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# Influence of Beveling and Ultrasound Application on Marginal Adaptation of Box-only Class II (slot) Resin Composite Restorations

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**Clinical Relevance**

Beveling box-only Class II cavities is necessary to improve the marginal quality of restorations. Where beveling is impossible or difficult to achieve, ultrasound may improve marginal quality.

## SUMMARY

**A laboratory study was performed to assess the influence of beveling the margins of cavities and the effects on marginal adaptation of the application of ultrasound during setting and initial light curing.**

**After minimal access cavities had been prepared with an 80 µm diamond bur, 80 box-only Class II cavities were prepared mesially and distally in 40 extracted human molars using four different oscillating diamond coated instruments: A) a U-shaped PCS insert as the non-beveled control (EMS), B) Bevelshape (Intensiv), C) SonicSys (KaVo) and D) SuperPrep (KaVo). In groups B–D, the time taken for additional bevel finishing was measured. The cavities were filled with a hybrid composite material in three increments. Ultrasound was also applied to one cavity per tooth before and during initial light curing (10 seconds). The specimens were subjected to thermomechanical stress in a computer-controlled masticator device. Marginal quality was assessed by scanning electron microscopy and the results were compared statistically.**

**The additional time required for finishing was B > D > C (*p*≤0.05). In all groups, thermomechanical loading resulted in a decrease in marginal quality. Beveling resulted in higher values for**

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**"continuous" margins compared with that of the unbeveled controls. The latter showed better marginal quality at the axial walls when ultrasound was used.**

**Beveling seems essential for good marginal adaptation but requires more preparation time. The use of ultrasonic vibrations may improve the marginal quality of unbeveled fillings and warrants further investigation.**

## INTRODUCTION

The traditional treatment of primary approximal caries has been challenged in recent years. More conservative forms, which focus on both tooth preservation and restoration longevity, have been recommended.[1] Two main techniques have been described for this purpose: box-type (saucer-shaped) and tunnel restorations. The latter are difficult to control, because of limited access, and their clinical performance has been poor.[1-2] Although there have been few clinical studies, restorations have demonstrated better clinical performance using box-type preparations.[3]

Marginal integrity is crucial for the long-term clinical results of adhesively placed restorations.[4] A major problem is polymerization shrinkage,[5-6] which may initiate failure of the composite–tooth interface, resulting in interfacial gaps, which can lead to microleakage, marginal discoloration and secondary caries.[7] Therefore, restoration placement techniques, although controversial, are widely regarded as influential in the modification of shrinkage stresses.[8] Incremental placement of light-activated resin composite has been recommended to decrease overall contraction by reducing the bulk of the material cured at one time.[9-10] The preparation of a bevel at the margins has been suggested to improve the bonding surface and reduce gap formation and microleakage.[11-12] Oscillating preparation systems that avoid damage to the adjacent teeth have been proposed to bevel the margins. These systems are reported to be easier to handle than conventional burs and are promoted as less time consuming.[13]

This study assessed the marginal quality of box-only Class II composite restorations after different margin preparations and with or without the application of ultrasound during setting and initial light polymerization. It was assumed that the thixotropic effects due to the application of ultrasound would reduce the development of stress by increasing material flow, thus leading to improved marginal quality. The authors of this study are not aware whether this issue has been addressed in the literature, except for seating adhesively placed indirect restorations and fissure sealing.[14-15] The null hypothesis tested was that there is no difference in marginal quality among the different beveling techniques, irrespective of whether ultrasound is applied.

