European Journal of Orthodontics 29 (2007) 430–436
doi:10.1093/ejo/cjm037
Advance Access publication 27 July 2007

A comparison of accuracy in bracket positioning between two techniques—localizing the centre of the clinical crown and measuring the distance from the incisal edge

David Armstrong*, Gang Shen*, Peter Petocz** and M. Ali Darendeliler*
*Department of Orthodontics, Faculty of Dentistry, Sydney Dental Hospital, The University of Sydney and
**Department of Statistics, Macquarie University, Sydney, Australia

SUMMARY The placement of orthodontic brackets is guided either by localizing the centre of the clinical crown (CC) or by measuring the distance from incisal edge (ME). The purpose of this study was to examine if there are any significant differences in the accuracy of bracket positioning between these two techniques.

Typodont models were simulated with a Class I malocclusion with severe crowding. Nineteen experienced orthodontists (12 males, seven females) with a mean age of 40.6 years bonded pre-adjusted straight-wire brackets (Victory MBT) on the typodonts. Each orthodontist was asked to bond 20 brackets on one typodont using the CC method and 20 brackets on another typodont using the ME method. The teeth were removed from the typodont and photographed for imaging analysis. The errors of bracket placement in the vertical, mesiodistal, and angular/tip dimensions were measured and the data were statistically assessed.

An overall test of significance, using all the data, rather than the means, demonstrated a significant vertical difference between the CC and ME methods, with the ME method more accurate vertically (mean CC = 1.19, mean ME = 1.10, $P = 0.002$) but no significant differences for mesiodistal (mean CC = –0.08, mean ME = –0.05, $P = 0.28$) or for tip (mean CC = –1.61, mean ME = –1.35, $P = 0.34$) errors. Analysis of the overall means and the arches independently showed that there was no significant difference in bracket accuracy between the two techniques ($P > 0.05$). Analysis of the teeth individually showed that the ME method was better in the vertical positioning for several upper and lower anterior teeth ($P < 0.01$) and poorer for the upper first premolars. The mean time taken to bond the 20 brackets showed no significant difference between two methods (CC 28.53 ± 9.51 versus ME 28.21 ± 10.43 minutes, $P > 0.05$). It is suggested that bracket bonding guided by measuring the distance from incisal edge may result in improved placement for anterior teeth. Archwire bending or bracket repositioning is still necessary to compensate for the inaccuracies with both techniques.

Introduction

The pre-adjusted appliance has provided great benefits to orthodontics with a gradual progression towards finishing, rather than an abrupt stage of wire bending as in the standard edgewise technique (McLaughlin and Bennett, 2003). Good finishing begins at the commencement of treatment with positioning of the brackets. If the brackets are positioned correctly and the tip, torque, and in–out compensations built into the appliance are suited to the patient's dentition, only minimal wire bending will be required (McLaughlin and Bennett, 1991).

Angle (1928) recommended that the ideal position to place the bracket should be at the centre of the labial surface of the tooth. Later, placement of the anterior bands at the junction of the middle and incisal thirds has been recommended (Balut *et al.*, 1992). These authors suggest that with the Tweed and Begg techniques the brackets be placed by measuring the distance from the incisal edge for anterior teeth and from the cusp tip for posterior teeth. Andrews (1976, 1979) developed the straight-wire appliance and proposed that the brackets should be placed at the midpoint of the facial axis (FA) point, as the midpoints of all the clinical crowns are located on the same plane (the Andrews plane): it was felt that the FA point was readily and consistently located. Ricketts (1976), and later Kalange (1999), advocated the use of marginal ridges to guide the vertical positioning of brackets and bands.

Some researchers have shown that the FA points between the teeth are not necessarily on the same plane (Dellinger, 1978; McLaughlin and Bennett, 1995) and this led to other recommendations for ideal bracket placement. McLaughlin and Bennett (1995) advocated the positioning of brackets at a measured distance from the incisal edge, with different vertical positions recommended for different sized teeth (Table 1). They felt that the use of a bracket placement chart with the use of a Dougherty gauge dramatically reduced the bracket placement errors in the vertical dimension, with a 50–60 per cent reduction in the need to reposition brackets.

