Original Article

Evaluation of CBCT Digital Models and Traditional Models Using the Little's Index

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ABSTRACT

Objective: To determine if measurements obtained from digital models from cone beam computed tomography (CBCT) images were comparable to the traditional method of digital study models by impressions.

Materials and Methods: Digital models of 30 subjects were used. InVivoDental (Anatomage, San Jose, Calif) software was used to analyze CBCT scans taken by a Galileos cone beam scanner (Sirona, Charlotte, NC) with a field of view of $15 \times 15 \times 15$ cm^3 and a voxel resolution of 0.125 mm. OrthoCAD (Cadent, Fairview, NJ) software was used to analyze impression scans of patients at different stages of orthodontic treatment. Impressions were taken using alginate and were mailed to OrthoCAD for digital conversion. The scans were then electronically returned in digital format for analysis.

Results: The maxillary mean scores for the Little's Index were 9.65 mm for digital models and 8.87 mm for InVivoDental models, respectively. The mandibular mean scores for the Little's Index were 6.41 mm for digital models and 6.27 mm for InVivoDental models, respectively. The mean overjet measurements were 3.32 mm for digital models and 3.52 mm for InVivoDental models, respectively. The overbite measurements were 2.29 mm for digital models and 2.26 mm for InVivoDental models, respectively. The paired *t*-test showed no statistical significance between the differences in all measurements.

Conclusions: CBCT digital models are as accurate as OrthoCAD digital models in making linear measurements for overjet, overbite, and crowding measurements (*Angle Orthod.* 2010;80:435–439.)

KEY WORDS: CBCT imaging; Digital models

INTRODUCTION

Imaging technology in the dental field has emerged as one of the most important aspects of diagnosing and treating oral disorders, especially since the advent of three-dimensional (3D) techniques. Methods used to examine the oral and maxillofacial anatomy have existed for many decades, dating back to the 1940s,[1] but current technologies have allowed for much faster analysis. These techniques include, but are not limited to, stereo photogrammetry, laser scanning, structured light, video imaging, 3D cephalometry, computed tomography (CT) scans, cone beam computed tomography (CBCT), magnetic resonance imaging, and ultrasound.[2]

Of particular interest is the reliability and accuracy of some of these newer techniques in relation to well-established methods, such as impressions and dental casts. Some comparisons of dental casts and digital scans of their impressions have found small, but significant differences between measurements when

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Accepted: October 2009. Submitted: August 2009.

using certain measurement criteria but still allow clinically acceptable measurements.[3–5] Other studies using alternate measurement criteria, such as the American Board of Orthodontics Objective Grading System, have found digital scans to have insufficient accuracy for several individual measurements compared with plaster casts[6–8]; however, such stringent measurement tolerances are not required for clinical efficacy. The reliability of measurements taken on digital models from impressions has been proven to be as good as or better than measurements taken on plaster casts.[9]

However reliable and accurate these measurements may be, they still involve the actual process of taking impressions and subsequent scan of these impressions, which can take up to 10 days to complete.[10] Most current imaging techniques, such as CBCT, could potentially eliminate the time-consuming and often uncomfortable process of taking impressions; however, newer methods must also be examined for safety, reliability, and accuracy.

CBCT imaging is a new radiographic technique that can take 3D images using a most current scanning technique that involves minimal patient discomfort. In addition, CBCT can provide instant results. The radiation dosage encountered in a typical CBCT scan is higher than in conventional techniques, such as panoramic radiographic imaging, but still significantly lower than dosages encountered than in a multislice CT.[11] CBCT can give the clinician a 3D representation of the teeth, but its accuracy and reliability for dental measurements have not been fully assessed. Past studies have analyzed CBCT accuracy of craniofacial landmarks and determined that measurements were statistically significantly different from measurements taken with a digital caliper but still clinically acceptable (90% of mean differences $<$2.00 mm).[12,13] Studies comparing CBCT to photostimulable phosphor plate imaging have concluded that CBCT is more accurate[14] and more reliable.[15]

The aim of this study was to determine whether measurements obtained from digital models from CBCT images were comparable with the traditional method of digital study models by impressions.

MATERIALS AND METHODS

Subjects

Digital records of 30 subjects were retrospectively reviewed, and the digital models were obtained. Both CBCT and OrthoCAD models need to be present and were obtained in a sequential manner.

