounced gag reflex or with cleft lip and palate or those who are at risk of aspiration or respiratory distress (Atia, El-Gheriani, & Ferguson, 2015). Moreover, storage of diagnostic models required storage space in the clinic. Stone models are subject to fracture, difficult to retrieval and may be loss.

In the 1980s the first digital intraoral scanner for dentistry was introduced by a Swiss dentist, Dr. Werner Mörmann, and an Italian electrical engineer, Marco Brandestini (Atia et al., 2015). The latest innovation to generate digital model is the direct generation of three-dimension (3D) models with an intraoral scanner. The intraoral scanner is designed for unit in the chairside that allows the orthodontist to scan the patient's dentition. The system offers various advantages, most notably elimination of the need for impressions (Naidu & Freer, 2013).

Nowadays, many intra-oral scanning devices for restorative dentistry and orthodontics have been developed. For example, iTero® (Align Technologies®, San Jose, California), Lava™C.O.S (3M® ESPE, Seefeld, Germany), Trios® (3 shape®, Copenhagen, Denmark), CEREC® AC (Sirona®, Bensheim, Germany) and E4D (D4D Technologies, Richardson, Texas). All devices have specific characteristics and require drying and powdering on the intraoral surfaces that might be difficult for clinical using except the iTero® and the Trios® (Atia et al., 2015).

Digital impression by using intraoral scanner was introduced in order to replace conventional dental impression. It has advantage in reducing patient discomfort because no need to take conventional impressions. Digital data is easy to transfer to dental laboratory or other clinicians for consultation and referral case by sending digital file instead of shipping (Quimby et al., 2004; Naidu & Freer, 2013; Cuperus et al., 2012; Wiranto et al. 2013).

After the first digital model was introduced in orthodontics, many research tried to find out the validity of laser surface scanning on the plaster models that generated from alginate or vinylpolysiloxane impressions. No significant difference was found in the assessments of linear inter-arch, overjet, overbite, and arch length measurements obtained from these digital models and their corresponding plaster models (Zilberman et al., 2003; Quimby et al., 2004; Leifert et al., 2009; Mullen, Martin, Ngan, & Gladwin, 2007; Santoro, Galkin, Teredesai, Nicolay, & Cangialosi, 2003; Stevens et al., 2006; Tomassetti, Taloumis, Denny, & Fischer Jr, 2001). It also appeared that these digital models are suitable for evaluation the peer assessment rating score and the American Board of Orthodontics (ABO) score. Diagnosis and treatment decisions were not different whether plaster or plaster scanning digital models were used (Rheude et al., 2005; Stevens et al., 2006; Baysal, Veli, & Uysal, 2013; Naidu, Scott, Ong, & Ho, 2009; Pachêco-Pereira, De Luca Canto, Major, & Flores-Mir, 2015; Whetten et al., 2006).

Taking digital impression by using intraoral scanner was the new technology. So, the study about validity and reliability of digital models from digital impression by using intraoral scanner compare with plaster models is still limit. In the recent years, intraoral scanner was introduced in Thailand and many dental clinic were tried to use digital impression in order to replace conventional dental impression. Hence, the aim of this study is to investigate the validity and reliability of digital models compare with plaster models by comparison of arch widths.

Methods and Materials

Human Ethics

This study was approved by Naresuan University Institutional Review Board for an approval of human ethics, complied with the Code of Ethics of the World Medical Association no. 824/58 (Declaration of Helsinki). After explained all of the experiment procedures, all of the subjects provided the written informed consents before the experiment started.

Sample Size Determination

The sample size was calculated form G*Power program (Version 3.1.9.2) by using F-tests family and statistical test was one-way ANOVA. The calculated sample size was 30 (effect size = 0.5, α error probability = 0.1, power = 0.75).

Inclusion criteria: Volunteers with all of the following criteria are included in this study.

- Fully erupted of permanent teeth from second molar to contralateral second molar in both jaws
- Age range 18-24 years old
- Normal crown morphology of tooth
- Class I normal occlusion or Class I malocclusion with mild crowding
- No missing or supernumerary tooth
- No proximal carious lesions or restoration that would affect mesiodistal crown morphology of tooth
- Undergo no active orthodontic treatment

All of the subjects were asked to take dental impressions and scan oral cavity by using intraoral scanner. The data from all subjects were divided into 3 groups.

Group 1: Diagnostic Models

Alginate (Kromopan®; LASCOD Spa, Italy) were used to take impressions from maxillary and mandibular arches from each volunteer. The ratio between the alginate powder and water is 1:1. The approximate mixing time, total working time, and setting time in oral cavity were 45, 105, and 30 seconds, respectively.

