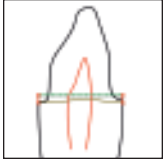


Evaluating Residual Dentin Thickness Following Various Mandibular Anterior Tooth Preparations for Zirconia Full-Coverage Single Crowns: An In Vitro Analysis



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The objective of this study was to evaluate the residual dentin thickness (RDT) after different tooth preparations. Ninety mandibular anterior teeth were divided into three groups: central incisors, lateral incisors, and canines. Specimens were prepared for single-crown coverage with shoulder, slight chamfer, and knife-edge finish lines. Specimens were sectioned and divided into four subgroups according to measurement areas: (1) buccal, (2) distal, (3) lingual, and (4) mesial. The RDT was analyzed statistically by means of one-way analysis of variance and Tukey post hoc test ($P = .05$). Significant differences were found for shoulder but not for slight chamfer and knife-edge finish lines. The interproximal areas wound up being critical due to thin RDT, potentially interfering with the structural and biologic integrity of teeth. (Int J Periodontics Restorative Dent 2015;35:41–47. doi: 10.11607/prd.1873)

Mandibular incisors are the smallest teeth in the dental arch; their anatomical dimensions are of great interest for both orthodontic and prosthetic treatment planning and can be used for determining functional and esthetic outcomes.^{1,2} In addition, they offer the lowest amount of tooth structure to be restored with full-coverage restorations.

Pulp tissue reactions due to prosthetic preparations is a major topic in fixed prosthodontics.^{3,4} Several factors have been described to contribute to pulp injury during tooth preparation procedures, such as drill rotation speed; the size, type, and shape of the cutting instrument; length of time the instrument is in contact with the dentin; and the amount of pressure exerted on the handpiece.⁵ Among other factors, the residual dentin thickness (RDT) has a critical influence on the possible subsequent pulp degeneration, whereas patient variables and restorative factors have little effect.³ To date, there is no consensus in the literature about the optimal RDT necessary to protect the pulp tissue.⁵

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Chandler reported that a 1.5-mm circumferential reduction left almost a third of teeth with less than 0.5 mm of peripulpal dentin⁶ and that excessive preparation led to pulpal exposure and subsequent loss of vitality. Such a phenomenon may result in early failure of restored units.^{6,7} Clinical studies have shown that 2.7% to 19% of initially vital teeth developed periapical pathologies following preparation for complete crowns after an observation period of 1 to 25 years.⁷⁻⁹ In an *ex vivo* study, Davis et al⁴ found that a majority of prepared teeth had regions with less than 1 (6) and 0.5 mm (3 of the 6); such thicknesses are reported to be potentially dangerous for pulpal integrity.^{3,10}

Successful technical reproduction of anatomical contours and profiles in prosthetic restorations is strictly associated with adequate tooth preparation.¹¹ Underreduction could lead to unsuitable labial and lingual contours at the cervical margin due to the overbulking of the crown necessary for adequate material strength, resulting in unsatisfactory emergence profiles, compromised esthetics, and marginal inflammation.¹²

Patients' increasing demand for improved esthetics has driven the introduction of all-ceramic restorations. The advantages of all-ceramic restorations compared with metal-ceramic restorations include improved biocompatibility and esthetics at reduced thicknesses.^{13,14} Dental prosthetic treatments are based on preserving sound tissues, generally requiring the removal of limited amounts of sound tooth structure,

including axial reduction and finish lines preparation.¹⁵ Modern adhesive technologies and high-strength ceramic materials with enhanced fracture toughness may facilitate the use of minimally invasive preparation techniques to prevent tooth weakening and pulp irritation, ensuring the mechanical performance of the prosthetic restoration.^{16,17} As a consequence, restoration dimensions with reduced coping thicknesses or less invasive finish lines, such as the slight chamfer, have been introduced into clinical practices.^{18,19} Some authors found that the knife-edge finish line is a promising alternative to chamfer finish lines because it provides the most acute marginal finish line by preserving a maximum of sound tissues.²⁰