The inclusion criteria included the following:

- Class I malocclusion,
- OrthoCAD models obtained by impression taking at initial examination as part of the routine records appointment,
- baseline CBCT images captured at the University of Texas Health Science Center at Houston Dental Branch Orthodontic department as part of the routine records appointment, and
- subject had to have all permanent dentition.

Imaging Device

The CBCT device used was the Sirona Galileos (Bensheim, Germany). The Galileos x-ray detector receives cone-shaped ConeBeam radiation beams, which result in 200 individual exposures from a 14-second cycle in a 220° segment. Volume dimensions of $15 \times 15 \times 15$ cm^3 capture an image at a high level of detail. The technology also allows for small region close-up views at double the detail without an additional scan. The large dental volume ranges from the bridge of the nose to the tip of the chin and the mandibular joints. It projects the bone structures with the same reliability as the soft tissue. The voxel size is between 0.15 mm and 0.30 mm. The image reconstruction time is approximately 4.5 minutes.

CBCT Method of Digital Study Model Acquisition

InVivoDental (Anatomage, San Jose, Calif) software was used to analyze 30 CBCT scans taken by a Galileos cone beam scanner (Sirona, Charlotte, NC) with a field of view of $15 \times 15 \times 15$ cm^3 and a voxel resolution of 0.125 mm. CBCT images were electronically sent via a secure Web site to the company Anatomage in a dicom format. These files were converted by a volume-rendering software, and a final 3D-generated model of the teeth was produced and analysis made on a proprietary software package.

Traditional Method of Obtaining Digital Study Models

OrthoCAD (Cadent, Fairview, NJ) software was used to analyze impression scans of 30 patients at different stages of orthodontic treatment. Impressions were taken using alginate and mailed to OrthoCAD for digital conversion. The scans were then electronically returned in digital format for analysis.

Parameters Measured

Little's Irregularity Index was used to measure distances between the teeth. Measurements were made by measuring the linear displacement of the anatomical contact points between the anterior six teeth on the maxilla and mandible in the horizontal

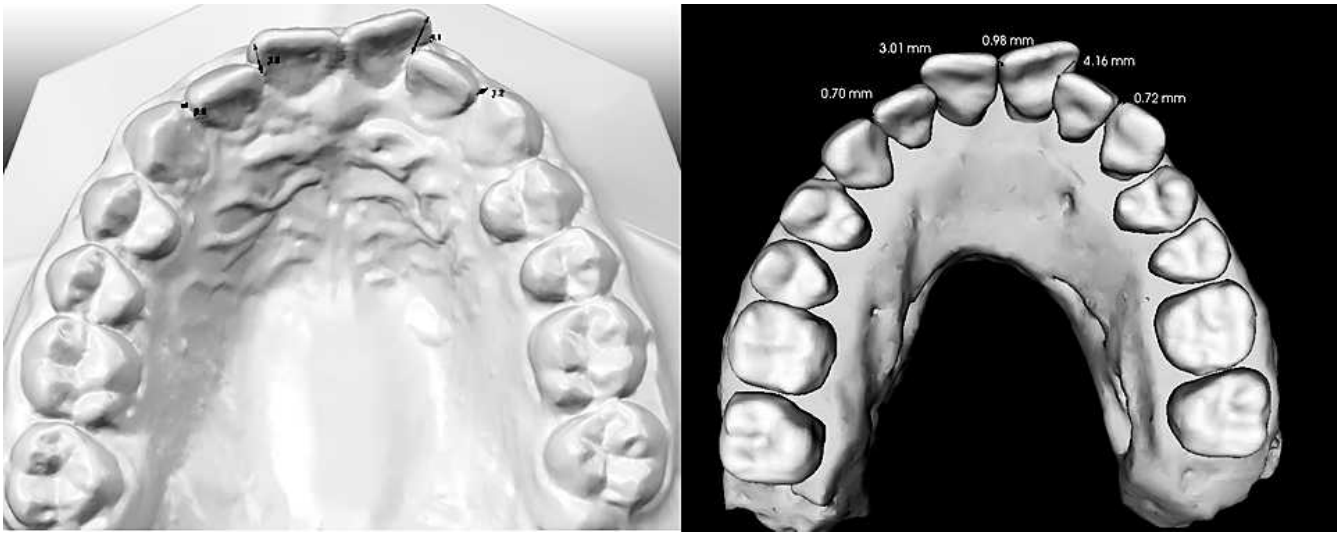

Figure 1. Maxillary Little's measurements.

occlusal plane (Figures 1 and 2). Perfect anatomical alignment would receive a score of zero. The sum of these measurements for each patient for the maxilla and mandible was considered to be the relative measure of crowding. Overbite and overjet were also measured for all patients. Measurements were taken consecutively for all patients using InVivoDental, followed by consecutive measurement of patients using OrthoCAD to remove potential bias.

