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Significant Effect of Environmental Lighting on Caries Incidence in the Cotton Rat (37954)

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Dental caries is a multifactorial disorder, the initiation and progression of which are affected by factors related to host susceptibility, oral microflora, and diet. Interlocking triple rings are frequently employed to demonstrate that microorganisms, fermentable carbohydrates, and a susceptible tooth surface are all requisite in the caries process. It is well established that lesions do not develop in gnotobiotic animals and that dietary modification such as carbohydrate restriction significantly restricts caries activity. There is a paucity of knowledge on the effect of specific environmental factors on caries incidence.

In an earlier study (1) it was found that lighting significantly affected caries incidence in the golden hamster. These animals were fed a diet containing 61% sucrose over a 15-week period. Under these conditions carious breakdown was very extensive and in many cases the crowns were virtually destroyed. The authors pointed out that this overwhelming involvement may have caused a loss of masticatory ability resulting in reduced chewing, ingestion, and absorption of food.

There was thus a need for the testing of the effects of light on caries incidence in a more sensitive model with a much less advanced state of destruction induced. Such a model has been developed for caries evaluation in which the cotton rat (*Sigmodon hispidus*) is weaned at 12 days of age and placed on a cariogenic diet (2). With a dietary sucrose level of approximately 6%, caries production is very rapid in all three molars and is reproducibly measurable after only 18 days on the diet.

The present study evaluates the effect of differences in environmental lighting in this more sensitive animal system and with a dietary sucrose content that is actually less than that characteristically ingested by western man (3).

Materials and Methods. Littermate cotton rats, 24 in each group, were maintained for 18 days under either incandescent light, cool-white fluorescent light (typical of standard office lighting), or artificial sunlight (VitaLite, a full-spectrum light source approximating sea-level solar irradiation (4), supplied by the Duro-Test Corporation, North Bergen, NJ). The incandescent source was six, 25-W unfiltered light bulbs providing approximately 38 fc of light, equivalent to a computed irradiance of approximately 360 $\mu W/cm^2$ measured at 290–700 nm. Foot candles were 420 under cool-white fluorescent and 360 under artificial sunlight, corresponding to computed irradiances of approximately 1350 and 1400 $\mu W/cm^2$, respectively. A comparison of spectral power distribution of light from incandescent, cool-white fluorescent, artificial sunlight, and natural outdoor light is shown in Fig. 1.

The animals were housed in specially constructed metal cages in a light-proof room. The suspension of a luminaire over each cage assured an even distribution of light. A metal shield was suspended over each cage in such a fashion that it overlapped the sides of the cage and provided an inviolate light seal. The animals were housed in individual compartments within the cage. Continuous light was provided throughout the 18-day period. Temperature

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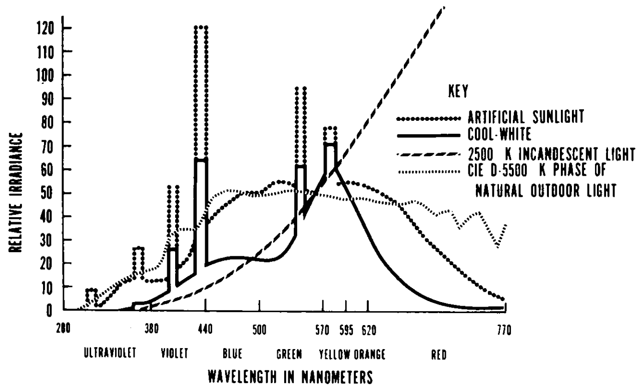

FIG. 1. Comparison of the distribution curves of artificial sunlight, cool-white light incandescent light, and natural outdoor light.

was held constant at 70°F and air circulation was controlled.

The test diet was prepared by mixing 940 g of oat flour, 300 g of alphacel, 120 g of sucrose, and 640 g of whole milk powder. Supplemental liver powder was added to this 6% sucrose diet. After 18 days of ad lib. exposure to this diet, the animals were sacrificed, the heads removed and defleshed, and the teeth scored for incidence and extent of fissure caries (5). The mean caries score was the average number of carious lesions and the mean extent score was the average of the severity ratings, ranging from one to five, assigned to each lesion.

Results. Means and standard errors for caries incidence and extent for the three experimental groups of animals, maintained under either incandescent lights, cool-white fluorescent lighting, or artificial sunlight, are presented in Table I. Chi-square analyses revealed no significant differences between the results for the incandescent lighting and the artificial sunlight. For animals housed under cool-white fluorescent lighting, however, caries incidence and extent were both significantly ($P < 0.001$) higher than for animals living under either of the other two lighting systems.

Discussion. There is evidence in the literature that the incidence of caries in humans is related to the hours of annual sunshine. Dunning (6) related the dental caries experience of a large military population in the United States to geographic map contours plotting annual sunshine. Ockerse (7) conducted a similar study in South Africa and found that hours of sunshine and dental caries were inversely correlated ($r = -0.879$). Thus, hours of sunshine could be related to synthesis of vitamin D, which has long been associated with the development of strong bones and teeth.

The specific importance of the uv portion of the spectrum in this regard is pointed out by Plathner and Taatz (8), who decreased caries incidence in hamsters on carbohydrate-controlled diets by twice-weekly ex-

TABLE I. Caries Incidence and Extent Under Various Lighting Conditions.

Light	Caries score[a]	
	Incidence	Extent
Incandescent	8.4 (1.6)	16.9 (3.2)
Cool-white fluorescent	12.5 (1.7)	25.2 (3.5)
Artificial sunlight	8.6 (1.4)	17.5 (3.0)

[a] Mean (SE).

posures of the animals to uv light. Overall caries frequency without uv light was 28.2%; with uv, the figure decreased to 15.4%.

