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An alternative to study model storage

O. H. Malik, M. Abdi-Oskouei and N. A. Mandall
School of Dentistry, University of Manchester, UK

SUMMARY The aim of this investigation was to evaluate whether the same orthodontic information can be obtained from study models and photographs of study models for the purposes of medico-legal reporting. Thirty sets of study models were obtained from orthodontic patients treated at the University of Manchester, UK. A mix of start and finish study models were chosen, with the start study models showing a range of malocclusions. Photographs of the study models were taken: anterior and right and left buccal views in occlusion and upper and lower occlusal views. Three examiners assessed the study models and photographs of the models in a random order. They recorded diagnostic information that would be useful for medico-legal reporting. This information was then compared for study models versus photographs of study models using intraclass correlation coefficients (ICCs) for interval data [overjet (mm), midline discrepancy (mm), and number of missing teeth] and kappa (κ) and percentage agreement for the remaining variables.

Generally, agreement between the information obtained from study models versus photographs of study models was high with κ values being above 0.70 for most variables. The exception to this was overbite with κ values ranging from 0.66 to 0.74. When ICCs were considered, again the two methods compared very favourably.

Introduction

The aim of this study was to evaluate whether the same orthodontic information can be obtained from study models and photographs of study models for the purposes of medico-legal reporting. The problem of space for long-term storage of study models is not new (Keating *et al*., 1984; McGuinness and Stephens, 1992). For medico-legal purposes, the Consumer Protection Act (1987) outlines retention of all patient records for no less than 11 years (British Dental Association, 2000) or, alternatively, until the patient is 26 years old (Machen, 1991). However, if the same information can be obtained from study models stored electronically, problems of space, cost of storage, and risk of damage are removed, while still fulfilling the medico-legal requirements.

The use of photographs, holographic images, or three-dimensional (3D) imaging systems for storing study models is well documented (Martensson and Ryden, 1992; Bell *et al.*, 2003; Garino and Garino, 2003; Hajeer *et al.*, 2004; Joffe, 2004). However, the previous literature has compared linear distance measurements obtained from study models and two-dimensional (2D) or 3D imaging methods (Bell *et al.*, 2003; Tran *et al.*, 2003; Paredes *et al.*, 2005) or Goslon yardstick ratings (Nollet *et al.*, 2004).

While linear measurements are important for research purposes, diagnostic descriptions, which are important for medico-legal reporting, have not previously been investigated. Furthermore, while undoubtedly, 3D imaging systems (Baumrind *et al.*, 2003) are the way forward for study model storage, at present, they are not in widespread use. As a result, photographs of study models formed the focus for this study as a cost-effective and more viable method.

Materials and method

Sample

Thirty sets of study models were obtained non-randomly from orthodontic patients treated at the University of Manchester, UK. Start and finish study models were chosen, with the start models showing a range of malocclusions. The type of malocclusion was defined according to the British Standards Institution incisor classification (1983). They comprised 12 Class I, eight Class II division 1, four Class II division 2, and six Class III study models in an attempt to provide an average range of malocclusion. Twenty-three study models were start and seven were finished cases.

Photographs of each set of study models were taken, using a Fujifilm Finepix S3 Pro digital camera (Fujufilm UK Limited, Bedford, UK) and a Nikon Macro speedlight 60 mm/1:2.8 D lens (Nikon UK Limited, Kingston-upon-Thames, Surrey, UK). The lens object distance was 30 cm. The models were set against a dark background to aid visualization. A millimetric ruler was placed at the edge of the photograph to aid the assessment of crowding, overjet, and midline discrepancy. The views taken were anterior, right and left buccal in occlusion (Figure 1), and upper and lower occlusal (Figure 2). Millimetric distances were calculated using dividers with the points placed on the photographs to measure distance. The divider points were then transferred to the ruler on the same photograph to measure the actual distance in millimetres.

Three examiners assessed the study models and photographs of the models in a random order. Two examiners were orthodontically qualified (OHM and NAM) and one examiner was a third year orthodontic postgraduate student

Figure 1 Anterior, left and right photographs of the study models (with millimetric ruler) in occlusion.