Measurements were taken independently by two observers, A and B, to test for reliability and examined using paired *t*-tests. None of the measurements between observers were found to be statistically significantly different at the $P < .05$ level, indicating adequate reliability of the respective measurements for the two observers. Comparison of measurements between observers A and B was limited to 10 randomly chosen measurements for InVivoDental and all 30 measurements for OrthoCAD. Measurements from InVivoDental and OrthoCAD taken by observer B were then examined using a paired *t*-test (Table 1).

For nonnormally distributed data, a Wilcoxon rank sum test was run. Tests were performed using SPSS (Chicago, Ill) statistical software.

RESULTS

The following results were obtained and are shown in Tables 1 and 2.

Little's Index

The mean maxillary score for the Little's Index was 9.65 mm for the digital models and 8.87 mm for the InVivoDental models, respectively. The mean mandibular mean score for the Little's Index was 6.41 mm for digital models and 6.27 mm for InVivoDental models,

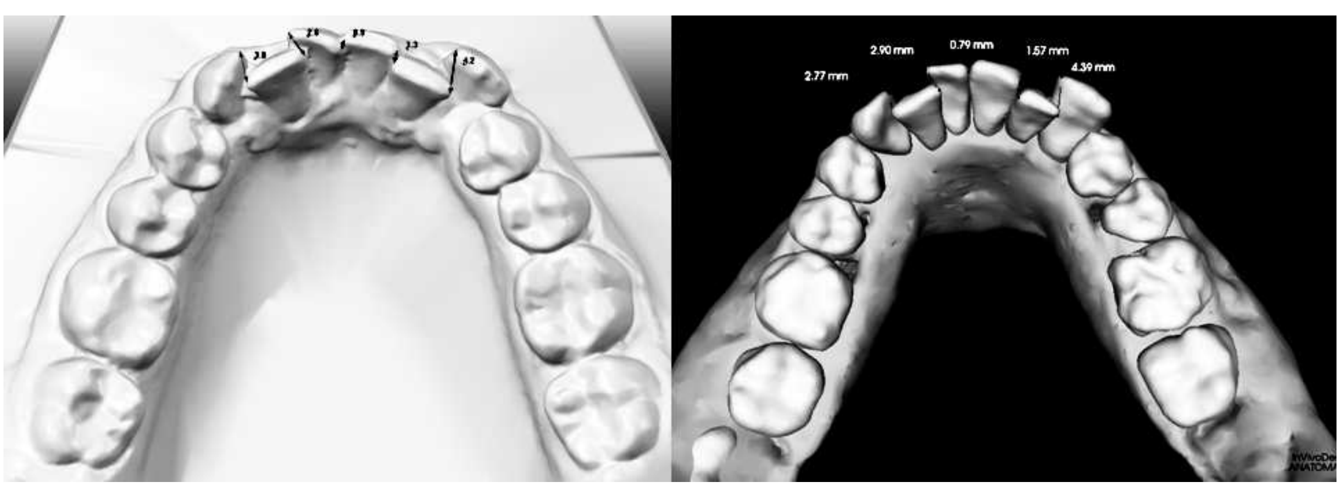

Figure 2. Mandibular Little's measurements.

Table 1. Statistical Analysis of Digital Model Pairs for InVivoDental and OrthoCAD

		Paired Differences					
					95% Confidence Interval of the Difference		
		Test	Mean Difference, mm	SD, mm	Lower, mm	Upper, mm	Significance (Two-Tailed)
Pair 1	OrthoCAD upper, InVivo upper	Wilcoxon sum rank	0.79	2.33	−0.08	1.66	.10
Pair 2	OrthoCAD lower, InVivo lower	Paired *t*-test	0.14	1.39	−0.38	0.65	.60
Pair 3	OrthoCAD OB, InVivo OB	Paired *t*-test	0.03	1.31	−0.46	0.52	.90
Pair 4	OrthoCAD OJ, InVivo OJ	Paired *t*-test	−0.20	1.67	−0.83	0.42	.51

respectively (Table 2). All of the results were found to be normally distributed except for the maxillary Little's Index measurements. The paired *t*-test showed no statistical significance between the difference in measurements for the maxillary and mandibular indices (Table 1). The Wilcoxon sum rank test showed that the maxillary measurements between OrthoCAD and InVivoDental were also not significantly different (Table 1).

