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Consistency of Labial Finish Line Preparation for Metal Ceramic Crowns: An Investigation of a New Bur

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Keywords
Preparation; geometry; shoulder; chamfer; angulation; coordinate measurement; crown

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The work presented in this paper formed part of the following: Seymour K: Variations in Labial Shoulder Geometry of Teeth Prepared to Receive Metal Ceramic Crowns. PhD Thesis, University of London, 1998.

Accepted July 19, 2006.

doi: 10.1111/j.1532-849X.2007.00238.x

Abstract

Purpose: Previous studies have reported on the difficulties inherent in preparing the labial aspect of teeth for metal ceramic crowns with consistency and also the implications for the definitive restoration of underprepared and overangled finish lines. In this study, a bur designed to prepare a 1.2-mm deep chamfer was tested and compared with two other bur kits.

Materials and Methods: Seventy-two teeth were prepared to receive metal ceramic crowns in vitro by students using one of the two bur kits or the new bur. Using a coordinate measuring machine (CMM), replicas of the prepared teeth were scanned in the mid-labial plane, and shoulder width and cavosurface angles were measured.

Results: The new bur produced preparations with a mean shoulder width and cavosurface angle of 1.146 ± 0.241 mm and $108 \pm 11^\circ$, respectively, compared with 0.626 $\pm$ 0.234 mm and $128 \pm 14^\circ$ produced by a commercially available standardized crown cutting bur system and 0.626 ± 0.218 mm and $124 \pm 15^\circ$ produced by the bur kit in use at our center at the time of the study. These differences were statistically significant at the 5% level, using Tukey's comparison of means.

Conclusions: Teeth prepared by the new bur had wider shoulders and lower cavosurface angles than teeth prepared either with a standardized crown cutting system or locally selected bur kit. The quality of labial preparations produced by the new bur in terms of closeness to the postulated "ideal" width and angulation warrants further investigation.

The dynamics for a successful metal ceramic restoration are varied. All stages involved, both clinical and laboratory, have to be meticulously carried out to construct a durable restoration that combines the strength and accuracy of the cast metal restoration with the esthetic qualities of porcelain.[1] The reasons for the failure of metal ceramic restorations have been broadly classified as:[2,3]

- material failures,
- mechanical-human failures,
- esthetic failures, and
- biological failures.

A failed crown has been described as one that was unserviceable, thus requiring repair or replacement.[4] Inadequate tooth preparation can lead to esthetic failures.[2,5,6] Biological failures such as caries, periodontal disease, and endodontic or periapical pathology may also result from inappropriate tooth preparation.[7] Thus, inadequate quality of tooth preparation seems to be a common thread contributing to metal ceramic crown failure.

While adequate tooth reduction is necessary to provide sufficient space for the metal and ceramic to satisfy both esthetic and mechanical requirements, such a reduction should be accomplished without endangering the pulp or supporting periodontal structures.[8] For example, the deeper the preparation, the greater the degree of inflammatory pulpal response.[9,10] Any compromise in shoulder width can have unfavorable consequences in terms of contour and esthetics.[11,12] Underpreparation has been cited as the main reason for many of the clinical problems associated with crowns.[13] On the other hand, wider shoulder finish lines should be prepared with caution so as not to overprepare and damage the pulp.[9]

There seems to be a general consensus regarding the principles and characteristics of the tooth preparation required for a metal ceramic crown, except with the configuration of the labial finish line.[14] Knife-edge (shoulderless), flat shoulder (butt-joint), 135° shoulder (long bevel, sloped shoulder), flat shoulder with 45° bevel (bevel shoulder), flat shoulder with 70° bevel (beveled shoulder), chamfer, and deep chamfer with bevel

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are some of the most frequently used finish line designs.[15] The most popular designs of finish lines also seem to be variants of the shoulder or chamfer.[11,16] It has been reported that the most commonly advocated labial finish line in the United Kingdom, in the United States, and in Puerto Rico is the flat shoulder.[14,15]

