

# Comparison of Convergence Angles Achieved in Posterior Teeth Prepared for Full Veneer Crowns

Paresh B. Patel\*, David G. Wildgoose† and Raymond B. Winstanley‡

**Abstract** - This study compares the convergence angle of preparations for posterior gold crowns made by fourth/fifth year undergraduate dental students, clinical teaching staff and general dental practitioners. Sixty dies were cast from impressions previously taken of clinical preparations by clinicians within each of the four groups. Each die was trimmed and sectioned in both mesio-distal and bucco-lingual planes before being projected using an overhead projector, thereby enabling the convergence angle silhouette to be measured. The results show the greatest convergence angle range to be produced by the least experienced students ( $10^{\circ}$ – $82^{\circ}$ ). However, no significant difference ( $p>0.05$ ) was found when students with one further year of experience were compared to experienced staff. The degree of conformity to the ideal taper ( $4^{\circ}$ – $14^{\circ}$ ) was no greater than 50% for any of the groups.

KEY WORDS: Convergence angle, Comparison study, Operator experience

## INTRODUCTION

The General Dental Council, in the second edition of “The First Five Years”,<sup>1</sup> considers that undergraduate dental students on graduation must be competent in the restoration of teeth using crowns and bridges. To achieve high standards with indirect restorative work there is a learning curve as with any procedure. However, by assessing the quality of the work carried out it is possible to gain an insight into the amount of time necessary to achieve adequate proficiency in a particular technique. This in turn aids academic institutions when planning undergraduate curricula. The current study aimed to assess a fundamental aspect of crown and bridgework in order to identify the standards being achieved.

The convergence angle (CA) of a preparation is the combined angle made by opposing axial walls when measured against the vertical. Retention and resistance are important factors when preparing a posterior tooth to receive a full veneer crown. Retention features are those which prevent the dislodgement of a crown along its path of insertion, e.g. forces acting along the long axis of the tooth. Resistance features are those which prevent crown dislodgement when oblique (non-axial) forces act on the tooth.

In theory a preparation with parallel walls would have the greatest retention and resistance form. Early authors had discussed parallel walls<sup>2,3</sup>, but seating a crown on such a preparation can be as difficult as preparing it. A fine degree of taper has been advocated to allow for elimination of preparation undercuts and to allow complete seating of the restoration<sup>4</sup>. The recommended degree of taper varies considerably in the literature, with values from  $4^{\circ}$  to  $14^{\circ}$  being suggested<sup>5,6</sup>.

Investigation of dies prepared by general dental practitioners<sup>7</sup>, prosthodontists<sup>8</sup> and dental students<sup>9</sup> have found that conforming to theoretical values of CA is, in practice, very difficult. Nevertheless, there has been very little work on the variation of CA between clinicians of varying experience. This study aims to investigate the CA achieved by undergraduate students, general dental practitioners (GDPs) and hospital based clinical staff.

The aims of this study were to determine whether there was a variation in CA for teeth prepared for full veneer crowns between student groups and experienced clinicians and to assess whether there was a variation in CA between the groups compared to those recommended in the literature. Additionally, to identify at what stage in the undergraduate course student groups reach a competency level comparable to their senior colleagues.

We also wished to determine the following:

- the more accurate of two methods identified in the literature by which CA may be measured and compare the CA produced by two operator student groups.
- whether there is any difference between two experienced clinician groups when CA are compared and compare student and experienced clinician groups and determine whether there is any significant difference in CA.

## MATERIALS AND DESIGN

Four operator groups were involved in the investigation: fourth and fifth year undergraduate dental students, general dental practitioners, and teaching staff experienced in prosthodontics. Dies were cast from impressions taken for the construction of full veneer posterior gold crowns on prepared teeth. Impressions from each operator group were selected randomly from impressions received at the dental laboratory both at the dental hospital and the independent laboratory. The dies were

\*BDS MFGDP (UK) MFDS RCS

†M.Phil, MCGI, LCGI, FETC, ILTM

‡BDS, MDS, FDSRCS(Ed)

sectioned mesio-distally and bucco-lingually and the CA measured. There were 60 dies in each group, giving 240 altogether. The silicone impressions used for the construction of the crowns were collected between April 2000 and December 2000 from the dental hospital and external laboratories. The sole criterion was that there should be at least one full veneer posterior crown preparation. An equal number of maxillary and mandibular molar and premolar preparations were included for each group. However, as the same CA is recommended for all posterior teeth, no distinction was made between first and second premolar and molar teeth.

