Second-Generation LED Light-Curing In Restorative Procedures

第二代修復治療用發光二極管固化燈

DESCRIPTION

In the following article, an LED lamp and its operation are described (including emission spectra, the various generations, power and light intensity). The effectiveness of second-generation LED lamps is shown through studies of microhardness and clinical cases.

INTRODUCTION

A new type of polymerization lamp appeared on the market at the beginning of this millennium. These are called LED lamps: lamps which, as the light emitter, use an electronic semiconductor component related to diodes, replacing halogen or plasma lamps [3, 16] It was the Japanese workers Iwakura and Ken who first had the idea of using LEDs in dentistry. The first experimental studies were performed by Kennedy and then the Englishman, Mills [10].

The manufacturers guarantee a life of between 50,000 and 100.000 hours. [14]

a. Emission spectra of LEDs

Compared to halogen lamps or plasma lamps, the emission spectrum of an LED is sufficiently narrow (a few tens of nanometers), making filters unnecessary. There is, moreover, considerable similarity between the sensitivity spectra of photo initiators (benzophenone, acetophenone, thioxanthen-9-one, diketones, and dl camphorquinone) in dental composites and the emission spectra of an LED emitting in the blue-violet range. [14, 16, 23] The less powerful (first-generation) LEDs width of sensitivity spectrum did not cover all the photo initiators, requiring it to have two types of LED, one centering on 440nm and the other on 470nm.

The spectrum of a halogen lamp (Figure 1) has a steady increase in

描述

在下面的文獻中我們將詳細介紹一種發光二極管燈及其操作方式 (包括輸出光譜、多種型號、功率和光線強度等) 。第二代發光二極管固化燈的效果將通過細微的硬度以及臨床病例的使用展現在大家面前。

介紹

一種新型的固化燈在本世紀推出，稱作發光二極管燈。這種燈使用了電子半導體元件相關的二極管來替代鹵素或等離子燈[3, 16]。發光二極管在牙科的應用概念首先由日本工作者Iwakura和Ken提出，首次試驗研究由Kennedy和Englishman, Mills [10]完成。

1、對發光二極管的描述和操作方式

用於牙科的二極管由發光材料或兩個電極夾著的成分構成，整個結構外面套有塑料。發光二極管的主要優點在於它們可以在低溫下操作，機械性能穩定、使

的和一個470奈米的。

鹵素燈的光譜(圖1)從紫外線到紅外線的能量輸出穩定增強。由於光敏發生劑只在藍色-紫色範圍內有敏感性，所以有必要使用低通過率的過濾器去除這些燈發出的大多數光譜，任何超出藍色範圍的光譜(從綠色到紅外線) 都必須被去除。允許通過的只有波長介於400到500奈米的藍色和紫色光線。

等離子燈的光譜(圖2) 依然太寬，範圍從紫外線到紅外線。為了只保留400到500奈米的部分，必須使用 “低通過” 和 “高通過” 的過濾器來過濾掉400奈米以下的任何光譜。

由於射線的熱量很高，鹵素燈和等離子燈都配有冷卻風扇，用以對過濾器散熱。

在使用發光二極管燈的例子中，對發光二極管選擇了窄光譜，而且僅在材料成分發光。由於我們不用降低光譜，所以就不再需要過濾器了，從而也不需要冷卻風扇。

1. Description and operation of a light-emitting diode (LED)

The diodes used in dentistry are composed of a specific light-emitting material or component sandwiched between two electrodes, the whole arrangement being enclosed in a plastic covering. The main advantages of LEDs are that they operate at low temperature, are mechanically stable, have a very long life, and a very narrow emission spectrum.

Unlike other light sources, LEDs are affected little by time. Light-emitting diodes show reliability comparable to that of other semiconductor devices.

the photo initiators are sensitive only in the blue and violet range, it is necessary to eliminate a large proportion of the spectrum emitted by these lamps, by using low-pass filters; everything beyond blue – from green to infrared – has to be eliminated. The only radiation allowed to pass is the blue and violet, i.e. short wavelengths in the range 400-500nm.