## METHODS AND MATERIALS

### Tooth Selection, Cavity Preparation and Filling Procedure

Forty human molars from the department's collection of extracted teeth were mounted centrally to roughened scanning electron microscopy (SEM) mounts (Baltec AG, Balzers, Liechtenstein) with super glue (Renfert Sekundenkleber Nr 1733, Dentex AG, Zurich, Switzerland) and embedded with chemically cured acrylic resin (Paladur, Heraeus Kulzer GmbH, Wehrheim, Germany). Dentin fluid pressure was simulated according to the method of Krejci and others.[16] Undersized Class II access cavities, with cervical margins located in the enamel, were prepared mesially and distally with water-cooled coarse diamond burs (80 µm; FG8614, Intensiv SA, Viganello, Switzerland). The teeth were then randomly assigned to four groups of 10 specimens each, and the cavities were finished using four different oscillating systems: A) a selectively diamond-coated U-shaped ultrasonic tip (PCS, EMS, Nyon, Switzerland) to prepare non-beveled control cavities, B) a beveled file (Bevelshape, Intensiv, Viganello, Germany), C) a selectively coated tip with an integrated marginal concavity (SonicSys, KaVo, Biberach, Germany) and D) a prototype file (SuperPrep, KaVo). Whereas Bevelshape and SuperPrep files were used in a special lockable EVA contra-angle (EVA INTRA 61 LRG, KaVo), the ultrasonic tips were inserted into and used in an ultrasonic device (Master Piezon, EMS) at medium energy. All preparations were made with low application pressure and water-cooling using the above mentioned finishing instruments but without adjacent teeth in place to ensure optimal beveling. The time taken for these three finishing procedures was measured.

To mimic a realistic operative setting, the teeth were placed in a custom-made typodont model (PPK, Zurich, Switzerland), with adjustable neighboring teeth. Transparent plastic matrices and light-reflecting wedges (Luciwedge, Hawe Neos, Bioggio, Switzerland) were placed for approximal restoration contouring. The enamel was etched with 35% phosphoric acid (Ultraetch, Ultradent, South Jordan, UT, USA) for 30 seconds and rinsed with water spray for 20 seconds. After the cavity had been carefully dried with air, a self-conditioning, maleic-acid-containing primer (Syntac Primer, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied for 15 seconds and gently air-dried before application of a second primer (Syntac Adhesive, Ivoclar Vivadent) for 20 seconds. After a gentle application of air, unfilled bonding resin (Heliobond, Lot D53729) was applied for 20 seconds and light-cured for 40 seconds (Optilux 500, Demetron Kerr Inc, Danbury, CT, USA). All restorations were placed in three separate, indirectly light-cured (60 seconds) increments (Figure 1). The first increment had a height of 1 mm. Before it was

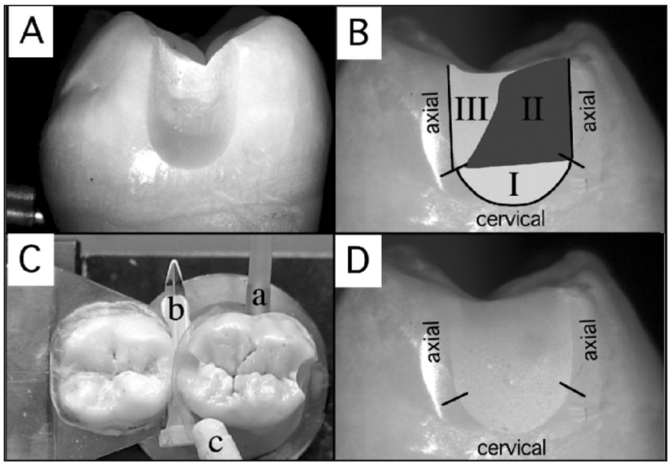


Figure 1. *Cavity preparation: (A) an unbeveled control cavity was filled in three separately placed and indirectly light-cured increments, (B) in a custom-made typodont model with adjustable neighboring teeth and (C) a: pin and plastic tube for pulpal pressure simulation; b: light-reflecting wedge; c: plastic tip for ultrasound application. The finished cavities were analyzed under SEM for marginal quality at the axial and cervical walls (D).*

filled, one cavity per tooth was randomly chosen to undergo the filling technique, with an additional application of ultrasound. A plastic-coated tip (PCS-Set, EMS) was placed bucally or orally at equatorial height, mesially or distally (Figure 1C). After placement and adaptation of each of the three increments, ultrasound was applied for 10 seconds before and during the first 10 seconds of light curing at medium energy.