The obtained impressions were immediately poured with a type III stone (Sirius®; Lafargeprestia, Thailand). The ratio between stone powder and water was 1:3.23 (31 ml/100 g). The mixing time, working time, and setting time were 1, 8, and 15 minutes, respectively. Forty minutes later, all models were removed from the impressions and cut by an electric trimmer (Whip Mix®, Kentucky, USA).

Digital impression (Digital models)

Group 2: Direct intraoral scan

The intraoral scanner Trios® 3 (3shape®, Copenhagen, Denmark) was used to scan the complete lower and upper jaws.

Group 3: Indirect scan (Scan on dental models)

The intraoral scanner Trios® 3 (3shape®, Copenhagen, Denmark) was used to scan the complete lower and upper study models.

Arch widths measurement in this study composed of inter-canine width, anterior arch width and posterior arch width. For measurement methods:

1. Inter-canine width is the distances between the cusp tip of a canine on one side and that on the other (Hashim & Al-Ghamdi, 2005) was measured.

2. Anterior arch width, there were differences of the reference points between maxillary and mandibular arches.

2.1 Anterior arch width measurement in the maxillary arch is the distance from the center of central groove of first premolar on one side to the other side (Chintawongvanich & Thongudomporn, 2013).

2.2 Anterior arch width measurement in mandibular arch is the distance from the most buccally area of contact point between first and second premolars on one side to the other side (Chintawongvanich & Thongudomporn, 2013).

3. Posterior arch width, there also difference in maxillary and mandibular arches.

3.1 Posterior arch width in maxillary arch is the distance between central pit of first molar on one side to the other was measured (Chintawongvanich & Thongudomporn, 2013).

3.2 Posterior arch width in mandibular arch is the distance between disto-buccal cusp tip of first molar on one side to the other side (Chintawongvanich & Thongudomporn, 2013).

Inter-canine width, anterior arch width and posterior arch width in maxillary and mandibular arches were measured. For group 1, all measurements are preform by using digital vernier caliper (Maca Chen®, China) with a high validity and resolution at 0.01 mm (Figure 1). For group 2 and 3 (Direct and indirect scan), all measurements were performed by using 3shape Ortho Viewer software (Figure 2).

Figure 1 Digital vernier caliper

Figure 2 3shape Ortho Viewer software

Two weeks after the initial assessment, the examiner measured ten randomly selected pairs of the plaster models, ten randomly selected pairs of the digital models from direct scanned and ten from indirect scanned. All of the measurements were performed by one examiner in order to reduce inter-examiner error.

Data Analysis

The intra-class correlation coefficient (ICCs) at a 95% confidence level was used to assess intra-examiner reliability of measurement on each group. The one-way ANOVA and post-hoc test were used to determine the validity of measurement between plaster models and digital models form direct intraoral scan and indirect scan on plaster models. The significant level at P < 0.05 was used.

Results

The intra-examiner reliability of all measurement showed significant excellent agreement (intra-class correlation coefficient, ICC > 0.800) at a 95% confidence level which showed that intra-examiner error could be neglected. In group 1, the ICCs of inter-canine width, anterior arch width and posterior arch width in maxillary arch were 0.995, 0.998 and 0.992. For mandibular arch were 0.996, 0.997 and 0.997. In group 2, the ICCs of inter-canine width, anterior arch width and posterior arch width in maxillary arch were 0.990, 0.999 and 0.990. For mandibular arch were 0.995, 0.987 and 0.988. In group 3, the ICCs of inter-canine width, anterior arch width and posterior arch width in maxillary arch were 0.990, 0.995 and 0.994. For mandibular arch were 0.992, 0.996 and 0.994.

Table 1 showed the means and standard deviations of inter-canine width, anterior arch width and posterior arch width in maxillary and mandibular arches. There were no statistical significant different from one-way ANOVA in all variable between 3 groups of method. Arch width measurements on the digital models from direct and indirect intraoral scans were corresponded to plaster models. The mean different between each groups were not exceeded 0.10 mm except mandibular inter-canine width was 0.133 between group 1 and group 3, mandibular posterior arch width was 0.108 between group 1 and group 2 and was 0.104 between group 2 and group 3.

