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Influence of Restorative Techniques on the Prevention of Dark Halos Around Class III Resin Composite Restorations

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Fabio Rizzante [1], Bruno Nicoliello [2], Beatriz Canin [2], Adilson Furuse [2], Victor Rosa [2], Sergio Ishikiriama [2]

1. Department of Reconstructive and Rehabilitation Sciences, James B. Edwards College of Dental Medicine, Medical University of South Carolina, Charleston, USA 2. Department of Operative Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo, Bauru, BRA

Corresponding author: Fabio Rizzante, fabio.rizzante@gmail.com

Abstract

The appearance of a dark halo around class III restorations is a common finding that may jeopardize the result in anterior restorations. This study evaluated the effects of different restorative techniques on preventing the appearance of the dark halo. Eighty bovine incisors were divided into eight groups (n=10), with the study factors being the cavosurface margin bevel in two levels (1.0 or 2.0mm) and the restorative technique in four levels (bevel coverage with opaque dentin shade resin in 0%, 50%, and 75%, and "internal mirror" technique); the response variable was the presence of the dark halo around restorations through visual examination by two blinded evaluators. Standardized "C-shaped" class III cavities were prepared and restored with Filtek Supreme resin composite (Solventum, St. Paul, Minnesota, USA) according to the restorative technique. Restorations were finished and polished after seven days, followed by storage in water for another 14 days and visual analysis. Grayscale digital cross-polarized pictures were evaluated by two calibrated examiners using a visual scale. To compare the techniques, the Kruskal-Wallis test was performed, followed by the Dunn test for individual analysis. The Mann-Whitney test was used to compare the different bevel extensions ($p<0.05$). Considering the restorative techniques, "internal mirror", 50% and 75% bevel coverage showed similar results and were more efficient than no bevel coverage with opaque resin (0%) in masking the dark halo. The partial coverage of the bevel at the cavosurface margin of cavities with opaque resin, as well as the internal mirror technique, are efficient in reducing the perception of the restoration contour. Partial bevel coverage with opaque resin and the internal mirror technique effectively reduce dark halo visibility in class III restorations, improving esthetic outcomes compared with no opaque resin coverage.

Categories: Dentistry
Keywords: anterior composite restoration, color-matching restoration, composite resin, esthetics dentistry, tooth shade matching

Introduction

A major challenge of restorative dentistry is to achieve the optimum results expected by the patient, especially when esthetics is a relevant factor [1,2]. To achieve excellence, dentists must understand the scientific principles and master the restorative techniques to reproduce tooth anatomy, function, and shade [1,3]. In this context, color matching plays a critical role in rendering restorations indistinguishable from the natural dentition [1,4].

Shade selection for resin composites used in anterior esthetic restorations is considerably more complex than in posterior teeth, particularly in class III and IV cavities. These types of cavities involve only a portion of the tooth structure, rather than its entirety, requiring the clinician to be well-trained in analyzing the morphology of the affected tooth and replicating it in a way that ensures seamless integration [5]. The challenge is increased in class IV cavities, which often exhibit intrinsic features such as defined mamelons, opalescence, and an opaque incisal halo [5,6].

The color of a natural tooth is determined by the interaction between the enamel, the dentin, and the light waves during refraction and reflection processes [1,7-9]. It is noteworthy that a beam of light contains several waves with different wavelengths. In some situations, these waves may overlap and can cause interference, which is defined as two overlapping waves at one point [10,11].

Light interference can be subdivided into destructive or constructive wave interference. The waves have peaks and valleys that determine their amplitude. Constructive wave interference happens when the peaks and valleys of the waves coincide, causing an increase in the wave amplitude. On the other hand, when the peaks of one wave coincide with the valleys of another wave, a decrease in the wave's amplitude occurs, and there is destructive interference of the wave [10,11].

Destructive wave interference can have an undesirable effect on esthetic restorations, perceived as a dark halo around resin composite restorations as a result of light wave annulment. Such an effect can compromise the esthetic results as it makes the restoration undesirably noticeable, even if it presents the proper shade [1,10,12-14].