Metal-ceramic restorations require an average tooth reduction of 1.5 to 2 mm to incorporate the metal framework, the opaque porcelain layer, and the glass-ceramic.^{11,21,22} On the contrary, all-ceramic restorations do not need to mask the framework, and 1 to 1.5 mm is considered enough to incorporate the entire prosthetic crown. In selected cases, the tooth-like appearance allows one to reduce the preparation thickness to 0.5 to 0.8 mm at the level of the preparation margin.^{11,21,22}

Although anatomical investigations reporting sound tooth structure thicknesses are present in the literature,^{2,23-26} there appears to be a lack of reports that deal specifically with RDT in mandibular anterior teeth after tooth preparation for full-coverage crowns.^{4,27}

The clinical assessment of the amount of RDT necessary for me-

chanical requirements, the strategic value of the remaining tooth structure, and the pulpal health are actually based on clinical advice. Periapical radiographs²⁸ and the Tooth Restorability Index²⁹ are tools to forecast the success rate of a restoration and help clinicians in decision making. However, it is currently hard for clinicians to know the RDT following crown preparation, a key factor in positive long-term prosthesis outcomes.

The aim of this *in vitro* study was to evaluate the RDT in mandibular anterior teeth after tooth preparation for veneered zirconia single crowns, comparing shoulder (SHO), slight chamfer (CHA), and knife-edge (KNE) finish lines.

The null hypotheses stated there is no association between the RDT within different areas (buccal, mesial, lingual, distal) and the finish-line preparation (ie, SHO, CHA, KNE) for veneered zirconia single crowns of mandibular central incisors, lateral incisors, and canines.

Method and materials

Sample collection

Ninety sound mandibular anterior teeth with no caries, previous restorations, or evidence of wear were selected. All of the teeth were extracted for periodontal reasons and were grouped according to type but with no regard to sex or race of the patient or whether they were from the right or left side. Central incisors, lateral incisors, and canines were included in the study.

Each tooth was examined with standardized digital radiographs (70 kV and 0.06 seconds) both in the mesiodistal and buccolingual directions in order to reduce the influence of pulp chamber size and shape variation. Only teeth with average coronal measures and pulp chamber width comparable to those cited in Stambaugh and Wheeler's anthropometric reports were included.^{24,30} Dental plaque, calculus, and periodontal fibers were removed using ultrasonic instruments and curettes. Teeth were disinfected with sodium hypochlorite (5.25%) for 1 minute. Thereafter, the teeth were stored in 1% thymol solution at 37°C in order to avoid dehydration of the specimens. Each tooth was embedded in a block of self-curing acrylic resin (Dura Lay, Lang Dental), leaving at least 2 mm of the root exposed so as to see the cemento-enamel junction (CEJ). A silicone impression (Affinis President PVS, Coltène/Whaledent) of each crown was made and then cut along the longitudinal axis on the mesiodistal and buccolingual planes. The impressions were used as templates to evaluate the amount of tooth reduction.

The teeth were divided into three preparation categories (SHO, CHA, KNE) comprising the following nine groups:

- Group 1: mandibular central incisors with SHO preparation
- Group 2: mandibular central incisors with CHA preparation
- Group 3: mandibular central incisors with KNE preparation
- Group 4: mandibular lateral incisors with SHO preparation

Table 1 Preparation thicknesses (mm) in different areas of the study samples

Tooth third	Tooth area	SHO	CHA	KNE
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	–
	Interproximal	1	0.6	–
	Lingual	1	0.6	–

SHO = shoulder; CHA = chamfer; KNE = knife edge.