In addition to creating space and the ability to withstand stress, achievement of the best fit between the crown and the tooth is a major factor in dictating the type of finish line design selected for a particular restoration.[17-19] Other factors, such as the ease of preparation,[20] development of optimal esthetics,[21] and marginal stability during the porcelain firing cycle,[22] also play a role in the selection of a particular finish line; however, it has also been reported that the marginal adaptation of the labial aspect of crowns following firing of the porcelain was not dependent on the type of finish line design, or specific metal–porcelain combination.[23] On that evidence, it was concluded that the finish line design and alloy prescription were a matter of clinical judgment and expertise.

An ideal finish line should allow for optimum thickness of both metal and porcelain to satisfy the mechanical and esthetic requirements. Depending upon whether a nonprecious (0.1 mm) or precious alloy (0.3–0.5 mm) is used, the thickness of the metal used varies. A minimum thickness of 0.7 mm of porcelain is required to achieve optimal esthetics. Thus, ideally this should be 1.2–1.5 mm in thickness.[22,24]

Another aspect of the preparation to be considered is the cavosurface angle. It has been suggested that the cavosurface angle should be on the order of 90–110°. If it is less than this, there will be unsupported tooth structure labially, which is liable to fracture in function, or prior to this, may fracture from the die during construction, compromising the final crown contour. If the angle exceeds 110°, the porcelain will be have a knife-edge, and thus be susceptible to fracture.[8,22] In either scenario, the marginal adaptation and the required emergence profile of the crown are impaired.

Previous reports have highlighted the difficulties of preparing teeth with consistent geometries. In one study, when 24 extracted teeth were prepared to receive metal ceramic crowns by three dentists, a mean shoulder width of 0.75 mm (±0.17 mm) was observed.[25] In another study, when 34 dies submitted by students to an in-house dental laboratory were measured, a mean shoulder width of 0.9 mm with a range of 0.5 to 1.8 mm was observed.[26] Consequently, researchers and manufacturers have sought to design bur kits or systems to aid in consistent preparation.[27] Therefore, the aim of this study was to test a novel dental bur that would consistently aid in the reduction of the tooth structure to the ideal dimensions required for a metal ceramic crown, the null hypothesis being that this new bur does not produce preparations with any different geometry than existing burs. The dimensions of particular interest were the shoulder width and cavosurface angle.

Materials and methods

Specimen preparation

Seventy-two anterior single rooted extracted teeth with intact labial surfaces were cleaned and using a random number generator (Excel, Microsoft, Redmond, WA) were distributed among nine fourth year undergraduate dental students, who had been randomly placed into three groups of three. All had received common tuition, in that all were members of the same tutorial group and were instructed in tooth preparation for metal ceramic crowns by the same tutor (KGS) at the same time. As part of this instruction, students were taught to attempt to prepare teeth with a 1.2-mm shoulder and a 90° cavosurface angle. Although it would be wrong to assume that all students learn at the same rate, all had passed a laboratory competency test enabling them to carry out crown and bridge treatments for patients, although they had not begun this work as yet. The extracted teeth used had intact labial surfaces, so that the preparations were not compromised by the students worrying overly about pulp location. Each student was asked to prepare his/her eight teeth to receive a metal ceramic crown with a labial finish line of 1.2-mm width, using one of three different sets of burs. The students prepared the teeth while holding the teeth in their hands, as was the common teaching practice at that time.

The first group of three students used a particular selection of burs for the tooth preparation. These burs were those used within the Centre for Adult Oral Health for extracoronal preparation at that time (called "BL" in this study) and consisted of:

- a small diamond fissure bur with 10° taper (ISO # 806 314 168 524 012),
- a wide-tapered tungsten carbide fissure bur with 10° taper (ISO # 500 314 168 006),
- a long-tapered diamond bur with a tungsten carbide tip and 5° taper (ISO # 806 500 314 198 020 014),
- a long parallel-sided tungsten carbide bur (ISO # 500 314 289 072 012), and
- a long-tapered tungsten carbide fissure bur with 10° taper (ISO # 500 315 187 072 016).