Contouring, finishing and polishing were performed after removal of the teeth from the typodont, under a stereomicroscope (Stemi 1000, Carl Zeiss AG, Oberkochen, Germany) at 12x magnification. Flexible abrasive discs (Sof-Lex, 3M ESPE, Seefeld, Germany) and abrasive polishing brushes (Occlubrush, Hawe Neos) were used with water-cooling.

### Thermomechanical Loading and SEM Analysis

Impressions of the restorations were made using polyvinylsiloxane of low viscosity (President Light Body, Coltène, Altstätten, Switzerland) to assess baseline marginal quality. These impressions were cast with resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium) for later comparison with replicas made after the teeth had been thermomechanically loaded.

Caries-free palatal cusps were used as antagonists. The test specimens were loaded in the center of the occlusal surface in a computer-controlled masticator device (CoCoM 2, PPK) and treated with 49 N at 1.7 Hz and simultaneous thermal stress, with temperature changes of 5°C and 50°C for five equivalent years (1,200,000 cycles). After this loading phase, replicas of these test specimens were made and examined, together with baseline replicas by SEM (Amray 1810/T, Carl Zeiss) at 15 kV and a working distance of 20–30 mm, to achieve comparable contrasts. The researcher was carefully trained in the established procedures to evaluate marginal adaptation and was blinded to the various specimens. A modified image analysis program (NIH Image 1.62, National Institutes of Health, Bethesda, MD, USA) was used to assess the quality of the total length of the margins on multiple images at a magnification of 200x. All the restorations were examined for "continuous margins" (no gaps, no interruption of continuity) and non-continuous "imperfect" margins (open gaps due to adhesive or cohesive failure; filling or enamel fractures related to restoration margins) and expressed as a percentage of the total margin length.

### Data Presentation and Analysis

Statistical analysis was performed with StatView Version 5 (Abacus Concepts Inc, Berkley, CA, USA). The times required for the finishing procedures were statistically compared using analysis of variance (ANOVA). Post hoc analysis was performed using the Scheffé's F test.

The results of the SEM analysis to evaluate margin quality were reported using median values and interquartile ranges (IQR). The Kruskal–Wallis one-way test of variance followed by the Mann–Whitney and Wilcoxon signed rank tests were used for individual comparisons. For all statistical analyses, the level of significance was set at 95%.

## RESULTS

### Time for Finishing

The two files, Bevelshape (group B) and SuperPrep (group D), required more finishing time than was required by the SonicSys insert (group C). The latter was fastest, with a mean finishing time of 1.5 minutes. The Bevelshape file was slowest (3 minutes) to achieve the desired rounded marginal configuration. The SuperPrep file required 2 minutes. The time taken differed significantly among all groups (Figure 2).

### SEM Analysis

Figure 3 shows the typical cavity configurations of the different treatment groups and instruments.

The results of the SEM analysis of the approximal marginal axial and cervical adaptations ("continuous margins") before and after thermomechanical loading of the fillings are shown in Table 1. All restorations, except those from the cavities finished with the Bevelshape file in combination with ultrasound, showed a significantly decreased marginal quality at the axial walls after loading. All treatment regimens resulted in a significant decrease in marginal quality at the cervical wall after loading. No significant differences were noted (before or after loading) between the different finishing modalities, irrespective of whether ultrasound was applied. The null hypothesis was accepted.

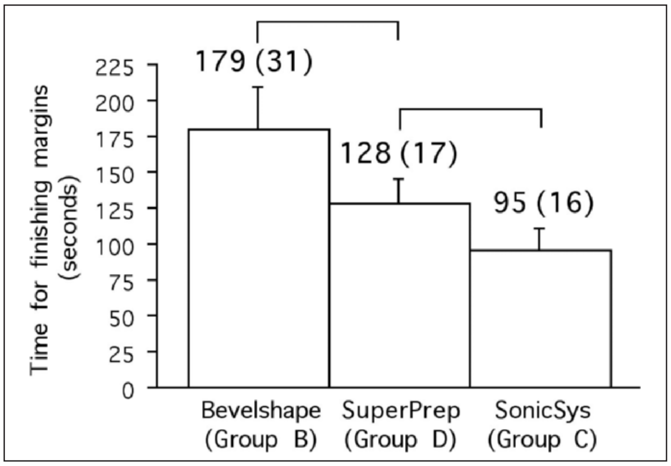


Figure 2. *Additional finishing times for groups B–D (bar charts; mean values, with standard deviations in brackets). Statistical differences are indicated with brackets* (p≤*0.05).*

