SCIENTIFIC SECTION

A randomized clinical trial comparing the accuracy of direct versus indirect bracket placement

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Objective: To determine the accuracy of direct or indirect bracket placement.

Design: A prospective, randomized comparison of 2 different methods of bracket placement.

Setting: Queens Hospital, Burton upon Trent, UK between February and May 2001.

Materials and method: Twenty-six consecutive patients requiring upper and lower MBT™ pre-adjusted Edgewise appliances had their labial segments bonded directly or indirectly according to a split mouth system of allocation. Before and after bond-up all brackets were photographed and measured from tracings to determine positional differences from the ideal.

Results: Using ANOVA (General Linear Model), vertical errors were found to be greater than those in the horizontal plane, which in turn were greater than angular errors ($p < 0.05$). Errors were greater in the maxillary arch than in the mandibular arch. There was no significant difference between the mean errors produced by the two methods of bracket placement.

Conclusions: Mean bracket placement errors were similar with both techniques.

Key words: Accuracy, bracket placement, direct bonding, indirect bonding, randomized clinical trial

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Introduction

The advent of pre-adjusted appliances has increased the importance of accurate bracket placement.[1] However, despite the clinical importance of accurate bracket placement relatively few studies have compared the accuracy of bracket placement by indirect and direct methods. It is often suggested that indirect bonding will allow more precise bracket location, but this has not always been supported by research.[2] For example, Aguirre *et al.* found that the technique improved vertical placement of brackets on maxillary canines, and the angulation of maxillary and mandibular canines.[3] In another study, Koo *et al.* noted improvements only in the vertical plane and then only on certain teeth.[4] Small sample sizes and inconsistency of methods used to evaluate bracket positioning as well as intra- and inter-examiner variability make it difficult to draw firm conclusions from the existing literature.[3]

The aim of the present study was to compare the accuracy of direct and indirect bonding techniques.

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Null hypothesis

There is no difference in the accuracy of bracket placement between direct and indirect bonding.

Materials and methods

Sample

We used a power calculation to determine that a minimum sample size of 22 patients was required with an alpha level of 0.05 and a power of 0.8 using previously published data.[4] As a result, 26 patients were enrolled in the trial from the waiting list of Queens Hospital, Burton on Trent. These patients all required treatment with upper and lower full arch fixed appliances. Pre-adjusted Edgewise brackets with a 0.022-inch slot (3M, Unitek, PO Box 1, Bradford BD5 9UY, UK) were used in the study. The following exclusion criteria were applied:

- Subjects with worn dentitions, fractured/restored incisal edges or cusp-tips, an apparent tooth size

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discrepancy and when anterior teeth were absent, as these features would adversely affect bracket placement.
- Cases where the initial malocclusion prevented ideal bracket placement, or where observation of the mesiodistal and angular position of the brackets was obscured by crowding.
- We decided that bracket accuracy would only be measured on incisors and canines, as the aesthetic consequences of incorrect bracket positioning are more serious on anterior teeth than elsewhere in the mouth. In addition, because the subjects were mostly children, ideal bracket placement on premolars is often not possible at that age because full clinical crown heights are not yet available. There is also some evidence that bracket placement errors are greatest in the labial segment.[3] Although Koo *et al*. showed a similar distribution of errors overall on all teeth it should be borne in mind that access to premolars was likely to have been less of a problem in their study because mannequins were used rather than patients.[4]

Random allocation method

The subjects had their labial segments bonded using one of the following split-mouth systems of allocation:

	Right	Left
Set up one	Indirectly placed	Directly placed
	Directly placed	Indirectly placed
Set up two	Directly placed	Indirectly placed
	Indirectly placed	Directly placed

The split mouth technique was used because each patient could act as their own control, which in turn allowed a reduction in total sample size without adversely affecting validity. In addition, the chosen method of randomization reduced variability according to patient access and co-operation.