(MA-O). Each examiner took approximately 3–4 minutes to measure one set of models or its photographic record. The following information was recorded:

- Incisor classification (British Standard Classification: Class I, Class II division 1, Class II division 2, and Class III) (British Standard Institute, 1983)
- Overjet (mm) (Figure 3)
- Overbite (increased, average, or decreased)
- Upper and lower midline discrepancy (mm)
- Right and left molar relationship (to the nearest half unit)
- Right and left canine relationship (to the nearest half unit)
- Upper and lower labial and right and left buccal segment crowding (mild, moderate, or severe), where mild is less than or equal to 4 mm, moderate more than 4 mm to less than or equal to 8 mm and severe more than 8 mm)
- Crossbite presence/absence
- The number of clinically missing permanent teeth (excluding third molars)

This information was then compared for study models versus photographs of study models using intraclass correlation coefficients (ICCs) for interval data [overjet (mm), midline discrepancy (mm), and number of missing teeth] and kappa (κ) and percentage agreement for the remaining variables.

Results

Table 1 shows the κ values and percentage agreement when comparing information obtained from study models versus photographs of study models. Generally, the agreement between the two methods was high with κ values being above 0.70 for most variables. The exception to this was overbite with κ values ranging from 0.66 to 0.74. When ICC was considered (Table 2), again the two methods compared very favourably.

Discussion

The data suggest that the clinical information gained from photographs of study models is comparable with that obtained from the models themselves. The variables recorded should, arguably, be adequate to write a medico-legal report, if required. Importantly, the ruler should be included in the images to allow measurement of overjet and crowding as accurately as possible.

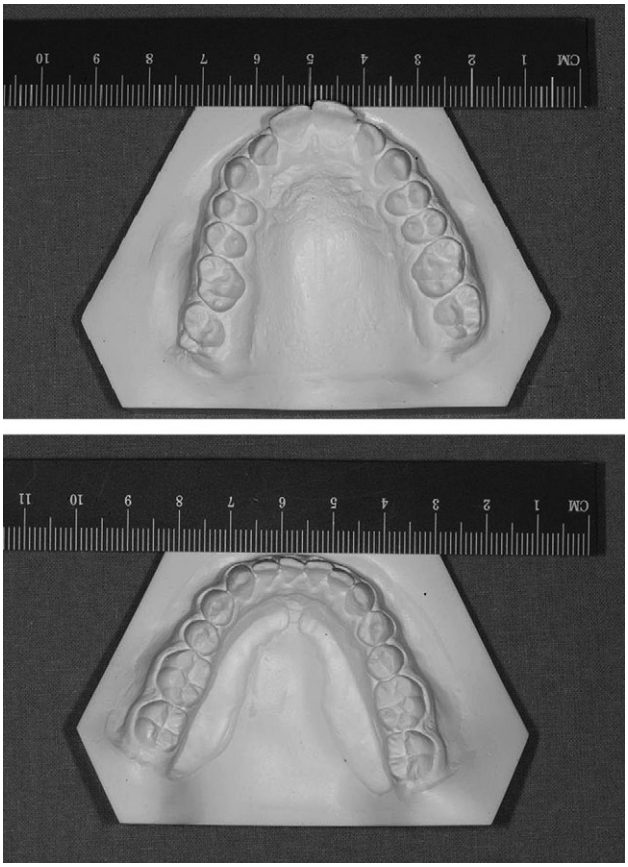

Figure 2 Upper and lower occlusal photographs (with millimetric ruler) of the study models.

