

Taper of Full-Veneer Crown Preparations by Dental Studentsat the University of the West Indies

Reisha N. Rafeek, BDS, MSc,¹ William A. J. Smith, DDS, MSc,¹ Kevin G. Seymour, BDS, MSc, PhD, DRD,² Lifong F. Zou, BSc, PhD,² & Dayananda Y. D. Samarawickrama, BDS, PhD²

¹ School of Dentistry Faculty of Medical Sciences, University of the West Indies, Mount Hope, Trinidad and Tobago ² Department of Adult Oral Health, Queen Mary's School of Medicine and Dentistry, London, UK

Keywords

Convergence angle; coordinates; metrology.

Correspondence

Reisha N. Rafeek, University of the West Indies, School of Dentistry Faculty of Medical Sciences, Mount Hope 0001, Trinidad and Tobago. E-mail: Reisha.Rafeek@sta.uwi.edu

Accepted: September 1, 2009

doi: 10.1111/j.1532-849X.2010.00625.x

ABSTRACT

Purpose: The ideal taper recommended for a full-veneer crown is 4° to 14° , but this is very difficult to achieve clinically, and studies on taper achieved by dental students have found mean taper measurements ranging from 11° to 27° . The objective of this study was to examine and compare the taper of teeth prepared for full-veneer crowns by dental students on typodonts in the laboratory and on patients, and also to compare the results with those of other dental schools.

Materials and Methods: Preparations were scanned by specialized metrology equipment that gave the taper of the preparation in a buccolingual (BL) and mesiodistal (MD) plane.

Results: No undercut was detected on any of the laboratory specimens; however, 12.5% of clinical specimens were undercut. The mean taper of the laboratory anterior specimens were 26.7° BL and 14.9° MD, and the laboratory posterior specimens were 18.2° BL and 14.2° MD. The mean taper of the clinical anteriors were 31.6° BL and 16.8° MD, and the clinical posteriors were 16.8° BL and 22.4° MD.

Conclusions: This study shows that although the taper achieved by dental students in the University of the West Indies when preparing teeth for full-veneer crowns was outside the ideal range of 4° to 14° , it is comparable to those achieved by dental students in other schools.

It is necessary to investigate the outcomes of teaching not only as part of curriculum development and ongoing quality audit, but also to examine the competency of graduates.¹ This can confirm that these students are on par with students of other dental schools in the reported literature. The preparation of a tooth for a full-veneer crown is a common procedure in general dental practice, and therefore it is essential that dental students are competent in achieving acceptable abutment taper. This study aimed to assess the taper of tooth preparations achieved by dental students at the School of Dentistry, University of the West Indies and to compare this to other dental schools.

The angle formed between opposing walls of the tooth preparation is called taper or convergence angle.² Retention of castings decreases with increasing taper and has been shown to be inversely proportional to taper or convergence angle.³ The retention of the full-veneer crown depends not only on taper but also the length and diameter of the walls of the preparation. The ideal taper recommended is 2° to 7° per axial wall or 4° to 14° total convergence angle,^{5,6}

At the School of Dentistry, University of the West Indies, dental students are taught full-veneer crown preparations in the Crown & Bridge Laboratory Course in the fourth year, and they are given lectures and handouts in the didactic sessions. In the practical sessions, live demonstrations are first conducted under a fixed mounted video camera with a magnified image on television monitors before students are expected to prepare plastic typodont teeth set in a mannequin phantom head, as this has been shown to improve performance during the teaching process.⁶ Students are taught to create a preparation with a 6° taper by holding a tapered bur parallel to the axial wall while cutting⁴; however, this target is rarely achieved in a clinical setting by dentists or dental students, and a target of 12° taper may be a more realistic criterion.⁷

There is a low correlation between preclinical laboratory performance on typodonts and clinical performance by dental students involving the preparation of a full-veneer crown.⁸ Several studies have been conducted measuring tapers achieved by dental students and have found mean tapers ranging from 11° to 27° ,^{5-7,9-13} while studies on specialists and general dental

practitioners have found mean tapers in the range 14° to 20° .^{12,14–16} Despite the higher than ideal tapers found in some studies, tapers of up to 20° have been shown to be clinically acceptable, with few crowns reported to have loosened or dislodged.^{10,11}

Taper has been measured by various methodologies,^{5,10,11} and this study uses a modern technology commonly used in the manufacturing industry, 3D coordinate metrology. It characterizes and defines the geometry of objects. This method has more recently been applied to human "freeform" surface measurements.¹⁷⁻¹⁹ The engineering machine has been adapted by software modification to analyze human freeform surfaces, and data acquisition is achieved by use of both optical laser probes and the stylus. Such measurement consists of three processes: the "extraction" of 3D coordinates relating to the surface of the sample; the interpolation of these coordinate data into mathematical formulae for them to be transformed into a computer image; and image analysis—where linear, angular, or volumetric measurements are produced as required.