Patients were each allocated a number 1–26 in turn when they were seen for consent and initial records. They were then allocated into one of the split-mouth set-ups using a randomization table.[5] A table of random sampling numbers was used to rearrange the numbers into two columns representing the two trial set-ups.[6] To reduce bias, an unweighted dice throw was used to physically randomize the order of the quadrants in which brackets were placed.

The set up was randomly allocated at the time that records were collected. This allowed for construction of the working models and transfer trays ahead of the bond-up appointment. During the trial the operator could not be blind to the method of bracket placement; nevertheless, measurements were made blindly by the same operator, 3 months after bonding, without reference to whether the bracket had been bonded directly or indirectly.

Ethical approval

Ethical approval was obtained from the Local Research Ethics Committee of South Staffordshire Health Authority. A patient information sheet was given to each patient in the study and written consent for entry into the trial was also obtained.

Model preparation

In addition to a set of study models, one set of working models for each patient in the trial was cast and the vertical facial axes of the clinical crowns were marked. The vertical dimension for bracket placement was then determined using the MBT™ Bracket Placement Chart. This chart allows the orthodontist to select a set of numbers representing the average centre of the clinical crown for a given patient.

The brackets were then placed on the models and their heights were checked with the aid of a height-measuring gauge to ensure ideal positioning as prescribed by the manufacturer. This aimed to give the operator the best opportunity to site each bracket in a demonstrably prescriptive position and optimize direct bracket placement.

Photographic technique

All the bracketed teeth were photographed at two-thirds magnification using a Yashica™ Dental Eye III (Single Lens Reflex) Camera as follows:

- The occlusal surface of each model was placed on a cross on an acetate so that the contact point of the central incisors lay over the intersection of the cross (Figure 1). A photocopy was then made onto a second acetate sheet.
- The acetate copy of the occlusal surfaces of the teeth could then be reversed (Figure 2) allowing a model to be consistently positioned over its photocopied image (Figure 3).
- Acetates were aligned over graph paper that had been secured on to a turntable at axis point 0/0. The intersection of the cross on the acetate was aligned at axis point 0/30 mm.
- The camera was placed in a fixed and recorded position in relation to the turntable with graph paper secured.

Figure 1 The occlusal surface of each model was placed on a cross on an acetate so that the contact point of the central incisors lay over the intersection of the cross

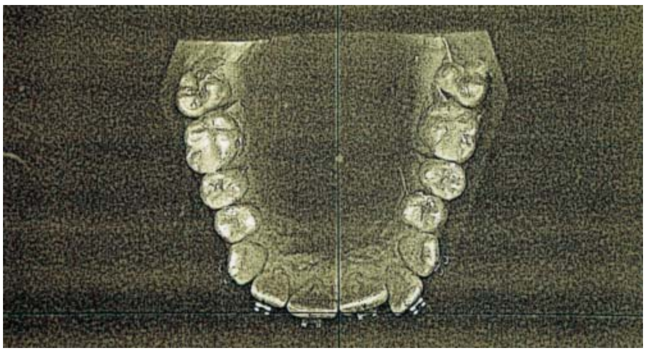

Figure 2 The acetate copy of the occlusal surfaces of the model teeth could then be reversed

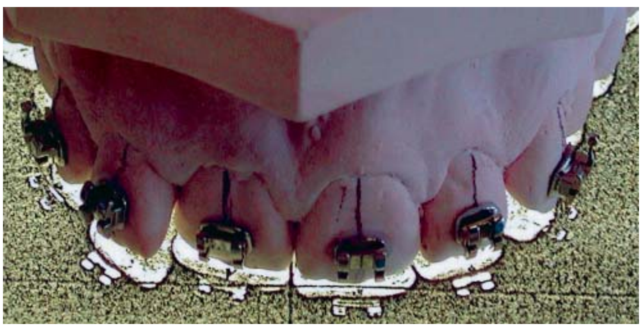

Figure 3 The reversed acetate copy of the occlusal surfaces of the model teeth could then be reversed allowing a model to be consistently positioned over its photocopied image

- A line was scored on the acetate perpendicular to the labial surface of each tooth. This allowed the camera lens to be accurately aligned to take photographs parallel to the labial surfaces of the teeth.