The spectrum of a plasma lamp (Figure 2) is still wider, ranging from ultraviolet to infrared. In order to keep only the 400-500nm part, a "low pass" filter and a "high-pass" filter for everything below 400nm must be used.

不像其它的光源，發光二極管受時間的影響很小，與其它半導體設備相比顯示出更高的可靠性。製造商通常提供介於50000到100000小時的使用壽命保證。(14)

a. 發光二極管的輸出光譜

相對於鹵素燈和等離子燈，發光二極管的輸出光譜足夠窄(幾十個奈米級)，從而不需要過濾。光敏發生劑(苯甲酮、苯乙酮、噸-9-酮、雙酮類diketones和樟腦)的光譜敏感度和發光二極管在藍色-紫色範圍內輸出的光譜非常的相似。(14, 16, 23) 第一代發光二極管的光譜敏感度寬度不夠強大，無法覆蓋所有的光敏發生劑，需要使用2種發光二極管，一個440奈米

與等離子燈或鹵素燈的能量進行比較(圖3)，發光二極管燈的所有能量都能被使用，但是後兩種燈只有50%到60%的能量能夠使用。於是人們常常說發光二級管燈的功率相當於其它燈的兩倍，這樣意味著一盞250兆瓦的發光二極管燈的功效等同於一盞500兆瓦的鹵素燈或等離子燈。事實上，經驗顯示這種功效比例基本為2倍有點過於誇大了(一些學者甚至認為能夠達到4倍的功效比例)，可能1.5倍的功效比例更為準確。