All impressions were coded in a manner that would not allow group identification. Once the process of measuring was complete the unique identifier code was broken to identify clinician group.

Prior to pouring any casts, all impressions were cleaned and any debris removed under running water before being air-dried using compressed air. A type IV die stone was used for casting each die. Before conducting any tests, all materials and equipment were stored for 24 hours in a dental laboratory monitored for temperature ( $23\pm 2^{\circ}\text{C}$ ) and humidity ( $50\pm 5\%$ ).

The powder:water ratios for mixing were those recommended by the manufacturer (100:20). The powder was added to the liquid within the mixing vessel of a mechanical spatulator (Multivac 2, Degussa, Germany). Mixing was initiated by hand for 30 seconds using a stainless steel spatula, with all further mixing being undertaken under a vacuum of 0.8 bar for a further 30 seconds (paddle speed of 360 rpm).

A surface tension reducing agent (Tensilab, Zhermack, Italy) was applied to the surface of each silicone impression before drying gently with air. Upon completion of mixing the vacuum was released and the contents carefully vibrated into each impression using a mechanical vibrator (Pulsar, Manfredi, Italy) before being left to set.

Each cast was allowed to set for one hour before being removed from the impression. The casts were sectioned in order to remove the individual dies using a diamond disc (Segment-O-Flex, Intensiv, Switzerland) with a cutting thickness of  $>0.2\text{mm}$ .

The margins of each die were exposed using a pear shaped tungsten carbide bur. With the two dies, one die was sectioned in the bucco-lingual plane and the second was sectioned in the mesio-distal plane using the same diamond flexi disc.

#### Determination of convergence angle

In order to determine the best method for measuring the degree of CA of the prepared dies (*Figure 1*), a pilot study was conducted to compare two methods previously reported in the literature. The first method projected the silhouette of the sectioned die onto a flat surface by means of an overhead projector (OHP)<sup>10,11</sup>. The second method used a series of photocopied images of the same dies which could be magnified to allow measurement of CA<sup>9</sup>.

To evaluate the accuracy and reproducibility of each method, ten dies were selected and measured by three independent operators. The results were analysed using



**Figure 1.** Sectioned dies ready for examination and measurement

a one-way analysis of variance (ANOVA), and a two-sample student (*t*-test) to determine whether any significant difference existed. It was found that in the photocopy method, two of the 18 determinations showed a statistical significance ( $p < 0.05$ ). In the OHP method, there was no statistically significant difference found between the operators. This latter method was therefore chosen, and in fact the operators involved in testing the two methods all reported that they found the OHP method to be more user friendly. All further results were recorded and analysed by means of a one-way analysis of variance (ANOVA), and two-sample student *t*-test for any significant differences.

#### RESULTS

The results for CA comparisons between each of the four groups are shown in *Table 1*. The mean preparation angles for fourth year students were approximately  $24^{\circ}$  and  $27^{\circ}$  for the respective bucco-lingual (BL) and mesio-distal (MD) surfaces. Fifth year undergraduate students achieved mean preparation angles of approximately  $15^{\circ}$  BL and  $16^{\circ}$  MD for the sections. When the determinations for clinical staff were assessed it was found that very similar CA means were achieved for both BL and MD surfaces of approximately  $17^{\circ}$ . General dental practitioners achieved mean CA of approximately  $15^{\circ}$  for both surfaces measured. These results were compared to the  $4^{\circ}$  to  $14^{\circ}$  recommended in the literature<sup>12</sup>.

Thirteen percent of BL and 3% of MD CA prepared by fourth year students and 43% for both BL and MD for students one year their senior were within the recommendations. Fifty percent of clinical staff and 70% of GDPs were within the range with the BL CA, but only 37% of clinical staff and 57% of GDPs achieved MD CA within those recommended (*Figures 2 and 3*).

