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Evaluating Residual Dentine Thickness Cervically Following Various Anterior Crown Preparations for Zirconia Full Coverage Single Crowns: An *in Vitro* Analysis

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Abstract

Background: A reduced residual dentine thickness following crown preparation has a conceivable impact on pulp degeneration by increasing the pulp's susceptibility to injury. In crown preparations, three different finishing lines are used. These are shoulder, chamfer, and knife edge. Each with its comparative advantages and disadvantages. There is inadequate scientific evidence on which of these finishing lines will leave the most amount of residual dentine, after standard crown preparations on mandibular incisors and maxillary lateral incisors to preserve their pulpal health. **Objective:** To evaluate residual dentine thickness following various cervical finishing lines of anterior crown preparations for zirconia full coverage. **Materials and Methods:** A prospective comparative study was conducted from September 2nd to November 5th, 2022, using mandibular incisors and maxillary laterals extracted from individuals between ages 18 to 30. Each of the three groups of teeth was randomly divided into three cervical margin preparations as follows: Shoulder (n = 15), chamfer (n = 15), and knife edge (n = 15). The teeth were disinfected and stored in 10% formalin. Silicone impressions followed by crown preparations were done on teeth mounted on phantom head manikins. The teeth were sectioned 0.5 mm coronal to the cemento-enamel junction using a separating disc and the mesial, distal, buccal, and lingual thickness were measured using a digital caliper. ANOVA analysis was applied to assess the difference in mean residual dentine thickness among the finishing lines and the Tukey

test used for mean comparison. Results: Knife edge finishing lines had 2.05 mm of residual dentine thickness, for upper lateral incisors lingually and had an amount of 1.55 mm and 1.47 mm for lower central teeth mesially and distally respectively. Shoulder finishing lines had an amount of 0.58 mm for lower lateral incisors mesially. Interproximal areas had the least amounts of residual dentine for shoulder and chamfer finishing lines of 0.58 mm and 0.78 mm respectively. **Conclusions:** There was a significant statistical difference in the thickness of residual dentine at the various cervical finishing line margins. The knife edge finishing line was protective enough for zirconia crown preparations.

Keywords

Residual, Dentine Thickness, Cervical, Finishing Margins

1. Introduction

The significance of residual dentine thickness in tooth preparation procedures when it comes to pulp tissue responses has been a subject of discussion for over a century [1]. During tooth tissue preparation for fixed prosthesis pulpal injury can occur due to the speed and heat generated by rotary instruments, duration of contact of cutting instrument to dentine, the amount of pressure put on the tooth during preparation as well as the surface of the different cutting instruments used in crown preparation [2]. Residual dentine thickness which is the distance between the crown preparation surface and the pulp has a credible impact on pulp degeneration [1].

Studies have demonstrated that the pulp becomes more vulnerable to severe injuries brought on by restorative events when the residual dentine thickness is reduced during crown fabrication [3] [4]. According to a study by Chandler *et al.* [5], a third of the tooth had less than 0.5 mm of peri-pulpal dentine after a 1.5 mm all-round reduction on maxillary incisors was performed during crown preparation; resulting in over-preparation of the tooth and subsequent loss of vitality. Early failure is inevitable in such instances. In a period of between 1 and 25 years, 2.7% to 19% of vital teeth that had crown preparation procedures became devitalized and associated with periapical pathologies [6]. Davies *et al.* [7] reported between 0.5 mm and 1 mm of residual dentine thickness in portions of prepared teeth. They concluded that this negatively impacted pulpal health [7].

Since prosthetic restorations need correct reproduction of anatomical contours; the tooth needs to be sufficiently prepared to make room for the crown. [8]. When the tooth is underprepared, contours at the labial and lingual part at the cervical margin are made to be bulky because adequate strength is needed for the material [9].

According to certain research, a residual dentine thickness of at least 2 mm is required to prevent pulpal injury [10] [11]. It has been discovered that to protect

the pulp against luting cements with cytotoxic effects like zinc phosphate and glass ionomer the residual dentine thickness should be 1 mm [12].