Table 1 Vertical heights for bracket positioning (units are in millimetres).

	Central	Lateral	Canine	First premolar	Second premolar
Upper arch	5.0	4.5	5.0	4.5	4.0
Lower arch	4.0	4.0	4.5	4.0	3.5

Regardless of which method is used for positioning brackets, there seems to be some margin of deviation from the ideal location and this is before operator error is taken into account. Measuring from the incisal edge and positioning at the FA point have been shown to be inaccurate for premolars and can lead to marginal ridge discrepancies between the premolars and molars and a lack of occlusal contacts with the opposing dentition (Eliades *et al.*, 2005). Fukuyo *et al.* (2004) digitized the models of 40 patients with normal occlusion and compared three methods of bracket placement (FA, height, and marginal ridge methods). The bracket positions relative to a constructed virtual bracket plane were determined. They found that even if the brackets were positioned ideally for each technique, vertical errors will still occur and, therefore, suggested modifications to bracket positions for each technique.

There are a number of prescriptions available, with the manufacturers recommending an optimum position to maximize the efficiency of prescriptions for tooth movement. It would be beneficial to know if there is a difference in the accuracy between the recommendations, as the less accurate the positioning of the brackets, the more poorly they perform. Incorrectly positioned brackets can render even the most customized prescription ineffective and increase treatment time and the number of archwire adjustments necessary (Carlson and Johnson, 2001).

The aim of this study was to compare the accuracy of bracket positioning between two methods of bracket placement—locating the bracket at the centre of the clinical crown (CC) and at a measured distance from the incisal edge (ME).

Materials and methods

Typodont simulating model

Thirty-eight typodont models were simulated with a Class I malocclusion with severe crowding, but no tooth was so severely displaced that it prevented ideal bracket placement (Figure 1). The typodont was custom-made from a rapid set polyurethane resin (Easy Cast, Barnes Products Pty. Limited, Bankstown, New South Wales, Australia) with each arch having two holes drilled posteriorly to allow them to be fitted to a modified adjustable typodont mount. Prior to placement of the typodont on the mount, the buccal surface of each tooth was prepared by sandblasting it for 10 seconds with 50 μm aluminium particles (Danville, San Ramon, California, USA). Custom-made synthetic latex lips (Spray/

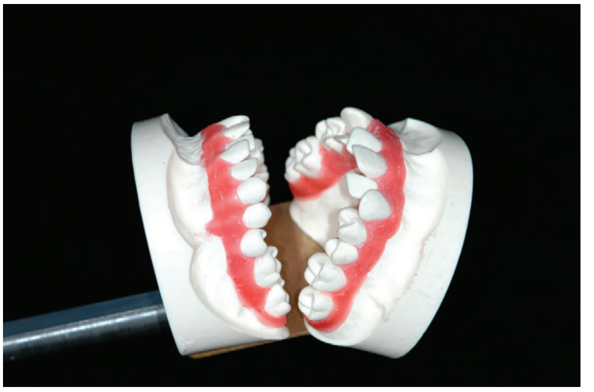

Figure 1 Typodont model simulated with a Class I crowding malocclusion.

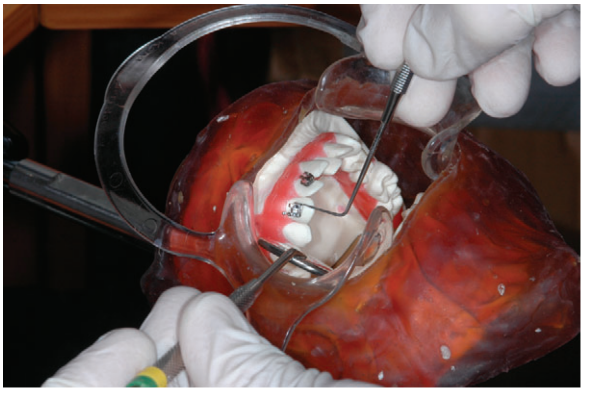

Figure 2 Placement of brackets is conducted at the typodont where custom-made synthetic latex lips are installed and a cheek retractor is placed to simulate a real clinical bonding scenario.

