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Accuracy of bracket placement by orthodontists and inexperienced dental students

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Background: Well-finished orthodontic treatment begins with accurate positioning of the brackets on the teeth.
Aims: To compare the positions of orthodontic brackets placed by experienced clinicians and inexperienced trainees.
Methods: Twenty orthodontists (13 male, 7 female) representing experienced specialists, and 20 final year dental students (10 male, 10 female) representing inexperienced trainees, were asked to bond pre-adjusted straight-wire brackets at the centres of the clinical crowns of the teeth in a Class I crowded typodont set-up. The teeth were removed from the typodont, placed in a standardised jig and photographed. The vertical, mesio-distal and angular (tip) positions of the brackets, relative to the centres of the clinical crowns, were measured with the aid of imaging software. The accuracy of bracket placement by the groups was compared.
Results: The dental students took significantly longer than orthodontists to place the brackets (50.65 ± 16.33 minutes vs 28.53 ± 9.51 minutes, $p < 0.001$), but were more accurate than the orthodontists at positioning the brackets vertically (0.90 ± 0.21 mm vs 1.19 ± 0.23 mm, $p < 0.001$). There were no statistically significant differences between the dental students and the specialists in either the mesio-distal or the angular/tip positions of the brackets ($p > 0.05$). Both groups tended to bond the brackets with a distal tip. The students had slightly more right-left differences than the orthodontists. Mesio-distal errors in bracket placement were associated with rotated and displaced teeth.
Conclusions: Accurate direct bonding of orthodontic brackets to teeth does not appear to be related to clinical experience or specialist training.
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Introduction

The developments of direct bonding and pre-adjusted appliances have allowed orthodontists to achieve good results with greater clinical efficiency. However, ideal bracket placement is often impossible due to the position of the teeth and operator error.[1] Poorly positioned brackets result in poorly positioned teeth, which can lead to multiple rebonding of brackets, longer treatment and/or a less than ideal final occlusion.[2] Indirect bonding has been advocated because it is more efficient, reduces chair time, maximises the use of assistants and is more accurate than direct bonding.[3,4]

Indirect bonding is more accurate than direct bonding for angular positioning of brackets on maxillary and mandibular canines and vertical positioning of brackets on the maxillary canines, but it is less accurate than direct bonding of brackets on the mandibular second premolars ($p < 0.01$).[5] Koo et al. confirmed that indirect bonding was more accurate than direct bonding with respect to the vertical dimension, but there were no statistically significant differences between direct and indirect bonding in either the angulation or the mesio-distal positions of the brackets.[6] Recently, it has been reported that in both methods, the mean bracket placement errors were similar.[7]

Taylor and Cook[8] looked at direct bracket placement on the anterior teeth in a typodont set-up, and found that angular judgements by the participants were less consistent than linear assessments. They reported that no participant was able to reposition a bracket in the same position: some participants could reposition brackets within a 2 degree limit, but others had a variability of 19 degrees. This questions whether the

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Figure 1. The simulated Class I malocclusion.

variation is due to experience or to natural ability.[8] Balut and coworkers[9] looked at the accuracy of 10 faculty members bonding brackets to teeth in five typodont set-ups. They reported means of 0.34 ± 0.29 mm for vertical discrepancies and 5.54 ± 4.32 degrees for angular discrepancies. Three faculty members had significant angular deviations and two faculty members had significant vertical deviations. These findings suggest that different operators have different abilities at placing brackets. Fowler[10] reported that training and experience reduced both the intra- and inter-clinician error, however the reductions were small. He also reported that more recently trained clinicians were more consistent and more accurate in identifying the long axes of clinical crowns than experienced clinicians.

It is uncertain whether the accuracy of bracket placement is related to clinical experience, recent training, natural ability or diligence.[11–13] This study was designed to compare the abilities of experienced clinicians and inexperienced dental students to bond orthodontic brackets in the centres of the clinical crowns of the teeth in a standardised typodont set-up. All participants were given the same set of instructions, and a typodont set-up was used to simulate the clinical situation and avoid some of the variables associated with patients.

Materials and methods

Participants

The participants represented two groups with different levels of clinical experience and knowledge of orthodontics: group 1 consisted of 20 orthodontists (13 male, 7 female) representing the experienced clinicians, and group 2 was composed of 20 final year dental students (10 male, 10 female) representing the dental trainees with no previous experience at positioning orthodontic brackets. All participants were right handed.