In recent years the aesthetic demands of patients have increased and more ceramic crowns such as zirconia are being used to restore anterior teeth. Zirconia crowns are more aesthetic and biocompatible [13]. Also do not cause attrition of opposing teeth which is characteristic of crowns made of porcelain bonded to metal [14]. Preservation of tooth structure is of paramount importance in modern dentistry; crown preparations for ceramic crowns such as zirconia have led to a reduction in the amount of tooth tissue removed due to reduced axial reduction and finishing line preparation [15]. This is because space is needed for only the ceramic unlike in porcelain fused to metal crowns. Different finishing lines have been used in the preparation of zirconia crowns. A chamfer, shoulder or more recently knife edge finishing lines have been the ideal margin of choice for all ceramic zirconia crowns. A chamfer finishing line is however preferred to shoulder due to less stress concentration because of the rounded internal angle of the finishing line, therefore reducing the probability of coronal fracture [16].

The knife edge finishing line was found as a good alternative to the chamfer and shoulder finishing lines because it preserves the most amount of sound tooth tissue [17]. All ceramic crowns made with zirconia placed with knife edge tooth preparations showed high fracture toughness and a fracture resistance in respect to the functional load minimums at a sufficient distance [18]. Poggio *et al.* [19], in their retrospective analysis of 102 zirconia crowns showed the clinical performance of zirconia crowns with knife edge margins was comparable to that observed with other margin designs.

There appears to be a lack of data on residual dentine especially on the smallest anterior teeth after tooth preparation for full coverage crowns even though anatomical investigations emphasizing sound tooth structure thickness have been well documented [15].

The objective of this paper was to determine the thickness of residual dentine using a digital caliper after tooth preparation using shoulder, chamfer, and knife edge finishing lines on the mesial, distal, lingual and buccal sides of mandibular central and lateral incisors as well as maxillary lateral incisors. Also, to compare the differences in thickness of residual dentine after tooth preparation with shoulder, chamfer, and knife edge finishing lines on the mesial, distal, lingual and buccal sides of mandibular central and lateral incisors as well as maxillary lateral incisors.

2. Materials and Methods

Ethical approval was sought from the institutional review Board of the Korle-Bu Teaching hospital (KBTH-IRB/00026/2022). The study was a prospective comparative study carried out from September 2nd to November 5th, 2022, at the Phantom head simulation laboratory of the University of Ghana Dental School. The study samples were 135 extracted teeth from the tooth bank of the University of Ghana Dental School. The teeth were whole adult teeth with fused apexes

and no fractures from adults between the ages of 18 and 30 years.

2.1. Sample Size Determination

The Sample size calculation seen in Figure 1 below is for a factorial design for two factors with each having three levels. G*Power version 3.1.9.4 was used to estimate the sample size as shown below. A statistical power of 0.80 was assumed, alpha level of 0.05 maximum effect size of 0.4. According to G*Power version 3.1.9.4 effect size ranges are 0.1 for small, 0.25 for medium and 0.4 for large. The highest effect size was chosen to be able to detect the significant difference. The estimated sample size was 111 for the 9 groups (3 groups each of upper laterals, mandibular central and lateral incisors with chamfer, shoulder, and knife edge preparations) to be studied, each group contained 12.33 approximately 12 teeth per group. However, 15 teeth were used per group to cater for any teeth that may not be sectioned correctly [20].

2.2. Study Samples

The sample was 135 teeth made up of maxillary lateral incisors as well as mandibular central and lateral incisors. The teeth were obtained from the tooth bank of the Oral Diagnosis clinic of the University of Ghana Dental School Korle-Bu.