These are shown in Figure 1. Figure 2 shows the intended finish line as produced by this bur kit.

The second group of three students used a standardized crown cutting bur system (called "K&B" in this study) (K&B System-Prep., Dusseldorf, Germany) to prepare the teeth according to the manufacturer's recommendations (Fig 3). The labial surface

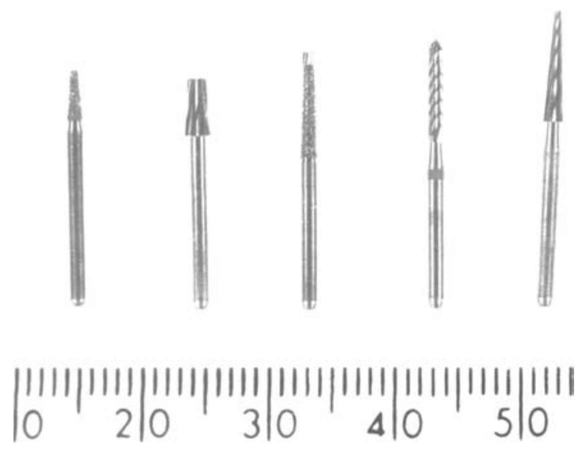

Figure 1 The bur kit used at the Centre for Adult Oral Health during the time of the study. Scale: mm.

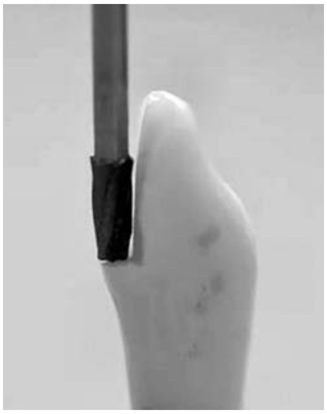

Figure 2 The finish line as produced by the bur kit used at the Centre for Adult Oral Health during the time of the study.

Figure 4 The finish line as produced by the standardized bur kit (K&B).

of the tooth is initially grooved to a depth of 0.5 mm along the gingival margin. Vertical depth orientation grooves are then cut to a depth of 1 mm. The bulk reduction is then completed to a depth of 1 mm, the shoulder region is completed with a tungsten carbide finishing bur to a depth of 1 mm and, for this particular bur kit, an internal angle of 120°. Figure 4 shows the intended finish line as produced by this bur kit.

The third group prepared its 24 teeth using a newly designed bur (called "NEW" in this study). Figure 5 is a photograph of the new bur as produced by Diama Limited (London, UK) to our specifications. It had a curved tip with 0.1-mm thickness of medium grade diamond grit coating and a noncutting tip as a depth limiter. Thus, the bur had the dimensions to theoretically produce a chamfer finish line of a minimum 1.2-mm width consistently. Figure 6 shows the intended finish line produced by this bur.

All the teeth were replicated on the labial surface in mid-blue light bodied poly(vinyl siloxane) impression material (Extrude, Kerr, UK), held in 12 × 12 × 8 mm^3 square brass tubes, following tooth preparation. Each replica was scanned in the mid-labial plane using a coordinate measuring machine (CMM) (Merlin II, International Metrology Systems, Livingstone, UK).

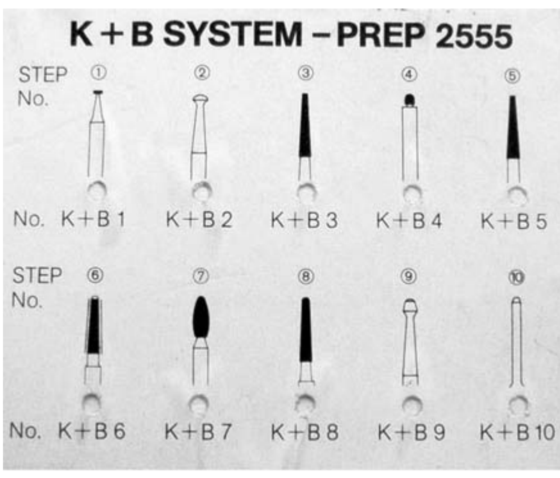

Figure 3 Diagram of the standardized bur kit (K&B).