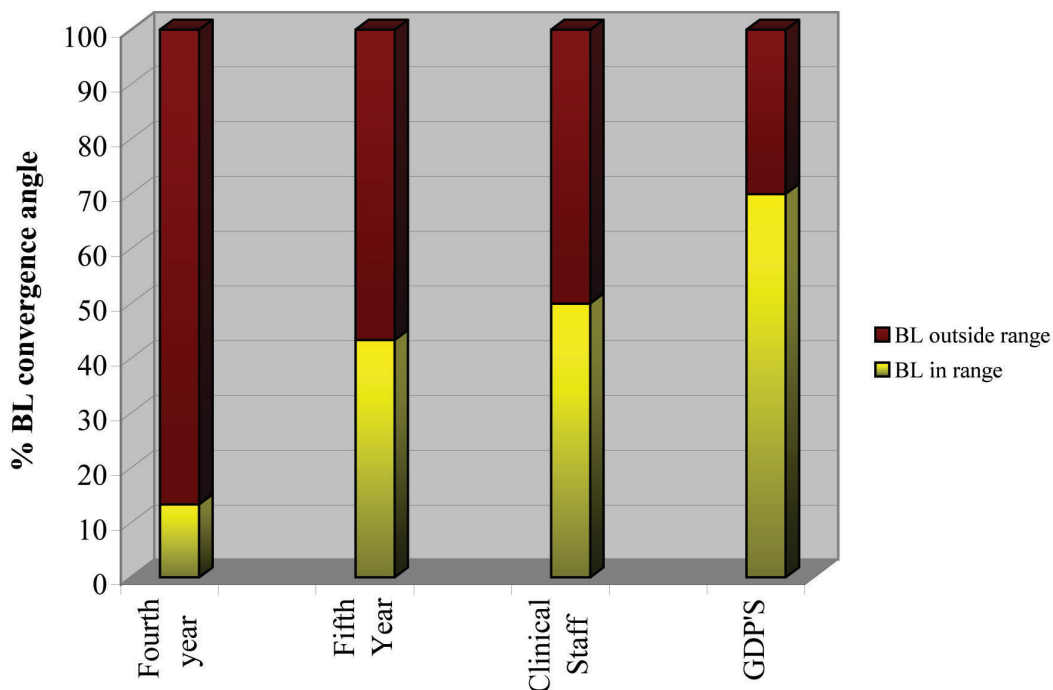
Although fourth year undergraduate students displayed the greatest angle of convergence range,  $11^{\circ}$  to  $51^{\circ}$  for BL and  $10^{\circ}$  to  $82^{\circ}$  for MD surfaces, fifth year students achieved angles nearest to the ideal,  $6^{\circ}$  to  $24^{\circ}$  for BL and  $3^{\circ}$  to  $26^{\circ}$  for MD surfaces when compared to all other groups. GDPs and clinical teaching staff achieved a CA close to that recommended in the literature ( $4^{\circ}$ ) at the lower end ( $8^{\circ}$ – $0^{\circ}$ ) in both sections. However, at the upper end the results were between  $31^{\circ}$  and  $44^{\circ}$ .

A one-way analysis of variance (ANOVA) and student *t*-tests comparing all four groups found a significant differ-

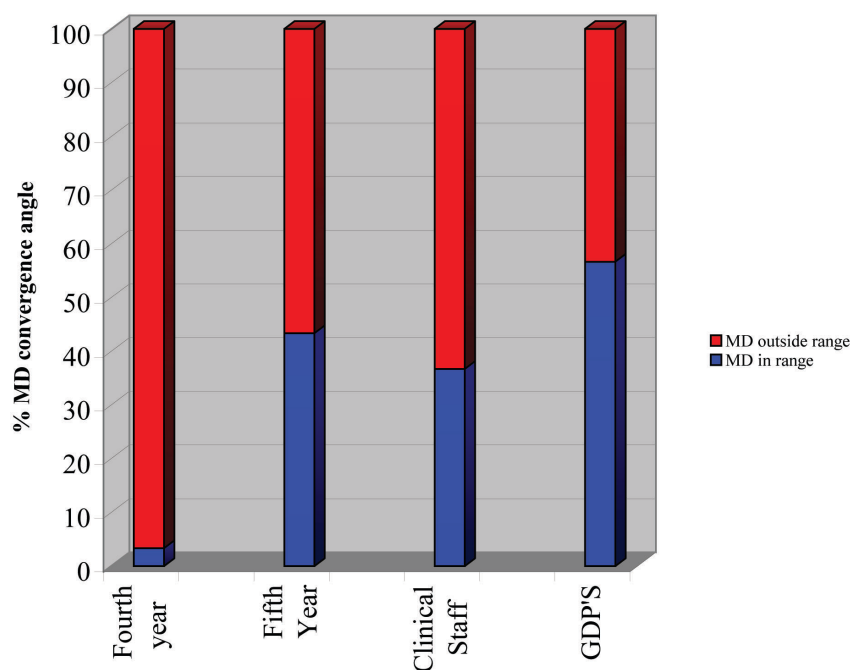
**Table 1.** Summary of results for the four clinical groups evaluated