Figure 2. The typodont with synthetic latex lips preventing direct vision of the premolar teeth.

Typodont set-up

Forty typodonts were set-up with the same Class I, crowded malocclusion. No tooth was so severely displaced that it prevented a bracket from being placed in the centre of the clinical crown (Figure 1). The typodont was then mounted on an adjustable rod to allow each operator to position the typodont as they would position a patient's head during bonding. Synthetic latex lips were used to prevent direct vision of the premolar teeth (Figure 2).

All participants were given a prepared handout with photographs illustrating the position each bracket was to be placed, and a selection of instruments (mirror, probe, periodontal probe, scaler, Hollenbach, flat plastic, rule and Unitek height gauge). They were also asked if they required any further instruments. Prior to the placement of the brackets the teeth were sandblasted with 50 mm alumina particles for 10 seconds. A cheek retractor (Sasa, Kongivor, Norway) was then placed, and the participants were asked to bond 20 Victory series low profile MBT brackets (3M Unitek, Monrovia, CA, USA) on the typodont teeth using Transbond (3M Unitek, Monrovia, CA, USA), and remove any excess adhesive. The brackets were then cured with the curing light available in each surgery. The time taken to complete the bonding was recorded. As the bond strengths of the brackets were not tested standardisation of the curing light was not necessary.

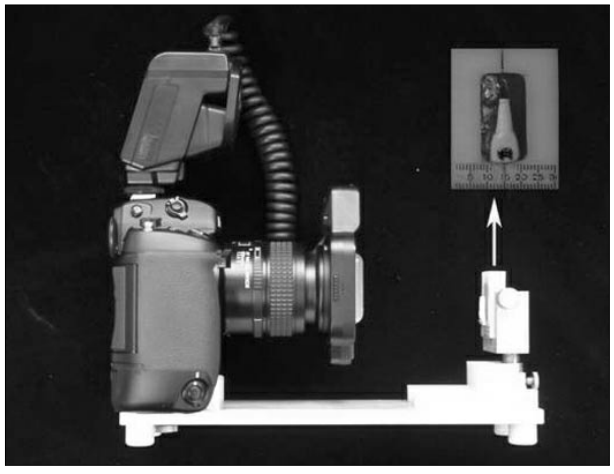


Figure 3. The photographic set-up used to record bracket placement on each tooth. A print of an upper central incisor is indicated by the arrow.

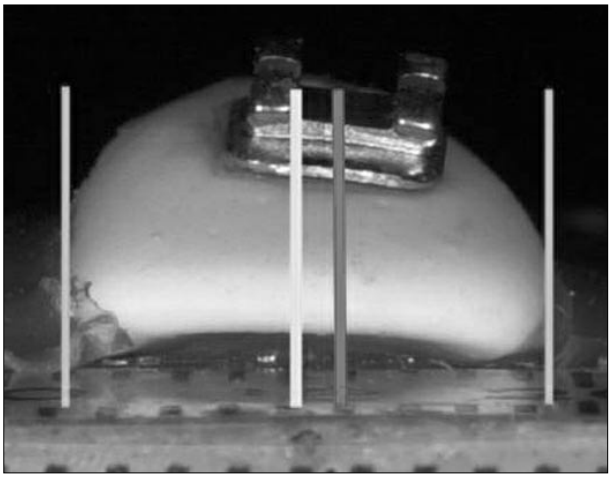


Figure 4b. Mesio-distal positioning error. The difference between the mesio-distal midpoints of the bracket (dark line) and the clinical crown (light line). The outer lines indicate the mesial and distal surfaces.

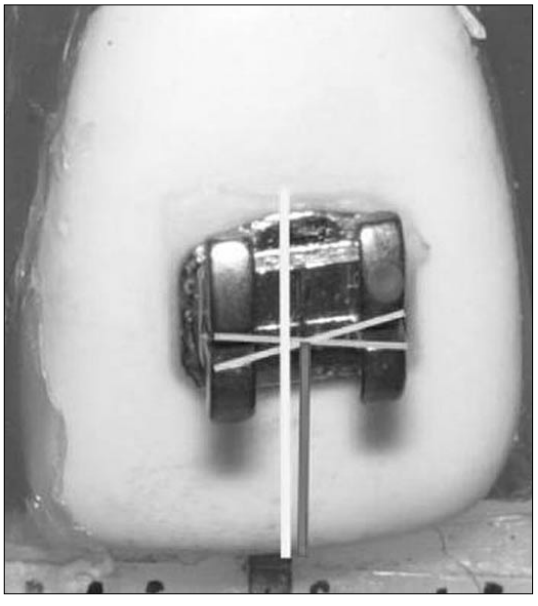


Figure 4a. Vertical positioning error. The difference between the centre of the bracket (dark line) and the incisal edge and the centre of the clinical crown and the incisal edge (light line).