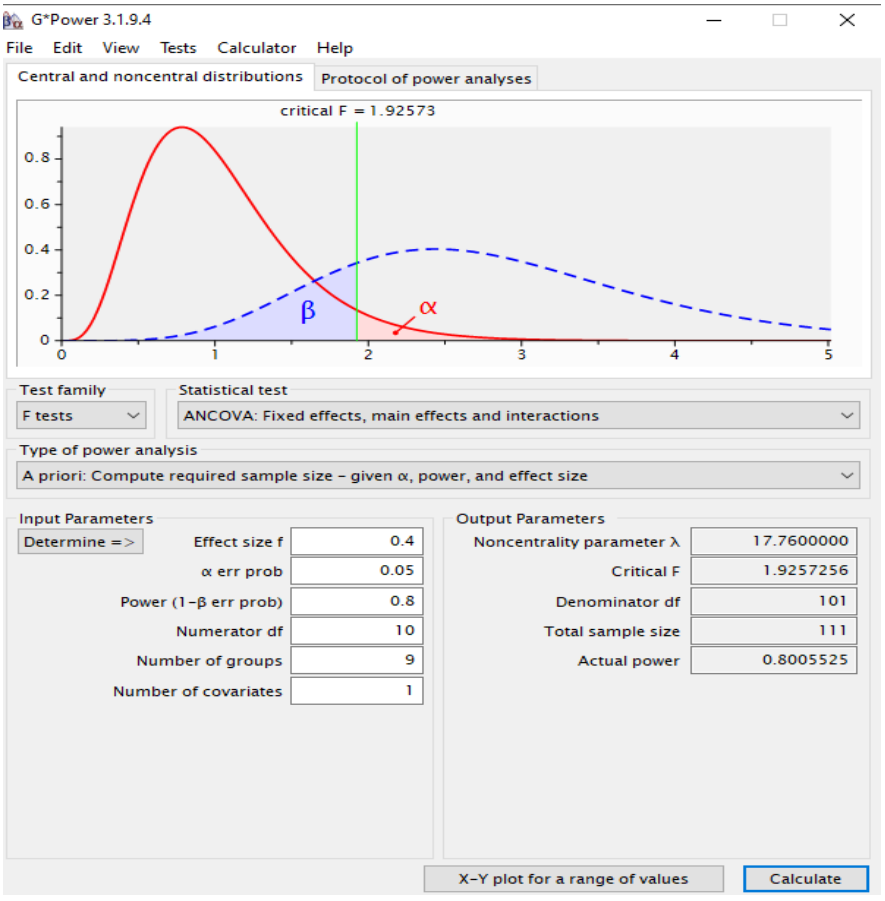

Figure 1. Sample size calculation.

2.3. Data Collection

The teeth were divided into different types according to teeth morphology by viewing each tooth using loops with a 3.5 magnification and a lamp source and stored individually in Eppendorf bottles with 10% formalin. X-rays were taken of each tooth in the buccolingual and mesiodistal direction and those that fell in the inclusion criteria were selected. Each tooth type was randomly divided using a simple sampling technique into the 3 cervical margin finishing types to be prepared (shoulder, chamfer and knife edge). The teeth were placed in Eppendorf vials and labeled according to the type of preparation to be prepared on the tooth. Each tooth was marked at the cemento enamel junction with a graphite pencil. The crown height buccolingually and mesiodistally from the cementoenamel junction, also the buccolingually and mesiodistally crown width 0.5 mm above the cervical margin were measured using a digital caliper. Two thirds of the root of each tooth was sectioned off using a separating disc. This was to reduce the length of the tooth to be able to fit into the socket of the phantom head and allow for the adaptation of acrylic in place of the root. Cold cure acrylic was adapted to it by pouring the acrylic in the stringy stage into a Vaseline lubricated socket of the phantom head model and positioning the tooth in the same socket. The corresponding screw was then cleaned with Vaseline and used to course threads in the acrylic whiles the acrylic was still not set.

Silicone indexes were made using silicone putty and sectioned mesiodistally for the first index and longitudinally along the long axis of the tooth for the second index. A third index was done which was divided into labial and lingual halves. The buccal half of this index was divided into a gingival and incisal half.

Preparations were done on the teeth according to the minimum standard preparation guidelines for the three different tooth preparations as shown in Table 1 below.

Reductions were done and verified with the help of the silicone indexes, UNC probe and a digital caliper.

Table 1. Shows the amount of tooth substance removed (mm) in different areas of the study samples.