Group	BL mean	BL SD	MD mean	MD SD	BL Range	MD Range
Fourth year	24.23°	± 11.23	27.03°	± 15.00	11–51°	10–82°
Fifth year	14.67°	± 5.04	16.33°	± 5.82	6–24°	3–26°
GDPs	14.33°	± 7.02	14.88°	± 7.39	8–36°	6–31°
Clinical staff	17.08°	± 10.39	16.77°	± 6.98	0–44°	5–33°

Key: BL = Bucco-Lingual, MD = Mesio-Distal, SD = Standard Deviation.



**Figure 2.** Bucco-lingual convergence angles as a percentage of each group compared to the ideal.



**Figure 3.** Mesio-distal convergence angles as a percentage of each group compared to the ideal.

ence ( $p < 0.05$ ) between the fourth year undergraduates and the other three groups when both bucco-lingual and mesio-distal CA were compared. No significant difference ( $p > 0.05$ ) was found between the other three groups.

## DISCUSSION

Although fourth year undergraduate students were under close supervision during the clinical procedures for full veneer crown preparations, they showed a significant difference ( $p < 0.05$ ) to the other three groups. This result although less than the ideal may be attributable to the year group having only recently completed their Advanced Restorative Course in crown and bridge techniques, taking time for the acquired knowledge to be extrapolated to the clinical environment. With more experience of direct clinical work this orientation may improve. When the results of mean values ( $\sim 24^\circ$  to  $27^\circ$ ) for this less experienced student group are compared to those found in previous studies ( $\sim 19$  to  $27^\circ$ ) for clinical preparations undertaken by students<sup>9,13-15</sup> they correspond closely. However, the experience levels of these student groups were not reported.

When the results for undergraduate fifth year students were compared to their fourth year colleagues they showed a marked improvement. This may be due to the structure of the fifth year clinical course, where students are expected to complete a considerable number of tooth preparations thereby increasing both their clinical skills and experience. However, when the results were compared between fifth year students and the more experienced clinical staff, or GDPs with in excess of 20 years experience no statistical difference was found ( $p > 0.05$ ). This suggests that many of the skills students require for such clinical work may be achieved during the period of one year.

When the CA range (BL  $6^\circ$ – $24^\circ$  and MD  $3^\circ$ – $26^\circ$ ) produced by fifth year undergraduates is compared to that previously reported by Kent<sup>8</sup> ( $8.6^\circ$ – $26.6^\circ$ ), the results are unexpectedly close. This group achieved a CA range slightly better than clinical staff and GDPs with many years of experience. This may be as a result of undergraduate students being under close clinical supervision when crown preparations are carried out. However, the GDPs and clinical staff have obviously deemed the preparations used in this study acceptable since crowns were made for them.

The findings of this investigation show that mean CA for the MD plane are greater than those of the BL in each group except clinical staff. This finding is supported in the literature by Leempoel<sup>7</sup>, who suggests that it is difficult to examine the MD aspects of crown preparations for undercuts; therefore the mean for this plane is likely to be greater than that of the BL. Other factors, which may lead to the differences in CA include:

- Access to teeth. Molar teeth are difficult to prepare, particularly the further back in the mouth they are.
- The identification of possible undercuts leading to over preparation out of caution.
- Tooth anatomy. The bucco-lingual inclination of molar teeth may exacerbate the degree of taper achieved.

Workers in the field of prosthodontics have suggested an ideal range of taper of  $4^\circ$ – $14^\circ$ <sup>12,14,16</sup>. However, as these values are based on experimental laboratory work, they could be deemed the 'mechanical ideal'. The advent of resin-based cements has led to alternative retention for crowns, with some studies<sup>17</sup> suggesting that the degree of taper becomes less significant when resin based adhesive luting cements are used.