- Group 5: mandibular lateral incisors with CHA preparation
- Group 6: mandibular lateral incisors with KNE preparation
- Group 7: mandibular canines with SHO preparation
- Group 8: mandibular canines with CHA preparation
- Group 9: mandibular canines with KNE preparation

Tooth preparation

In each group, the specimens were randomly divided to be prepared with SHO (n = 10, control), CHA (n = 10), and KNE (n = 10). The preparation thicknesses (Table 1) and geometries (Fig 1) were congruent with data reported in the literature.^{14,21} According to tooth preparation, the reduction of the axial walls was performed with different burs, mounted on an air-turbine hold on a parallelometer surveyor (ISO DENTALFARM Surveyor-Parallelometer, A3502, Batch 10/06, C.I.E. DENTALFARM). The total occlusal convergence (TOC)

angle was set and controlled at 10 degrees to slightly taper the axial walls.^{14,21,31} The following preparation protocols were adopted:

- SHO finish line preparation: diamond cylindrical bur with rounded angles 2.1 mm in diameter (shape no. 881, ISO 314141534021, 100- μ m granulometry, Intensiv); half bur was used to measure and control the amount of tooth reduction.
- CHA finish line preparation: diamond cylindrical bur with rounded angles 1.2 mm in diameter (shape no. 881, ISO 314141534012, 100- μ m granulometry, Intensiv); half bur was used to measure and control the amount of tooth reduction.
- KNE finish line preparation: diamond bur with rounded angles 1 mm in diameter (shape no. 863, ISO 314250534010, 100- μ m granulometry, Intensiv); the bur was used to remove the undercuts of the axial walls.

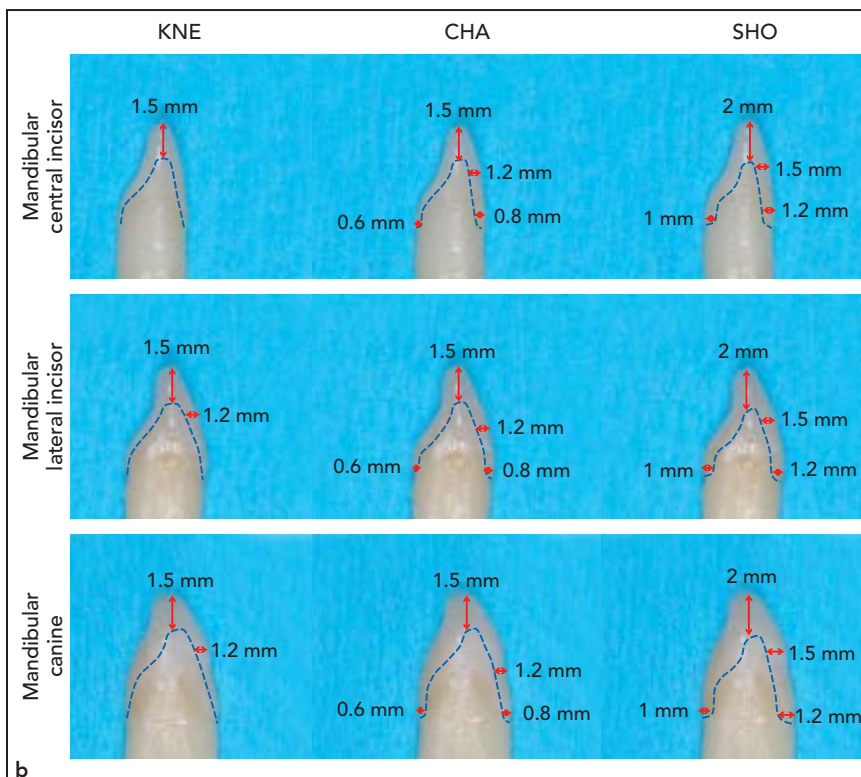
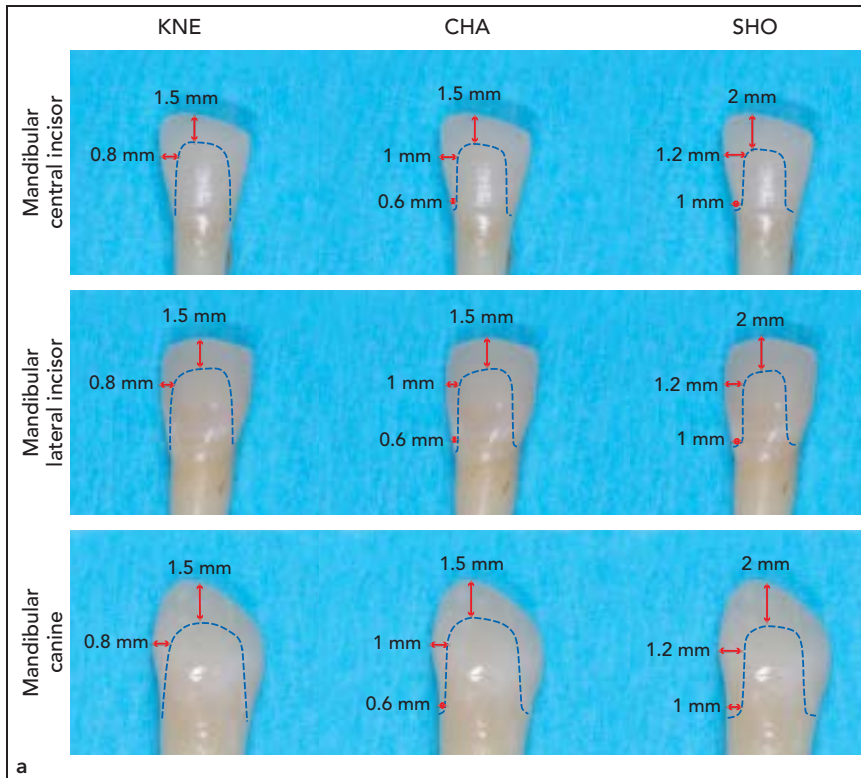


