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ORIGINAL ARTICLE

Digital images as an alternative to orthodontic casts in assessing malocclusion and orthodontic treatment need

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Abstract

Objective. To investigate the potential use of two-dimensional digital images as an alternative to orthodontic casts in the assessment of malocclusion and orthodoantic treatment need. ***Material and Methods.*** Assessment of malocclusion (Angle's classification of molars, overjet, and overbite) and orthodontic treatment need (Index of Orthodontic Treatment Need (IOTN): Dental Health Component (DHC) and Aesthetic Component (AC)) was conducted on 313 study casts and their images by two trained and calibrated examiners. Agreement of orthodontic treatment need and Angle's molar classification was assessed employing Kappa statistics (κ). Agreement of overjet and overbite (measured in mm) was assessed in comparison and correlation analyses. Inter- and intra-examiner reliability of assessment was investigated. ***Results.*** There was substantial agreement of the molar relationship classifications ($\kappa > 0.70$), orthodontic treatment need as assessed by IOTN-DHC ($\kappa = 0.79$) and IOTN-AC ($\kappa = 0.56$) between measurements obtained from orthodontic casts and their images. There was also substantial agreement of measurements of overjet and overbite as obtained from orthodontic casts and their images. The standardized directional differences of overjet and overbite were ≤ 0.2. The intra-class correlation coefficients of assessments of overjet and overbite obtained from orthodontic casts and their images were > 0.90. Inter- and intra-examiner reliability for the assessment of malocclusion and orthodontic treatment need was acceptable. ***Conclusion.*** Two-dimensional digital images can be used as an alternative to casts in assessment of malocclusion and orthodontic treatment need.

Key Words: *Dental, dental models, photography*

Introduction

Orthodontists have long relied on replicas of patients' dentition to facilitate assessment from sagittal, vertical, and transverse planes in diagnosis and treatment planning. Traditionally, impressions are taken of patients' dentition and orthodontic casts are fabricated according to specific guidelines [1]. A number of measurements are made on the orthodontic casts, such as overjet, overbite, and sagittal molar relationship, in assessing malocclusion [2]. In addition, several orthodontic treatment need indices have been developed for use with orthodontic casts in determining priority in terms of patients' need for orthodontics, as well as in assessing improvement in occlusion following orthodontic care [3–5].

Although orthodontic casts have been a useful aid to orthodontists, there are significant costs involved in replicating patients' dentition through the course of orthodontic treatment. Moreover, storing a series of orthodontic casts (each set requires approximately 700 cm^3 of space) for many years, which is a requirement for medico-legal reasons, can be a significant financial burden, particularly in urban areas where space is at a premium [6,7]. Furthermore, with increasing time of storage, transportation, and use of models, damage to and loss of orthodontic casts are common [8].

Digital images such as three-dimensional digital imaging (3DI) are beginning to replace traditional orthodontic casts in technologically advanced countries [9]. However, the costs of producing 3DI orthodontic casts may be prohibitive for most orthodontists in many countries owing to the requirement for silicone impressions and the need to send overseas for digitizing. Moreover, there is no objective means of evaluating orthodontic treatment

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results via the computer from a digital study model [10]. Furthermore, there is conflicting evidence regarding the accuracy of using 3DI orthodontic casts in the assessment of occlusion [9,10]. The use of two-dimensional digital images (2DI) to simulate a patients' dentition is emerging as a potential alternative to clinical assessment (chair-side assessments) and to other replicas of patients' dentitions [11,12]. 2DI is a quick and durable way of obtaining records of patients' dentition, and readily transmitted for referrals, consultations, presentations, and use in multicenter studies [13]. As digital technology develops, the costs involved in both taking and storing 2DIs have reduced to such an extent that they are becoming widely used, even in developing countries. However, it is accepted that there are some technical difficulties in the use of 2DI in replicating patients' dentition (which is three-dimensional) and problems with examiner reliability in assessing 2DI [14]. Thus, in generating and assessing 2DI, a standardized approach is required. Given the lack of information comparing the use of 2DI of orthodontic casts in assessing malocclusion compared to stone orthodontic casts, this study aimed to answer the following research question: Can digital images be used as an alternative to orthodontic casts in the assessment of malocclusion and orthodontic treatment need?

The aims of this study were to investigate the level of agreement between orthodontic casts with their digital images and to assess inter- and intra-examiner reliability in the assessment of malocclusion and orthodontic treatment need.