Data collection

The pre- and postpreparation replicas were scanned in the mid-labial plane using a CMM. They were scanned unidirectionally in the positive *y*-axis. As the finish lines of the teeth prepared with the new bur were intended to finish with a deep chamfer (Fig 6), it presented a problem in terms of measuring the width of the finish line. The curves produced by the new bur meant that simple measurement of this width could not be done. Therefore, the width of the preparation was taken as the distance from a line constructed as a continuation of the radicular aspect of the tooth under investigation (unprepared portion) and a perpendicular from this line, taken at the point where the curved portion of the preparation ended, on the axial wall. In Figure 7, "*x*" represents this finish-line width measurement. These finish-line widths and cavosurface angles were measured ten times from a profile constructed in the mid-labial plane using analytical software (Accudat, International Metrology Systems) with in-house modifications. One operator collected the data (KGS), and the CMM was calibrated prior to each run of experiments using standard spheres of known dimension.

Data analysis

One-way ANOVA was used to analyze any differences among the means of the finish-line width and cavosurface angle prepared by the three students within each group. Tukey's comparison of means was also used to assess the difference in the quality of tooth preparation following the use of each of the three bur types or systems.

Figure 5 Photograph of the new bur (NEW). Courtesy of Diama Limited, London, UK. Dimension: mm.

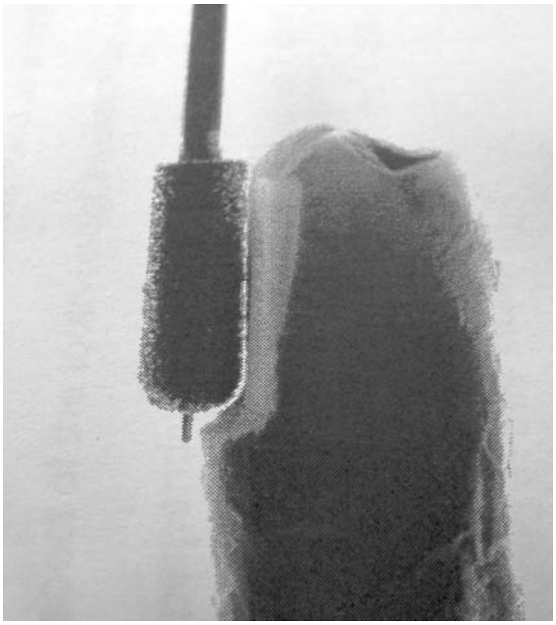

Figure 6 The finish line as produced by the new bur.

Results

Table 1 shows the finish line width and cavosurface angle data for teeth prepared with the new bur along with data for teeth prepared using the two types of bur kits investigated.

Gaps in the table represent scans where the cavosurface angle was unable to be identified and measured.

Within each group, when students used the BL burs, of the 24 preparations, only one had a finish-line width over 1 mm (1.021 mm) with a group mean of 0.626 mm (±0.218 mm). The preparation with the over 1 mm finish line had a cavosurface angle of 121°, which put it outside the ideal range. Only three preparations had cavosurface angles in the 90 to 110° range, with a group mean of 124° (±15°). ANOVA demonstrated a statistically significant difference in the shoulder width among the three students. Tukey's comparison of means indicated that Student 1 prepared shoulders significantly wider than did Students 2 and 3 at the $p < 0.05$ level.