Fig 1 Preparation geometry and thicknesses in different areas of the study samples. (a) Buccal view. (b) Interproximal view. KNE = knife edge; CHA = chamfer; SHO = shoulder.

The incisal reduction was performed manually to 1.5 mm and the lingual reduction was performed manually to 1 mm for all samples with an occlusal preparation bur (shape no. 368, ISO 314257524021, 100- μ m granulometry, Intensiv). The connection areas between axial walls were adjusted manually, and all internal angles were rounded. During tooth preparation, the amount of tissues removed was controlled with the silicone templates and a scaled probe.

Sample measurement

After tooth preparation, all of the teeth were sectioned perpendicularly²⁵ to the longitudinal axis 0.5 mm coronally to the CEJ. Each section was divided into four subgroups according to the area to be measured: a = buccal, b = distal, c = lingual, d = mesial (Fig 2).²⁵ Then, they were measured using a digital caliper with 0.01-mm accuracy (previously calibrated). Each measurement was performed five times at separate intervals (3 days apart) in order to avoid the measurements being affected by a degree of repetitions. Maximum and minimum values were discarded, and the remaining three measurements were averaged.

Statistical analysis

The data were statistically analyzed with SPSS version 20.0 software (SPSS).

Having verified that data distribution was normal in each group

Fig 2 Sample measurement sections: location of the (left) cross-sectional cut and (right) measured areas.