Bonding

Once photographs had been taken of all the bracketed teeth those brackets in quadrants to be bonded directly were discarded to allow for tray construction over those brackets to be placed indirectly. The Burton Indirect Bonding Technique was used for tray construction and indirect bracket placement.[7]

The patients in the trial had their appliances fitted both directly and indirectly according to which set up had been allocated at the beginning.

Measurement method

- Alginate impressions were taken over the brackets *in situ* and die stone models were cast.
- Models were photographed using the acetates described above with the location lines.
- All photographs were scanned into a PC and stored as JPEG files.
- Two sets of the 3M Unitek MBT™ brackets were measured and the results averaged so that the linear measurements for height and width could be calculated to scale. These values provided a fixed reference point for comparison with the study casts of the bracketed models to confirm that there was no distortion in the impressions. Had there been distortion with the impression technique then the magnitude of this could have been calculated from the known bracket dimensions. Error associated with the potential distortion was then ruled out at the same time as the photographic technique was shown to be reproducible.
- The outline of the crowns of the teeth with brackets *in situ* prior to bond-up, together with the vertical outline of the tie wings, were then traced manually at ×15 magnification.
- The vertical outline of the tie wings and the vertical and horizontal midlines of the post bond-up pictures were added to the first tracing in order to identify vertical, horizontal and angular differences.

Where the gingival aspect of the vertical dimension on the bracket base was obscured in the taking of the impressions, this line was constructed after bonding from the known value of the vertical dimension of the bracket prior to bond-up. Calculation of the horizontal and vertical components of the differences between the center of a bracket ideally placed and its actual position derived linear measurements. For each tooth the linear measurements were calculated using a scale of known bracket dimensions. This was necessary since, although the camera angulation and photographic magnification remained constant, natural tooth inclinations were variable. Angular differences, measured in degrees, were calculated using Pythagoras' theorem with a minus value denoting a more distal angulation than desirable. Linear measurements were recorded in millimeters, a minus value denoting a more distal position than ideal in the horizontal placement of the bracket and a minus value in the vertical plane indicating a more incisal position.

On the rare occasions where the images of the crowns pre and post-bond up could not be superimposed accurately the pictures were superimposed on the mesio-incisal edges of the incisors and the mesial arm and cusp tips of the canines. This situation only arose when crowns had continued to erupt between initial collection of records and fitting of the appliances.

Photographic and tracing reproducibility

For reproducibility testing 10 randomly selected teeth with brackets *in situ* on the pre-bond-up models from different patients were photographed twice in order to assess the reliability of the method. The photographic images were traced and superimposed on the original to check for variations in vertical, horizontal and angular dimensions. In addition, 10 superimpositions were repeated 1 month after the initial tracings to test for reproducibility of the tracing technique.

Results

Reproducibility testing

The Pearson correlation coefficient for each type of error was close to unity, for the measurement of the vertical, mesiodistal and angular measurement errors. Error analysis using an estimation of mean square error, ranged from 0.004 mm and 0.109° for angular errors.[8] Student *t*-tests detected no systematic bias.

Main study

Summary results are shown in Table 1.

In order for the whole data set to be analyzed together, angulation errors were converted into linear measurements by converting degrees into radians and using the bracket height as the radius of a circle with the length of the arc being the linear expression of angular difference.

A positive error value in the horizontal error direction indicates that a bracket was mesially placed with respect to the ideal; a negative value indicates a distally placed bracket. A positive vertical error indicates that a bracket was more incisally placed on the tooth than ideal and a negative sign indicates a gingivally placed bracket. Positive angular errors indicate mesial tilting of a bracket whilst negative angular errors indicate a more distal tilt.

