Tooth lightening: a new concept for maximizing surface aesthetics

By Professor Laurence J. Walsh

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With the current strong levels of interest by patients in reducing the aging-related yellow shades within their teeth by bleaching, it is surprising that greater attention has not been directed to other means of reducing yellowness. This paper looks at the concept of "tooth lightening" using simple in-office and supporting at-home measures, as opposed to "tooth whitening" using peroxides.

The concept is based on exploiting a number of well-established optical properties of teeth, enamel and water under visible light conditions. These are presented step-wise in Tables 1-3 and the accompanying Figures 1 and 2. The scientific foundations of the tooth lightening concept rest largely on altering the short wavelength (blue) scatter of enamel and reducing its transmission of yellow light, although there are minor accompanying changes such as reduced red absorption which also occur.

The clinical stages in tooth lightening are as follows. Firstly, the reflection of light and the backscatter of the shorter wavelengths of light are enhanced by a gentle microabrasion procedure (ADA Item 116) using 37% phosphoric acid etching for 20 seconds followed by gentle application of flour of pumice or graded abrasive pastes at low rotational speeds. The etching step enhances subsequent subsurface mineral changes. Patients then apply GC Tooth Mousse Plus™ each night immediately before bed for at least 2 weeks. The reduced yellow transmission and increased backscatter of blue light from the enamel will cause a subtle reduction in yellow.

The procedure can precede in-office or at-home whitening treatments, to establish optimal enamel properties and aesthetics, or can follow other cosmetic treatments. Two typical cases are shown in Figures 3 and 4. A variety of surface polishing agents can be used to maximize reflectivity without losing the natural surface contours.

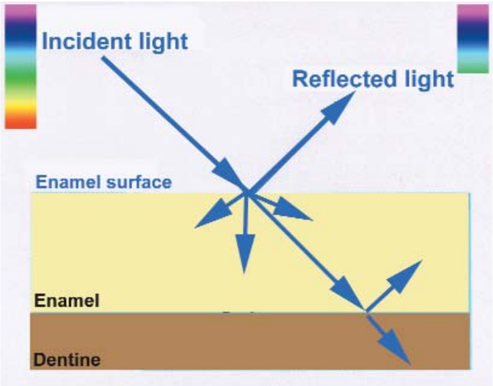

Figure 1. Simplified representation of the interactions of light with enamel and dentine. At the tooth surface, there is reflection and scatter, but limited absorption. With transmission into the tooth, further reflection, scattering and absorption events occur. Selective enhancement of the shorter wavelengths of light provides the lightening effect.

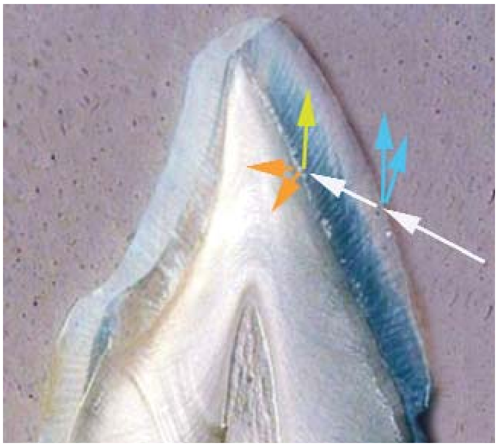

Figure 2. Ground section of a human maxillary central incisor tooth showing some of the major interactions at the enamel and dentine boundaries.