dip latex, Barnes) were then fitted followed by a cheek retractor placement (Sasa, Kongivor, Norway). This was to ensure a realistic clinical situation where the premolar teeth had to be bonded with the use of a mirror and not by direct vision (Figure 2). The mount was attached to the side of a table so each operator could modify its position to represent a patient in a supine position.

The operators and bracket bonding

Nineteen experienced orthodontic specialists (12 males, seven females) participated in this study. Their mean age was 40.6 years (range 29–53) and their mean years of experience was 8.3 years (range 1–25). They were asked to bond pre-adjusted straight-wire brackets (Victory series, low profile, MBT, 3M, Unitek, Monrovia, California, USA) on the simulated typodont models. All participants were given a prepared handout, with photographic images, defining the exact position each bracket was to be placed. Each operator was asked to bond 20 brackets on one typodont with the CC method and 20 brackets on another typodont with the ME method. The FA point was perceived as the vertical midpoint along the long axis of the CC (Andrews, 1979), while the measured distances from the ME of different teeth were adopted as those defined by McLaughlin and Bennett (1995; Table 1).

The operators were given a selection of instruments [mirror, probe, periodontal probe, scaler, ½ hollenbach, flat plastic, ruler, and height gauges (4–5.5 mm, 3M Unitek)] and were asked if they required any other instruments. The teeth were then primed and bonded with Transbond (3M, Unitek). The time taken to place the brackets for each technique was recorded. The brackets were set using the available curing light at each surgery. As the bond strength of the brackets were not to be tested, standardization of the curing lights was not necessary.

Examination of the accuracy of bracket placement

The teeth were removed and placed in individually made jigs (Odontosil, Dreve-Dentamid GmbH, Unna, Germany). Twenty jigs were manufactured, one for each tooth. The jigs could be positioned in two ways in a mount, which fitted on one end of a specially constructed photographic jig (Figure 3). A Nikon D1 with a Nikon 110 lens was fitted on the other end of the jig and two digital photographs were taken (one buccal and one occlusal). The images were saved as Joint Photographic Expert Group images and then opened using an imaging system (AnalysSIS Pro 3.1, Munich, Germany) and calibrated using the ruler attached to the jig. The images were magnified 200 per cent and three measurements were made by one author (DA) to identify the error of bracket positioning (Figure 4). Each measurement was repeated three times, 1 week apart and an average was taken. The three measurements were as follows:

Vertical positioning error (Figure 4a): The vertical position of the bracket was measured from the incisal edge to the vertical midpoint of the bracket archwire slot, which was located by constructing two diagonal lines from the four corners of the slot. The vertical positioning error was

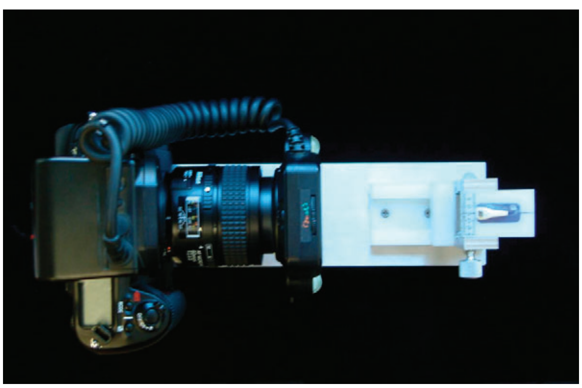

Figure 3 Photographic jig set up to acquire digital images of the tooth with bonded bracket, based on which the error of bracket placement is measured.

