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ORIGINAL ARTICLE

# Influence of preparation design on the quality of tooth preparation in preclinical dental education

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**Abstract** *Background/purpose:* One of the major educational goals in preclinical dental education is to learn tooth preparation techniques. The purpose of this study was to evaluate the influence of different preparation designs on the development of the manual dexterity of students, in order to perform a state-of-the-art tooth preparation.
*Material and methods:* Seventy-two 1st semester students were divided into two groups and educated in tooth preparation for a ceramic anterior single crown. One group received cylindrical burs with a rounded edge to prepare a typodont model with a shoulder finishing line, while the other group had cylindrical burs with round noses to prepare a chamfer finishing line. All preparations were digitized and evaluated using special software focusing on the parameters of preparation depth and preparation angle. In addition, violation of the adjacent teeth was estimated. Data was statistically evaluated at a level of significance of 5%.
*Results:* The preparation design used did not show a statistically significant influence on the preparation depth or on the preparation angle. A trend to a higher tooth structure removal as required was detected. Furthermore, no influence of the type of preparation design on the number of violated adjacent teeth was found.
*Conclusion:* In preclinical dental education, the type of preparation design was found to have no influence on the measured parameters representing the quality of the preparation.
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## Introduction

There is a general recognition that adequate tooth preparation is essential for the fit of fixed prosthodontics. Insufficient tooth preparation appears to be responsible for premature failures due to biological aspects, such as caries and endodontic or periodontal disease complications.[1] Therefore, tooth preparation is an important skill that has to be taught in dental education.

However, although various techniques and programs containing manikin exercises and computer-based simulation training have been developed, acquiring the desirable manual dexterity needed for intraoral tooth preparation seems to be one of the most challenging tasks within preclinical training.[2] This might be aggravated by the fact that there is almost no consensus among clinicians concerning the preparation technique and the most suitable finish line, resulting in a large number of aspects that have to be taken into consideration by preparation novices.

Thus, particularly in the case of finish lines, different recommendations have been made to improve esthetics, minimize marginal fitting irregularities, and reduce stress concentration at the margins.[3] The most popular designs are modifications of the shoulder or chamfer finishing line, which generate surfaces almost perpendicular to the loading direction and are clearly identifiable to both the dentist and the laboratory technician.[1,4–6] Moreover, both the distinct chamfer and a shoulder finishing line with a rounded inner edge are used for comparable indications, e.g., the production of all-metal as well as milled all-ceramic crowns.[7–9] According to a survey concerning preclinical prosthodontic programs in German-speaking dental schools, about 95% of all educational institutions declared they taught the chamfer finishing line. The shoulder finishing line was taught in about 60% of the institutions.[10]

In the past decade, in order to strengthen contemporary aspects within the dental curriculum, preclinical training time has been reduced to address more clinical content to dental students.[2] Thus, the question arises of whether the skilled handling of only one finish line could be enough. This would lead to a desirable reduction of the instruments and acquisition costs for the students.[11] Additionally, in terms of organization and hygiene, it seems more valid to provide a reduced number of instruments for dental treatment. This aspect was enhanced by the results of Morrison and Conrod.[12] They showed that used burs are often sterilized ineffectively before their reutilization.

However, there are few investigations evaluating whether the chamfer or shoulder finishing line is easier for students to learn. No scientific studies have stated that chamfer finishing lines are superior to other finish lines.[13]

Based on the results of the above mentioned survey, the chamfer finishing line is more often taught and therefore might be easier to learn. The purpose of this investigation was to evaluate whether dental students' performance in defined finish-line production would be consistently improved by the use of a certain preparation design: a chamfer or a shoulder finishing line. The working hypothesis tested whether it would be easier to achieve the requirements of a state-of-the-art preparation using the chamfer instead of a shoulder finishing line. The dimensions of particular interest were the width of the preparation, the preparation angle, and the number of the affected adjacent teeth.

## Materials and methods

The study was conducted during the first preclinical training courses within the School of Dentistry at the Martin Luther University, Halle-Wittenberg, Germany in 2012 and 2013. Ethics approval was obtained from the institutional review board. Seventy-two dental students participated in the study and were randomly divided into Group A and Group B. First, students were introduced to ideal preparation parameters including a smooth, 1.0–1.5 mm wide chamfer or shoulder finishing line that follows the rise and fall of the gingiva, a distinct and continuous finish line void of spikes and lips, 6–10° combined convergence angle, a 90-degree angle of the preparation line to the tooth surface, a functional cusp bevel, 1.5–2.0 mm occlusal reduction, and an overall rounded and smooth finish. A practical demonstration of the preparation technique was provided and an additional presentation was placed on the virtual learning environment prior to the preparation session. Prior to this study, the 1st semester students had completed manual dexterity exercises in order to develop the necessary dexterity and skill with an electric handpiece using the "Learn-a-Prep" resin layers (No. 15810; Whip Mix Corp., Louisville, KY, USA). After this first practical exercise, students prepared solitary premolars and molars performing all the working steps necessary to prepare a tooth.