這並不意味著鹵素燈中的放射計不能用於發光二極管燈中，尤其是當後者釋放冷光源時，但是基本上需要將功效放大1.5到2倍。

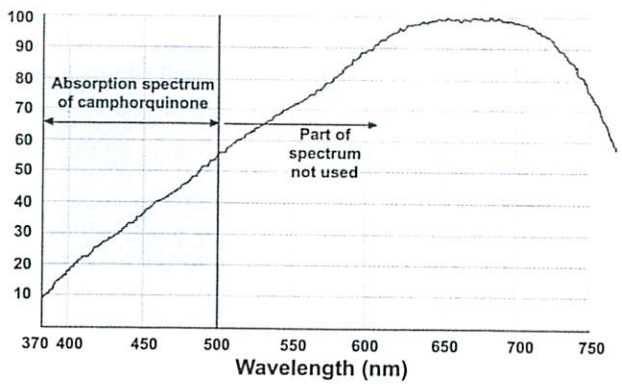

Figure 1
Emission spectrum for a halogen lamp

圖1
鹵素燈的輸出光譜

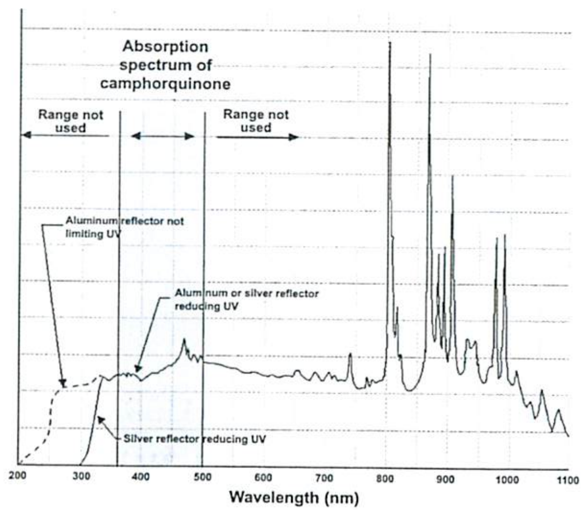

Figure 2
Emission spectrum of a plasma lamp

圖2
等離子燈的輸出光譜

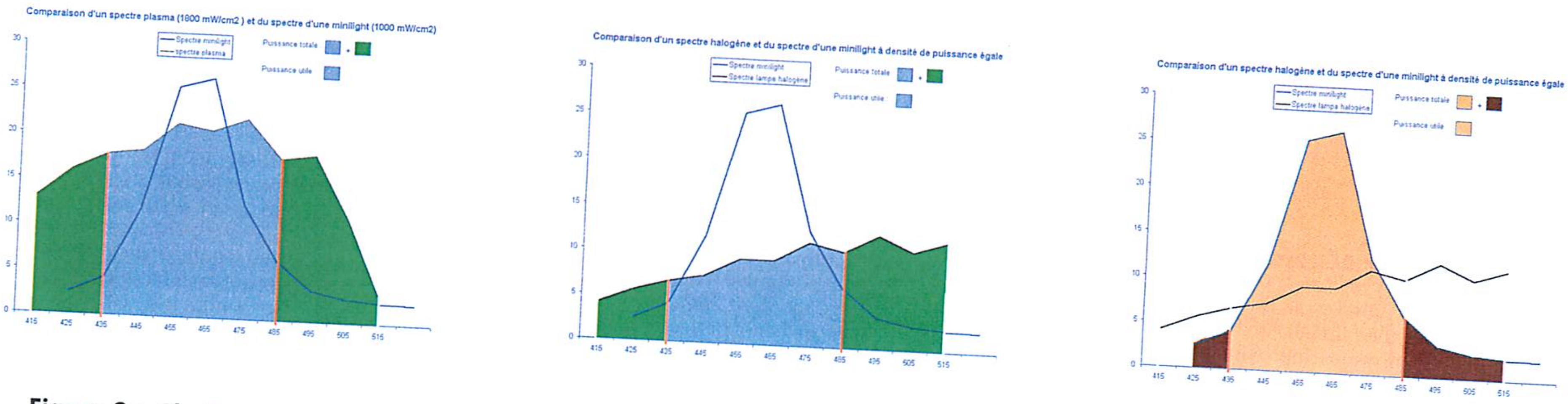

Figure 3a, 3b, 3c
Comparison of various spectra

圖3a, 3b, 3c
不同光譜的比較

As radiation has a high heat level, halogen and plasma lamps are fitted with cooling fans to dissipate heat from the filters.

In the case of an LED lamp, the spectrum of LED selected is narrow and appears only in the area of the component material. As we do not need to reduce it, the use of filters is not necessary, so there is no need for a fan.

If we compare the energy of an LED lamp with that of a plasma or halogen lamp (Figure 3), all of the energy of the LED lamp can be used, whereas only 50-60% of that produced by the other two types is useful. People therefore often say that an LED lamp is twice as effective as another lamp of equal power. Claims are made that a 250mW LED lamp was as effective as a halogen or plasma lamp of 500mW. In fact, experience has shown this factor of 2 (and some authors referred to a factor of 4)

It goes without saying that a radiometer in a halogen lamp does not work for an LED lamp, in particular because the latter emits cold light. There is also the fact that it would be necessary to multiply by 1.5 to 2 the value displayed.

b. Different generations of LED

First generation LEDs used a number of LEDs and the power rarely exceeded 250mW. The second generation appeared in early 2003; these generally use a single LED and are much more powerful, at 600mW. The large increase in power suggests that in four or five years time LED lamps may replace halogen lamps. This observation should, however, be qualified by considering the low energy of radiation from an LED (i.e. "cold light" at the short wavelengths), and this factor could make them unsuitable for some thermo-reactive treatment processes, such as those using bleaching products. The leading first-generation products were 3M's Freelight (190mW), Dentsply's NRG (220mW) and – most powerful of the three – GC Corporation's e-light (250-280mW).

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b. 不同型號的發光二極管

第一代發光二極管燈使用多個發光二極管，功率很少能夠超過250兆瓦。第二代產品在2003年早期上市，使用了單個發光二極管，功率要大得多，達到600兆瓦。功率方面的增加意味著在4年到5年的時間內發光二極管將替代鹵素燈，但是這個結論必須要考慮發光二極管的低能量輻射(比如短波長的"冷光源")，這個因素可能使發光二極管不適合一些熱反應治療，如那些需要使用漂白產品的治療。第一代產品中的領先品牌是3M的Freelight(190兆瓦)，Dentsply的NRG (220兆瓦) 以及功率最大的GC 公司的e-light (250-280兆瓦)。

