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Clinical Procedures to Avoid the 'Dark Halo' in Restorations with Direct Composite Resins

(Introducing the Concept of Destructive Interference in Restorative Dentistry)

Abstract: The 'dark halo' present in the enamel surrounding anterior composite restorations spoils the appearance of the restoration and is very difficult to control. This article offers an explanation for its causes and proposes clinical solutions. The behaviour of the transmitted light may be handled through the use of an 'internal mirror' made with a shade of opaque white composite resin and through the right choice of the enamel shade, seeking sufficient diffusion of the light. Another innovative concept is that of 'chroma balance', which may be generally achieved through the use of more or less intensive dentine shades, different from the one which was originally chosen.
Clinical Relevance: From study of the behaviour of light in bodies, and especially in teeth and restorations, it may be possible to find the cause of the 'dark halo' effect, which relates to the optical property called the 'destructive interference of the light'.
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In order to be effective in restorative dentistry and to achieve the aesthetic goals we seek, several procedures must be understood and mastered. Among these, a knowledge of illuminant light and a way of handling how it behaves is of crucial importance.[1]

There are several aspects of the behaviour of light that need to be understood:

- The 'language of colour': value, hue and chroma;
- The passage of light through a body: transparency, translucency and opacity;
- The absorption and emission of light by atoms: opalescence (with its dichroic effect) and a property that is not often named and least of all used in dentistry: 'the diffusion of light'. According to *The Optical Society of America*, 'diffusion' is the scattering of light by reflection or transmission. The definition of 'transmission' is the conduction of radiant energy through a medium. In this article, the term 'diffusion' refers to 'diffusion by transmission'; and, finally
- An aspect related to luminescence: fluorescence.[2]

By studying, understanding the application and finally comprehending the role each one of these properties plays, the outcome of treatment should more precisely relate to restorations in terms of their optical behaviour.[3]

There are other fundamental elements to be considered, such as texture, shine, reflection patterns, anatomy (at all levels) and, of course, function.[4]

However, returning to the topic of the 'behaviour of light', it is necessary to analyse the property that this article focuses on: 'the destructive interference of light'.

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The destructive interference of light. Its clinical relevance

In aiming to achieve efficient aesthetic results, a clinical problem which is often difficult to solve may have to be faced, namely the 'dark halo', which may accompany Classes III and IV composite resin restorations and may be seen in the enamel around these restorations.

Light is an electromagnetic wave: there is a variable electrical field (E) and a magnetic field (H), one perpendicular to the other. In Figure 1 the values of both fields are 'frozen' in a given instant for the different points of the ray. A ray of light is an unachievable concept in practice; it is thus more accurate to talk about a beam: a beam is made up of a group of rays.[5]

All the light-related phenomena that the dentist observes in the teeth and in the materials used for reconstruction belong to the field of Physics and are governed by the laws of Optics. The great difference between

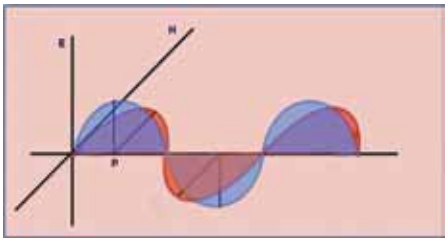
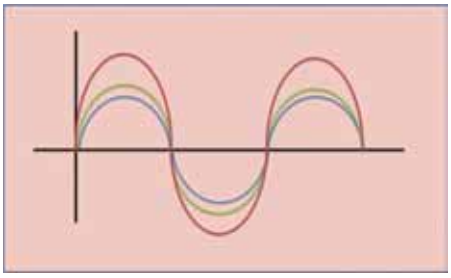


Figure 1. Wave of light with its two fields.

a



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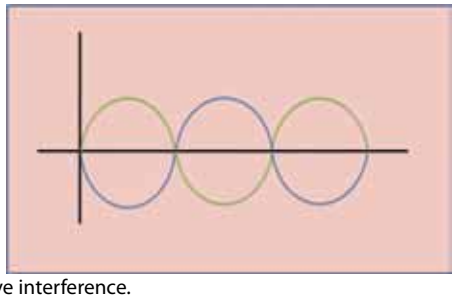

Figure 2. **(a)** Constructive interference; **(b)** destructive interference.