Material and methods

Study sample

From a random sample of 1,247 twelve-year-old Hong Kong children included in an Oral Health Survey 1984–1985, a subsample of 412 Chinese subjects (208 F and 204 M) with both cephalograms and orthodontic casts was obtained [15].

Capturing images

2DIs were obtained with a digital camera (Canon® 350D DSLR with Macro Ring Lite MR-14EX) fixed on a purposely fabricated mount to allow photographs of the orthodontic casts to be captured in a standardized manner (Figure 1). The orthodontic casts were placed in the center of the plastic board with a grid (for easy centering) and photographed from different angles with standardized settings for the required measurements. Seven images were taken of each orthodontic cast: right buccal (perpendicular to right buccal segment); left buccal (perpendicular to left buccal segment); frontal-mandibular (perpendicular to the posterior aspect of the lower cast); overjet (perpendicular to mid-sagittal suture); frontal (parallel to mid-sagittal suture); occlusal mandibular (perpendicular to lower occlusal plane); and occlusal maxillary (parallel to upper occlusal plane).

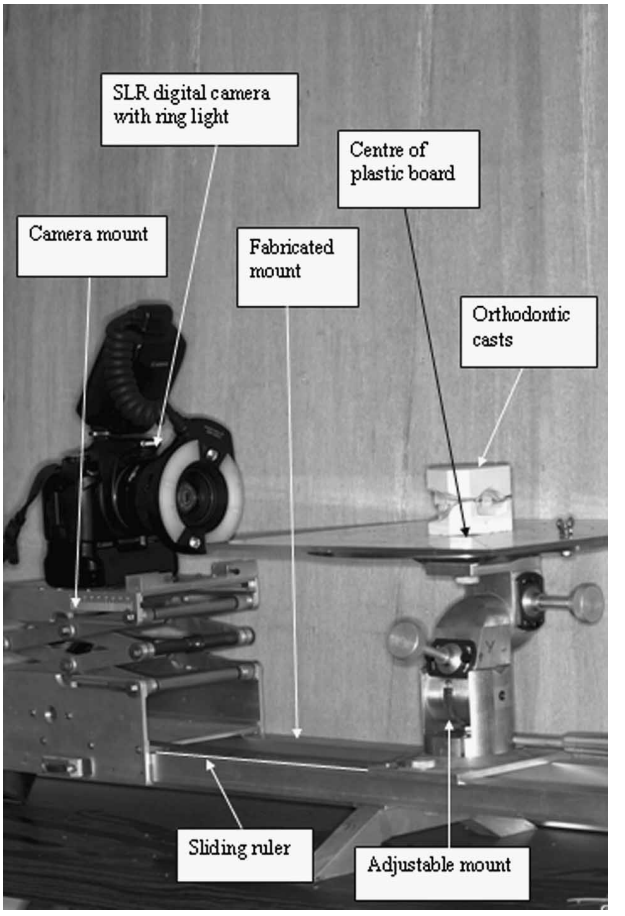

Figure 1. The set-up for photographing stone study casts comprises: 1. A Canon® 350D DSLR camera with Macro Ring Lite MR-14EX. 2. A piece of flat plastic board with grid for easy centering of the stone study casts. 3. A specially fabricated mount to standardize angulations and focal distance and comprising three components: (i) a camera mount; (ii) a sliding ruler for measurement of photographic distance; and (iii) an adjustable mount for connecting to the flat plastic board.

Data collection

Two trained and calibrated examiners among the authors (WM and LZ) assessed the orthodontic casts using dividers and standard rulers to measure overjet and overbite to the nearest 0.5 mm, and to classify molar relationship. Overjet was measured from the labial surface of the lower incisor to the labial surface of the upper. The maximum distance to the nearest 0.5 mm for both central incisors was recorded, keeping the ruler parallel with the occlusal plane [16]. Overbite, which is the overlap of the incisors in the vertical plane, was measured by first marking a line on the labial surface of the incisors of the lower orthodontic cast with the most overlapped vertical distance by the upper central incisors and

then the maximum vertical distance was measured from the marked line to the incisal edges [17]. If there was an open bite, overbite was measured as the negative value of the minimum vertical distance measured between the upper central incisors and the lower incisors. Molar relationship was measured parallel to the buccal segment and was classified as Class I if the mesial buccal cusp tip of the upper 1st molar was within half a cusp width anterior or posterior to the mesial buccal groove of the lower 1st molar, where the size of a cusp was defined as the size of the mesial buccal cusp of the relevant upper 1st molar [18]. If the mesial buccal cusp tip of the upper 1st molar was more than half a cusp width distal to the mesial buccal groove of the lower 1st molar, molar relationship was classified as half a unit Class III; if more than a full cusp width, then molar relationship was classified as full unit Class III. Half unit and full unit Class II molar relationships were classified in a similar way. From the orthodontic casts, orthodontic treatment need by the Dental Health Component and Aesthetic Component of Index of Orthodontic Treatment Need (DHC-IOTN) were also assessed [3].