The effects of the five main variables — direction of error, tooth type, side of mouth, upper or lower jaw, and method of bracket placement — were analysed by means of MANOVA using a General Linear Model (GLM) in Minitab® (Minitab Inc., 3081 Enterprise Drive, State College, PA 16801-3008, USA.) along with the effects of the main interactions between them (Table 2). Between group differences were further compared using Tukey's Pairwise Comparisons (Table 3). For this test a similar sign for two groups in the cross-tabulation indicates a significant difference between them. Different signs indicate that the difference is not significant.

Table 4 shows overall means and ranges for different types of errors. This shows that, although the mean values are similar following direct and indirect placement, the ranges of each type of error are greater for direct placement than for the indirect method.

Discussion

The results of this study show that there is no difference in the overall accuracy of bracket placement between direct and indirect bonding (Table 1). However, our

Table 1 Summary of results by tooth

Tooth	Directly placed brackets						Indirectly placed brackets					
	Vertical (mm)		Horizontal (mm)		Angular (°)		Vertical (mm)		Horizontal (mm)		Angular (°)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
13	−0.27	0.28	−0.65	0.46	0.31	0.29	−0.27	0.08	−0.14	0.20	0.04	0.12
12	−1.67	2.91	−0.51	0.43	0.26	0.07	−0.03	0.20	−0.21	0.16	0.05	0.12
11	−0.33	0.34	−0.05	0.25	0.17	0.38	−0.29	0.14	−0.12	0.22	0.01	0.14
23	−0.18	0.33	−0.16	0.55	0.03	0.25	−0.14	0.13	0.01	0.11	−0.06	0.12
22	−0.23	0.20	0.22	0.46	−0.07	0.23	−0.13	0.13	0.04	0.19	−0.03	0.07
21	−0.23	0.32	0.19	0.36	−0.06	0.27	−0.30	0.11	−0.08	0.21	−0.03	0.11
33	−0.16	0.23	−0.54	0.77	0.30	0.20	−0.25	0.28	−0.11	0.16	0.06	0.21
32	0.06	0.36	0.18	0.06	−0.01	0.58	−0.16	0.22	0.04	0.15	0.08	0.14
31	−0.13	0.26	0.06	0.20	0.08	0.15	−0.21	0.29	−0.17	0.20	−0.02	0.06
43	−0.07	0.27	−0.07	0.27	0.01	0.26	−0.23	0.18	−0.06	0.24	0.06	0.20
42	0.14	0.27	0.14	0.27	−0.07	0.23	−0.15	0.20	0.12	0.21	0.08	0.14
41	−0.15	0.38	−0.15	0.38	−0.10	0.15	−0.23	0.18	0.04	0.22	−0.02	0.06

Table 2 Statistical analysis of main interactions using ANOVA

Source	DF	Sum of Squares	Mean of squares	*F*	*p*
Error	2	6.721	4.035	37.06	0.000
Teeth	2	0.409	0.039	0.36	0.698
Right/left	1	0.218	0.665	6.10	0.014
Upper/lower	1	0.660	1.323	12.15	0.001
Direct/indirect	1	0.000	0.108	0.99	0.320
Error*teeth	4	1.940	0.581	5.34	0.000
Error*right/left	2	0.420	0.469	4.31	0.014
Error*upper/lower	2	0.668	0.672	6.17	0.002
Error*direct/indirect	2	0.130	0.240	2.20	0.112
Teeth*right/left	2	0.147	0.273	2.50	0.083
Teeth*upper/lower	2	1.037	0.660	6.06	0.002
Teeth*direct/indirect	2	0.490	0.360	3.31	0.037
Right/left*upper/lower	1	0.453	0.863	7.93	0.005
Right/left*direct/indirect	1	0.375	0.762	7.00	0.008
Upper/lower*direct/indirect	1	0.290	0.579	5.31	0.021
Error	620	67.514	0.109		
Total	691	96.771			