Beveling the enamel at the cavosurface margin of the cavity enhances adhesion and marginal sealing by exposing enamel prisms in a transverse orientation and removing the aprismatic enamel layer, along with structurally weak prisms surrounding the cavity, which also contributes to better masking of the restorative interface and improved esthetic outcomes [15-18]. Nevertheless, the undesirable dark halo can be observed even in beveled margins depending on the chosen restorative approach [10].

Although the bevel is limited to the enamel margins, different combinations of translucent and opaque resin composites can be used during the restoration, which can generate variable esthetic outcomes [1,13,14]. For example, covering the bevel with excessive use of translucent resin can generate reflective waves and destructive interference with the appearance of a dark halo [10,14].

Within this context, different restorative techniques have been proposed to manage dark halos around class III resin composite restorations, such as covering the bevel with opaque resins and the “internal mirror” technique, which uses an internal white opaque resin composite layer to reflect the incident light and increase the value of the adjacent enamel region to compensate for the effects of destructive interference [10]. Nevertheless, there is a lack of information about the esthetic outcomes of the different techniques.

Therefore, the primary aim of the present in vitro study was to compare the esthetic outcomes of different techniques to restore the beveled enamel margins around class III preparations using resin composite. The null hypotheses tested were: (1) there would be no significant differences in esthetic results between the restorative techniques evaluated; and (2) bevel extension would have no significant influence on the esthetic results of the restorations.

Materials And Methods

This study used a 4x2 factorial design with the study factors being the extension of the enamel cavosurface bevel in two levels (1mm and 2mm) and the restorative technique in four levels (according to the percentage of bevel coverage using an opaque resin composite: 0%, 50%, 75%, and 0% + “internal mirror”) (Figure *1*). The response variable was the visual perception of the dark halo determined by a three-level score.

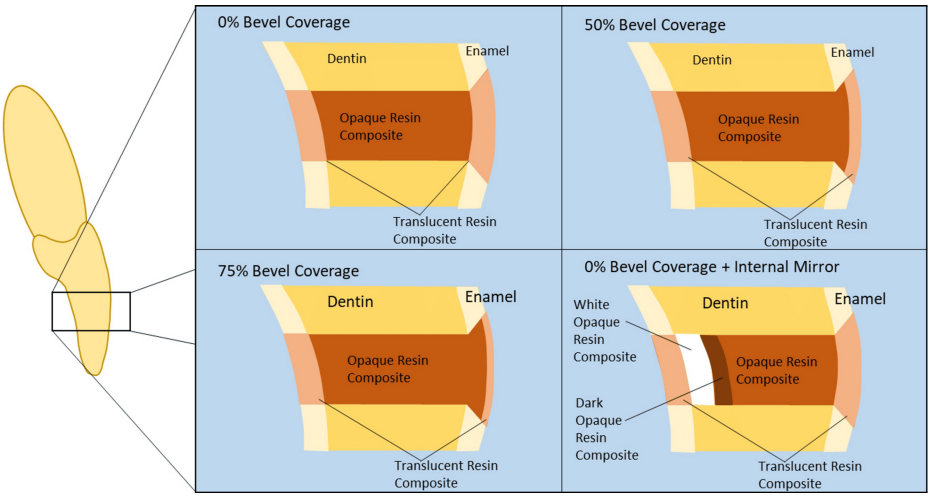


FIGURE 1: Schematic representation of the restorative technique groups

The image was created by the authors using Adobe Photoshop (Adobe Inc., San Jose, California, USA).

Preparation of specimens

Eighty eligible freshly extracted bovine teeth with standardized size and color had the buccal enamel polished using a sequence of sandpaper discs (Microdont, São Paulo, SP, Brazil) with three different decreasing granulations to minimize the specimens’ surface texture and optimize the visual analysis.