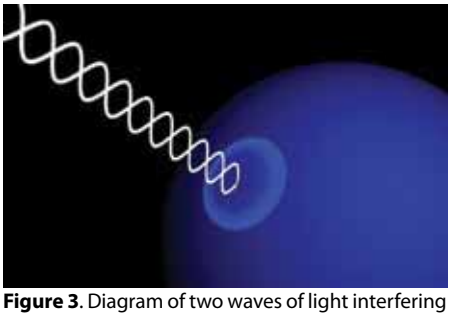

Figure 3. Diagram of two waves of light interfering with one another.

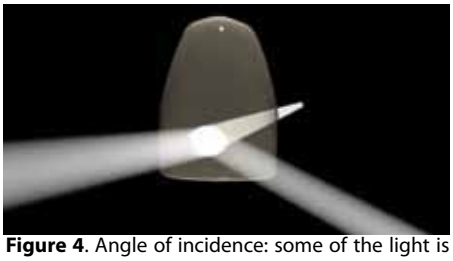

Figure 4. Angle of incidence: some of the light is reflected and another part penetrates the tooth, showing the refraction angle.

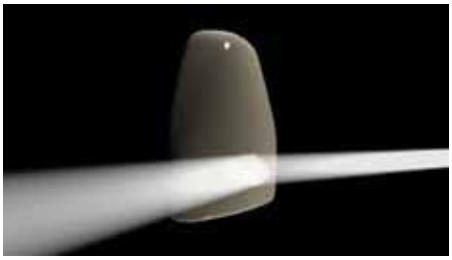

Figure 5. Incidence of the beam of light with a very small angle.

a

b

Figure 6. (a) Class III composite resin restoration. The 'dark halo' is visible. **(b)** Another case showing the 'dark halo' around a Class III composite resin restoration.

the topics dealt with in Optics texts, even in the advanced ones, and the reality the dentist faces, lies in the complexity of the tooth, which can vary according to the patient, such as the time in his/her life. There are even differences in the behaviour of the light within the same tooth, depending on the locations, layers, coat variants and internal properties of different restorative materials.

An intensive optical study, together with a clear knowledge of the characteristics and properties – especially optical – of teeth, as well as restorative materials, allows us to have a clear understanding of the basic principles and the concepts derived from them, in order to develop techniques which allow us to achieve the optimal result.[6]

Looking for the causes and their explanations in all the matters which link Dentistry and Optics entails an effort which goes beyond the clinician's abilities: it needs to be done by researchers. However, succinct theoretical support shall be provided for each topic where necessary. The intention is simply to promote further research into this area and any other related areas. The complexity of this topic goes far beyond the aim of providing minimal information about those items which belong to the field of Optics and are relevant to the complex system of the tooth, with or without restorations, and the aim of this article is not to provide solutions.

From the clinical point of view, we face a frequent clinical problem: the so-called 'dark halo' surrounding Class III or IV restorations made of a direct aesthetic material (generally composite resin). In this article, the causes underlying this phenomenon are investigated and clinical techniques to avoid it are proposed, thereby achieving the desired aesthetic level. Only by clinicians putting these techniques into practice can their efficiency be tested.