Table 3 Tukey's pairwise comparisons of all variables

Group	Vertical	Mesio-distal	Canine	Lateral incisor	Right side	Maxilla Direct
Mesio-distal	*					
Angular	*	*				
Lateral incisor			NS			
Central incisor			NS	NS		
Left side					NS	
Mandible						*
Indirect						NS

NS = not significant. * = Significance at the 0.05 level.
95% confidence intervals for significant interactions (mm):
Vertical –0.17 to –0.24 Angular –0.02 to –0.10 Mandible –0.01 to –0.09
Mesio-distal 0.00 to + 0.08 Maxilla –0.07 to –0.015

Table 4 A summary of bracket placement errors

Method	Error	Mean (mm)	SD	Minimum	Maximum	Range
Direct	Vertical	–0.27	0.46	–1.67	0.14	1.81
	Horizontal	–0.11	0.30	–0.65	0.22	0.87
	Angular	0.08	0.14	–0.07	0.31	0.38
Indirect	Vertical	–0.20	0.08	–0.30	0.03	0.27
	Horizontal	–0.05	0.10	–0.21	0.12	0.33
	Angular	0.02	0.05	–0.06	0.08	0.14

results reveal that errors in the vertical plane were significantly greater than those in the mesio-distal plane. This may have occurred because tooth crowns are generally less wide than they are long and there may be less scope for bracket positioning errors. Directly bonded brackets tend to be placed more gingivally than the ideal position. Previous studies have shown no significant operator errors in judging horizontal bracket positioning[9]. Mesio-distal errors, however, were significantly greater than angular differences.

Table 2 shows significant differences for placement errors between right and left sides of the mouth, and between upper and lower teeth. The placement method had no overall effect upon mean placement accuracy. Nevertheless, the presentation of errors for combined tooth types reveals that the error ranges are much smaller when indirect placement is used. For example, the vertical error range for direct placement is 1.81 mm, compared with only 0.27 mm for the indirect placement. Our results indicate that the main advantage of indirect placement is that it reduces the envelope of error of bracket position in each of the three directions examined. Vertical errors with direct placement were especially marked and outside that advocated by Andrew.[11]

Methodological differences make it difficult to compare the present results with those of other studies. For example, Aguirre *et al*.[3] and Balut *et al*.[10] did not consider mesio-distal errors, although clinically such errors can cause rotational irregularities. Furthermore, It can be difficult to assess mesio-distal errors, particularly where teeth overlap, but Koo *et al*.[4] felt able to do so by sectioning model teeth with a saw in an *ex vivo* study.

It was also interesting that we found that errors in angular placement of brackets were small and less than those either in the vertical and mesio-distal dimension. This suggests either that the various bracket design features that aid alignment are particularly effective or that the operator in this study was most accurate in this respect when placing brackets and this contrasts with previous findings,[9–11] which have shown that clinicians could consistently locate the vertical facial axis of teeth, but that they were less accurate at estimating tooth angulations.[10] Furthermore, Andrews[11] found that operators were poor at judging angular measurements.

There has been disagreement in the literature regarding the accuracy of indirect bonding when compared to the standard direct technique. The present results show no significant overall difference between direct and indirect bonding in terms of accuracy in bracket placement. However, indirect placement does reduce the envelope of error of bracket position.

Conclusions

- There was no difference between mean bracket placement errors for direct or indirect methods.
- The range of error in the three directions assessed were greater for direct than indirect placement.
- The magnitude of the findings are of clinical relevance.

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Authors and Contributors

TH was responsible for study design; obtaining sponsorship; seeking ethical approval; performing the trial and recording the results obtained; securing logistic, administrative, and technical support and data interpretation; drafting, critical revision, and final approval of the article. DS was responsible for conception of the study and patient recruitment. AD was responsible for drafting, critical revision, and final approval of the article. PR was responsible for data and statistical analysis; drafting, critical revision and final approval of the article. PR is the guarantor.

Pat Watkin provided the working models and indirect bonding trays used in the study. Mike Sharland and Marina Tipton provided photographic assistance. 3M Unitek provided the MBT™ brackets used in the study.

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