The teeth were individually stabilized in a lab condensation silicone putty (Zetalabor; Zhermack, Badia Polesine, Rovigo, Italy) matrix, and class III cavities were prepared at the middle third of the mesial surface

of each tooth using a 2.9mm diameter spherical diamond bur (#3018; KG Sorensen, Cotia, SP, Brazil). Cavities were standardized in a "C-shape" involving the entire buccal-lingual extension, with 5mm height and 5mm width. The 1.0 or 2.0mm extensions of a flat bevel at the buccal cavosurface angle were made using a conical diamond bur (#3203; KG Sorensen, Cotia, SP, Brazil), positioned 45° in relation to the external surface, following the different groups. Samples were then divided into eight groups (Table *1*).

Groups	Restorative Protocol
1B0	1.0mm bevel, 0% covered with opaque resin
1B50	1.0mm bevel, 50% covered with opaque resin
1B75	1.0mm bevel, 75% covered with opaque resin
1BIM	1.0mm bevel, 0% covered with opaque resin and “internal mirror” technique
2B0	2.0mm bevel, 0% covered with opaque resin
2B50	2.0mm bevel, 50% covered with opaque resin
2B75	2.0mm bevel, 75% covered with opaque resin
2BIM	2.0mm bevel, 0% covered with opaque resin and “internal mirror” technique

TABLE 1: Study groups according to the bevel extension and opaque resin coverage extension over the bevel (n=10)

All cavity’s dimensions were confirmed with a digital caliper before the restorative stage. For the restorative protocol, all cavities were etched with 37% phosphoric acid gel for 15 seconds only in enamel, rinsed for 20 seconds, and dried with absorbent paper. A layer of the adhesive system (Single Bond Universal; Solventum, St. Paul, Minnesota, USA) was applied with a microbrush, air-dried, and light-cured using a 1200 mW/cm^2 LED light-curing unit (Ultrablue IV; Microdont, São Paulo, SP, Brazil) for 20 seconds.

The restorations were performed using Filtek Supreme resin composite (Solventum, St. Paul, Minnesota, USA), with shade A2E used for the translucent enamel layers (lingual and buccal walls) and shade A2D for the opaque dentin layer covering the bevels at different proportions according to group allocation (Figure *2*). For the "internal mirror" technique, a translucent resin (A2E) was used to create the lingual wall, followed by a white opaque dentin layer (WD) and a darker body resin (A6B) layer to balance the color saturation of the final restoration. Subsequently, the opaque dentin resin (A2D) was applied to fill the cavity, and the final buccal enamel layer was restored using translucent resin (A2E) over the entire bevel (Figure *2D*). In all groups, the incremental technique was used, and each increment was light-cured for 20 seconds.