The important observation in the present study was that the cool-white fluorescent lighting led to a highly significant ($P < 0.001$) increase in caries activity when compared to the incandescent and the artificial sunlight environments. If the incandescent group had not been included in the study, and based on the present literature, it would have been tempting to conclude that it was the low uv contribution of the cool-white fluorescent lighting that was responsible for the caries increase. In consideration of this point it is necessary to review briefly the spectral characteristics of the lights utilized in this study.

Natural sunlight (CIE-D/5500) at 360 fc has the following characteristics: mid-uv (290–320 nm) = 4:6 $\mu W/cm^2$; near-uv (320–380 nm) = 87.6 $\mu W/cm^2$. This corresponds closely to the uv values of the natural outdoor simulating light employed in this study. The artificial sunlight at 360 fc had mid- and near-uv values of 7.3 and 73.0 $\mu W/cm^2$, respectively, and is described as a combination continuum and line spectrum in which the energy in addition to the uv characteristics is relatively uniformly distributed over the visible spectrum (Fig. 1). The color temperature is about 5500°K. The cool-white fluorescent lighting is also a combination continuum and line spectrum in which most of the radiant energy is concentrated in the yellow and green portion of the spectrum. The color temperature is about 4200°K and, as utilized in this study, had an illumination level of 420 fc. The ultraviolet characteristics of this cool-white light differ markedly from natural and artificial sunlight. In the 290- to 320-nm range the value is zero and in the 320- to 380-nm range, the value is only 13.0 $\mu W/cm^2$. The total photic energy emitted by the fluorescent bulbs was lower for the artificial sunlight than the cool-white since the former contains a smaller proportion of the more luminous wavelengths, particularly emissions in the 500- to 600-nm range. The incandescent spectrum is a continuum characteristic of a thermal radiator at a color temperature of about 2500°K. Accordingly, its spectrum is very rich in red radiation compared to blue. In ultraviolet components this light is even lower than the cool-white fluorescent lighting. There is zero measurement in the 290- to 320-nm range and the measurement at 320–380 is only 0.08 $\mu W/cm^2$.

Since the data showed no difference in caries between the artificial sunlight and incandescent lighting, yet revealed a highly significant ($P < 0.001$) increase in caries with cool-white fluorescent lighting, it appears that the relatively low uv component in the cool-white fluorescent lighting is not the single factor responsible for the increase in caries. While these results do not indicate that uv deprivation will necessarily increase caries incidence, they do validate the concept that environmental lighting affects caries incidence (1). In this very sensitive animal system, with 12-day-old cotton rats maintained for only 18 days on a diet containing only 6% sucrose, it is clearly demonstrated that the emission characteristics of cool-white fluorescent lighting are responsible for a highly significant increase in dental caries.

Other light influences on dental tissues have been reported. Total incisor growth is significantly greater for artificial sunlight-exposed, young, male, Sprague–Dawley rats than for those raised in darkness (9). In addition, wavelength rather than light intensity appears to affect the growth of the tooth germ in the newborn rat (10). In our study a wavelength effect may also be implicated because incandescent light and artificial sunlight have proportionally more red radiation than does cool-white fluorescent light. Thus, a study of the action spectrum of light upon dental caries incidence is indicated.

There is no direct evidence in the present study that the salivary glands of the cotton rats were altered by the different light exposures. However, we have recently reported that light deprivation brings about highly significant decreases in the rate of resting parotid gland function in the human (11) as well as changes in the chemical composition of parotid saliva (12). The possibility of a direct effect of light on salivary gland function that may indeed affect caries incidence is thus suggested.

Summary. The effect of differences in environmental lighting on dental caries in the cotton rat was studied. The animals were exposed to either incandescent, cool-white fluorescent, or artificial sunlight environments over an 18-day period while ingesting a diet containing approximately 6% sucrose. Both the incidence and extent of caries were significantly ($P < 0.001$) higher in animals housed under cool-white fluorescent lighting than for either of the other two groups.

1. Sharon, I. M., Feller, R. P., and Burney, S. W., Arch. Oral Biol. 16, 1427–1432 (1971).
2. Madsen, K. O., and Edmonds, E. J., J. Dent. Res. 42, 867–873 (1963).
3. Huxley, H. G., New Zealand Dent. J. 67, 85–98 (1971).
4. Thorington, L., Parascandola, L., and Cunningham, L., J. Illum. Eng. Soc. 1, 33–41 (1971).
5. Shaw, J. H., Schweigert, B. S., McIntire, J. M., Elvehjem, C. A., and Phillips, P. H., J. Nutr. 28, 333–345 (1944).
6. Dunning, J. M., Int. Dent. J. 15, 462–487 (1965).
7. Ockerse, T., Doctor of Science Thesis, University of Pretoria (December, 1947).
8. Plathner, C. H., and Taatz, H., Deut. Zahn-, Mund-, Kieferheilk. 30, 121–126 (1959).
9. Nakamoto, T., and Wilson, R. H., J. Dent. Res. 48, 461–466 (1969).
10. Nakamoto, T., and Wilson, R. H., Arch. Oral Biol. 15, 195–204 (1970).
11. Shannon, I. L., Feller, R. P., and Suddick, R. P., J. Dent. Res. 51, 1642–1645 (1972).
12. Shannon, I. L., and Suddick, R. P., Arch. Oral Biol. 18, 601–608 (1973).

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