Table 1 Comparison of the mean values of arch widths

	Arch widths	***n***	**Group 1 Mean (SD)**	**Group 2 Mean (SD)**	**Group 3 Mean (SD)**	**ANOVA *P* value**
Maxillary arch	Inter-canine width	30	34.460 (2.168)	34.373 (2.134)	34.465 (2.165)	NS
	Anterior arch width	30	37.707 (2.604)	37.726 (2.607)	37.696 (2.602)	NS
	Posterior arch width	30	48.613 (2.337)	48.629 (2.308)	48.585 (2.364)	NS
Mandibular arch	Inter-canine width	30	26.451 (1.897)	26.384 (1.867)	26.318 (2.045)	NS
	Anterior arch width	30	36.338 (1.831)	36.361 (1.844)	36.357 (1.830)	NS
	Posterior arch width	30	47.808 (2.146)	47.700 (2.157)	47.804 (2.164)	NS

Distances are depicted in mm, NS = Not Significant ($P < 0.05$)

Discussion

In the literatures, there were a few comparative studies of arch widths measurement between digital models from intraoral scanner and plater models which is the gold standard. The result of this study showed that both digital models from direct scan intraorally and indirect scan on plaster models using Trios® 3 intraoral scanner are valid, reliable and reproducible methods. So, intraoral scanner can be used to measure arch widths in orthodontic diagnosis process.

The results of our study showed that there were no statistical significant differences between both digital and plaster models for arch widths measurement.

Similarity to the studies of Atia et al. (2015) that was used Trios® intraoral scanner to scan direct intraorally and on the plaster models in 40 subjects, they also used extraoral model scanner (D700) to scan on the plaster models. They found that there were no significant differences between digital and plaster models.

In contrast to the study of Quimby et al. (2004), they found that the measurements of maxillary inter-canine width, maxillary and mandibular inter-molar widths, overjet and overbite by using the computer-based models were significantly greater than measurements made on the plaster models but mandibular inter-canine width was not significant difference. This significant difference may be due to the separate impressions were used to fabricated digital and plaster models and time elapse before the irreversible hydrocolloid impressions were poured in plaster models. For plaster models group, the impressions were poured within one hour. But in computer-based models group, the impressions were disinfected, wrapped in a moist paper towel, and placed in a sealed plastic bag and sent to the company to fabricated computer-based models. This may be result of dimensional change of irreversible hydrocolloid impression (Erbe, Ruf, Wöstmann, & Balkenhol, 2012). Reuschl, Heuer, Stiesch, Wenzel, & Dittmer, (2015) found that measurement of mandibular inter-molar width form digital models were significantly larger than plaster models in both examiner 1 and 2 but others transversal measurements were not significantly differences. The error of the measurement technique is likely to reside in point identification rather than being a function of the measuring device or software (Fleming et al. 2011).

Our study showed that there were no statistical significantly different of all variables between three methods of measurement. Although, scanning on lower arch intraorally was difficult due to the tongue but our result showed that there were no statistical significant different in digital models group compared with plaster models group. However, the intraoral scanner cannot generate 3D object form moving tissue. Therefore we cannot scan on the floor of mouth and the 3Shape Ortho Viewer software cannot mark the point on un-scanned area. Therefore, it is impossible for measurement arch height from this software.

Generally, digital models have shown a high degree of accuracy for measurement in orthodontics (Mullen et al., 2007). The replacement of plaster models with digital models has further potential benefits including instant accessibility of 3D information without need for the retrieval of plaster models from a storage area, the ability to perform accurate and simple diagnostic set-ups of various extraction patterns, virtual images may be transferred anywhere in the world for instant referral or consultation and objective model grading analysis, for example, for Peer Assessment Rating (PAR) or American Board of Orthodontics (ABO) scoring (Fleming et al., 2011; Atia et al., 2015; Naidu & Freer, 2013; Cuperus et al., 2012; Zilberman et al., 2003). However, the accuracy of measurement in digital models depends on point identification of each user and this may cause some error and reduce validity of measurement (Fleming et al., 2011). Digital models require special equipments such as intraoral scanner and its software that are not available in every clinic compare to conventional plaster models.

Conclusion and Suggestion

From the results of this study, we can conclude that the digital models scanned from direct intraoral and indirect scan on plaster models are validity, reliability and reproducibility method. Digital models can be used to obtain arch widths for orthodontic diagnostic purposes. Especially, in the patients with pronounced gag reflex or in some groups of patient like cleft lip and palate, using intraoral scanner instead of conventional impression can reduce patient discomfort. Digital data can save in the computer which no need storage space in the clinic like plaster models that maybe need entire room for storage. Digital models were also easy to transfer to dental laboratory and other clinician for consultation or referral case by sending digital files instead of shipping. Although, scanning on lower arch intraorally was difficult due to the tongue but our study confirmed that the validity and reliability of digital models did not affected by the tongue. However, the limitation of the intraoral scanner which cannot scan on the floor of mouth and the 3shape Ortho Viewer software that we used cannot mark the point on un-scanned area, measurement of arch height is impossible.

In the future, it is possible to use digital models instead of conventional plaster models due to its advantages that mentioned above. Further study should compare tooth size by using these methods to confirm the effective of intraoral scanner.

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