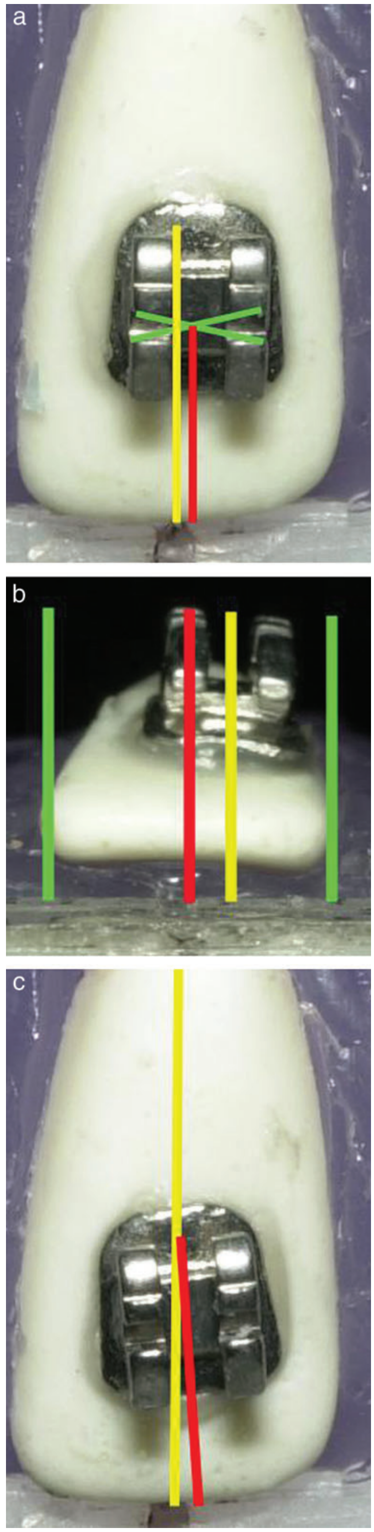

Figure 4 Measurement of the error of bracket placement. (a) Vertical positioning error is defined as the deviation of the vertical height of the bracket (red line) from the vertical height of the clinical crown centre (yellow line). (b) Mesiodistal positioning error is defined as the deviation of the occlusal midpoint of the bracket (red line) from that of the tooth (yellow line). (c) Angular (tip) positioning error is defined as the deviation of the bracket angulation (red line) from that of the tooth long axis (yellow line).

then calculated by subtracting this measurement from (1) the actual distance between the CC and the ME or (2) the defined measured distance for that particular tooth (Table 1). Positive values indicated occlusal placement and negative values gingival placement.

Mesiodistal positioning error (Figure 4b): This was measured from the occlusal image with the midpoint of the tooth being identified, and the horizontal distance from the midpoint of the tooth to the midpoint of the bracket measured. Mesial placement was defined as a positive value and distal placement as a negative value.

Angular/tip error (Figure 4c): This was identified by measuring the intersecting angle between the vertical scribe line on the bracket and the long axis of the CC. If the bracket was tipped mesially the value was recorded as positive and if distally a negative value was recorded. Positioning the bracket with a mesial tip would result in a final distal tip of the crown.

Statistical analysis

The accuracy of bracket placement was analysed using the Statistical Package for Social Sciences (Windows, release 12.0, SPSS Inc., Chicago, Illinois, USA). Analysis of variance models were used to investigate the overall differences between the two methods (CC and ME) for each type of error (vertical, mesiodistal, angular/tip). These analyses allowed for differences between teeth (by including the tooth as a fixed factor) and orthodontists (by including subject as a random factor). Paired *t*-tests were used to investigate the errors associated with placement of individual teeth and the comparisons between left and right sides of the mouth. Since a large number of related (non-independent) tests were carried out, P values <0.01 were used to indicate significance. The method error was calculated by remeasuring one quadrant (the lower right) for three participants and then rephotographing and measuring again. Although the error of method/measurement is generally reported as the standard deviation (SD) within repeated measurements (Bland, 2000) it is also common to calculate the coefficient of variation (CV) by dividing the SD by the mean and expressing it as a percentage. However, it should be noted that if measurements are positive and negat ive, with a mean close to zero (as in the case of mesiodistal and angular errors), then the CV will be artificially high (Table 2).