第二代發光二級管燈出現在2003年早期，例如3M Espe's Freelight 2, Medical Universal's LeDeLight, Kerr's L.E.Demetron, Satelec's Mini LED 以及Ultradent's Ultra Lume等。作為當代的發光二級管燈其功率在400兆瓦到600兆瓦之間。我們在缺乏更嚴謹的研究情況下可以推斷它們的功率與目前市場上所有的鹵素燈是一樣的(圖4a、b、c)。

A second generation of LED lamps appeared early in 2003 such as, 3M Espe's Freelight 2, Medical Universal's LeDeLight, Kerr's L.E.Demetron, Satelec's Mini LED and Ultradent's Ultra Lume. As the power of the current LED lamps is between 400mW and 600mW, we can – in the absence of more rigorous studies – consider them to be equal to any of the halogen lamps on the market (Figures 4a, b, c).

c. Power and density of power

A lamp, of whatever type, has a power rating that relates to emission of light by the bulb, expressed in mW. As an example, the MiniLED™ – the lamp used in our experiments – power is approximately 550mW, though the power rating is rarely quoted in any literature. People prefer to consider the figure for intensity of light falling on the composite. This means power per surface area, measured as mW/cm^2.

In our example, the lamp produces 550mW, measured at the far point (or tip) of the light guide, which is 7.5mm in diameter. The circle of 7.5mm implies an area of about half a square centimeter ($A = \pi r^2$). This means, per cm^2, the light intensity of this lamp would be 550 x 2 = 1100mW/cm^2. Using a smaller light guide, of 5.5mm diameter (with a corresponding area of 0.25 cm^2), the intensity of light received, and concentrated on that small area, would be four times as great, giving 550 x 4 = 2200mW/cm^2.

In fact, this is not altogether accurate, because the smaller the tip and more concentrated the light, the greater the losses. It is, therefore, more reasonable to talk of the intensity being in the region of 1700-1800mW/cm^2 [11]

Very often, the tips of LED lamps are smaller (7.5 or 8mm) than those of halogen lamps (10-12mm). This is because LED lamps use what are called turbo tips that are wider at the entrance than at the exit; this makes the light diverge more. At 2mm, at the level of a cusp, the diameter of the beam projected by the light conductor in the LED lamp is close to that of a halogen or plasma lamp, where the divergence is less.

It is, in principle, undesirable to use a wide light guide tip in an LED lamp. In clinical use, an LED lamp is a good choice, as its power is stable over time, ergonomically it is practical (noiseless, cordless) and there is virtually no rise in pulp temperature. A study that Palmer [13] presented to the IADR at San Diego in 2002, compared the rise in temperature caused by three types of lamps and showed the effectiveness of LEDs:

- 0.9°C after 40 seconds with an LED
- 3.6°C after 40 seconds with a conventional halogen lamp
- 1.9°C after 10 seconds with a fast halogen lamp
- 6.4°C after 10 seconds with a plasma lamp

2. Microhardness and exposure time

Studies investigating microhardness using second-generation LED technology have shown good results [7, 8, 21]. It was possible to measure polymerization of the materials employed clinically by using microhardness [4, 14, 17]. Two studies showed that – with LED technology – the results are satisfactory and exposure times are more compatible with general practitioners' everyday work.

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c. 功率和強度

任何類型的燈都有一個燈泡輸出光線的功率等級，用兆瓦表示。比如我們在實驗中使用的MiniLED™的功率大約是550兆瓦，然而功率等級幾乎不被引用在任何文獻中。人們更傾向於了解真正照在複合體上面的光線強度。這意味著單位表面面積的功率，用兆瓦/每平方厘米表示。

在我們的例子中，固化燈產生550兆瓦功率，用燈光導向裝置的遠端(或頂端)測得，直徑為7.5毫米。直徑7.5毫米意味著面積達到半平方厘米($A = \pi r^2$)。這樣可以算出這種固化燈的每平方厘米的光照強度為550x2=1100兆瓦/每平方厘米。使用小一點的5.5毫米直徑的光線導向裝置(產生的面積為0.25平方厘米)，則在這個更小的區域能夠獲得更強的光照強度，達到550x4=2200兆瓦/每平方厘米。