When the students used the standardized bur system (K&B), none of the finish lines prepared were in the 1.2 to 1.5 mm range. This group had a mean of 0.626 mm (±0.234 mm). Only one preparation had a cavosurface angle less than 110° (95°); this group had a mean cavosurface angle of 128° (±14°). ANOVA revealed no statistically significant difference among individual students for either shoulder width or cavosurface angle. An unpaired *t*-test showed no significant difference between preparations using the standardized commercial bur system or the regular dental school burs in terms of shoulder width or cavosurface angle.

When the students used the new bur (NEW), ANOVA revealed no significant differences among students in terms of finish line width or cavosurface angle, with means of 1.146 mm (±0.241 mm) and 108° (±11°) for finish-line width and cavosurface angle, respectively; however, when the pooled data were examined for all three bur types, ANOVA revealed statistically significant differences among these pooled groups ($p = 2 \times 10^{-12}$). Tukey's comparison of means at the 5% level indicated that the teeth prepared with the new bur had significantly wider finish lines than those prepared with either the "regular" school kit (BL) or the Meisinger kit (K&B).

When pooled data for cavosurface angle are examined, ANOVA reveals a statistically significant difference between groups ($p = 0.003$). This is shown in Table 2. The Tukey's comparison of means indicates that the cavosurface angles of the teeth prepared with the new bur were statistically significantly smaller than those prepared with the other two systems at the 5% level.

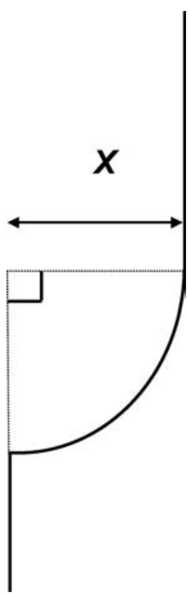

Figure 7 Measuring the width of the deep chamfer.

Discussion

None of the preparations made by students with either a selection of burs in common use at that time (BL) or the standardized type (K&B) approached the 1.5 mm, 90° shoulder advocated as the "ideal."[14] The use of a commercial standardized crown cutting system did not seem to significantly improve shoulder preparation geometry. This might have been because the students were overly timid when using an unfamiliar system. Additionally, we believe that burs with wider tips than those provided with the kit used in this study would be required to prepare a flat 1.5-mm shoulder. The maximum bur width at the tip in this kit was only 1 mm.

In the case of teeth prepared with the new bur, of the 24 preparations replicated and scanned, 14 had a finish-line width of 1 to 1.5 mm. Depending on the choice of alloy used for the final crown, such a preparation might be acceptable.[14] Three of the preparations had finish lines wider than 1.5 mm, with the widest preparation only 0.087 mm greater than 1.5 mm. Seven were underprepared, although apart from one tooth, all these underprepared teeth had finish lines greater than 0.8 mm width.

Table 1 Finish line width and cavosurface angle measurements of teeth prepared by students using three bur types or systems

Burs	BL finish line width (mm)	BL cavosurface angle (°)	student	K&B finish line width (mm)	K&B cavosurface angle (°)	student	NEW finish line width (mm)	NEW cavosurface angle (°)	Student
	0.798	103	1	1.157	124	4	1.008	109	7
	0.627		1	0.825	129	4	0.992	115	7
	0.869	144	1	0.783	95	4	1.095	102	7
	0.913	154	1	0.615	115	4	1.259	126	7
	0.879	150	1	0.718	120	4	1.268	91	7
	1.021	121	1	0.905	116	4	1.543	90	7
	0.899	132	1	0.626		4	1.307	98	7
	0.698	132	1	0.462	134	4	1.587	110	7
	0.739	101	2	0.693	116	5	1.031	115	8
	0.382	119	2	0.756	151	5	1.068	93	8
	0.384	110	2	0.477	133	5	0.897	120	8
	0.854	148	2	0.626		5	0.908	101	8
	0.466	119	2	0.648	141	5	0.977	126	8
	0.923	127	2	0.403	136	5	0.541	96	8
	0.454	113	2	1.150	145	5	1.522	100	8
	0.458	123	2	0.561	135	5	1.374	110	8
	0.381		3	0.601	117	6	1.215	99	9
	0.460	125	3	0.531	115	6	1.276	126	9
	0.384	120	3	0.626		6	1.223	97	9
	0.386	120	3	0.247	147	6	0.982	108	9
	0.476	112	3	0.349	142	6	1.198	110	9
	0.480	112	3	0.365	113	6	1.305	118	9
	0.627		3	0.273	137	6	1.030	110	9
	0.476	120	3	0.626		6	0.892	111	9
Mean	0.626	124		0.626	128		1.146	108	
Standard deviation	0.218	15		0.234	14		0.241	11	
95% Confidence interval	0.539–0.713	118–130		0.532–0.720	122–134		1.050–1.242	103–112	