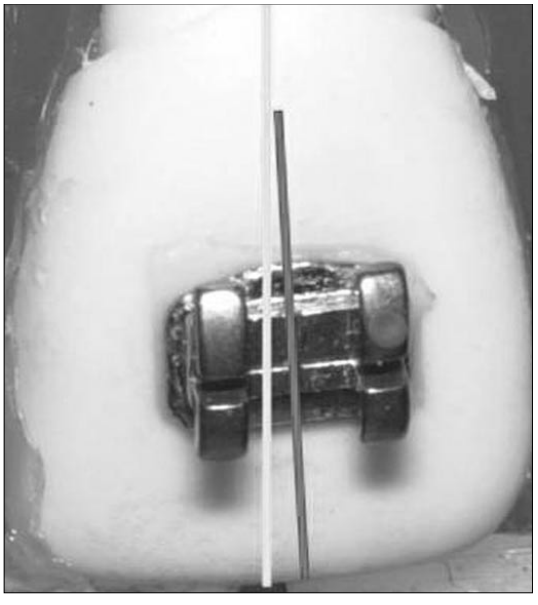


Figure 4c. Angular (tip) positioning error. The angle between the long axis of the bracket (dark line) and the long axis of the clinical crown (light line).

Identifying the bracket placement deviation or error

The teeth were removed from the typodont and the excess wax removed. Each tooth was then placed in an individually made jig (Odontosil, Dreve-Dentamid GMBH, Germany) and two digital photographs were taken (buccal and occlusal) using a Nikon D1 fitted with a Nikon 110 lens (Figure 3). The digital images were opened using AnalysSIS Pro 3.1 (Soft imaging system, Munich, Germany) and magnified to the same scale using the rule attached to the jig. The vertical position, the mesio-distal position and the angulation of the brackets were measured three times, and the mean of the three measurements used in all subsequent calculations.

The positioning errors were:

1. Vertical positioning error. Two diagonal lines were drawn across the archwire slot to locate the centre of the slot. The vertical height of the bracket was then measured from the incisal edge to the intersection

Table I. Errors in bracket placement by orthodontists and dental students.

	Teeth*	15		14		13		12		11	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Vertical	Orthod	1.31	0.31	0.66	0.44	1.34	0.55	1.26	0.36	2.24	0.44
	Student	1.18	0.39	0.37	0.36	0.63	0.55	0.77	0.34	1.70	0.27
Mesio-distal	Orthod	0.10	0.15	-0.15	0.18	-0.12	0.22	-0.24	0.12	-0.11	0.24
	Student	0.11	0.30	-0.16	0.22	0.09	0.36	-0.25	0.16	-0.14	0.24
Tip	Orthod	-2.13	4.28	-4.57	4.74	-2.04	4.24	1.32	1.62	-2.26	3.91
	Student	-4.84	3.92	-6.42	4.46	-5.87	3.86	-0.83	3.75	-1.66	2.73
	Teeth	21		22		23		24		25	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Vertical	Orthod	2.08	0.36	1.47	0.29	1.68	0.59	0.77	0.41	0.89	0.26
	Student	1.31	0.37	1.02	0.39	1.00	0.52	0.38	0.37	0.86	0.38
Mesio-distal	Orthod	-0.13	0.26	-0.02	0.20	-0.02	0.29	-0.12	0.25	-0.23	0.29
	Student	-0.03	0.19	-0.15	0.15	-0.01	0.377	0.04	0.35	-0.47	0.35
Tip	Orthod	-0.45	2.76	1.52	2.95	-2.22	5.395	-1.17	4.89	-3.34	4.49
	Student	0.69	2.371	2.55	2.39	0.23	4.692	-4.00	5.96	-2.78	3.50
	Teeth	45		44		43		42		41	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Vertical	Orthod	0.77	0.54	0.70	0.58	1.19	0.33	1.28	0.33	1.02	0.34
	Student	0.98	0.49	0.71	0.48	0.65	0.51	1.07	0.32	0.93	0.27
Mesio-distal	Orthod	-0.06	0.43	-0.26	0.33	-0.02	0.21	-0.04	0.13	-0.23	0.16
	Student	-0.38	0.22	0.14	0.57	0.22	0.33	-0.05	0.17	-0.05	0.15
Tip	Orthod	-0.27	6.24	0.33	3.92	-2.03	3.41	-4.62	2.80	-0.49	1.99
	Student	0.66	3.50	-1.00	4.61	0.82	3.74	-2.27	2.50	0.48	2.26
	Teeth	31		32		33		34		35	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Vertical	Orthod	1.23	0.37	1.34	0.39	1.27	0.39	0.57	0.50	0.83	0.47
	Student	0.87	0.37	1.05	0.41	0.87	0.32	0.72	0.48	0.90	0.53
Mesio-distal	Orthod	0.03	0.16	-0.02	0.14	-0.14	0.28	-0.18	0.34	0.15	0.41
	Student	-0.11	0.18	-0.29	0.20	-0.07	0.29	-0.33	0.48	0.06	0.63
Tip	Orthod	-1.49	2.85	-2.10	3.55	-3.00	3.49	-4.20	3.82	1.60	5.36
	Student	-1.94	2.14	-0.25	2.46	-2.57	3.04	-2.74	4.39	0.93	5.70