The objective of this study was to assess and compare the taper of teeth prepared for full-veneer crowns by dental students achieved on typodont teeth in a preclinical laboratory setting and that achieved on patients under clinical supervision, and to compare this with other dental schools.

Materials and methods

Laboratory specimens

Preparations for full-veneer crowns were done by fourth-year dental students working in the laboratory on typodont teeth under examination conditions. Both anterior (n = 49) and posterior casein teeth (n = 50) were prepared. The anteriors were all incisors, and the posteriors were all molars. The anterior teeth were prepared for a porcelain-fused-to-metal (PFM) crown with a labial shoulder margin and a palatal chamfer margin. The posterior teeth were prepared for a full-gold crown with chamfer margins. The students are taught the preparations with the use of depth grooves and also putty indices as reduction guides. The taught sequence of preparation is occlusal reduction, buccal and palatal reduction, followed by the proximal axial reduction.

These teeth were then scanned, and the degree of taper determined both buccolingually (BL) and mesiodistally (MD). Figure 1 shows an example of a tooth being scanned. The teeth are digitized by a stylus of SM25-1 fixed on Triclone 90 (Renishaw, Gloucestershire, UK). The digitization is conducted by Tracecut Controlling Software Package (Renishaw), and the digitization parameters are set up as such: the stylus diameter is 1.0 mm, the sample interval (scanning pitch in both X and Y directions) is 0.1 mm, scanning speed is 500 mm/min, and scanning deflection is 0.5 mm. As the tip is a sphere with 1-mm diameter, and as it has been calibrated before the digitization process, wherever the contact is on a freeform surface, it is always a tangent contact at the digitizing point; therefore, the coordinates of the point (X, Y, and Z) are compensated to its precise position in X, Y, and Z. These digitized data are reconstructed into a solid 3D image (Fig 2) using Cloud software package (UCL, London, UK). Two angle measurements from each sample are made at the midsection across buccal and lin-



Figure 1 A die being scanned by the Triclone 90.

gual surfaces and mesial and distal surfaces, and this gives the taper angle in the BL plane and the MD plane, respectively. This measurement is unique in that it is truly 3D freeform surface digitization, rather than 2D profiling. Also the data analytical software can lay the image in a particular alignment in the 3D space; therefore, the mid-BL and mid-MD angles can be calculated at the same plane for each of the samples, and this eliminates the potential error in angle calculation from sample misalignment.



Figure 2 Digitized data reconstructed into a solid 3D image using Cloud software package.

Clinical specimens

Treatment in the dental school provided by dental students is carried out under supervision of a clinical instructor. Approval for this study was obtained from the university research committee, but no special instructions that would change from routine clinical procedure were given to either staff or students. Twenty anterior and 20 posterior teeth prepared clinically by fifth-year dental students for full-veneer castings between January and October 2004 were included in the study. These students had been in clinic since Year 3, so they had 2 years of clinical experience, but only 1 year of experience with crown and bridge.

The anterior teeth were all PFM preparations, and the posterior teeth were either PFM preparations or full-gold crown preparations. Fourteen incisors, six canines, eleven premolars, and nine molars were prepared.

Several posterior teeth were root treated and had either amalgam cores with or without dowels placed, or cast dowel/cores. The anterior teeth had composite restorations or core buildups, with or without dowels if root treated, as the clinical need dictated. Impressions were taken of the prepared teeth in an addition-cured poly(vinyl siloxane) impression material (Reprosil, Dentsply Caulk, Milford, DE). The patients were not screened or selected for this study, but rather the first 20 anterior and posterior impressions approved by a clinical instructor as acceptable to fabricate the casting during the time period were included in the study. No additional instructions were given to either students or clinical staff. The only change in routine was that the impression was poured twice. The impression first pour was used to fabricate the casting, and then a second pour was made for a sectional die used to measure the taper.²⁰ Type IV die stone (Vel Mix, Kerr Corp., Orange, CA) was used and was mixed under vacuum and poured. After setting, the dies were trimmed specifically with the standing base milled to be flat to the long axis of the prepared tooth. The sides were also milled so the buccal and palatal were parallel to each other as were the mesial and distal. A pilot study showed that Quick Set Die Spacer Blue (Belle de St. Claire, Kerr Corp.) was needed for the machine to effectively read the preparation. The die spacer was painted over the crown preparations in two layers according to manufacturer's instructions, to overcome the incompatibility of the pink stone to the probe. The interval between the first and second coating was 25 minutes. The purpose of placing the die spacer was to smooth the surface texture, and one layer did not render the surface smooth. Also, the scanning time was much longer, with one layer as much of the surface texture was recorded, which was exhaustive to the data capture. The placement of the second layer allowed the probing tracer to follow