Therefore, it is suggested that electronic 2D images of study models may be retained for medico-legal purposes, removing the need to store study models for long periods of time. An additional advantage is that if study model information needs to be circulated for medico-legal reporting, it is easier to make multiple copies for circulation to the various interested parties. However, using electronic 2D images of study models assumes that electronic data can be stored reliably for 11 years and, as there is some doubt

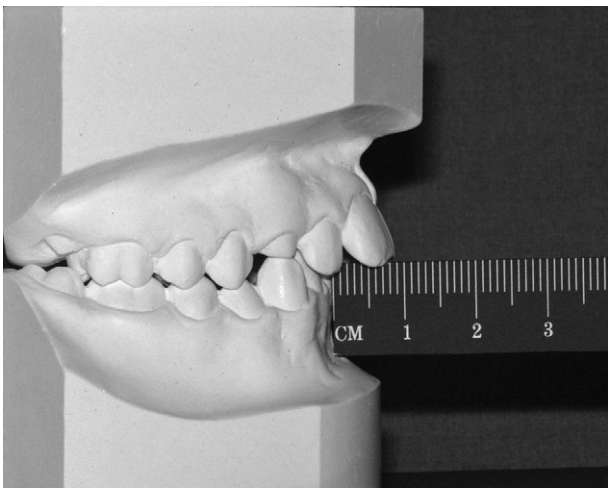

Figure 3 Millimetric ruler to measure overjet.

Table 1 Kappa values (κ) and percentage agreement comparing study models and photographs of study models.

Variable	Examiner	κ (SE)	% agreement
Incisor relationship	1	0.84 (0.088)	88
	2	0.84 (0.106)	89
	3	0.90 (0.071)	89
Overbite	1	0.66 (0.126)	65
	2	0.69 (0.014)	69
	3	0.74 (0.101)	74
Right molar	1	0.89 (0.071)	89
	2	0.93 (0.062)	93
	3	0.94 (0.057)	94
Left molar	1	0.94 (0.052)	94
	2	0.89 (0.071)	89
	3	0.89 (0.075)	89
Right canine	1	0.88 (0.080)	88
	2	0.80 (0.089)	78
	3	0.89 (0.072)	89
Left canine	1	0.80 (0.110)	73
	2	0.89 (0.089)	78
	3	0.80 (0.089)	80
Upper labial segment crowding	1	0.81 (0.086)	81
	2	0.86 (0.073)	86
	3	0.86 (0.071)	87
Lower labial segment crowding	1	0.94 (0.051)	94
	2	0.81 (0.087)	81
	3	0.90 (0.065)	90
Right upper buccal segment crowding	1	0.77 (0.153)	89
	2	0.83 (0.114)	83
	3	0.92 (0.078)	92
Left upper buccal segment crowding	1	0.77 (0.153)	89
	2	0.80 (0.131)	80
	3	0.91 (0.081)	91
Right lower buccal segment crowding	1	0.89 (0.104)	95
	2	0.90 (0.901)	90
	3	0.90 (0.091)	90
Left lower buccal segment crowding	1	0.93 (0.073)	95
	2	0.92 (0.073)	92
	3	0.84 (0.103)	84
Crossbite (present/absent)	1	0.87 (0.090)	89
	2	0.87 (0.090)	89
	3	0.80 (0.109)	80

over this, it would be safer to also store the images as photographic prints.

It is difficult to compare the κ scores and ICC in this study with other published work, as previous papers have either examined agreement between examiners for treatment planning (Baumrind *et al.*, 1996; Ribarevski *et al.*, 1996; Lee *et al.*, 1999) or linear measurements only from study models versus electronic images (Martensson and Ryden, 1992; Tran *et al.*, 2003; Joffe, 2004).

It was noticeable that κ scores and percentage agreement were low for overbite and this could be explained by the assessment being more subjective (increased, average, or decreased). This was particularly difficult to record from photographs as overbite depth in millimetres could not be assessed. The examiners also found that recording of which teeth were involved in anterior or posterior crossbite was difficult from the photographs because the image could not be viewed from different angles. As a result, crossbites were recorded as present or absent. This is a drawback to the described method that could easily be overcome by a 3D imaging system.