* FDI notation

Vertical and mesio-distal deviations in mm, tip/angular deviations in degrees

of the lines (Figure 4a). The vertical positioning error was calculated by subtracting this measurement from the actual centre of the clinical crown (length of the clinical crown/2).[14] Positive values indicated displacement towards the incisal edge and negative values displacement towards the gingival margin.

2. Mesio-distal positioning error. This was measured from the occlusal image. The midpoint of the tooth was identified, and the horizontal distance from the midpoint of the tooth to the midpoint of the bracket measured (Figure 4b). Deviations from the midline were given the following sign: positive (mesial) and negative (distal).

3. Angular/tip positioning error. This was defined as the angle between the vertical scribe line on the bracket and the long axis of the clinical crown. The two lines were highlighted and the software calculated the intersecting angle (Figure 4c). If the bracket was tipped mesially the value was recorded as positive, and if it was tipped distally a negative value was recorded.

Table II. Comparison of the errors in bracket placement by orthodontists and students, significant findings only.

Deviation/Tooth	Orthodontists		Students		*p*	More accurate
	Mean	SD	Mean	SD		
Vertical 13	1.34	0.55	0.63	0.55	<0.001	Student
Tip 13	-2.04	4.23	-5.87	3.86	<0.001	Orthod
Vertical 12	1.26	0.36	0.77	0.34	<0.001	Student
Vertical 11	2.24	0.44	1.70	0.27	<0.001	Student
Vertical 21	2.07	0.36	1.31	0.37	<0.001	Student
Vertical 22	1.47	0.29	1.02	0.39	<0.001	Student
Vertical 23	1.67	0.59	1.00	0.52	<0.001	Student
Vertical 24	0.77	0.41	0.38	0.37	<0.003	Student
Mesio-distal 45	-0.06	0.43	-0.37	0.22	<0.005	Orthod
Vertical 43	1.19	0.33	0.65	0.51	<0.001	Student
Tip 42	-4.62	2.80	-2.27	2.50	0.008	Student
Mesio-distal 41	-0.23	0.16	-0.05	0.15	0.001	Student
Vertical 31	1.23	0.37	0.87	0.37	<0.004	Student
Mesio-distal 32	-0.02	0.14	-0.29	0.20	<0.001	Orthod
Vertical 33	1.27	0.39	0.87	0.31	0.001	Student

Vertical and mesio-distal deviations in mm, tip/angular deviations in degrees

Data statistics

The accuracy of the bracket placement was analysed using the Statistical Package for the Social Sciences (SPSS for Windows, Release 12.0, SPSSInc, Chicago, Illinois). Since multiple and related tests were performed, a significance level of $p = 0.01$ was used in all tests. The measurement error was calculated by remeasuring the brackets in one quadrant (the lower right) for three participants. The method error was determined using the coefficient of variation (CV), which is the standard deviation divided by the mean expressed as a percentage.[15] It revealed that there was no significant difference between repeated measurements.