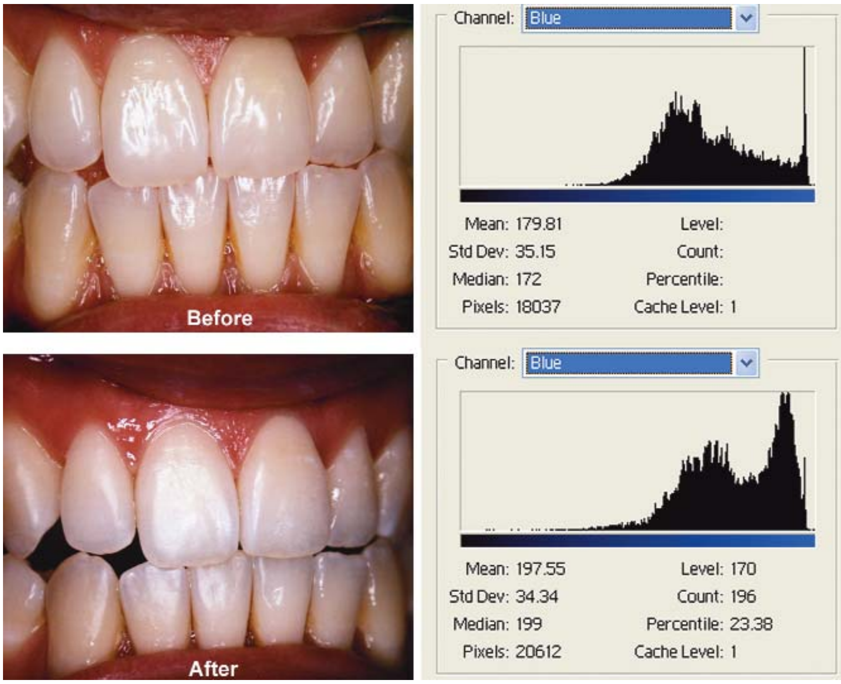

Figure 3. Clinical case of a 26 year old female, showing immediately before and 4 weeks after tooth lightening treatment, with blue pixel intensity data for tooth 11 showing an increase between the two. Note the bimodal nature of the pixel distribution in the "after result", which occurs because of increased reflection of light. Case taken from Ref. 15.

Table 1. Optics of human teeth

- The light that penetrates the surface of a tooth and enters it is refracted due to the fact that light travels faster in air, than in water or in solid apatite materials.
- Tooth colour is determined by the paths of light inside the tooth, and attenuation of light along those paths.[1]
- Colours of natural teeth have a wide range (greater colour space) than represented on existing shade guides,[2,3] however yellow is the base colour which causes the greatest distress when patients are asked to rate their own tooth colour. The human eye is more sensitive to green and yellow light than to blue or red - because of the numerical difference in cones (colour photoreceptors).[4]
- Both reddish and yellowish colours of natural teeth tend to increase from the incisal to cervical, whereas translucency decreases. The middle and incisal thirds are the most visible during speech and in normal function, and thus yellowness here attracts the greatest attention.[5]
- While a significant yellow fluorescence emission is excited from enamel under visible blue or ultraviolet lighting conditions, this makes little contribution to the perceived colour of natural teeth under normal "white light" lighting conditions.1
- Attenuation of light within the tooth is caused by several different factors, but primarily by scattering and absorption. Scattering of light disperses it, without changing the wavelength. Scattering can be forward or backwards in direction.
- Light is transmitted through enamel and dentine to the pulpal surface, with the light following the path of the enamel prisms and dentinal tubules. Enamel and dentine together collect and distribute light within the tooth.[6]
- Light bends when it moves through dentine, in other words, dentine is optically anisotropic. Moreover, light propagation in human dentine exhibits a strong directional dependence.
- It was originally thought that both enamel prisms and dentinal tubules acted as optical fibers,[6] however it is now well established that the tubular structure is the predominant cause of scattering in dentine.[7,8]
- Multiple scattering events occur within the dentine tubules due to its cylindrical structure (and to a lesser extent by peri-tubular collagen fibers), and not by fiberoptic effects, as had been previously assumed.[9-12]