事實上這並不完全精確，因為使用越小的光源頂端，光照就更集中，然而損失也越大。所以認為強度介於1700到1800兆瓦/每平方厘米之間是更為合理的。[11]

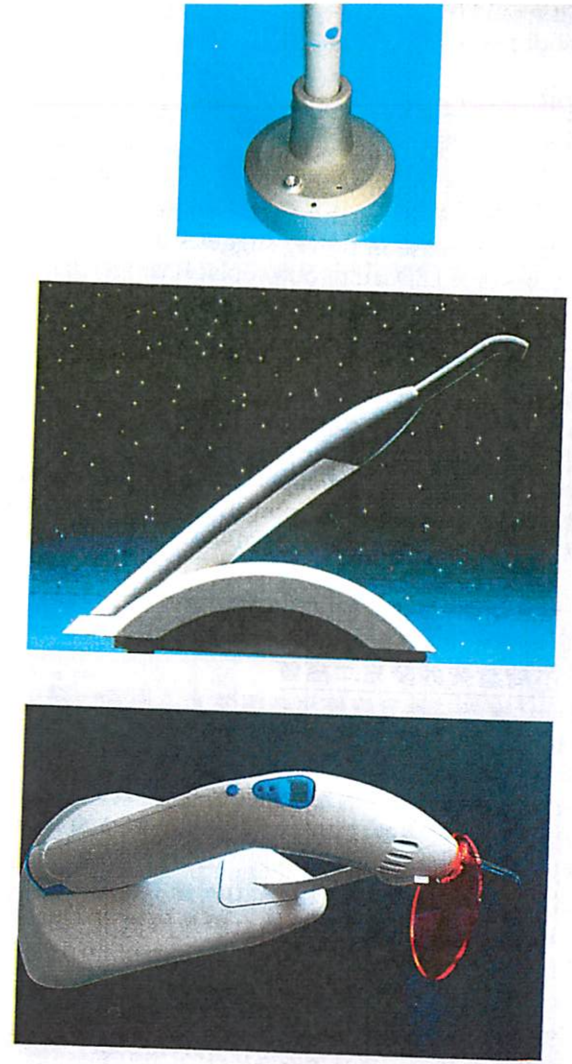


Figure 4a, 4b, 4c
Second-generation LED lamps

圖4a, 4b, 4c
第二代發光二極管燈

a. *Time and microhardness*

Light curing of composite materials or polymers using halogen lamps requires an exposure time of 20-40 seconds [1]. Clinicians must, however, be prepared to extend the time, especially when having to effect polymerization through the enamel or a mould, or when using composites that are opaque or dark-colored [22]. A composite material must be completely polymerized in order to be biocompatible and avoid the possibility of side effects. The degree of polymerization for a composite also depends on the nature and composition of the material. In addition, the degree of polymerization depends on the composite's curing reaction, i.e. on the wavelength at which its components react. [16, 19, 20, 24]

Does polymerization using LED technology enable the irradiation time to be reduced? A study and analysis measuring the time needed to obtain good in-depth hardness was performed.

Method: The aim of this study was to obtain the same hardness value at a depth (2mm) for a "reference" halogen lamp (Kerr/Demetron Optilux 501) and for an LED lamp (Satelec's Mini LED™). Moulds 2mm thick (Figure 5) were filled with nine different composites and then irradiated following the recommendations from the manufacturer of the halogen lamp. The microhardness was measured with a Leica VMHT 30 microhardness tester 30 minutes after irradiation. Then, for the LED lamp, irradiation time was adjusted to obtain the same hardness, at a depth, with the various composites. We thus found the time needed to get the same result as with the halogen lamp.