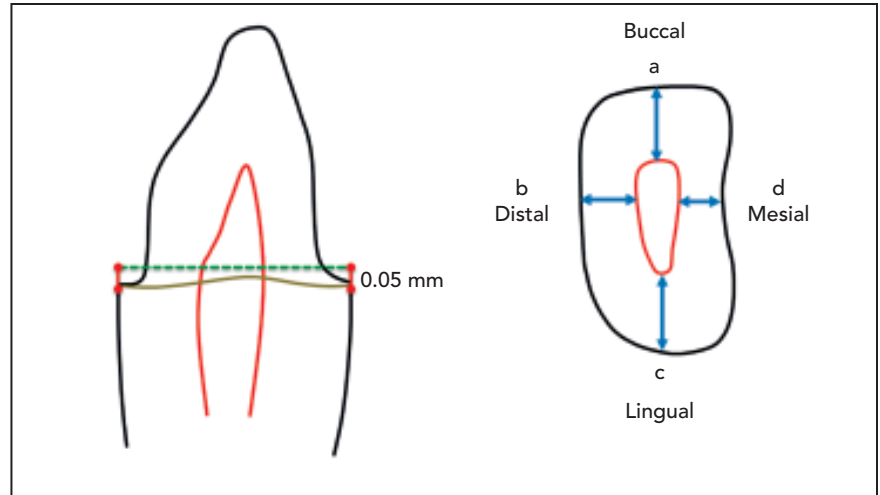


Table 2 Mean values (mm) and SDs of the analyzed residual dentin thickness*

			Measured areas			
Group	Mandibular teeth	Finish lines	a	b	c	d
1		SHO	1.40 ± 0.08 ^A	0.73 ± 0.05 ^A	1.38 ± 0.07 ^A	0.64 ± 0.03 ^A
2	Central incisor	CHA	1.96 ± 0.04 ^B	1.27 ± 0.03 ^B	1.83 ± 0.24 ^B	1.21 ± 0.03 ^B
3		KNE	1.94 ± 0.05 ^B	1.24 ± 0.04 ^B	1.96 ± 0.03 ^B	1.27 ± 0.02 ^C
4		SHO	1.32 ± 0.24 ^A	1.31 ± 0.08 ^A	1.61 ± 0.05 ^A	1.27 ± 0.03 ^A
5	Lateral incisor	CHA	2.05 ± 0.12 ^B	1.89 ± 0.14 ^B	2.18 ± 0.14 ^B	1.82 ± 0.24 ^B
6		KNE	2.08 ± 0.03 ^B	1.93 ± 0.04 ^B	2.14 ± 0.04 ^B	2.04 ± 0.03 ^B
7		SHO	1.95 ± 0.10 ^A	1.63 ± 0.01 ^A	2.16 ± 0.10 ^A	1.30 ± 0.0 ^A
8	Canine	CHA	2.67 ± 0.16 ^B	2.25 ± 0.22 ^B	2.80 ± 0.10 ^B	1.98 ± 0.24 ^B
9		KNE	2.70 ± 0.03 ^B	2.22 ± 0.04 ^B	2.82 ± 0.04 ^B	2.00 ± 0.05 ^B

*For each tooth type and measured area (a = buccal, b = distal, c = lingual, d = mesial; SHO = shoulder, CHA = chamfer, KNE = knife edge) statistically significant differences were labeled with different superscript letters. Each subgroup was analyzed independently by means of one-way ANOVA. ($P < .05$).

(Kolmogorov-Smirnov test) and that group variances were homogenous (Leven's test), the one-way analysis of variance (ANOVA) was applied to assess the statistical significance of differences in RDT among the finishing lines at each area in each tooth type. The Tukey test was used for multiple comparisons, as needed.

The level of statistical significance was set at $P < .05$.

Results

The recorded RDT mean values and the results of the statistical analysis are summarized in Table 2.

In central incisors, the minimum value recorded was 0.64 mm for SHO in the mesial area; the maximum value recorded was 1.96 mm for both CHA and KNE in the buccal and lingual areas, respectively.

In lateral incisors, the minimum value recorded was 1.27 mm for SHO in the mesial area; the maximum value recorded was 2.18 mm for CHA in the lingual area.

In canines, the minimum value recorded was 1.30 mm for SHO in the mesial area; the maximum value recorded was 2.82 mm for KNE in the lingual area.

Statistically significant differences were found for SHO but not for CHA and KNE in all subgroups except for subgroup 1d in which significant differences were found among the three finish line preparations.