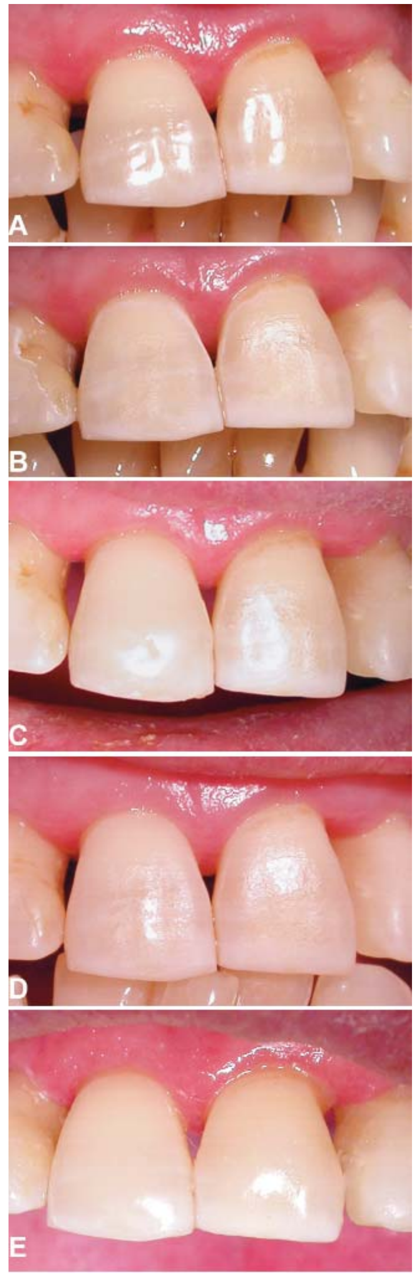

Figure 4. Clinical case of a 57 year old male. A, Baseline image. B, After polishing disks were used on the maxillary central incisors. C, After fine graded pastes were used. D, Second appointment after using Tooth Mousse for 4 weeks. E, Final appearance after application of a surface coat of a protective nano-filled resin layer (G-Coat Plus). Note the even distribution of light from the tooth surfaces.

Table 2. Optics of human enamel

- Absorption of light by human enamel is low. In enamel, the organic (protein) component, mostly aromatic amino acids, is responsible for most or all of the limited absorption which occurs.[13]
- Yellow and red light are highly transmitted by normal enamel, and thus can both reflect from the dentino-enamel junction and transmit back through enamel to the surface.[14]
- Scattering of light by enamel is high. This is critical, since while tooth colour is determined mainly by dentine, enamel plays a significant role in modifying tooth colour by scattering the shorter wavelengths in the visible blue range.[1]
- Reflectance of light from the enamel surface increases linearly from 400 nm (blue) through to 600 nm (red).[1]
- Shorter wavelengths of visible light (blue and violet) have a much higher scatter coefficient than longer wavelengths (yellows and reds). This is why visible blue and violet wavelengths in the non-dental environment cause dazzle effects in rain, fog and snow, and cause problems with glare.
- In enamel, it is the hydroxyapatite crystals themselves which contribute significantly to scattering, rather than the prism structure.[7,8] For this reason, dissolution of crystallites or their incomplete formation will affect the scatter of light.
- The more porous the enamel, the less it scatters short (blue) wavelengths of light. The more the enamel scatters blue light, the lighter it appears.[1]

Table 3. The influence of water present in the enamel

- Enamel contains 7-10% water by volume as one of its normal constituents, and this water affects its ability to both absorb and scatter light.
- For early carious lesions and other enamel conditions with increased subsurface water, longer wavelengths of yellow and red are preferentially reflected back to the surface. This radiance change is mainly determined by the lack of mineral and the increased water content in these lesions.[7,8]
- Even without the development of white spot lesions or altered enamel formation, microscopic subsurface water voids are common as enamel is never perfectly mineralized. These water rich areas can undergo subsurface remineralization by repeated topical application of CPP-ACP (Recaldent) products.[15,16]
- Restoring mineral to these water rich areas should, therefore, change the scatter of short wavelengths of light and thereby alter the appearance and colour of the enamel surface.
- Micropolishing the enamel surface makes tooth shade lighter and less yellow, and this effect is enhanced upon air-drying, which removes subsurface moisture.[17]
- This provides a rationale for micropolishing in combination with subsurface remineralization.

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