As for cavosurface angle, the bur was designed to produce one approaching 90 °, but it appeared that it was producing an angle in excess of this in 23 out of the 24 cases, although only three were in excess of 120°.

The use of this new bur as a standardized system for preparation seemed to improve the preparation geometry compared with the other systems tested, where teeth were significantly underprepared. Both BL and K&B bur systems were designed to produce flat shoulders of 1.2- to 1.5-mm width, whereas the new bur was designed to produce a deep chamfer. Although the new bur appeared rather wide at first glance, only three teeth were overprepared and then only by less than 0.1 mm. Seven were underprepared, but this may be a further reflection of the students' timidity when using an unfamiliar bur. It is strange that six teeth were prepared with a chamfer more than 1.2-mm wide, as this was the width that the bur was designed to cut. The manufacturers made the burs to a tolerance of $\pm 10\ \mu$m (Diama Limited), so variation in width of the bur should not account for this overpreparation. The steel tip is blank and designed to be used as a depth limiter, preventing overcutting; however, it is only effective if the bur is held parallel to the long axis of the tooth.

Table 2 ANOVA results

Source of variation	SS	df	MS	F	P-value	F crit
Shoulder width						
Between groups	4.319126	2	2.159563	40.4091	2.42E-12	3.129642
Within groups	3.687531	69	0.053442			
Total	8.006657	71				
Cavosurface angle						
Between groups	4644.766	2	2322.383	6.243648	0.003385	3.14526
Within groups	23061.48	62	371.9594			
Total	27706.25	64				

Students were asked to prepare the extracted teeth, holding each tooth in the hand. This was the common method taught in this institute at that time, although has since been revised to give students a more realistic rehearsal for the clinical environment. Students also used extracted human teeth rather than Typodonts as this was and still is common teaching practice. Nine students were used in the study, as this represented one group of students, and consequently this entire group had received identical teaching. Because of time constraints, with students undertaking this project alongside their normal work, it was not possible to allow the students to use all of the burs used in the study.

Although it is assumed that the ideal cavosurface angle for a shoulder preparation should be in the region of 90°,[14,27] it has been suggested that a 90° preparation might leave unsupported enamel prisms which could dislodge during cementation of the crown. Hence, Bass and Kafalias[27] designed their system to produce a finish line with an external angle of 110 to 120°; however, it may be that preparing teeth to the shoulder widths seen in this study might have serious consequences for the pulp.[10]

Incidentally, all three students using the new bur remarked on its simplicity of use in the laboratory. Of course, these results are taken from a small experimental group; however, the trends that are evident here warrant further investigation. It is also not known what effect the high-speed rotation of the blank tip of this bur had on either the marginal dentine, or would have on the periodontium if it contacted the soft tissue. The use of a control bur without a depth limiter would also allow investigation of the importance of such a limiter in tooth preparation consistency, although work by Dunne[28] has indicated that the errors of visual perception are common in dentistry and would affect the consistency of preparations. A depth limiter serves to overcome these difficulties.[29,30] Such aspects warrant further investigation.

Conclusion

Within the limitations of this study, the following may be concluded: the preparations produced by the new bur were significantly wider and consequently nearer the "ideal" dimension than those produced with either of the other types of bur kits or systems studied

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