At the end of the 1st semester, all students were instructed to prepare an upper first incisor (11, OK V16; KaVo Dental GmbH, Biberach, Germany) with a finish line width of 1.0–1.5 mm for an all-ceramic crown fabricated by computer-aided design and computer-aided manufacturing. This was prepared using an electric handpiece on a typodont in a phantom head. To control the reduction, a sectioned index made from addition-cured silicone impression material (Panasil Putty; Kettenbach, Eschenburg, Germany) was fabricated prior to tooth preparation.

Group A's students ($n = 36$) used cylindrical burs with a rounded edge with Ø 1.2 mm and Ø 1.6 mm (ISO 806 314 111 534 012 / 016; 806 314 111 514 012 / 016; Komet Dental, Lemgo, Germany) to prepare a shoulder finishing line and Group B's students ($n = 36$) used cylindrical burs with a round nose with Ø 1.2 mm and Ø 1.6 mm (ISO 806 314 141 534 012 / 016; 806 314 141 514 012 / 016; Komet Dental) to prepare a chamfer finishing line.

During the preparation process, students were supervised by experienced assistant professors to avoid manipulation. Additionally, adjacent teeth were controlled visually by an experienced assistant professor and divided into "affected" and "not affected." In the case of an affected adjacent tooth, the whole preparation had to be redone.

To determine the preparation angle and width of the preparation margin depending on preparation line, each preparation was digitized (D710; 3 Shape, Copenhagen, Denmark). Shoulder width and preparation angle

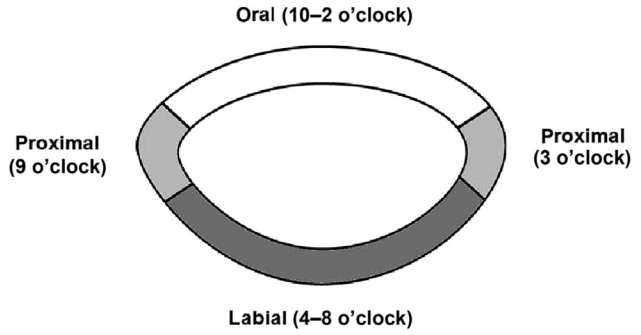


**Figure 1** Measurement segments of the width of the finish line according to the clock.

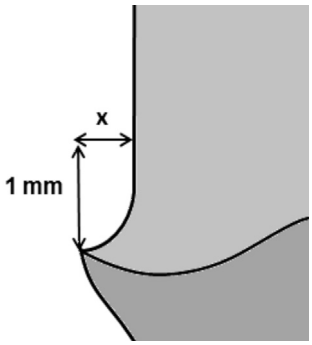


**Figure 2** The width of the finish line (*x*) was measured 1 mm above the real finish line as the shortest distance to the stump surface.

measurements were recorded using a measuring software.[14] Statistical analysis was done using SPSS 22.0 (IBM, SPSS Inc., Chicago, IL, USA) for Windows.

To analyze the influence of the finish line on the angle of the preparation margin, the program determined the insertion axis and measured areas with the same preparation as $< 0°$, 0–3°, 3–6°, 6–9°, 9–12°, and $> 12°$.[14] The measured values ($cm^2$) were analyzed descriptively and compared for each finish line using *t*-tests.

To analyze the influence of the type of finish line on the differences of the width of the finish line, it was divided into four segments according to the clock and the tooth surfaces (Figure 1).

In order to analyze the preparation width, the program projected a copy of the preparation margin 1 mm above the real finish line and measured the shortest distance from the each point of this copy to the prepared stump (Figure 2).[14] For each segment, means and standard deviations were calculated and analyzed using descriptive statistics as well as Fisher's exact tests. The width of the finish line between 1.0 mm and 1.5 mm was rated as a "success."

## Results

The values of the width of the finish line measurements are presented in Table 1. Independently of the finish line and tooth surface investigated, the means reached values between $1.6 \pm 0.2$ mm (Group A) and $1.7 \pm 0.3$ mm (Group B), or above the upper tolerance limit of 1.5 mm. In general, most students tended to prepare too much rather than too little, reaching maximum values of 2.6 mm (Group B, oral). As the minimum value still provided 0.9 mm (Group B, labial), the minimum thickness for all-ceramic crowns was reached in almost all preparations, even though the lower tolerance limit of 1.0 mm was exceeded. At least one-third of all students achieved the recommended tolerance limit. To strengthen the statistical validity, and with reference to the mean values, the tolerance limit was extended from 1.0 mm to 1.7 mm.