Results

The mean age of the orthodontists was 41 years (SD: 7.61 years; Range: 29–53 years), with on average of 8.88 years of experience (SD: 7.36 years; Range: 1–25 years). The mean age of the students was 26.4 years (SD: 4.08 years, Range: 23–42 years). The time taken by the orthodontists to bond the 20 brackets was significantly shorter (Mean: 28.53 minutes; SD: 9.51; $p < 0.001$) than the time taken by the dental students (Mean: 50.65 minutes; SD: 16.33).

The means and standard deviations of the three measurements (vertical, mesio-distal and tip) for each tooth are given in Table I, and the significant findings in Table II. The majority of the tip errors were negative, which suggests that the participants tended to bond the brackets with a distal tip (Table I). This tendency was not statistically significant.

Brackets bonded by the orthodontists were placed more incisally than the brackets bonded by the dental students (All, i.e. both upper and lower teeth: Orthodontists 1.19 ± 0.23 mm; Dental students 0.90 ± 0.21 mm, $p < 0.001$; Upper arch: Orthodontists 1.37 ± 0.27 mm; Dental students 0.92 ± 0.26 mm, $p < 0.001$). The vertical errors were then assessed relative to their mean bracket position vertically, and the dental students were slightly more accurate overall (Orthodontists: 0.56 ± 0.11; Dental students: 0.46 ± 0.07 mm, $p = 0.001$). There were no statistically significant differences between the groups when the mesio-distal and tip errors were compared (Table III).

When the side-to-side differences in placement were determined the orthodontists had significant ($p < 0.01$) right-left differences for the following teeth: Vertical and mesio-distal errors: Teeth 15, 25; 12, 22; Vertical error: Teeth 13, 23; Mesio-distal error: Teeth 41, 31; Tip error: Teeth 44, 34. The dental students

Table III. The difference in error of bracket placement between the upper and lower dental arches.

		Orthodontists		Students		
		Mean	SD	Mean	SD	*p*
Vertical	All	1.19	0.23	0.90	0.21	**0.000**
	Upper	1.37	0.27	0.92	0.26	**0.000**
	Lower	1.02	0.24	0.87	0.26	0.075
Vertical relative to the mean	All	0.56	0.11	0.46	0.07	**0.001**
	Upper	0.60	0.13	0.51	0.10	**0.024**
	Lower	0.44	0.15	0.37	0.07	0.053
Mesio-distal	All	-0.09	0.06	-0.09	0.09	0.983
	Upper	-0.11	0.06	-0.10	0.07	0.707
	Lower	-0.08	0.11	-0.08	0.14	0.833
Tip	All	-1.61	1.02	-1.54	1.25	0.857
	Upper	-1.59	1.41	-2.30	1.84	0.180
	Lower	-1.63	1.25	-0.79	1.40	0.054

Paired *t*-test, significant values in bold
Vertical and mesio-distal deviations in mm, tip/angular deviations in degrees

Table IV. Comparison of the mesiodistal errors in bracket placement with the initial tooth position (+ mesial, - distal).

Tooth	Mesio-distal		Initial position	Error
	Mean	SD		
15	0.10	0.23	Distal rotation	Mesial
12	-0.25	0.14	Palatal	Distal
11	-0.12	0.24	Mesio-palatal rotation	Distal
22	-0.08	0.18	Palatal	Distal
43	0.10	0.30	Distal rotation	Mesial
41	-0.14	0.17	Lingual	Distal
32	-0.15	0.22	Mesio-lingual rotation	Distal
35	0.11	0.53	Distal rotation	Mesial

had more significant right-left differences than the orthodontists ($p < 0.01$): Vertical and mesio-distal errors: Teeth 15, 25; Vertical and tip errors: Teeth 13, 23; 12, 22; 11, 21; Tip error: Teeth 41, 31; Mesio-distal and tip errors: Teeth 42, 32; 43–33; Mesio-distal error: Teeth 45, 35 (Table II).

The teeth with the greatest malpositions were assessed and there was a trend for tooth position to be associated with specific mesio-distal errors in placement of the brackets (Table IV).