Table 2 Method error analysis.

Type of measurement		Standard deviation	Mean	Coefficient of variation
Method 1	Vertical	0.0182	1.0310	1.77
	Tip	0.1313	−3.7370	3.51
	Mesiodistal	0.0054	−0.1527	3.52
Method 2	Vertical	0.0370	1.070	3.46
	Tip	0.1714	−3.655	4.69
	Mesiodistal	0.0204	−0.143	14.25
Method 3	Vertical	0.1451	1.0179	14.25
	Tip	0.5787	−3.7801	15.31
	Mesiodistal	0.0269	−0.1598	16.81

Method 1, measurements repeated on the same image (replicate measurements); Method 2, replicate measurements with the image was reassessed and recalibrated; and Method 3, replicate measurements with the teeth rephotographed.

Results

The mean time taken to bond the 20 brackets was 28.53 minutes (SD 9.51) for the CC placement and 28.21 minutes (SD 10.43) for the ME method. There was no statistically significant difference between the two techniques.

The mean and SD were calculated for each tooth (CC and ME) and are demonstrated in Table 3, and the statistically significant differences in Table 4. Neither the age nor the years of experience of the orthodontists affected the accuracy of bonding.

Overall the vertical, mesiodistal, and tip errors were not statistically significantly different with either the CC or the ME method (Tables 3 and 4). When assessing the arches independently, there was also no statistically significant difference between the two methods of bracket placement (Table 5). The errors for the vertical dimension assessed relative to the mean and for the arches independently and overall were not statistically different (Table 5).

An overall test of significance between the two methods (CC and ME) using all the measurements rather than comparing the means is more likely to demonstrate small differences as significant. The overall test demonstrated a significant difference in the vertical between the CC and ME methods, with the ME method more accurate (mean CC = 1.19, mean ME = 1.10, $P = 0.002$) but no significant differences for mesiodistal (mean CC = −0.08, mean ME = −0.05, $P = 0.28$) or for tip (mean CC = −1.61, mean ME = −1.35, $P = 0.34$) errors.

The teeth were paired and a *t*-test was performed to identify if there were any differences in accuracy comparing the right and left sides. For the CC method, there were significant error differences ($P < 0.01$) in the vertical and mesiodistal error for teeth 15–25, vertical for 13–23, vertical and mesiodistal for 12–22, mesiodistal for 41–31, and tip for 44–34. For the ME method, there were significant error differences ($P < 0.01$) in the vertical and mesiodistal for 15–25, vertical for 14–24, vertical for 13–23, mesiodistal for 41–31, tip for 42–32, vertical for 43–33, and vertical and tip for 44–34.

Although there were no statistically significant differences in the tip error between the two methods of bracket placement, the majority of the errors were negative, which suggested a trend to bond the brackets with a distal tip.

Table 3 The error of bracket positioning by orthodontic specialists bonding the brackets guided by localizing the centre of the clinical crown (CC) and measuring the distance from the incisal edge (ME). Units are in millimetres or degrees.