the surface profile rather than the details of the surface texture. As the spacer was evenly distributed on each side of the buccal, lingual, mesial, and distal surfaces, the angles of BL and MD remain the same.

To evaluate the degree of taper of the prepared tooth, the die stone was placed in a vice grip and scanned by specialized metrology equipment. This gave the exact taper of the preparation in a BL plane and MD plane. Twenty anterior and 20 posterior dies were measured. All results were recorded, and data were analyzed by means of one-way analysis of variance (ANOVA) and Student's *t*-tests for any significant differences.

Results

The most common teeth prepared in this study were incisors (49 laboratory, 14 of the clinical specimens), followed by molars (50 laboratory, nine of the clinical specimens). Table 1 shows the summary of the results of mean taper and the range of tapers for each of the four groups.

Laboratory specimens

There was no undercut detected on any of the laboratory specimens (as compared to the clinical specimens where 12.5% were undercut). The mean tapers of the laboratory anterior specimens were 26.7° (BL) and 14.9° (MD), and the lab posterior specimens had a mean taper of 18.2° and 14.2° in the BL and MD planes, respectively. The overall mean taper for the laboratory specimens was 22.5° (BL) and 14.5° (MD). The greatest mean taper occurred while preparing the BL on the anterior specimens.

Clinical specimens

The mean tapers achieved on the clinical specimens, however, were greater, with the mean taper of the anterior clinical specimens 31.6° in the BL plane and 16.8° in the MD plane; the clinical posteriors were 16.8° in the BL plane and 22.4° in the MD plane. The overall mean tapers for the clinical specimens were 24.2° (BL) and 19.6° (MD). The greatest mean taper of the clinical specimens also occurred while trying to prepare the BL walls in the anterior specimens.

Table 2 shows the percent of specimens falling within the ideal taper range of 4° to 14° , and Figure 3 shows a graph of mean tapers and standard errors achieved for each group. The preps had a wide range, particularly the BL taper of the anteriors, both lab (3° to 62°) and clinical (7° to 68°) (Table 1). The MD taper range was lower in the laboratory specimens than in the clinical specimens, and a greater percentage of these

Table 1 Mean tapers and range of tapers (excluding undercut teeth) in buccolingual (BL) and mesiodistal (MD) planes. (SD = Standard deviation)

Group	BL mean	BL SD	MD mean	MD SD	BL range	MD range
Lab anteriors (n = 49)	26.7°	14.1°	14.9°	7.7°	3°-62°	1°-31°
Lab posteriors (n $=$ 50)	18.2°	7 .1°	14.2°	5.0°	4°-32°	7°-29°
Clinical anteriors (n $= 20$)	31.6°	18.8°	16.8°	15.9°	7°-68°	1°-57°
Clinical posteriors (n $=$ 20)	16.8°	12.3°	22.4°	12.8°	9°-37°	5° - 48°

Table 2 Percentage of specimens falling within ideal taper range of 4° to 14°

MD
45%
62%
30%
20%

fell within the ideal taper range. Although the mean tapers achieved were lower, there was no significant difference detected between the mean tapers achieved in the laboratory compared to the clinic (p > 0.05) except for the MD taper of posterior teeth (p < 0.05). When comparing anterior and posterior tooth preparations, anterior BL tapers were significantly higher than posterior BL tapers (p < 0.05) in both laboratory and clinical specimens; however, there was no significant difference in the MD tapers of anterior and posterior preparations of both clinical and laboratory specimens.

When examining taper within the same group of tooth preparations, the anterior BL tapers were significantly higher than the anterior MD tapers in both laboratory and clinical specimens (p < 0.05). The posterior BL tapers were significantly higher than the posterior MD tapers only in the laboratory specimens, and there was no significant difference in the clinical specimens.