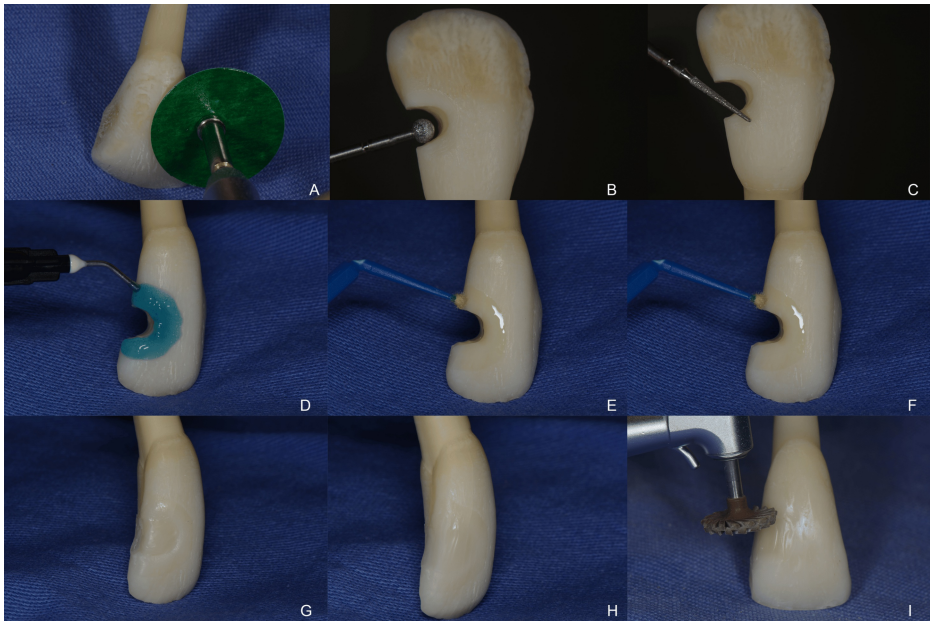


FIGURE 2: Sample preparation and restorative sequence

(A) Initial polishing; (B) cavity preparation; (C) enamel beveling; (D) acid conditioning; (E) application of adhesive system; (F) making the lingual wall; (G) 50% coverage of the bevel with opaque resin; (H) final layer with translucent resin; and (I) final polishing of the restoration.

After restoration, all specimens were stored in deionized water at 37°C for seven days, followed by finishing with a conical multilaminated bur (#9714FF; KG Sorensen, Cotia, SP, Brazil) and polishing with diamond rubber polishers (Swivel #9150 and #9837; Jota AG, Rüthi, Switzerland) (Figure *2*). The specimens were then stored in deionized water for an additional 14 days until analysis.

Restoration analysis

The 80 specimens were placed on a stand with a black background and photographed using a cross-polarization technique. For this purpose, a DSLR Nikon D5200 camera (Nikon, Tokyo, Japan) was used, and polarizing filters were adapted to both the Nikon Micro Nikkor 105-mm lens and twin flashes (R1C1; Nikon, Tokyo, Japan). The filters (flashes and lens) were positioned perpendicularly to each other in order to provide crossed planes of polarization and remove the glare that could interfere with the visual analysis. Pictures were taken in raw format with ISO 100, f/22, and a shutter speed of 1/125 at 15cm from the specimens, with the flashes set to through-the-lens (TTL) mode [4]. The color-generated images were randomized and transferred to a grayscale pattern using Adobe Photoshop Lightroom software (Adobe Inc., San Jose, California, USA).

The grayscale images were evaluated on a Dell QHD monitor (model U2717D/DA; Dell, Round Rock, Texas, USA) to assess the restorations visually. Following training and calibration, which achieved an inter-rater agreement exceeding 70%, two experienced, blinded evaluators independently assessed the visual perception of a dark halo around the resin composite restorations using a three-point scale: 0, absent; 1, barely visible; and 2, visible.

Statistical analysis

The Kappa concordance coefficient was used to evaluate the degree of agreement among the evaluators. For the comparison between the techniques, the collected data were submitted to the Kruskal-Wallis test followed by the Dunn test for individual analysis. The Mann-Whitney test was used to compare the different extensions of the bevel. A level of significance of 5% was adopted for all analyses.

Results

The inter-observer reliability analysis of the data obtained a Kappa index of 0.752, which represents a substantial agreement among the evaluators (Table *2*).

Group	n	Evaluator 1	Evaluator 2
1B0	10	2	2
1B50	10	0.5	0.5
1B75	10	0.5	0.5
1BIM	10	1	1
2B0	10	2	2
2B50	10	0	0
2B75	10	0	0
2BIM	10	0.5	1

TABLE 2: Median scores assigned by each examiner to each group

There was no significant statistical difference considering the bevel extension. Regarding the restoration technique, the absence of bevel coverage with opaque resin resulted in a higher score (more observable dark halo) than the other techniques. The partial bevel coverage (50% and 75%) and “internal mirror” techniques were similarly efficient at avoiding the dark halo perception around the restorations (Table *3*).

Factor		N	Median	p
Bevel	1mm bevel	40	1*	0.184
	2mm bevel	40	0.5*	
Restorative Technique	0%	20	2	<0.001
	50%	20	0*	
	75%	20	0*	
	Internal mirror	20	1*	

TABLE 3: Statistical analysis of the factors studied

Values with an asterisk (*) represent the absence of a statistically significant difference within the same factor (p>0.05).