Overjet Measurements

The mean overjet measurements were 3.32 mm for digital models and 3.52 mm InVivoDental models, respectively (Table 2). These data were found to be normally distributed. The paired *t*-test showed no statistical significance between the differences in measurements.

Overbite Measurements

The overbite measurements were 2.29 mm for digital models and 2.26 mm for InVivoDental models, respectively (Table 2). These data were found to be normally distributed. The paired *t*-test showed no statistical significance between the differences in measurements.

DISCUSSION

A variety of methods exist to diagnose malocclusions in orthodontics. One such method is Little's Irregularity Index, and this is used as a measure of anterior arch crowding. Its value is the sum of the distances of the tooth contact points along the occlusal axis. The intercontact positions can reflect displacement and rotation irregularities. The degree of crowding is indicated by greater displacement between the contact points. A comparison of measurements between 3D scans of impressions and CBCT images using Little's Irregularity Index could provide a new perspective on accuracy and reliability within the digital format. Orthodontists also commonly use several other measurements during routine orthodontic diagnosis, two of which are overbite and overjet. The overbite distance is the maximum vertical distance between the top of a patient's mandibular central incisor and the bottom of the maxillary incisor. The overjet distance is the maximum horizontal distance between these same two teeth. The traditional method of evaluation of these measurements is by plaster cast study models and/or digital models.

Although linear anatomical measurements were not significantly different for either program, resolution of dental anatomy using CBCT, as agreed upon by observers, was less than that of OrthoCAD. Measurements between figures differed because of decreased edge contours from the CBCT. It was often difficult to establish the anatomical contact points using the mandibular CBCT images because they are found along the mesial and distal edges of adjacent teeth. Because of decreased mandibular incisor integrity, anatomical contact points of the lower mandibular incisors were established by both observers for CBCT images. As a result, further work needs to be done to both the software and imaging system to improve the final model.

The minimum interobserver mean difference found in the overbite measurements of OrthoCAD can likely be attributed to its inclusion of a feature designed exclusively to measure overbite and overjet. The mean intraobserver values include the sum of all five measurements taken to establish a Little's Irregularity Index. Thus, the intraobserver mean differences for measurements taken between OrthoCAD and InVivo yield an approximate average tooth-to-tooth measure-

Table 2. Means and Standard Deviation of Parameters Measured

	Little's Index, Maxillary, mm	Little's Index Mandibular, mm	Overjet, mm	Overbite, mm
OrthoCAD	9.65 ± 4.80	6.41 ± 3.59	3.32 ± 2.35	2.29 ± 1.60
InVivoDental	8.87 ± 5.35	6.27 ± 3.59	3.52 ± 2.10	2.26 ± 1.76

ment discrepancy of 0.156 mm for the maxilla and 0.027 mm for the mandible.

Studies using OrthoCAD images have previously established them as clinically acceptable.[4,5,12] These results indicate that Little's Irregularity Index, overbite, and overjet measurements taken with InVivoDental software from a CBCT are also clinically acceptable. In addition, the times taken to make measurements using both software systems were comparable.

The results of this study show that digital models generated from CBCT imaging not only offer diagnostic information but also other information such as bone levels, root positions, and TMJ status are also captured. These are not present on OrthoCAD models. Orthodontists can also eliminate the use of dental impression materials for diagnostic casts. If, however, the clinician needs an indirect setup, he or she must take an impression for that purpose. The idea of gathering all diagnostic records from a single CBCT scan is most intriguing to the orthodontic profession. As computer technology improves, the occlusal distortion in the CBCT models should also improve. With the constantly improving CBCT technology, the ability to gather all diagnostic records from a single CBCT scan seems imminent. Future research needs to be conducted for surface shape and volumes of CBCT images.

CONCLUSION

- CBCT digital models are as accurate as OrthoCAD digital models in making linear measurements for overjet, overbite, and crowding measurements.

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