The differences between the initial and terminal measurements are shown in Table 2. Data on marginal deterioration, expressed as a percentage loss of the perfect margin, showed no significant differences between samples with and without the application of ultrasound. The null hypothesis was only rejected for data obtained at the axial walls in cavities without beveling or the application of ultrasound. Unbeveled samples (group A) with no application of ultrasound showed significantly greater marginal deterioration at the axial walls than did groups B and D.

Filling fractures were very rare before and after loading (≤3%) and were not analyzed. Significant enamel fractures were predominantly observed in the unbeveled samples at the axial and cervical walls after

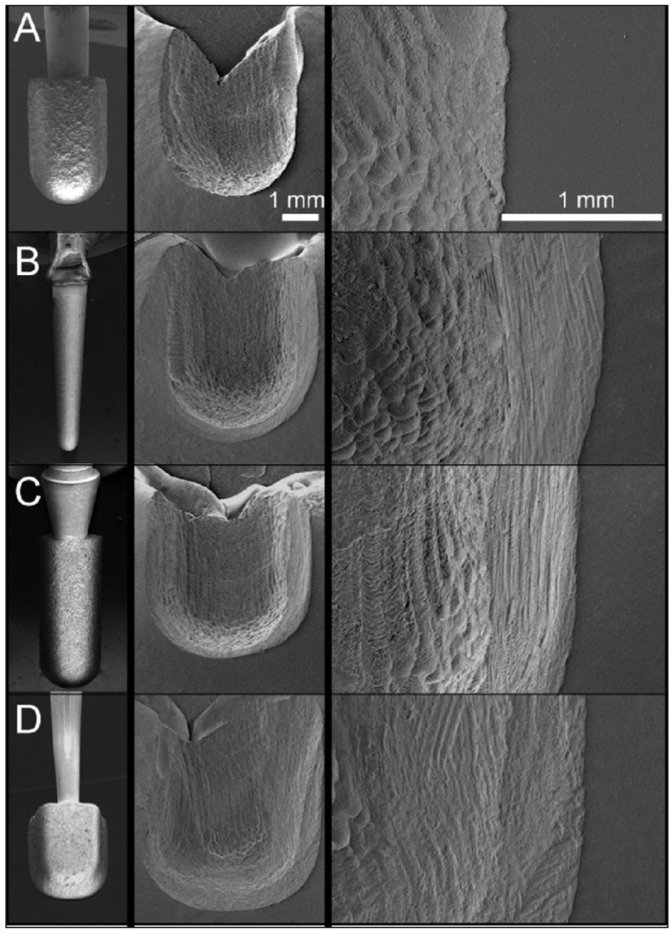


Figure 3. *The left column shows the different instrument tips (groups A–D) used in this study. An overview of each cavity preparation (10x) and a detailed image of the margin configuration (200x) are also shown.*