		FINISHING LINES		
Tooth third	Tooth area	SHOULDER	CHAMFER	KNIFE EDGE
Incisal	-	1.5	1.5	1.5
Middle	Buccal	1.5	1.2	1.2
	Interproximal	1.2	1	0.8
	Lingual	1.5	1.2	1.2
Cervical	Buccal	1.2	0.8	0.1
	Interproximal	1	0.6	0.1
	Lingual	1	0.6	0.1

The teeth were sectioned 0.5 mm coronal to the cemento enamel junction mesiodistally and the mesial and distal residual dentine measured. The teeth were then sectioned 0.5 mm coronal to the CEJ buccolingually and the buccal and lingual residual dentine measured (Figure 2).

CALCULATION OF AMOUNT OF ENAMEL AND DENTINE

The amount of enamel and dentine before the crown preparation was calculated by adding the amount of residual dentine measured at the mesial (M), distal (D), lingual (L) and buccal (B) sides cervically to the amount of crown reduction done on that side as was shown in Figure 3.

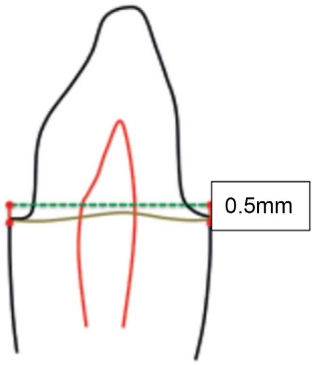

Figure 2. Sample measurements after preparations: cross section [24].

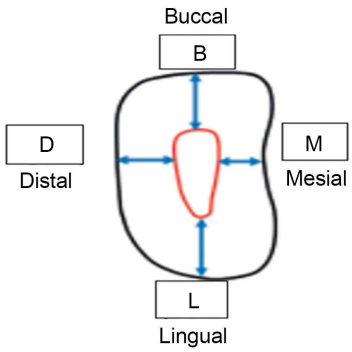

Figure 3. Sample measurement sections: areas to be measured [24].

2.4. Data Management and Analysis

The data was entered directly into the excel work sheet and cleaned and exported into SPSS version 25 software for statistical analysis. The descriptive summary of the residual dentine thickness was presented as means and standard deviations. The one -way analysis of variance ANOVA was applied to assess the statistical significance of difference in mean residual dentine thickness among the different finishing lines at each area in each tooth type. The Tukey test was used for pair wise mean comparison (means of any two groups). The level of statistical significance was set at $P < 0.05$.

3. Results

A total number of 135 teeth made up of 45 teeth each of maxillary lateral incisors, mandibular centrals incisors and mandibular lateral incisors were prepared.

The buccolingual tooth widths at the cervical region were wider than the mesiodistal widths for all three types of teeth. Lower central teeth averagely had a smaller size compared to the other two teeth both mesiodistally and buccolingually followed by lower lateral teeth. The average tooth widths for upper lateral teeth were wider than those for lower central and lower lateral teeth. This was shown in Table 2.

In Table 3 teeth measurements before tooth preparations for upper lateral teeth showed a difference of 0.1 between teeth sizes mesially. For upper laterals, distally the mean averages were the same for teeth to be prepared for chamfer and knife edge at 1.62 mm with a difference of 0.04 mm between them and that to be used for shoulder preparations, which was 1.58 mm. Upper lateral teeth to be used for chamfer and knife edge preparations had similar means at 2.02 and 2.05 respectively whiles that for shoulder preparations was at 2.28 mm. For lower central and lower lateral teeth those to be used for shoulder preparations had means which showed a slightly higher enamel dentine thickness mesially and distally compared to those for chamfer and knife edge preparations. For lower centrals the mean buccally for shoulder preparations showed it to be slightly higher than that for chamfer and knife edge

Table 4 shows that shoulder preparations for all three teeth had the least amount of residual dentine thickness, especially at the mesial and distal areas with the least at the mesial parts of lower lateral teeth and distal part of upper lateral teeth. Knife edge preparations showed the most amount of residual dentine for all three tooth types. The means for the lower central teeth showed similar amounts of residual dentine thickness for both shoulder and chamfer preparations mesially and distally. Lingual and buccal chamfer preparations were however higher than that for shoulder in lower central teeth. Statistically significant differences were seen across the preparations (0.001).