Teeth		15		14		13		12		11	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Vertical	CC	1.31	0.31	0.66	0.44	1.34	0.55	1.26	0.36	2.24	0.44
	ME	1.34	0.39	0.97	0.32	0.74	0.39	1.49	0.43	1.79	0.72
Mesiodistal	CC	0.10	0.15	−0.15	0.18	−0.12	0.22	−0.24	0.12	−0.11	0.24
	ME	0.05	0.26	−0.20	0.28	0.00	0.19	−0.11	0.21	−0.07	0.19
Tip	CC	−2.13	4.28	−4.57	4.74	−2.04	4.24	1.32	1.62	−2.26	3.91
	ME	−0.86	4.69	−4.23	4.12	−1.61	3.24	1.10	2.61	−2.04	3.19
Teeth		21		22		23		24		25	
Vertical	CC	2.08	0.36	1.47	0.29	1.68	0.59	0.77	0.41	0.89	0.26
	ME	1.70	0.67	1.53	0.45	1.16	0.42	1.30	0.43	0.88	0.42
Mesiodistal	CC	−0.13	0.26	−0.02	0.20	−0.01	0.29	−0.12	0.25	−0.23	0.29
	ME	−0.10	0.28	0.00	0.16	0.06	0.32	−0.19	0.26	−0.31	0.26
Tip	CC	−0.45	2.76	1.52	2.95	−2.22	5.40	−1.17	4.89	−3.34	4.49
	ME	−1.37	1.54	1.10	1.90	−0.80	5.43	−1.03	5.89	−2.99	3.46
Teeth		45		44		43		42		41	
Vertical	CC	0.77	0.54	0.70	0.58	1.19	0.33	1.28	0.33	1.02	0.34
	ME	0.59	0.49	1.10	0.44	1.22	0.30	1.08	0.34	1.00	0.35
Mesiodistal	CC	−0.06	0.43	−0.26	0.33	−0.02	0.21	−0.04	0.13	−0.23	0.16
	ME	0.07	0.32	−0.20	0.36	−0.02	0.33	−0.02	0.14	−0.25	0.24
Tip	CC	−0.27	6.24	0.33	3.92	−2.03	3.41	−4.62	2.80	−0.49	1.99
	ME	0.45	4.03	0.60	5.08	−1.93	2.52	−4.68	1.95	−0.16	3.19
Teeth		31		32		33		34		35	
Vertical	CC	1.23	0.37	1.34	0.39	1.27	0.39	0.57	0.50	0.83	0.47
	ME	1.09	0.40	1.24	0.34	0.88	0.43	0.41	0.44	0.53	0.79
Mesiodistal	CC	0.03	0.16	−0.02	0.14	−0.14	0.28	−0.18	0.34	0.15	0.41
	ME	0.01	0.13	−0.01	0.21	−0.12	0.33	−0.09	0.30	0.18	0.74
Tip	CC	−1.49	2.85	−2.10	3.55	−3.00	3.49	−4.20	3.82	1.60	5.36
	ME	−1.83	2.01	−2.09	2.41	−2.55	2.38	−3.58	3.29	3.00	5.83

SD, standard deviation.

Table 4 The significant differences in error of bracket placement between the two techniques (CC, localizing the centre of the clinical crown; ME, measuring the distance from the incisal edge). Units are in millimetres.

Tooth	CC		ME		*P* value	More accurate
	Mean	SD	Mean	SD		
Vertical 14	0.66	0.44	0.97	0.32	0.001	CC
Vertical 13	1.34	0.55	0.74	0.39	<0.001	ME
Mesiodistal 12	−0.24	0.12	−0.11	0.21	0.009	ME
Vertical 11	2.24	0.44	1.76	0.72	0.008	ME
Vertical 23	1.68	0.59	1.16	0.42	<0.001	ME
Vertical 24	0.77	0.41	1.30	0.43	<0.001	CC
Vertical 42	1.28	0.33	1.07	0.34	0.004	ME
Vertical 33	1.27	0.39	0.88	0.43	0.002	ME

SD, standard deviation.

Prior to this study, there were no published reports from which the variability of the difference in positioning errors between CC and ME could be ascertained, so power calculations were unable to be carried out in advance. Having carried out the procedures, it was confirmed that the sample size of 19 orthodontists was adequate to determine clinically significant differences between CC and ME if they occurred. For the vertical and mesiodistal errors, it was felt that differences of 0.25 mm for upper central and lower incisors (11, 21, 31, 32, 41, 42) and 0.50 mm for other teeth would be clinically important. On the basis of observed variability, the present sample of 19 achieved 77 per cent power in the incisor teeth, and over 95 per cent power for other linear measurements. A sample of size 19 would also achieve 85 per cent power to identify differences of 2 degrees in incisor teeth and 3 degrees in other teeth.