Interference

Interference is defined as two waves overlapping at one point. This overlap produces a figure or an interferential diagram which is most easily observed in the waves produced on the still surface of water – a good study model – but more difficult to achieve with light. The fundamental condition which must be fulfilled is that both waves must keep a difference in their constant phase all the time, ie that the waves used are *coherent*. When this is achieved, the interference may show either a reinforcement or a weakening of the beams of light, known as 'constructive' and 'destructive' interference, respectively.[7]

In constructive interference, the wave's valleys and peaks coincide (blue) with those of the other one (green), causing an increase in the width (height) which, in the case

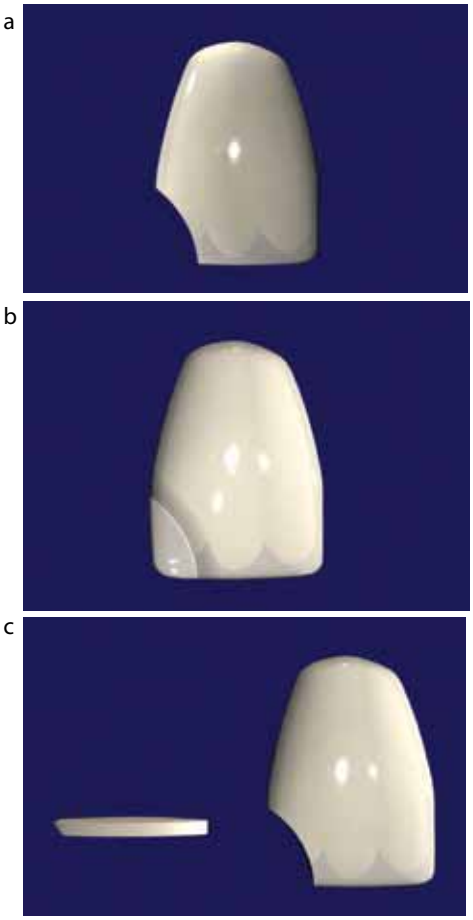

Figure 7. (a) Fracture of an angle: Class IV. **(b)** Restoration with direct aesthetic material (probably a composite resin): the 'halo' appears. **(c)** A cross-section is taken to study the phenomenon in detail.

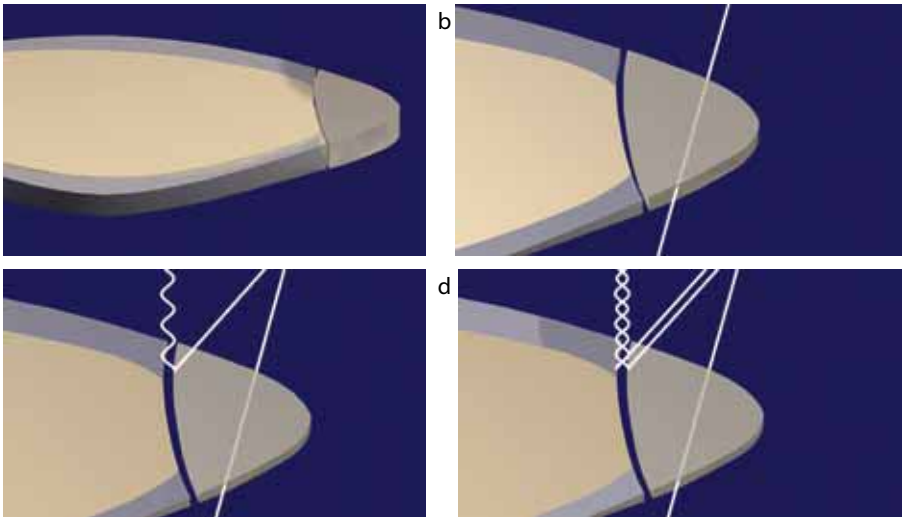

Figure 8. (a) When the direct composite resin is placed (*and not before*), a shadow appears on the vestibular enamel (the 'halo'). **(b)** Rays of light get lost towards the palate, through the composite resin (as is natural). A gap can be seen between the composite resin and the tooth, which corresponds to the adhesive layer. **(c)** A ray is reflected on the inner surface of the resin. (The incident rays have been drawn as straight lines in order to simplify the drawing and those reflected as waves, in order to understand the problem). **(d)** A second ray, parallel to the previous one, is reflected on to the outer surface of the enamel, interfering with the previous one. Thus the conditions for the 'halo' are created and the 'halo' is seen (a shadowed area on the vestibular enamel surface).

of light, translates as luminous intensity (red) (Figure 2a).