Thus, the preparation success with a shoulder or chamfer finishing line was analyzed for each tooth surface by defining the preparation success as the width of the finish line of 1.0–1.5 mm first and 1.0–1.7 mm second.

On the oral side, the number of students who reached the tolerance limit increased from the first ($n = 8$ for both groups) to the second analysis ($n = 20$ for Group A, $n = 14$ for Group B). However, neither the first nor the second analysis revealed any relevant differences between both groups (Table 2). On the labial side, the number of students who reached the tolerance limit was higher in both analyses in Group B than in Group A (Table 3). However, neither the first nor the second analysis revealed any significant difference between the groups.

On the proximal side, the number of students who reached the tolerance limit increased from first ($n = 13$ for both groups) to second analysis ($n = 22$ for Group A, $n = 17$ for Group B). However, neither the first nor the second analysis revealed any statistical relevant difference between both groups (Table 4).

Concerning the preparation angle, both groups showed undercuts (areas $< 0°$) and converging areas of more than 12°. However, no correlation was found between the size of the area and the two groups (Table 5). In both groups, students affected up to four teeth before they finished the preparation of an upper incisor. The number of affected

**Table 1** Descriptive statistics of the width of the finish line (mm).

| | | *n* | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Group A | Labial | 36 | 1.679 | 0.328 | 0.918 | 2.220 |
| (shoulder finishing line) | Approximal | 36 | 1.616 | 0.223 | 1.208 | 2.127 |
| | Oral | 36 | 1.725 | 0.331 | 0.942 | 2.270 |
| Group B | Labial | 36 | 1.573 | 0.288 | 0.884 | 2.129 |
| (chamfer finishing line) | Approximal | 36 | 1.599 | 0.349 | 0.949 | 2.335 |
| | Oral | 36 | 1.748 | 0.310 | 1.202 | 2.552 |

SD = standard deviation.

**Table 2** Crosstab for the analysis of preparation success of Group A and Group B on the oral side firstly defined as a width of the finish line between 1.0 mm and 1.5 mm, and secondly as 1.0–1.7 mm.

| | | Group A (shoulder finishing line) | Group B (chamfer finishing line) | Sum | P |
|---|---|---|---|---|---|
| Preparation success oral (1.0–1.5 mm) | No | 28 | 28 | 56 | > 0.99 |
| | Yes | 8 | 8 | 16 | |
| Sum | | 36 | 36 | 72 | |
| Preparation success oral (1.0–1.7 mm) | No | 16 | 22 | 38 | 0.238 |
| | Yes | 20 | 14 | 34 | |
| Sum | | 36 | 36 | 72 | |

**Table 3** Crosstab for the analysis of preparation success of Group A and Group B on the labial side firstly defined as a width of the finish line between 1.0 mm and 1.5 mm, and secondly as 1.0–1.7 mm.

| | | Group A (shoulder finishing line) | Group B (chamfer finishing line) | Sum | P |
|---|---|---|---|---|---|
| Preparation success labial (1.0–1.5 mm) | No | 29 | 23 | 52 | 0.188 |
| | Yes | 7 | 13 | 20 | |
| Sum | | 36 | 36 | 72 | |
| Preparation success labial (1.0–1.7 mm) | No | 22 | 15 | 37 | 0.157 |
| | yes | 14 | 21 | 35 | |
| Sum | | 36 | 36 | 72 | |

adjacent teeth in Group A was 45 (mean teeth per student = 1.25) and in Group B was 51 (mean teeth per student = 1.41) (see Tables 6 and 7).

## Discussion

There were no statistically significant differences detected concerning the quality of the preparation between the two types of finish lines, so the working hypothesis has to be rejected. In contrast to the majority of studies investigating the width of the finish line, we found that most of the participants removed too much rather than too little tooth structure.[3,15] This might be due to the fact that the available studies evaluated the preparations of experienced dentists. Their awareness of biological complications implicated by distinct tooth structure removal might have been higher than those of the preparation novices who lacked any clinical experience. Furthermore, students might have been afraid of affecting the adjacent teeth because this implied the repetition of the preparation.