Discussion

This study was designed to compare the 'ability' of two groups, each with a different experience of clinical orthodontics, to bond brackets to the centres of the clinical crowns of teeth in a standardised typodont set-up. The groups were experienced specialists and undergraduate dental students, and both groups were given the same instructions at the start. The accuracy of each participant to bond brackets in centres of the clinical crowns was assessed by measuring the deviations of the bonded brackets from the defined positions given to each participant. Not surprisingly, the orthodontists completed the exercise in slightly more than half the time taken by the students, with fewer side-to-side errors, but with a small, but statistically significant, difference in vertical positioning. The orthodontists placed the brackets more incisally than the students, although the latter also placed the brackets more incisally than requested. Although there was a tendency for the position of a tooth to predispose towards certain errors in placement, for example, brackets on mesio-lingually rotated teeth tended to be placed more distally, the errors in placement were small and, it could be argued, may not be of clinical significance.

Many orthodontists will agree that the pre-adjusted orthodontic appliances are an efficient and effective means of treating most malocclusions. Patient response to treatment can be an important limiting factor as well as the orthodontist's ability to precisely place an appliance.[16] Identification of bracket positioning errors is important, as poorly placed brackets may result in more archwire adjustments,

replacement of incorrectly placed brackets and increased treatment time.[2] Although the finishing stage of treatment invariably requires the archwires to be modified because appliance prescriptions are based on averages, accurate placement of brackets at the start of treatment is considered to be an important step towards successful treatment.[17]

It was not surprising to find that the orthodontists needed less time to bond the 20 brackets than the dental students. With their greater experience of, and familiarity with, the materials one would expect them to perform the task more quickly and efficiently than the students. There was no time limit imposed on the participants, so the inexperienced students had ample time to complete the task.

On average, the upper central incisor brackets bonded by the orthodontists were placed about 0.5 mm more incisally than the brackets bonded to the same teeth by the students. Other brackets had greater or lesser errors in placement. These findings may not be randomly distributed, but may be due to one or more of the following factors: the students followed the instructions more carefully than the orthodontists; the students were better than the orthodontists at identifying the centres of the clinical crowns; the orthodontists may have subconsciously placed the brackets more incisally because this is a common procedure in practice. All participants were asked to follow the instructions on the handout and not to modify the positions of the brackets to compensate for specific aspects of the malocclusion.

Both groups bonded the brackets more incisally than requested. This is in agreement with Koo et al.[6] who reported that directly placed brackets tended to be placed towards the incisal edge, but in contrast to others[7] who found that directly placed brackets tended to be towards the gingival margins (–0.27 ± 0.46 mm). The vertical errors in this study (Orthodontists: 1.19 ± 0.23 mm; Dental students: 0.9 ± 0.21 mm) appear to be greater than the errors reported by other investigators (Table III). Other researchers[8] studied the accuracy of bracket placements within or beyond a 0.5 mm range, and reported that more brackets fell within the range than outside it, which suggests that brackets can be accurately positioned vertically. In the present study the vertical errors relative to their means (Orthodontists: 0.56 ± 0.11 mm; Dental students: 0.46 ± 0.07 mm) are similar to those obtained by Balut et al. (0.34 ± 0.29 mm).[9]

Typodonts are frequently used for training in fixed appliance technique, but they are unable to exactly recreate the clinical situation. In particular, the teeth we used lacked a clearly demarcated cemento-enamel junction, which may have contributed to the vertical errors.[18] All teeth were set up 'fully erupted' so that the participants did not have to estimate the position of the cemento-enamel junction.

There were no statistically significant differences between the orthodontists and dental students in relation to the mesio-distal or tip errors (Table I and II). The mesio-distal errors in this study (Orthodontists: –0.09 ± 0.06 mm; Dental students: –0.09 ± 0.09 mm) are comparable to the errors reported in other studies (0.19 ± 0.12 mm;6 –0.11 ± 0.30 mm;[7] +/- 0.22 mm[10]). The tip errors we found (Orthodontists: –1.61 ± 1.02 degrees; Dental students: –1.54 ± 1.25 degrees) are comparable to the errors also reported by other investigators (2.57 ± 1.79 degrees;[6] 5.54 ± 4.32 degrees[9]), but were greater than those reported by Hodge et al.,[7] who reported the smallest angular discrepancies (0.08 ± 0.14 degrees).