Digital images of the orthodontic cast were assessed using the computer program ImageJ [19], allowing masked assessment of orthodontic casts. A standard ruler placed at the center of the plastic board was photographed horizontally and perpendicular to the camera. This was used to standardize a scale for ImageJ to perform linear measurements on-screen. Overjet, overbite, molar relationship, and IOTN-DHC and IOTN-AC were determined from the computer screen. The same examiners (WM and LZ) conducted the assessments on both digital images and plaster casts. Assessments of the digital photographs were conducted masked of assessments on the plaster casts. Inter- and intra-examiner reliabilities were continuously monitored through the data-collection process by randomly reassessing 5 out of every 25 assessments (20%).

Data analysis

Agreements of categorical data: molar relationship and orthodontic treatment need were assessed employing the Kappa statistic (κ) [20]. Agreements of continuous data: overjet and overbite were assessed in comparison and correlation analyses. Comparison analysis was assessed using the paired sample *t*-test by calculating the mean directional differences (MDDs) and standardized directional differences (SDDs) [21]. Correlation analysis was assessed by calculating the intra-class correlation coefficients (ICCs) [22].

Results

Sample characteristics

Among the sample of 412 orthodontic casts, 76% (313) were amenable for assessment; 99 orthodontic casts were excluded from the assessment because of breakage, loss, or defects. The occlusal characteristics of the sample are given in Table I and shown in Figure 2.

Orthodontic casts – images' agreement (Table II)

Overbite and overjet measurements from images of orthodontic casts when compared with measurements from orthodontic casts were of similar magnitude: Compared to zero, the MDD of overbite was statistically significant ($p < 0.001$). When the MDDs were standardized, the magnitude of the directional difference for overjet was –0.07 and 0.21 for overbite. The mean absolute differences of overjet and overbite measured from orthodontic casts and their images were 0.56 mm and 0.33 mm, respectively. The 95% agreement interval for overjet directional difference was –1.52 mm to 1.41 mm and for overbite directional difference –0.80 mm to 0.99 mm. Intra-class correlation coefficients for both overjet and overbite were >0.90. For molar relationships, the agreements as measured by κ statistic were 0.81 and 0.77 for left and right molar relationships, respectively. For orthodontic treatment need as measured by IOTN-DHC and IOTN-AC, the agreements as measured by κ statistic were 0.79 and 0.56, respectively. For molar relationships obtained from orthodontic casts and their images, there was no categorical difference of more than half a molar cusp width (Figure 2).

Examiner reliability

Inter-examiner reliability – orthodontic casts (Table III). The MDDs of overjet and overbite were less than a

Table I. Proportions of inter-arch occlusion classes measured from orthodontic casts by molar relationship, overjet and overbite

		Class III	Class III subdivision	Class I	Class II subdivision	Class II
Sagittal	Molar relationship	1.3% (4)	5.3% (16)	70.8% (213)	19.3% (58)	3.3% (10)
	Overjet[1]	0.3% (1)		80.1% (250)		19.6% (61)
		Open bite[1] (<0 mm)	Ideal overbite[1] (0 to 2 mm)	Moderate deep bite[1] (2 to 5 mm)	Severe deep bite[1] (5 mm or more)	
Vertical	Overbite	0.0% (0)	18.5% (58)	76.4% (239)	5.1% (16)	

[1]Categorized as in National Health and Nutrition Estimates Survey III 1989–1994, USA [25].