The Medical Defence Union, London, UK, were supportive of the concept of a photographic record of study models, as long as the original study models were available throughout the whole course of treatment and the retention phase. Their additional comments included:

1. In general, the courts will accept the best evidence available. Accordingly, if study model casts are no longer available, but good quality photographs of the casts are, the photographs could be admitted in evidence as part of the clinical records.
2. Hard copies of the photographs should be annotated with the patient's name, date of birth, date of the photographs, and the name of the person taking the photograph.
3. If the photographs are held digitally, in addition to the information in point 2, it is important that the images are backed up regularly, with the backup secured off site. The software should incorporate an audit trail to prove the images and patient data have not been amended in any way.

Conclusion

The same orthodontic information can be obtained from study models and photographs of study models for the purposes of medico-legal reporting.

Table 2 Comparison of study models and photographs of study models using interclass correlation coefficients.

Variables	Examiner 1	Examiner 2	Examiner 3
Missing teeth	1.000	1.000	0.973
Overjet	0.999	0.999	0.998
Midline discrepancy	0.935	0.973	0.947

Address for correspondence

Dr N. A. Mandall
Department of Orthodontics
Tameside General Hospital
Fountain Street
Ashton-under-Lyne
Lancashire OL6 9RW
UK
E-mail: nicky.mandall@tgh.nhs.uk

References

Baumrind S, Carlson S, Beers A, Curry S, Norris K, Boyd R L 2003 Using three-dimensional imaging to assess treatment outcomes in orthodontics: a progress report from the University of the Pacific. Orthodontics and Craniofacial Research 6 (Supplement 1):132–142

Baumrind S, Korn E L, Boyd R L, Maxwell R 1996 The decision to extract: Part 1—interclinician agreement. American Journal of Orthodontics and Dentofacial Orthopedics 109: 297–309

Bell A, Ayoub A F, Siebert P 2003 Assessment of the accuracy of a three-dimensional imaging system for archiving dental study models. Journal of Orthodontics 30: 219–223

British Dental Association 2000 Advice sheet B1: ethics in dentistry. BDA, London

British Standards Institution 1983 British Standard Incisor Classification. Glossary of Dental terms BS4492. British Standard Institute, London

Consumer Protection Act 1987 (Commencement no. 1) Order. Her Majestyus Stationery Office, London

Garino F, Garino B 2003 From digital casts to digital occlusal set-up: an enhanced diagnostic tool. World Journal of Orthodontics 4: 162–166

Hajeer M Y, Millett D T, Ayoub A F, Siebert J P 2004 Applications of 3D imaging in orthodontics: part II. Journal of Orthodontics 31: 154–162

Joffe L 2004 OrthoCAD™: digital models for a digital era. Journal of Orthodontics 31: 344–347

Keating P J, Parker R A, Keane D, Wright L 1984 The holographic storage of study models. British Journal of Orthodontics 11: 119–125

Lee R, Macfarlane T, O'Brien K 1999 Consistency of orthodontic treatment planning decisions. Clinical Orthodontics and Research 2: 79–84

Machen D E 1991 Legal aspects of orthodontic practice: risk management concepts. British Association of Orthodontists. Newsletter 91: 4

Martensson B, Ryden H 1992 The Holodent system, a new technique for measurement and storage of dental casts. American Journal of Orthodontics and Dentofacial Orthopedics 102: 113–119

McGuinness N J, Stephens C D 1992 Storage of orthodontic study models in hospital units in the U.K. British Journal of Orthodontics 19: 227–232

Nollet P J *et al.* 2004 Photographs of study casts: an alternative medium for rating dental arch relationships in unilateral cleft lip and palate. Cleft Palate-Craniofacial Journal 41: 646–650

Paredes V, Gandia J L, Cibrian R 2005 New, fast, and accurate procedure to calibrate a 2-dimensional digital measurement method. American Journal of Orthodontics and Dentofacial Orthopedics 127: 518–519

Ribarevski R, Vig P, Vig K D, Weyant R, O'Brien K 1996 Consistency of orthodontic extraction decisions. European Journal of Orthodontics 18: 77–80

Tran A, Rugh J D, Chacon J A, Hatch J P 2003 Reliability and validity of a computer-based Little irregularity index. American Journal of Orthodontics and Dentofacial Orthopedics 123: 349–351