However, in light of the findings in this study, there is perhaps a need for improvement in the preparations carried out by all groups. The National Health Service annually spends a considerable amount of resource in the provision of full veneer crowns, and although preparations with greater CA may be satisfactory, the long term prognosis is not as certain as that where preparations are carried out to more defined parameters.

## CONCLUSIONS

The findings from the study show that

- Although each of the selected groups had mean convergence angles outside the range recommended ( $4^\circ$ – $14^\circ$ )<sup>12</sup>, all but one group were within  $3.1^\circ$  of the maximum prescribed.
- Only fourth year undergraduate students showed a significant difference ( $p > 0.05$ ) to other groups when both BL and MD convergence angles were compared.
- Experienced staff produced preparations with closely corresponding BL and MD convergence angles  $> 0.6^\circ$ .
- General dental practitioners achieved mean convergence angles close to those recommended in the literature.

## ADDRESS FOR CORRESPONDENCE

David G. Wildgoose, Department of Adult Dental Care, School of Clinical Dentistry, Clarendon Crescent, Sheffield S10 2TA, UK. E-mail: d.g.wildgoose@sheffield.ac.uk

## REFERENCES

1. *The First Five Years. A Framework for Undergraduate Dental Education*. 2nd edn. London: General Dental Council, 2002.
2. Conzett, J.V. The gold inlay. *Dent. Cosmos.*, 1910; **52**:1339.
3. Ferrier, W.I. Cavity preparation for gold foil, gold inlay and amalgam operations. *J. Nat. Dent. Assoc.*, 1917; **4**:441.
4. Jorgenson, J.D. The relationship between retention and convergence angle in cemented veneer crowns. *Acta. Odont. Scan.*, 1955; **13**:35–39.
5. Mack, P.J. A theoretical and clinical investigation into the taper achieved on crown and inlay preparations *J. Oral. Rehabil.*, 1980; **7**:255–265.
6. Tylman, S.D. and Malone, W.F.P. *Theory and practice of fixed prosthodontics*. 7th edn. St Louis: C.V. Mosby, 1978; 27–31.
7. Leempoel, P.J.B., Lemmens, P.L.M., Snoek P.A. and van 't Hof, M.A. The Convergence angle of tooth preparations for complete crowns. *J. Prosthet. Dent.*, 1987; **58**:414–416.
8. Kent, W.A., Shillingburg, H.T. and Duncanson, M.G. Jr. Taper of clinical preparations for cast restorations. *Quintessence. Int.*, 1988; **19**:339–345.
9. Noonan, J.E (jr). and Goldfogel, M.H. Convergence of the axial walls of full veneer crown preparations in a dental school environment. *J. Prosthet. Dent.*, 1991; **66**:706–708.
10. Johnson, A. The effect of five investing techniques on air bubble entrapment and casting nodules. *Int. J. Prosthodont.*, 1992; **5**:424–433.

11. McCormick, J.T., Antony, S.J., Dial, M.L., Duncanson, M.G. Jr. and Shillingburg, H.T. Wettability of elastomeric impression materials: effect of selected surfactants. *Int. J. Prosthodont.*, 1989; **2**:413-420.
12. Shillingburg, H.T., Hobo, S. and Whitsett, L.D. *Fundamentals of fixed prosthodontic*, 2nd edn. Chicago: Quintessence Publ Co, 1981: 79-80.
13. Eames, W.B., O'Neal, S.J., Monterio, J., Miller, C., Roon, J.D. (jr) and Cohen, K.S. Techniques to improve the seating of castings. *J. Am. Dent. Assoc.*, 1978; **96**: 432-437.
14. Ohm, E. and Silness, J. The convergence angle in teeth prepared for artificial crowns. *J. Oral. Rehabilitation.*, 1978; **5**:371-375.
15. Weed, R.M., Suddick, R.P. and Kleffner, J.H. Taper of clinical and typodont crowns prepared by dental students. *J. Dent. Res.*, 1984; **4**:286: 1036 (Abst).
16. Occhionero, R.L. and Demarco, T.J. *Clinical Dental Science Review*. New York: Arco Publ Co, 1979; 45-54.
17. el-Mowafy, O.M., Fenton, A.H., Forrester, N. and Milenkovic, M. Retention of metal ceramic crowns cemented with resin cements: Effects of preparation taper and height. *J. Prosthet. Dent.*, 1996; **76**:524-529.