Discussion

In this study, the overall mean tapers achieved were higher than the recommended range of 4° to 14° ; however, the results were similar to many other clinical studies involving dental students.^{5,9-13} Noonan and Goldfogel⁵ found mean tapers of 19.5° (BL) and 18.5° (MD) in 909 clinical posterior full-gold crown preparations done by students in a US dental school. This study closely matched those, with 16.8° (BL) and 22.4° (MD) mean tapers. Sato et al¹¹ assessed 63 clinical posterior preparations of students in a Japanese dental school and found mean tapers of 18.8° (BL) and 19.2° (MD). Patel et al¹² investigated the posterior clinical preparations of fourth- and fifth-year dental students as well as staff and general dental practitioners. The fifth-year students produced mean tapers of 14.7° (BL) and 16.3° (MD).

Mack⁹ obtained 25 clinical specimens from five UK dental schools and reported an overall mean taper of 22.1° for anteriors and 25.4° for posteriors, which was similar to this study, with overall mean tapers of 24.2° for anteriors and 19.6° for posteriors. Ohm and Silness¹⁰ also looked at anterior and posterior clinical specimens from dental students in Norway and found mean tapers of 22.5° (BL) and 12.8° (MD) compared to 24.2 (BL) and 19.6 (MD) for this study.

Studies investigating taper achieved in the laboratory also yielded similar results to those achieved in this study. Robinson and Lee⁶ assessed laboratory posteriors in a UK dental school and found overall mean tapers of 14° to 15° , which is close to the overall mean taper of 16.8° found in this study. Smith et al⁷ assessed both anterior and posterior teeth prepared in the laboratory by US dental students and found mean tapers in the range of 12° to 20° , which is similar to this study, with a mean taper range of 14° to 27° for laboratory-prepared specimens. A more recent study¹³ comparing laboratory posterior preparations done by dental students in Egypt, the United States, and Saudi Arabia found mean tapers achieved in the range of 15° to 20° (BL) and 14° to 20° (MD). This study closely matches those with mean tapers of 18.2° (BL) and 14.2° (MD).



Figure 3 Mean tapers (with error bars) achieved for each group of tooth preparations (Lab = Laboratory; Clin = Clinical; BL = buccolingual; MD = mesiodistal). The specimens with the greatest mean tapers were the BL of the anterior clinical and laboratory tooth preparations. This demonstrates students' difficulty in preparing an adequate lingual/palatal wall on anterior teeth to oppose the buccal aspect of the tooth preparation, both in the laboratory and on patients.

The dental students in this study achieved a 19.6° overall mean taper for clinical posterior specimens, very similar to that achieved by dentists in a study conducted in the United States by Nordlander,¹⁴ who found an overall mean taper of 19.9° from 208 preparations. Another study in the United Kingdom¹² on clinical posterior specimens that included dentists as hospital-based clinical staff and general dentists found mean tapers of 17° for staff and 14.6° for general dentists. Kent et al¹⁵ examined 418 clinical dies of Shillingburg's preparations over 12 years and found a mean taper of 14.3° with a range 8° to 26°.

Students may be able to do "better" crown preparations or improve the taper and quality of the preparations by paying more attention to detail,¹⁷ using magnification loupes, and also using putty matrices as reduction guides. Recent investigations into a new bur found the quality of labial preparations for metal-ceramic crowns was enhanced,²¹ and suggest the use of standardized new burs may be warranted.

Taper is not the only factor to consider in the retention of fixed restorations; length and diameter of the preparations also play a role in retention of the casting. The use of resin-bonded cements also affect retention and may reduce the relevance of the 4° to 14° "ideal" taper, as laboratory studies have shown better retention of crowns with up to 24° and 35° taper cemented with resin cements when compared to crowns cemented with zinc phosphate cement on 6° to 12° tapers.^{22,23} Adhesive restorations, such as the adhesive onlay, are a more conservative alternative to the full-coverage crown, and a practitioner would have to demonstrate additional skills, for example, restoration design, incorporating other features into the preparation, such as bevels, determination of draw, and the preparation of divergent walls within boxes. With the modern trends in fixed prosthetics and focus on implants, perhaps future research may be directed into assessment of a wider variety of preparation features, which measure a greater variety of student hand skills; however, from an academic teaching perspective, the measurement of taper of full-crown preparations is still a reasonable gauge of student hand skills and useful from the perspective of comparability with other studies. The success of full-coverage crowns not only depends on taper and the technical expertise of the operator but many other factors, including patient's occlusion, diet, and oral hygiene, and a clinical study should be conducted within the dental school to assess the long-term success of these restorations placed by dental students.