In destructive interference, the peaks of one of the waves coincide with the valleys of the other so that, working together, they will annul the vibratory phenomenon: there is no wave, therefore *there is no light* (Figure 2b). This explanation requires certain conditions, such as the fact that all the rays must have the same wavelength (represented by the Greek letter lambda λ), which means that we need to work with only one colour of light[8] (Figure 3).

However, in our day-to-day work, the light is white; therefore it is a mixture of different λ. It is at this point that the rays with a given λ (or, less strictly, those of a given wavelength) will interfere destructively. The destructive interference of white light happens according to hues ('colours') or at least according to groups of hues. In those spots where the long λ from the red rays interfere destructively, the hue of the resulting light will be bluish and vice versa.[9]

As long as the points of interference for the different hues are separated, the interference bands will appear more defined and coloured (as is the case with puddles of water on the street which have a thin coat of oil on the surface: we can see colours). As long as the points of interference of the different hues are together, the interference bands shall appear darker.[7] This is the case with teeth. There is a 'dark halo' and, if studied in more detail, slight hue differences can be seen.

It is important to stress the fact that the word 'dark', which we normally use to refer to this undesired effect after the restoration of a tooth, is the conjunction of interferences caused at neighbouring spots (Figures 4 and 5).

Clinically, that unaesthetic halo cannot be seen from all angles. Thus, the beam's (or the rays') incidence axis plays a very important role.

Figure 5, which shows a very low angle of incidence, could provide an explanation of this destructive interference with white light: the 'interference' by 'reflection', such as the case in the 'Lloyd's Mirror' study.[7]

To illustrate this phenomenon, it is easy to understand that:

- The 'halo' is visible with incidences near 90°;
- The tooth's surface is a curve;
- 'Dark' does not mean black or grey, but with different hues;

None of the above elements rules out this theory, at least to explain most of the phenomena.

If the patient presents a 'dark halo', it changes according to the axis of incidence of the light, enhancing its presence or reducing it.

What causes the dark halo?

A 'dark halo' is illustrated in Figure 6 and the sequence of events that results in this 'halo' being formed is illustrated in Figures 7 and 8.

What clinical solutions are there to avoid the 'halo'

The use of composite resin to avoid the 'halo' is shown in Figure 9.

Is it possible to eliminate the light's destructive interference?

The answer is no. It is not possible to exercise any kind of influence on the waves

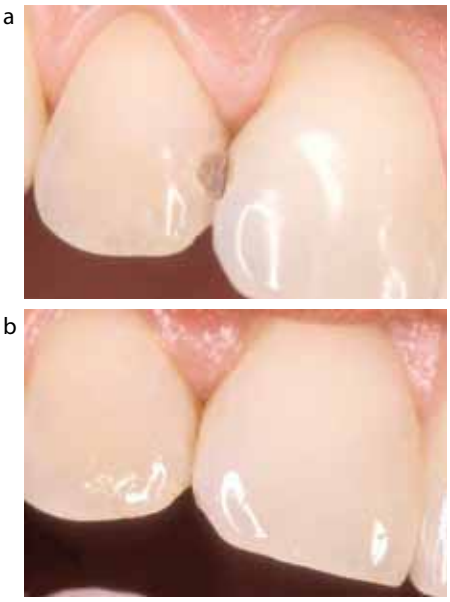

Figure 9. (a) Class III cavity. **(b)** Class III composite resin. The 'dark halo' is not visible.