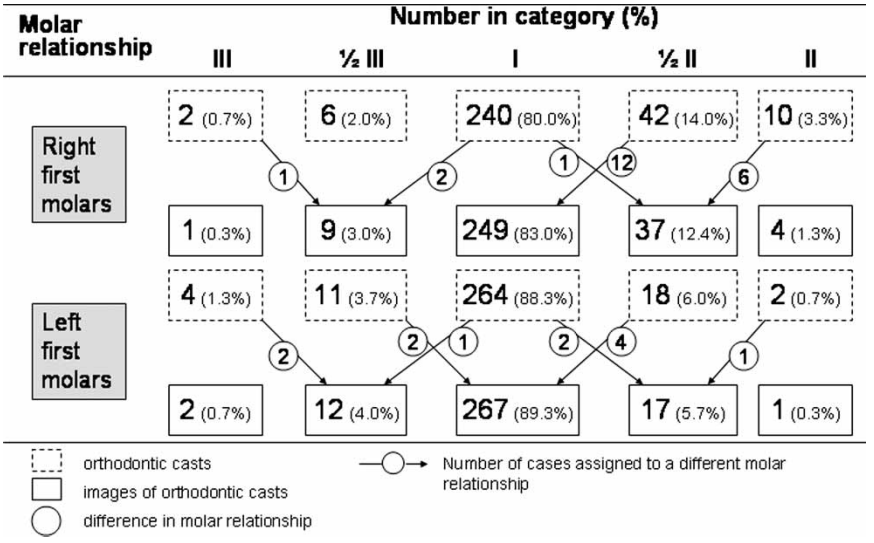

Figure 2. Molar relationships categorized from orthodontic casts and their images.

quarter of a millimeter and one-tenth of a millimeter, respectively. The MDDs were statistically significant for overjet ($p < 0.01$). The SDDs for overjet and overbite were -0.47 and -0.04, respectively. The intra-class correlation coefficients for overjet and overbite agreements were both >0.90. Inter-examiner agreements as measured by κ statistic for molar relationships and IOTN-AC were >0.70 and for IOTN-DHC κ 0.62.

Inter-examiner reliability – images of orthodontic casts (Table IV). For images of orthodontic casts, MDDs of overjet and overbite were both <0.10 mm. The SDDs of overjet and overbite were <0.2 and <0.1, respectively. Intra-class correlation coefficients for overjet and overbite agreements were both >0.90. Inter-examiner agreements as measured by κ statistic for molar relationships and IOTN-DHC were >0.70. The κ value for IOTN-AC was -0.02.

Intra-examiner reliability – orthodontic casts (Table III). The MDDs of overjet and overbite were both less than one tenth of a millimeter. The SDDs for overjet and overbite were 0.08 and -0.12, respectively. Intra-class correlation coefficients for overjet and overbite agreements were both >0.80. Intra-examiner agreements as measured by κ statistic for molar relationships, IOTN-DHC and IOTN-AC, were >0.70.

Intra-examiner reliability – images of orthodontic casts (Table IV). The MDDs of overjet and overbite were both less than one tenth of a millimeter. They were statistically significant for overbite ($p < 0.05$). The SDDs of overjet and overbite were -0.24 and -0.49, respectively. Intra-class correlation coefficients for overjet and overbite agreements were both >0.90. Inter-examiner agreements as measured by κ statistic for molar relationships, IOTN-DHC and IOTN-AC, were >0.90.

Table II. Agreement between orthodontic casts and their images in assessing overjets and overbites

	Assessment from										
	Orthodontic cast		Image		Directional differences			Absolute difference			
Measurement	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	D§	Mean (mm)	SD (mm)	Correlation	95% Agreement interval (mm)
Overjet	3.50	1.63	3.55	1.52	−0.05	0.75	−0.07	0.56	0.50	0.94 †	−1.52 to1.41
Overbite	2.71	1.20	2.61	1.10	0.10***	0.46	0.21	0.33	0.33	0.96 †	−0.80 to 0.99
Left molars										0.81 #	
Right molars										0.77 #	
IOTN-DHC (≥4)										0.79 #	
IOTN-AC (≥7)										0.56 #	

***$p < 0.001$.
†Intraclass correlation coefficient.
#Kappa statistic.
SD = standard deviation.
§Standardized difference D = mean directional difference/standardized deviation of directional differences ($D \leq 0.2$, small; $0.2 \leq D \leq 0.5$, moderate; and $D \leq 0.8$, large).

Table III. Inter- and intra-examiner agreements in the measurements of overjet, overbite, molar classification, and orthodontic treatment need from orthodontic casts

	Directional difference						Absolute difference				Correlation		95% Agreement interval	
	Inter-examiner			Intra-examiner			Inter-examiner		Intra-examiner		Inter-examiner	Intra-examiner	Inter-examiner	Intra-examiner
Measurement	Mean (mm)	SD (mm)	D§ (mm)	Mean (mm)	SD (mm)	D§	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)			(mm)	
Overjet	−0.20**	0.42	−0.47	0.07	0.78	0.08	0.32	0.34	0.50	0.60	0.96 †	0.93 †	(−1.03, 0.63)	(−1.47, 1.61)
Overbite	−0.02	0.42	−0.04	−0.07	0.54	−0.12	0.25	0.34	0.27	0.47	0.93 †	0.85 †	(−0.84, 0.81)	(−1.12, 0.99)
Left molars											0.72 #	0.77 #		
Right molars											0.89 #	0.70 #		
IOTN-DHC (≥4)											0.62 #	0.73 #		
IOTN-AC (≥7)											0.79 #	0.99 #		