Discussion

According to the results of this study, all of the tested null hypotheses were rejected ($P < .05$), because there were statistically significant differences among the analyzed finish lines in mandibular central incisors, lateral incisors, and canines. No statistically significant differences were found between CHA and KNE finish lines in all the tooth types and areas except for the mesial area of central incisors.

A suitable preparation design with adequate material thickness is paramount to guarantee the strength of the all-ceramic restorations.^{17,32,33} KNE has been reported as an alternative to CHA for minimally invasive treatments, particularly in anterior regions.^{20,32} According to the more recent minimally invasive dentistry concepts, the present study focused on more conservative finish lines.

Tooth preparation for veneered zirconia single crowns has been examined in this *in vitro* study since it can be considered the worst clinical scenario for all-ceramic prostheses, representing the type of metal-free restoration with the highest minimum thickness.^{32,33}

To date, SHO preparations can be considered no longer indicated for all-ceramic restorations because they do not require a large amount

of sound tooth removal. In addition, this invasive preparation could imply biologic costs, such as pulp irritation.^{3,6}

In the literature, an RDT of 2 mm has been reported to be a key factor in preventing pulpal damage.³ Later, RDTs of 1 mm and 0.5 mm were investigated to highlight the effects of luting agents and tooth preparation on the dentin and the pulp.⁵ However, this topic remains controversial. Nevertheless, young age and extent of coronal tooth destruction were reported as predicting factors for root canal therapy following extensive dentin preparation.³⁴

Davis et al found that in maxillary central incisors the entire specimens had regions with less than 2 mm of RDT after a shoulder preparation. A consistent percentage of the prepared teeth had regions with an RDT of less than 1 mm and a smaller percentage with less than 0.5 mm, although in isolated small areas particularly along the buccal-proximal line angles.⁴

In this study, the average measurements recorded were less than 2 mm in all of the specimens except for KNE and CHA in mandibular canines and in buccal and lingual areas of mandibular lateral incisors. A half specimen exhibited an RDT of less than 1.5 mm, and in central incisors with SHO preparation an RDT of less than 1 mm was recorded in proximal areas.

The results of this *in vitro* study did not show any statistically significant difference between CHA and KNE in terms of sound tooth removal, except for the subgroup 1d ($P =$

.008). This result could be ascribed to the pronounced mesial concavity, typical of mandibular central incisors. These findings suggested that KNE does not provide a more conservative prosthetic treatment than CHA, even if both are less invasive in comparison with SHO.

Only teeth with average measurements comparable to those reported in Stambaugh and Wittrock²⁴ and Wheeler's³⁰ investigations were included in the present study. Nevertheless, anatomical and chromatic variability should be taken into account when planning a prosthetic treatment. In particular, the RDT in the interproximal areas resulted in being the thinnest for all finish lines in the current study; consequently, in terms of teeth smaller than those selected for this study, careful attention should be paid in such areas because of the potential interference with the structural and biologic integrity of teeth.

In addition, following tooth preparation, clinical considerations such as young age and the extent of coronal tooth destruction were reported as predictors for pulpal injury³⁴ that could not be taken into account in an *in vitro* study.

For all of the investigated finish lines, the minimum thickness required for incorporating the framework and the veneering ceramic was chosen as described in the literature,^{11,22} although more invasive preparations could be necessary in clinical practice. The mean RDT reported for SHO clearly demonstrated that it was the most invasive finish line, whereas CHA and KNE were comparable in the results.

Conclusions

Within the limitations of this in vitro study, the CHA and KNE finish lines wound up being comparable in terms of tissue removal, whereas the SHO finish line was significantly more invasive. The interproximal areas were critical, potentially interfering with the structural and biologic integrity of teeth, particularly mandibular central incisors.

Considering the limitations of the present in vitro investigation due to the anatomical and chromatic variability of teeth, as well as the operator-sensitive preparation technique, further investigations will be necessary to confirm the results of this study.

Acknowledgments

The authors reported no conflicts of interest related to this study.

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