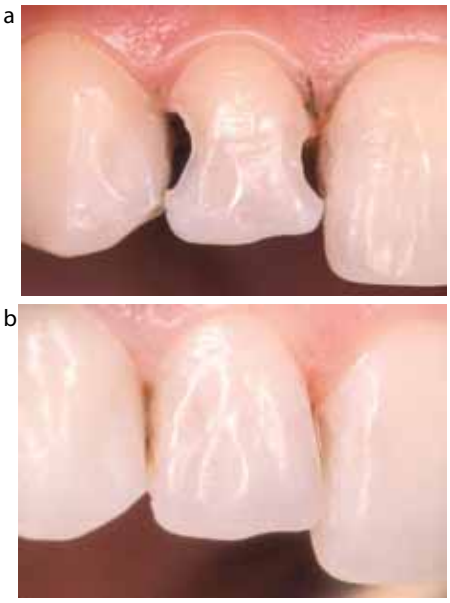

Figure 10. **(a)** Class III cavities. **(b)** Composite resin restorations in Class III cavities. The 'dark halo' is not visible.

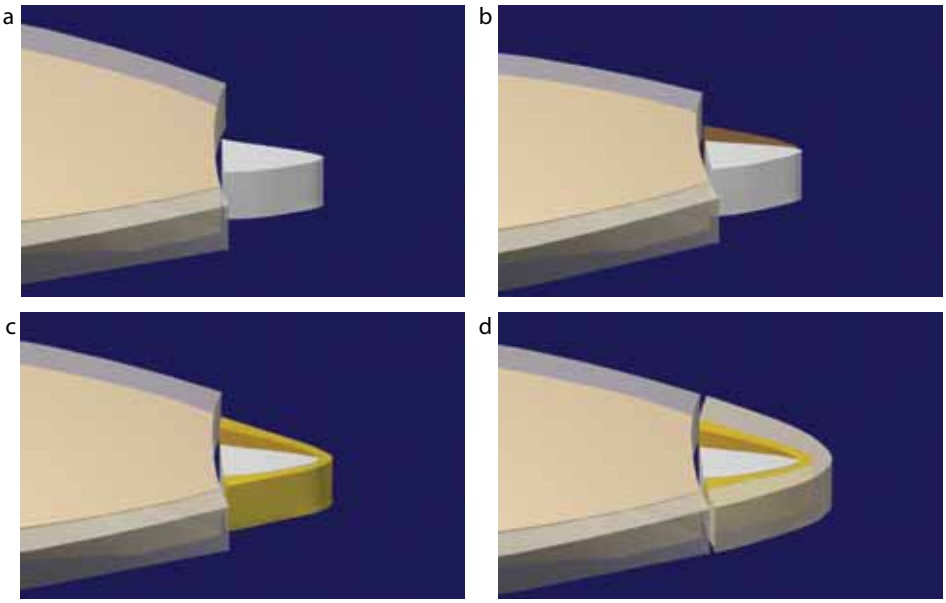

Figure 11. (a) A 'mirror' is placed at the centre of the restoration, parallel to the final vestibular edge. The aim of this 'mirror' is to recover the light that generally continues all the way to the palate. It is made with a light block (highly white and opaque resin). It is not recommended to place it on the palatal section, except in the case of extremely thin teeth. **(b)** After placing opaque white, it is necessary to 'balance the chroma'. If the dentine were placed directly, the final value and chroma would vary (the value would increase and the chroma would decrease). This is better achieved with intensives in extremely thin layers (A5, A6, B5, etc) with the help of a condenser, for example. **(c)** If there is enough space, the dentine space is completed with dentine shades: A1, A2, A3, A3.5, A4, B1, B2, etc. The following rule must be respected: use dentine shades for the dentine area and enamel shades for the enamel area. This applies to all cases, whatever the restoration. **(d)** The material to be used for the reconstruction of the enamel must be very carefully chosen: it is important to be able to differentiate translucent enamels from opalescent enamels (and in some cases it is useful to use transparent or even iridiscent enamels).