**$p < 0.01$.
†Intraclass correlation coefficient.
#Kappa statistic.
SD = standard deviation.

Table IV. Inter- and intra-examiner's agreements in the measurements of overjet, overbite, molar classification, and orthodontic treatment need from images of orthodontic casts

	Directional difference						Absolute difference				Correlation		95% Agreement intervals	
	Inter-examiner			Intra-examiner			Inter-examiner		Intra-examiner		Inter-examiner	Intra-examiner	Inter-examiner	Intra-examiner
Measurement	Mean (mm)	SD (mm)	D§ (mm)	Mean (mm)	SD (mm)	D§ (mm)	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)			(mm)	
Overjet	−0.07	0.51	−0.14	−0.06	0.26	−0.24	0.32	0.40	0.19	0.18	0.94 †	0.99 †	(−1.06, 0.92)	(−0.56, 0.44)
Overbite	0.00	0.19	0.02	−0.07*	0.15	−0.49	0.12	0.14	0.10	0.13	0.98 †	0.99 †	(−0.37, 0.38)	(−0.36, 0.22)
Left molars										0.78 #	0.99 #			
Right molars										0.90 #	0.99 #			
IOTN-DHC (≥4)										0.81 #	0.92 #			
IOTN-AC (≥7)										–0.02 #	0.99 #			

*$p < 0.05$.
†Intraclass correlation coefficient.
#Kappa statistic.
SD = standard deviation.

Discussion

Although a high response rate was achieved in this study, approximately a quarter of study casts were lost, damaged, or had defects which prohibited them from being included in the analyses 20 years after the records were originally obtained in the oral health survey. This highlights the need for an alternative form of storage to traditional orthodontic casts such as digital images. Since the ability of 2DI to convey information of occlusion for the purpose of orthodontic assessment is uncertain, this study was undertaken to determine the value of 2DI in assessment of malocclusion and orthodontic treatment need.

The inherent reliability difficulties in the measurement of overjet, overbite, and molar relationship, clinically or on orthodontic casts, relate in part to lack of consensus in the literature on how overjet, overbite, and molar relationship should be assessed. Thus, systematic bias may arise due to different definitions of these measures from orthodontic casts. In this study, the definitions of overjet by Stephens & Bowden [16], overbite by Mitchell & Mitchell [17], and molar relationship by Angle [18] with more detailed modifications to reduce systematic bias, were followed.

The agreement between the measurements of overjet obtained from orthodontic casts and their images could be interpreted as substantial [22,23]. However, the 95% agreement interval of approximately 3 mm observed may be of slight concern from a clinical perspective. For overbite, there was a statistically significant difference between the average measurement from orthodontic casts and their images according to the paired sample *t*-test. However, the observed 0.1 mm difference is unlikely to be of clinical importance. SDDs of 0.21 suggested close to "excellent agreement", and intra-class correlation coefficient >0.80 suggested "excellent agreement" [22,23]. The 95% agreement interval of <2 mm was clinically reasonable.

Agreement of the molar relationships obtained from orthodontic casts and their 2DI could be interpreted as "substantial agreement" ($\kappa > 0.60$). Agreement of orthodontic treatment as assessed by orthodontic casts and their 2DI could be interpreted as "substantial" when IOTN-DHC was employed to assess orthodontic treatment need ($\kappa > 0.60$), and "moderate" when IOTN-AC was employed to assess orthodontic treatment need ($\kappa > 0.40$) [24].

ICC values obtained from inter- and intra-examiner reliability assessment of overjet and overbite on both orthodontic casts and their 2DI could be interpreted as "excellent agreement" [22]. Inter- and intra-examiner reliability assessment of molar relationships and orthodontic treatment needs as assessed by Kappa could be interpreted as "substantial" or better; except for a "disagreement" in inter-examiner reliability of IOTN-AC in the assessment of 2DI. The disagreement observed was likely to have occurred due to the relatively small sample size of those categorized as having a treatment need by IOTN-AC [24].

In conclusion, there was substantial agreement in the assessment of malocclusion and orthodontic treatment need from orthodontic casts and their 2DI when a standardized approach was employed in obtaining and assessing digital images. This suggests that 2DI can be used as an alternative to casts in assessment of malocclusion and orthodontic treatment need [25].

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