Table 1: *SEM analysis of the approximal axial and cervical adaptations (percentage continuous margin) before and after thermomechanical loading of the fillings with and without the application of ultrasound (median value, with IQR in brackets; NS = not significant).*

| | Percentage of Continuous Margin Without Ultrasound Application | | | Percentage of Continuous Margin With Ultrasound Application | | |
|---|---|---|---|---|---|---|
| **Axial** | **Before Loading** | | **After Loading** | **Before Loading** | | **After Loading** |
| Group | | *P* | | | *P* | |
| A | 93 (17) | 0.0051 | 42 (36) | 84 (11) | 0.0077 | 68 (20) |
| B | 93 (32) | 0.0051 | 76 (36) | 94 (28) | NS | 85 (41) |
| C | 89 (14) | 0.0093 | 55 (35) | 82 (21) | 0.0166 | 80 (30) |
| D | 86 (13) | 0.0284 | 74 (24) | 82 (21) | 0.0069 | 66 (59) |
| | **Without Ultrasound** | | | **With Ultrasound** | | |
| **Cervical** | **Before Loading** | | **After Loading** | **Before Loading** | | **After Loading** |
| Group | | *P* | | | *P* | |
| A | 89 (17) | 0.0069 | 45 (45) | 92 (15) | 0.0069 | 45 (23) |
| B | 72 (47) | 0.0284 | 40 (83) | 90 (18) | 0.0051 | 86 (51) |
| C | 89 (26) | 0.0069 | 45 (63) | 93 (50) | 0.0051 | 36 (46) |
| D | 87 (20) | 0.0077 | 77 (29) | 73 (53) | 0.0499 | 50 (68) |

Table 2: *SEM analysis of the difference between initial and terminal measurements (median value, with IQR in brackets). Identical superscript capitals represent significant differences between the different finishing modalities in one column. The results of the statistical comparisons (significance,* P*) of restorations placed without and with the application of ultrasound are presented in the median column (NS = not significant).*

| **Axial** | **Without Ultrasound** | | **With Ultrasound** |
|---|---|---|---|
| Group | | *P* | |
| A | 37 (21)[A,B] | 0.0081 | 14 (13) |
| B | 15 (11)[A] | NS | 7 (19) |
| C | 27 (17) | NS | 20 (25) |
| D | 10 (14)[B] | NS | 11 (12) |
| **Cervical** | **Without Ultrasound** | | **With Ultrasound** |
| Group | | *P* | |
| A | 43 (27) | NS | 40 (23) |
| B | 24 (28) | NS | 16 (25) |
| C | 32 (31) | NS | 31 (30) |
| D | 13 (15) | NS | 13 (23) |

Table 3: *SEM analysis of the enamel fractures after loading (median value, with IQR in brackets). Identical superscript capitals represent significant differences between the different finishing modalities in one column. The results of the statistical comparisons (significance,* P*) of restorations placed without and with the application of ultrasound are presented in the median columns (NS = not significant).*

| **Axial** | **Enamel Fractures** | | |
|---|---|---|---|
| Group | **Without Ultrasound** | | **With Ultrasound** |
| | | *P* | |
| A | 23 (18)[A,B] | NS | 17 (11)[A,B] |
| B | 0 (5)[A] | NS | 0 (5)[A] |
| C | 3 (14) | NS | 5 (15) |
| D | 0 (10)[B] | NS | 1 (7)[B] |
| **Cervical** | **Enamel Fractures** | | |
| Group | **Without Ultrasound** | | **With Ultrasound** |
| | | *P* | |
| A | 9 (19)[A] | NS | 27 (45)[A] |
| B | 0 (0)[A] | NS | 0 (0)[A] |
| C | 5 (12) | NS | 1 (5) |
| D | 2 (5) | NS | 2 (8) |

loading, as shown in Table 3. Figure 4 shows representative SEM images of margins classified as either "continuous," imperfect" or "enamel fractures."

## DISCUSSION

Polymerization shrinkage is regarded as a major limitation of resin composite materials. It may lead to gap