Discussion

This study was designed to identify if there were any significant differences in accuracy of positioning of orthodontic brackets between the two methods (CC and ME). The time taken to position the brackets was 28.53 minutes (SD 9.51) for the CC method and 28.21 minutes (SD 10.43) for the ME method, indicating that there is no advantage in terms of chair time between the two techniques.

The overall analysis and the assessment of the arches independently showed that there were no statistically

Table 5 The difference in error of bracket placement between the upper and lower dental arches for the two techniques (CC, localizing centre of the clinical crown and ME, measuring distance from the incisal edge). Units are in millimetres.

		CC		ME		*P* value
		Mean	SD	Mean	SD	
Vertical	All	1.19	0.23	1.10	0.25	0.045
	Upper	1.37	0.27	1.29	0.30	0.018
	Lower	1.02	0.24	0.91	0.25	0.200
Vertical, relative to the mean	All	0.56	0.11	0.52	0.16	0.044
	Upper	0.60	0.13	0.48	0.20	0.073
	Lower	0.44	0.15	0.46	0.15	0.614
Mesiodistal	All	−0.09	0.06	−0.07	0.06	0.946
	Upper	−0.11	0.06	−0.09	0.09	0.004
	Lower	−0.08	0.11	−0.05	0.08	0.769
Tip	All	−1.61	1.02	−1.27	0.82	0.495
	Upper	−1.59	1.41	−1.27	1.47	0.114
	Lower	−1.63	1.25	−1.28	0.97	0.039

SD, standard deviation.

significant differences in accuracy of bracket positioning between the two techniques (Table 3), indicating that there appears to be no advantage in one technique over the other. Conversely, an overall test of significance between the two methods using all the measurements rather than comparing the means demonstrated a significant difference in the vertical between the CC and ME methods, with the ME method more accurate (mean CC = 1.19, mean ME = 1.10, $P = 0.002$). However, this statistical method is more likely to show small differences as significant with the difference between the means 0.09 mm, which would not be clinically significant. However, analysis of the teeth individually suggested that the ME method was more accurate in vertical positioning for several upper and lower anterior teeth and less accurate for the upper first premolars (Table 4). This may indicate that it is more accurate to bond these teeth a measured distance from the incisal edge. However, the operators tended to bond incisally and the correct bracket position for the ME method was more incisal than that for the CC method. Therefore, possibly by default, the brackets ended up closer to the correct position. The majority of the operators did not use the height gauges available. They either estimated the bracket positions for both techniques or used the periodontal probe, and only one operator measured the teeth to identify the centre of the CC. This possibly reflects the fact that as specialists they are bonding brackets on a daily basis and feel that their perception of distance is as accurate as measuring. Koo *et al.* (1999) reported that the use of height gauges does not necessarily reduce the range of error. They found that there was a wide range of variation in height measurements when bonding using a boon gauge (overall mean 0.35 mm, SD 0.26). They suggested that this could be due to tilting of the gauge, which affects the accuracy of the height measurement. Their investigation demonstrated less vertical error than the present study (CC 1.19 ± 0.23 mm, ME 1.10 ± 0.25 mm). Therefore, it is possible that if the operators measured the teeth and used the height gauges, the accuracy of bracket placement in the vertical dimension could have been improved.

Aguirre *et al.* (1982) found that for linear (vertical) measurements, there was a trend for left-side bonds to be more accurate in the upper arch, direct or indirect, and right-side bonds to be more accurate in the lower arch. However, in this study although there were statistical differences in both techniques when comparing the right and left sides, there was no specific pattern (Table 5). This may indicate that it was no more difficult to place brackets on either side.

For both techniques, there appeared to be a trend for the brackets to be bonded with a distal tip. This may be due to the fact that the long axes of the typodont teeth were hard to identify correctly, or that the scribe line was difficult to align with the long axis.

In this study, the finding that the pattern of the error in bracket positioning was very similar between the techniques is in agreement with that of Balut *et al.* (1992) who suggested that there was a basic human limitation in the direct placement of brackets in the mouth.