The initial position of the tooth may influence bracket placement. For example, when a tooth is rotated the error is likely to be in the opposite direction to the direction of rotation. A bracket is more likely to be placed mesially on a tooth with a distal rotation and, conversely, a bracket is more likely to be placed distally on a tooth with a mesio-palatal rotation. If a tooth is palatally placed the error is likely to be incisal and distal. There was also a tendency for all participants to place the brackets with a slight distal tip.

The right-left comparisons did not indicate a particular trend in bracket placement. Other investigators have reported a trend for left side bonds (direct and indirect) to be more accurate in the upper arch, and right side bonds to be more accurate in the lower arch.[5]

It has been stated that errors in bracket placement are related to the skill of the operator, tooth structure, size of the clinical crowns and tooth position.[9] This study demonstrated that with a prepared handout even orthodontically inexperienced operators can perform as well as, if not better than, experienced operators in accuracy of bracket placement, albeit at a cost of increased time. This suggests that operator experience may not be an important factor determining the accuracy of bracket positioning.

As mentioned earlier, the present study may have evaluated the influence of clinical experience on the errors of bracket placement. Further studies will be needed to identify if other factors affect the accuracy of bracket positioning.

Conclusions

1. Orthodontists and senior dental students have similar errors in direct bonding of orthodontic brackets.

2. The provision of clear instructions enabled the dental students to place brackets as accurately as experienced clinicians, although they did require more time to do so.

3. The initial position of a tooth may influence accurate bracket placement, even when there is adequate space for the bracket.

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References

1. Garino F, Garino GB. Computer-aided interactive indirect bonding. Prog Orthod 2005;6:214–23.
2. Carlson SK, Johnson E. Bracket positioning and resets: Five steps to align crowns and roots consistently. Am J Orthod Dentofacial Orthop 2001;119:76–80.
3. Kalange JT. Ideal appliance placement with APC brackets and indirect bonding. J Clin Orthod 1999;33:516–26.
4. Sondhi A. Bonding in the new millennium: Reliable and consistent bracket placement with indirect bonding. World J Orthod 2001;2:106–14.
5. Aguirre MJ, King GJ, Waldron JM. Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. Am J Orthod 1982;82:269–76.
6. Koo BC, Chung C, Vanarsdall RL. Comparison of the accuracy of bracket placement between direct and indirect bonding techniques. Am J Orthod Dentofacial Orthop 1999;116:346–51.
7. Hodge TM, Dhopatkar AA, Rock WP, Spary DJ. A randomized clinical trial comparing the accuracy of direct versus indirect bracket placement. J Orthod 2004;31:132–7.
8. Taylor NG, Cook, PA. The reliability of positioning preadjusted brackets: an in vitro study. Br J Orthod 1992;19: 25–34.
9. Balut N, Klapper L, Sandrik J, Bowman D. Variations in bracket placement in the preadjusted orthodontic appliance. Am J Orthod Dentofacial Orthop 1992;102:62–7.
10. Fowler PV. Variations in the perception of ideal bracket location and its implications for the preadjusted edgewise appliance. Br J Orthod 1990;17:305–10.
11. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets – are standards as expected? Angle Orthod 2004;74:450–3.
12. Chen S, Chen YX, Li W. A study on the center height of clinical crowns for the people with normal occlusion in Chengdu area. Hua Xi Kou Qiang Yi Xue Za Zhi 2004;22:138–41.
13. Muchitsch AP, Droschl H, Bantleon HP, Blumauer D, Stern G. The effect of the vertical bracket position on the orthodontic finish. Fortschr Kieferorthop 1990;51:195–203.
14. Andrews LF. The Straight-wire appliance. Br J Orthod 1979;6:125–43.
15. Bland, M. An Introduction to Medical Statistics. 3rd edn. Oxford: Oxford University Press. 2000; pp 269–272.
16. Poling R. A method of finishing the occlusion. Am J Orthod Dentofacial Orthop1999;115:476–87.
17. Bai D, Luo SJ, Chen YX, Xiao LW. The clinic skill in fixed appliance based on characteristics of Chinese normal Occlusion. Hua Xi Kou Qiang Yi Xue Za Zhi 2005;23:32–4.
18. Henao SP, Kusy RP. Frictional evaluations of dental typodont models using four self-ligating designs and a conventional design. Angle Orthod 2005;75:75–85.