Discussion

Beveling of the cavosurface margin in anterior teeth cavities can be used to reduce microleakage and to improve retention, resistance, and esthetics [15,16]. However, there is no consensus in the literature regarding its extension or ideal restorative technique to improve the esthetic outcomes.

The use of resin composites with different translucence/opacity characteristics aims to reestablish the natural optical properties of the teeth and make restorations that are invisible to the observer [6,14]. The esthetic results are compromised when the bevel is inadequately restored, resulting in a dark halo around the restoration’s margins, even when the resin shade is adequate [10].

In the present study’s results, it was possible to verify that the total coverage of the surrounding bevel with a translucent resin composite resulted in greater visibility of the dark halo, meaning that the restoration would be more perceptible. The partial coverage of the inner portion of the bevel with an opaque resin composite (less translucent), either at the 50% or 75% ratio, was necessary to reduce the destructive interference of the light and mask the resin-tooth interface. Such results agree with the literature and suggest that it is crucial to cover the internal line of the bevel regardless of the percentage of coverage [9,10,14,17].

The "internal mirror" technique was also capable of masking the tooth-restoration interface, relying on the use of an internal opaque white resin as a solid/opaque “background” for the restoration, and compensating

the increased value with a darker composite [10]. Although this technique showed results similar to the groups covering the bevel with an opaque resin, it can be more technically sensitive, and controlling the thickness and final value of the restorations can be challenging. Considering the difference in the capacity of masking the restoration's interface, the first null hypothesis (there will be no significant differences between the restorative techniques) was rejected.

Although it has been shown that a longer bevel promotes better stress distribution and fracture resistance [16,18], no differences were observed regarding the esthetic outcomes; therefore, the second null hypothesis (there will be no significant differences between the bevel extension) was accepted.

One could ask about the choice not to use more sophisticated devices for color perception analysis (such as a spectrophotometer), as it could eventually evidence further differences among the tested groups [12]. Nevertheless, the two highly experienced operators achieved substantial agreement (as observed by the Kappa analysis) when evaluating photos projected on a screen with high magnification, meaning that further possible nuances in shade should not be clinically relevant.

Even though bovine teeth do not reproduce all the morphological and physicochemical characteristics of human teeth, previous studies have indicated that they may be suitable substitutes for in vitro studies [19]. Nevertheless, the findings should be interpreted within the constraints of this experimental model and should not be directly extrapolated to human teeth without further validation. Despite standardization of size and color, the specimens had subtle differences in color saturation, which would require different proportions of resin composite to achieve perfect color matching. Considering that the aim of the present study was to analyze the presence of the dark halo around the restorations' margins, the photos were converted to a black-and-white scale to standardize hue and saturation, and the cross-polarization technique was also used to avoid the reflection of the flash over the enamel, which could also interfere with the visual analysis [4]. In addition, only the resin composite shades and restorative techniques included in this study were evaluated; therefore, the findings should not be generalized to other materials, shade systems, or simplified and single-shade composites.

Future research should evaluate shade matching outcomes considering different cavity geometries and resin shades and techniques, including the recently released "single shade" or "simplified shade" resin composites.

Conclusions

The partial coverage of the bevel at the cavosurface margin of cavities with opaque resin, as well as the internal mirror technique, is effective in reducing the perception of the restoration contour. The extension of the bevel was not a determining factor in the perception of the dark halo around the restorations.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Fabio Rizzante, Bruno Nicoliello, Sergio Ishikiriama, Adilson Furuse

Drafting of the manuscript: Fabio Rizzante, Victor Rosa, Adilson Furuse

Critical review of the manuscript for important intellectual content: Fabio Rizzante, Bruno Nicoliello, Sergio Ishikiriama, Adilson Furuse, Beatriz Canin

Acquisition, analysis, or interpretation of data: Bruno Nicoliello, Victor Rosa, Sergio Ishikiriama, Beatriz Canin

Supervision: Sergio Ishikiriama

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** Ethics Committee on the Use of Animals (CEUA) issued protocol number exempt - not applicable. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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