Table 2. Mean values (mm) of the width of the teeth mesiodistally and buccolingually before preparations at the cervical level.

Group	Teeth	Finish Line	Mesiodistal width cervical (MDce)	Buccolingual width cervical (BLce)
1	Upper Lateral Incisors	**Shoulder**	3.51 ± 0.25	5.53 ± 0.33
2		**Chamfer**	3.65 ± 0.25	5.62 ± 0.30
3		**Knife Edge**	3.68 ± 0.48	5.78 ± 0.35
4	Lower Central Incisors	**Shoulder**	3.57 ± 0.27	5.58 ± 0.57
5		**Chamfer**	3.28 ± 0.15	5.48 ± 0.57
6		**Knife Edge**	3.60 ± 0.21	5.30 ± 0.36
7	Lower Laterals Incisors	**Shoulder**	3.63 ± 0.40	5.57 ± 0.29
8		**Chamfer**	3.27 ± 0.18	5.47 ± 0.23
9		**Knife Edge**	3.60 ± 0.21	5.30 ± 0.36

Table 3. Mean values (mm) and Standard deviations (SDs) of computed enamel dentin thickness before preparations at the cervical level.

			Measurement			
			Mean enamel dentine thickness before preparations (mm ± SD)			
Group	**Mandibular teeth**	**Finish Line**	**Mesial (Mce)**	**Distal (Dce)**	**Lingual (Lce)**	**Buccal (Bce)**
1	Upper Laterals	**Shoulder**	1.70 ± 0.09	1.58 ± 0.16	2.28 ± 0.41	2.23 ± 0.31
2		**Chamfer**	1.52 ± 0.31	1.62 ± 0.22	2.02 ± 0.32	2.11 ± 0.15
3		**Knife Edge**	1.60 ± 0.10	1.62 ± 0.18	2.05 ± 0.21	1.80 ± 0.20
4	Lower Centrals	**Shoulder**	1.60 ± 0.12	1.63 ± 0.18	2.08 ± 0.22	2.30 ± 0.12
5		**Chamfer**	1.52 ± 0.23	1.43 ± 0.30	2.25 ± 0.25	2.22 ± 0.11
6		**Knife Edge**	1.55 ± 0.16	1.47 ± 0.18	2.05 ± 0.21	2.02 ± 0.20
7	Lower Laterals	**Shoulder**	1.58 ± 0.22	1.65 ± 0.28	2.15 ± 0.29	2.03 ± 0.22
8		**Chamfer**	1.38 ± 0.20	1.45 ± 0.10	2.13 ± 0.17	2.05 ± 0.14
9		**Knife Edge**	1.55 ± 0.16	1.47 ± 0.18	2.12 ± 0.33	1.97 ± 0.21

Table 4. Mean values (mm) and standard deviations (sds) of residual dentin thickness after preparations cervically.

			Mean residual dentine thickness after preparation (mm ± SD)			
Group	**Mandibular teeth**	**Finish Line**	**Mesial (AMce)**	**Distal (ADce)**	**Lingual (ALce)**	**Buccal (ABce)**
1	Upper Laterals	**Shoulder**	0.70 ± 0.09	0.58 ± 0.16	1.28 ± 0.41	1.03 ± 0.31
2		**Chamfer**	0.92 ± 0.31	1.02 ± 0.22	1.42 ± 0.33	1.32 ± 0.15
3		**Knife Edge**	1.60 ± 0.10	1.62 ± 0.19	2.05 ± 0.21	1.80 ± 0.20
4	Lower Centrals	**Shoulder**	0.60 ± 0.12	0.63 ± 1.18	1.08 ± 0.22	1.10 ± 0.12
5		**Chamfer**	0.60 ± 0.12	0.63 ± 0.18	1.65 ± 0.25	1.42 ± 0.11
6		**Knife Edge**	1.55 ± 0.16	1.47 ± 0.18	2.05 ± 0.40	2.02 ± 0.28
7	Lower Laterals	**Shoulder**	0.58 ± 0.22	0.65 ± 0.28	1.15 ± 0.29	0.83 ± 0.22
8		**Chamfer**	0.78 ± 0.20	0.85 ± 0.10	1.53 ± 0.17	1.25 ± 0.14
9		**Knife Edge**	1.55 ± 0.16	1.47 ± 0.17	2.12 ± 0.33	1.97 ± 0.21
		P value	0.001	0.001	0.001	0.001