The results of this article were based on 3D measurements, in that the data coordinates and the angulation measurements were digitized. These results covered measurements in the laboratory and clinic, anterior and posterior, and BL and MD. The techniques of digitization technology and coordinate metrology have been used to study a variety of clinical problems over the past 15 years or so,¹⁷ relating to geometry pre- and postpreparation. The visual impact of its graphic package also lends itself to be developed further as an educational tool.

Conclusion

This study shows that although the taper achieved by dental students of the University of the West Indies when preparing teeth for full-veneer crowns was outside the ideal range of 4° to 14° , it is comparable to those achieved by other dental students in the United Kingdom, Europe, Japan, Egypt, Saudi Arabia, and the United States.

References

- Rafeek RN, Marchan SM, Naidu RS, et al: Perceived competency at graduation among dental alumni of the University of the West Indies. J Dent Educ 2004;68:81-88
- 2. Rosenstiel E: The taper of inlay and crown preparations. Br Dent J 1975;139:436-438
- Jorgensen KD: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 1955;13:35-40
- 4. Shillingburg H, Hobo S, Whitsett LD, et al: Fundamentals of Fixed Prosthodontics. Chicago, Quintessence, 1997, pp. 119-138
- Noonan JE, Goldfogel MH: Convergence of axial walls of full veneer crown preparations in a dental school environment. J Prosthet Dent 1991;66:706-708
- Robinson PB, Lee JW: The use of real time video magnification for the pre-clinical teaching of crown preparations. Br Dent J 2001;190:506-510
- Smith CT, Gary JJ, Conkin JE, et al: Effective taper criterion for the full veneer crown preparation in preclinical prosthodontics. J Prosthodont 1999;8:196-200
- Curtis DA, Lind SL, Brear S, et al: The correlation of student performance in preclinical and clinical prosthodontic assessments. J Dent Educ 2007;71:365-372
- Mack PJ: A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. J Oral Rehabil 1980;7:255-265
- Ohm H, Silness J: The convergence angle in teeth prepared for artificial crowns. J Oral Rehabil 1978;5:371-375
- Sato T, Mutawa N, Okada D, et al: A clinical study on abutment taper and height of full cast crown preparations. J Med Dent Sci 1998;45:205-210
- Patel PB, Wildgoose DG, Winstanley RB: Comparison of convergence angles achieved in posterior teeth prepared for full veneer crowns. Eur J Prosthodont Restor Dent 2005;13:100-104
- Ayad MF, Maghrabi AA, Rosenstiel SF: Assessment of convergence angles of tooth preparations for complete crowns among dental students. J Dent 2005;33:633-638
- Nordlander J, Weir D, Stoffer W, et al: The taper of clinical preparations for fixed prosthodontics. J Prosthet Dent 1988;60:148-151
- Kent WA, Shillingburg HT, Duncason MG: Taper of clinical preparations for cast restorations. Quintessence Int 1988;19:339-345
- Eames WB, O'Neal SJ, Monteiro J, et al: Techniques to improve the seating of castings. J Am Dent Assoc 1978;96:432-437
- Seymour KG, Zou LF, Samarawickrama DYD, et al: Assessment of shoulder dimensions and angles of porcelain bonded to metal crown preparations. J Prosthet Dent 1996;75:406-411
- Cherukara GP, Seymour KG, Samarawickrama DYD, et al: A study into the variations in the labial reduction of teeth prepared to receive porcelain veneers – a comparison of three clinical techniques. Br Dent J 2002;192:401-404

- Rafeek RN, Marchan SM, Seymour, et al: Abutment taper of full cast crown preparations by dental students in the UWI School of Dentistry. Eur J Prosthodont Restor Dent 2006;2:63-66
- Johnson GH, Craig RG: Accuracy of four types of rubber impression materials compared with time of pour and a repeat pour of models. J Prosthet Dent 1985;53:484-490
- 21. Seymour KG, Cherukara GP, Samarawickrama DY, et al: Consistency of labial finish line preparation for metal ceramic

crowns: an investigation of a new bur. J Prosthodont 2008;17:14-19

- 22. Zidan O, Ferguson GC: The retention of complete crowns prepared with three different tapers and luted with four different cements. J Prosthet Dent 2003;89:565-571
- El-Mowafy OM, Fenton AH, Forrester N, et al: Retention of metal ceramic crowns cemented with resin cements. Effects of preparation taper and height. J Prosthet Dent 1996;76:524-529

Copyright of Journal of Prosthodontics is the property of Wiley-Blackwell and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.