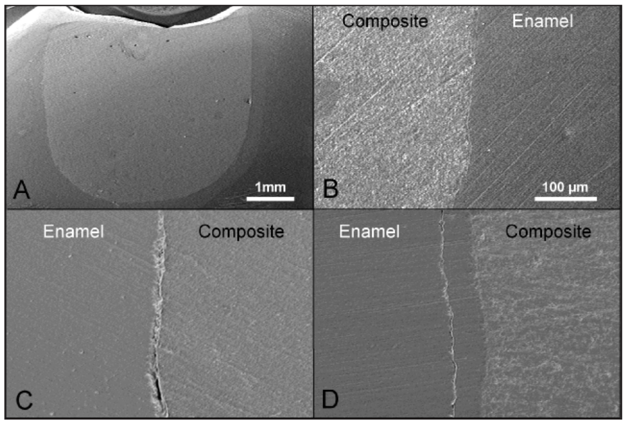


Figure 4. *SEM overview of a filling (16x, A) and representative margins at higher magnification (200x), classified as "continuous margin" (B), "imperfect" (C) and "enamel fracture" (D).*

formation, marginal discoloration, postoperative sensitivity and secondary caries.[17] The latter contributes significantly to clinical failure and to the replacement of resin composite restorations.[18-19] The stress generated during polymerization of resin composite fillings is also influenced by other factors, which are related to the material, technique, cavity preparation and their respective interactions.[20] Examples of these include volumetric polymerization shrinkage, elastic modulus and flow of the resin composite material, its adherence to the cavity walls and the configuration factor. This study focused mainly on the configuration of the cavity margin and resin composite flow in box-only Class II preparations. Beveling improved the marginal quality at the axial walls. However, it must be acknowledged that, despite beveling, a marked loss of marginal integrity was observed for all finishing techniques, especially at the cervical margin. When using oscillating preparation instruments in box-only Class II fillings, Hugo and others found a similar loss of marginal quality.[21-22] In their studies, the initial marginal quality was between 80% and 95% and decreased to values between 40% and 75%. Opdam and others reported significantly reduced microleakage in similar cavity configurations when the margins were beveled. Moreover, enamel cracks along the margins were only seen along the unbeveled margins, which is consistent with the results of other studies.[12,23-24] Thus, shortcuts in tooth preparation (no beveling) are not advisable, especially in view of the short time (maximum 3 minutes) required for beveling. Beveling leads to an accentuated etching pattern and an enlarged adhesive surface.[25-26]

A possible limitation of this investigation was that no undermining excavation was performed to better simulate the clinical excavation of caries. However, previous laboratory work has shown that additional excavation does not necessarily affect marginal integrity or microleakage.[11] Furthermore, excessive excavation may lead to unsupported areas of enamel, especially at the cervical margins, which may lead to additional enamel cracking and should therefore be avoided.[27]

This study provides interesting insight into the role of flow characteristics. It has shown that the application of ultrasonic energy, especially in unbeveled samples, resulted in a significantly reduced loss of marginal integrity after thermomechanical loading, a finding supported by another recent study by Peutzfeldt and Asmussen.[20] These authors showed that the flexural modulus and bond strength were less significant determinants of gap formation than viscous flow. The effect of flow was explained as follows: during the light-curing process, the resin matrix is converted to a polymer network, thus leading to closer packing and shrinkage. Shrinkage is compensated for by viscous flow until the resin reaches its gel point.[28] At that time, the viscous flow is reduced shortly after commencing light curing and stress is transferred to the cavity walls. Thereafter, shrinkage is largely counteracted by adherence and plastic flow. The influence of the thixotropic effects on viscous and plastic flow has, to the knowledge of the authors of the current study, received little attention in the literature. Although the use of vibrational energy has been shown to improve the insertion of indirect restorations using viscous resin composite materials,[14] this study is the first to demonstrate the beneficial potential of this approach to direct restorations. However, the desired effect was not evident in the cervical regions of the beveled samples. It can be assumed that the plastic tip was not ideally placed in the direct vicinity of the small cavity. Ultrasound was probably not effectively transferred to the margins or to the resin composite material applied in the first increment, especially in the cervical area. Nevertheless, this approach warrants further attention, in that it might improve the overall filling quality of other types of direct restorations.

## CONCLUSIONS

This *in vitro* study has shown that beveling box-only Class II fillings is necessary for achieving better marginal integrity and reducing enamel fractures. The application of ultrasound reduced marginal deterioration after thermal and mechanical stress in unbeveled cavities. This preliminary observation warrants further study to evaluate this interesting effect.

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