4. Discussion

4.1. Teeth Sizes

The average teeth size for upper lateral teeth in this study was lower than what was recorded by Sheid *et al.* [21] who did his study in Ohio. They were also lower than that seen in a study by Sekhon *et al.* [22] who did their study in a north Indian population. This can be due to racial dimorphism. Talat *et al.* [23] also

recorded a higher mesiodistal crown width for lower lateral teeth in a Yemenis and Jordanian population as compared to this study. In their study however the measurements were not taken from the cervical margin thereby explaining the discrepancies. The sizes for lower central and lower lateral teeth in this study were however similar to the study by Sheid *et al.* [21]. Teeth sizes of the different teeth used for the different preparations were of a similar size for all preparations.

4.2. Residual Dentine Thickness Cervically

Upper lateral incisors with shoulder preparations had the least mean amount of residual dentine thickness distally whiles the lower central and lateral incisors had the least amounts mesially. They were lower than the amounts needed to protect the pulp from cytotoxic effects as recommended by Pameijer *et al.* [12]. Chamfer preparations on the three teeth prepared had the least mean residual dentine thickness mesially. The mesial and distal residual dentine thicknesses on lower central and lateral incisors with chamfer preparations was lower than the recommended 1mm by Stanley *et al.* [24] and Pameijer *et al.* [12]. Devitalization of the pulp could therefore occur over time. Literature search did not reveal any research done evaluating residual dentine on upper lateral teeth with chamfer and shoulder preparations. But for the lower central incisors apart from the mesial thickness, which was similar, the amounts seen at the other 3 sides was less than the amounts seen on the same tooth in chamfer and shoulder preparations in the study by Borelli *et al.* [25].

4.3. Comparing the Differences in Thickness of Residual Dentine after Tooth Preparations Cervically

After the preparations, at the cervical region for upper lateral teeth, those that had shoulder preparations had the least amount of residual dentine at all sides compared to chamfer and knife edge preparations. The mean residual dentine thickness for knife edge preparations cervically on all three teeth prepared were all above 1mm. All areas of these preparations had adequate dentine to protect the pulp. The knife edge preparations done on all three teeth were less than what was seen in the study by Borelli *et al.* [25]. Racial dimorphism can account for the reduced amount of residual dentine thickness seen in this study compared to the aforementioned studies [21]. Teeth in the West African sub-region could be smaller in all dimensions than what was seen in a Caucasian population as was seen in the study by Borreli *et al.* [25]. Therefore, leading to a reduced amount of residual dentine thickness after shoulder, chamfer and knife edge preparations.

4.4. Determining If the Differences between the Finishing Lines Were Statistically Significant (Cervically)

The ANOVA SPSS analysis for the mesial, distal, lingual and buccal after the preparation cervically showed a statistically significant difference across the mesial, distal, buccal and lingual with a significance level of 0.001 across the preparations and across the groups. This was different from what was seen in the

study by Borelli *et al.* [25] cervically where statistically significant differences were seen for shoulder but not for chamfer and knife edge.

5. Conclusion

The finishing line knife edge was more conservative of tooth structure cervically while shoulder preparations were the most destructive. There was a significant difference in the thickness of the residual dentine after shoulder, chamfer, and knife edge tooth preparation of mandibular central and lateral incisors as well as maxillary lateral incisors. The knife edge finishing line cervically for zirconia crown preparations was protective enough for the selected anterior teeth. For good pulpal health, the recommended finishing line according to this study is the knife edge.

6. Limitations

The measurements were done manually which could bring about errors though this was accounted for by intra operator calibration.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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