The evidence showed that neither technique proved perfect accuracy in bracket positioning. This further requires the orthodontists to either add compensating bends into the archwires or reposition the brackets to compensate for the bracket placement errors throughout the course of treatment. On the other hand, more advanced techniques in locating the brackets are required to secure reliable bracket positioning. Hopefully with the introduction of three-dimensional computer-generated models, it will become more practical to place brackets in a more ideal position for individual cases compensating for tooth size and shape, tooth malposition in the arch, and operator skill. It is expected that these ideal positions could be transferred by custom-made transfer jigs manufactured by either a third party, or an in-house milling machine, and then indirectly bonded to improve clinical efficiency and potentially to reduce treatment time (Ciuffolo *et al.*, 2006).

Conclusions

1. Placement of brackets in the positions determined by measuring the distance from the ME appears to be more accurate in the vertical dimension for the upper and lower anterior teeth.
2. The extent of error of bracket placement, regardless of which technique was used, demonstrates that archwire bending adjustments or repositioning of brackets will be necessary to achieve acceptable treatment results.

Address for correspondence

M. Ali Darendeliler
Department of Orthodontics
Faculty of Dentistry
University of Sydney
Level 2
2 Chalmers Street
Surry Hills
New South Wales 2010.
Australia.
E-mail: adarendel@dentistry.usyd.edu.au

Funding

This study was supported by Dental Board NSW, Australia (Grant No. R2456).

References

Aguirre M J, King G J, Waldron J M 1982 Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. American Journal of Orthodontics 82: 269–276

Andrews L F 1976 The straight-wire appliance. Origin, controversy, commentary. Journal of Clinical Orthodontics 10: 99–114

Andrews L F 1979 The straight-wire appliance. British Journal of Orthodontics 6: 125–143

Angle E H 1928 The latest and best in orthodontic mechanism. Dental Cosmos 70: 1143–1158

Balut N, Klapper L, Sandrik J, Bowman D 1992 Variations in bracket placement in the preadjusted orthodontic appliance. American Journal of Orthodontics and Dentofacial Orthopedics 102: 62–67

Bland M 2000 An introduction to medical statistics, 3rd edn. Oxford University Press, Oxford, pp. 269–272

Carlson S K, Johnson E 2001 Bracket positioning and resets: five steps to align crowns and roots consistently. American Journal of Orthodontics and Dentofacial Orthopedics 119: 76–80

Ciuffolo F 2006 Rapid prototyping: a new method of preparing trays for indirect bonding. American Journal of Orthodontics and Dentofacial Orthopedics 129: 75–77

Dellinger E L 1978 A scientific assessment of the straight-wire appliance. American Journal of Orthodontics 73: 290–299

Eliades T, Gioka C, Papaconstantinou S, Bradley T G 2005 Premolar bracket position revised: proximal and occlusal contacts assessment. World Journal of Orthodontics 6: 149–155

Fukuyo K, Nishii Y, Nojima K, Yamaguchi H 2004 A comparative study of three methods of bracket placement. Orthodontic Waves 63: 63–70

Kalange J T 1999 Ideal appliance placement with APC brackets and indirect bonding. Journal of Clinical Orthodontics 33: 516–526

Koo B C, Chung C, Vanarsdall R A 1999 Comparison of the accuracy of bracket placement between direct and indirect bonding techniques. American Journal of Orthodontics and Dentofacial Orthopedics 116: 346–351

McLaughlin R P, Bennett J C 1991 Finishing and detailing with a preadjusted appliance system. Journal of Clinical Orthodontics 25: 251–264

McLaughlin R P, Bennett J C 1995 Bracket placement with preadjusted appliance. Journal of Clinical Orthodontics 29: 302–311

McLaughlin R P, Bennett J C 2003 Finishing and preadjusted appliances. Seminars in Orthodontics 9: 165–183

Ricketts M R 1976 Bioprogressive therapy as an answer to orthodontic needs. American Journal of Orthodontics 70: 241–267