**Table 4** Crosstab for the analysis of preparation success of Group A and Group B on the approximal side firstly defined as a width of the finish line between 1.0 mm and 1.5 mm, and secondly as 1.0–1.7 mm.

| | | Group A (shoulder finishing line) | Group B (chamfer finishing line) | Sum | P |
|---|---|---|---|---|---|
| Preparation success approx. (1.0–1.5 mm) | No | 23 | 23 | 46 | > 0.99 |
| | Yes | 13 | 13 | 26 | |
| Sum | | 36 | 36 | 72 | |
| Preparation success approx. (1.0–1.7 mm) | No | 14 | 19 | 33 | 0.344 |
| | Yes | 22 | 17 | 39 | |
| Sum | | 36 | 36 | 72 | |

**Table 5** Descriptive statistics of the size ($cm^2$) of the different preparation angles' area and the P-values of the *t*-test comparison.

| | | *N* | Mean | SD | P |
|---|---|---|---|---|---|
| Area with preparation angle < 0° | Group A | 36 | 198 | 156 | 0.510 |
| | Group B | 36 | 226 | 199 | |
| Area with preparation angle 0–3° | Group A | 36 | 334 | 159 | 0.917 |
| | Group B | 36 | 331 | 163 | |
| Area with preparation angle 3–6° | Group A | 36 | 530 | 160 | 0.218 |
| | Group B | 36 | 483 | 154 | |
| Area with preparation angle 6–9° | Group A | 36 | 505 | 111 | 0.174 |
| | Group B | 36 | 468 | 119 | |
| Area with preparation angle 9–12° | Group A | 36 | 380 | 108 | 0.397 |
| | Group B | 36 | 358 | 110 | |
| Area with preparation angle > 12° | Group A | 36 | 2172 | 283 | 0.328 |
| | Group B | 36 | 2235 | 252 | |

SD = standard deviation.

**Table 6** Mean values of the number of the affected adjacent teeth for Group A and Group B.

| | Mean affected | SD |
|---|---|---|
| Group A (shoulder finishing line) | 1.25 | 1.42 |
| Group B (chamfer finishing line) | 1.41 | 1.50 |

SD = standard deviation.

In contrast to other investigations, our study evaluated not only the labial but also the proximal and oral tooth surfaces, for which the preparation has higher demands, especially for preparation novices because they cannot be inspected directly. The preparation of a whole tooth might aggravate the estimation of the width of the finish line as well. In general, we tried to counteract an under- or overpreparation by a sectioned index, whose use led in other studies to an augmented observance of the tolerance limit compared with free-hand preparation.[3] Another

**Table 7** Crosstab of the affected and nonaffected adjacent teeth for Group A and Group B.

| | Number of affected teeth | | | | | P |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | |
| Group A (shoulder finishing line) | 15 | 9 | 3 | 6 | 3 | 0.982 |
| Group B (chamfer finishing line) | 15 | 6 | 3 | 9 | 3 | |

possibility for evaluating the preparation's width is the use of burs with a guide pin.[16]

It has to be taken into account that our results are only valid for a chamfer finishing line preparation done with a cylindrical bur with a round nose. As reported by Hooper et al.,[17] torpedo-shaped burs are commonly used in dental education. In general, the rationale for bur selection and its application is not addressed in the literature, or in standard operative and prosthodontic texts. There are few scientifically supported references for bur-type selections.[18]

According to Boening et al[16] rounded cylinder burs revealed a perceived better guidance compared to torpedo burs. This clinical experience is in accordance with the observations of Mansueto et al.[6] Their investigation showed that dental students felt more comfortable with round-ended burs to create a chamfer finish line.

Concerning the retentive surface area, no differences could be found between the two types of finish lines. Unfortunately, comparable data is not available because the known investigations concentrated on the evaluation of the preparation angle.[19–21] However, instead of the preparation angle, the retentive surface area seems to be important for the retention of fixed prosthodontics.[22] In addition, it has to be recognized that neither bur had a tapered design. Further investigations should therefore evaluate whether the use of tapered burs influences the retentive surface area in cases of preparations by novices.

With regard to the measuring technique, it has to be emphasized that the method used in this study was only recently introduced and is comparable with the coordinate measuring machine applied in previous studies.[15] The retentive surface area, as well as finish line's width, was determined independently of an examiner by a computer program, thereby reducing the investigator-dependent error arising by free-hand measurements.

In general, the quality of the preparations revealed a wide dispersion range between different students, which is especially denoted by the number of adjacent teeth. Thirty students finished their preparation without having touched any adjacent teeth, whereas the remaining 42 students affected up to four teeth. These students proved their need for more manual dexterity training than their fellows. They were encouraged to improve their tactile abilities at a haptic virtual dental education device (Simodont Dental Trainer; MOOG, Amsterdam, The Netherlands) performing additional manual dexterity exercises in the subsequent preclinical training course. In accordance with LeBlanc et al.,[23] the implementation of virtual training reality was found to be an effective additional training method for the development of students' operative dentistry skills.

Although the quality of the preparations varied highly among the students, no relevant difference was found that depended on the design of the finish line. As both the chamfer and the shoulder finishing line with a rounded inner edge are used for comparable indications, it should be considered whether a future focus on one finish line's design would be more effective and thereby give more time for the teaching of additional modern educational content such as computer-aided design and computer-aided manufacturing techniques.

## Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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