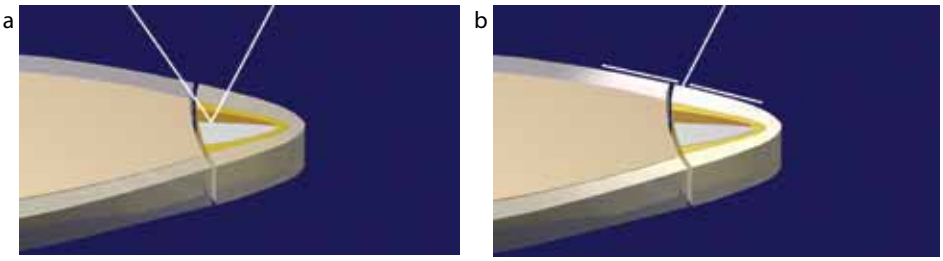

Figure 12. (a) The beam of light, which originally continued its route towards the palate, now returns to the area to be illuminated. **(b)** The diffusing enamel directs beams of light towards the surrounding enamel.

of light inside the mouth or on the teeth in order to avoid this negative phenomenon (Figure 10).

However, it is possible to find a different mechanism of action. The author proposes a procedure illustrated in Figure 11.

It is important to determine which kind of enamel the tooth has on the edge of the cavity, so as to be able to choose correctly. In this case, where the aim is to *illuminate* the area where there is a destructive interference, it is necessary to use a high *diffusion* enamel. The idea would then be to take the light towards the 'dark' area in the restoration: this can be done with a diffusion enamel (such as an opalescent with a good diffusion, but one which will not raise the value too much since, because of this characteristic, many of the beams of light reflect more than on a neutral one or on one with a lower value).

The diffusing enamel plus the 'mirror' made with the opaque white will prevent the interference from being seen (it is still there, but is no longer visible) (Figure 12).

Clinical Case

A clinical case has been cited to illustrate the technique used (Figures 13–26).

Figure 13. Pre-operative view.

a

b

Figure 14. (a, b) Elimination of failed restorations and apparent decay.

Figure 15. Self-limiting phosphoric acid: *UltraEtch* (Ultradent Products Inc, USA).

Figure 16. Primer and adhesive material: *PQ1* (Ultradent Products Inc, USA).

Figure 17. Photopolymerization.

Figure 18. White opaque 'mirror': *Amelogen Plus* (Ultradent Products Inc, USA). Opaque White (OW).

Figure 19. 'Intensity balance': *Amelogen Plus* Dentine A5.

Figure 20. Confirmation of the resin colour (the tooth is dehydrated).

Figure 21. Application of *Amelogen Plus* Dentine A2.

Figure 22. Application of light diffusing enamel: *Amelogen Plus* Enamel Neutral (EN).

Figure 23. Application of light diffusing enamel: *Amelogen Plus* Enamel White (EW).

Figure 24. Confirmation of the resin colour (the tooth is dehydrated).

Figure 25. Polishing: using cups, discs and *Hi Shine* jiffy tips.

Figure 26. Post-operative view.

Conclusions

From a study of the behaviour of light on bodies, and especially on the teeth and restorations, the cause of the 'dark halo' effect has been highlighted, relating to the optical property called 'destructive interference of the light'.

Having identified the nature of this phenomenon, clinical procedures to avoid or to minimize its appearance have been outlined. These procedures are based upon a stratification different from the direct composite resin restoration, including an opaque hue to block the light completely and to reflect it towards the affected area of the enamel ('internal mirror'), and the choice of a diffusing enamel which would allow us to illuminate the dark area, diverting the beams of light to the adjacent area. A useful concept of 'chroma balance' has been introduced to achieve the desired saturation.

In conclusion, it would seem to be possible to avoid the appearence of the 'dark halo' effect using the techniques presented above, based upon the study of its cause, the destructive interference of the light.

The clinical experience presented here is still not conclusive but, with analysis, presents encouraging signs for this particular hypothesis.

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