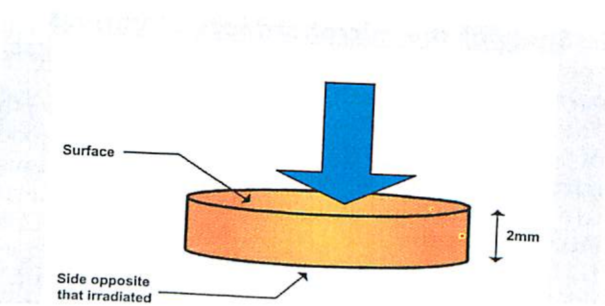


Figure 6a

圖6a

Mfr 製造商	Composite 複合體	Shade 色度	Time Recommended by mfr 鹵素燈製造商建議照射時間	Time obtained w/Mini LED™ 發光二極管照射時間
Cavex	Quadrant Universal LC	A3	20s	8 sec
Kuraray Medical	Clearfil AP-X	A3	20s	8 sec
Dentsply Detrey	DEFINITE omc	A3	10s	10 sec
Kerr	XRV Herculite enamel	A3	Not available	10 sec
Kerr	XRV Herculite prodigy	A3	40s	10 sec
3M	Z100 MP	A3	40s	5 sec
3M	Filtek Z250	A3	20s	7 sec
Dentsply Detrey	Spectrum TPH	A3	20s	7 sec
Ivoclar Vivadent	Tetric Ceram Cavifil	A3	40s	10 sec

Composite sample being irradiated

圖5
複合體樣品被照射中

通常，發光二極管的光照頂端(7.5或8毫米)要比素鹵燈(10到12毫米)的小。這是因為發光二極管燈應用了渦輪頂端，在入口處較寬而在出口處較窄，使得光線更分散。在直徑2毫米的情況下，在頂端的層面，由發光二極管燈射出的光線直徑接近鹵素燈或等離子燈的光線直徑，但是分叉程度小。

原則上不建議在發光二極管燈上使用寬的光導向裝置。在臨床上發光二極管是好的選擇，因為它的功率穩定、操作更符合人體功學(無噪音、無線) 並且泵的溫度幾乎不會升高。Palmer [13]在2002年聖地亞哥IADR上展現的研究結果顯示，通過對鹵素燈、等離子燈和發光二極管燈三種燈泵溫度上升程度的比較，發光二極管的效果最佳。

- 使用發光二極管40秒後上升0.9度
- 使用傳統鹵素燈40秒後上升3.6度
- 使用快速鹵素燈10秒後上升1.9度
- 使用等離子燈10秒後上升6.4度

2. 顯微硬度和曝光時間

對第二代發光二極管技術的顯微硬度調查顯示良好的結果。[7, 8, 21] 可以應用顯微硬度對臨床試用的材料進行固化測試。[4, 14, 17]兩個研究顯示-使用了發光二極管技術- 結果令人滿意，而且曝光時間與多數操作者每天的工作相適應。

a. 時間和顯微硬度

使用鹵素燈對光固化複合體材料和複合體進行固化需要20到40秒的曝光時間[1]。臨床醫師通常還需要預留額外的時間，尤其是對牙釉質或模型上的材料進行固化的時候，或是使用不透明或深色複合體的時候。[22]複合體材料必須充分固化才能達到生物兼容性並避免副作用。複合體的固化程度除了取決於材料的本質和成分之外，還取決於複合體的固化反應，如材料成分對波長的反應等[16, 19, 20, 24]。

使用發光二極管技術真的能使照射時間減少嗎？我們作了一個為獲得良好深度硬度所需時間的研究和測試。

Figures 7a, 7b, 7c

圖7a, 7b, 7c

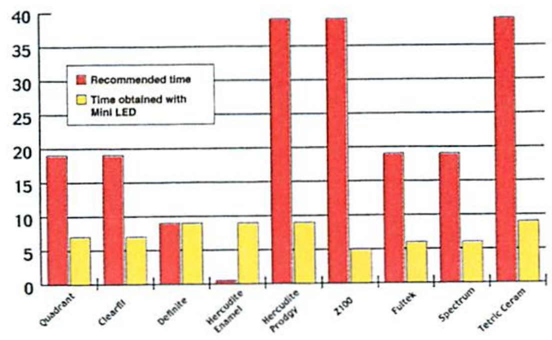
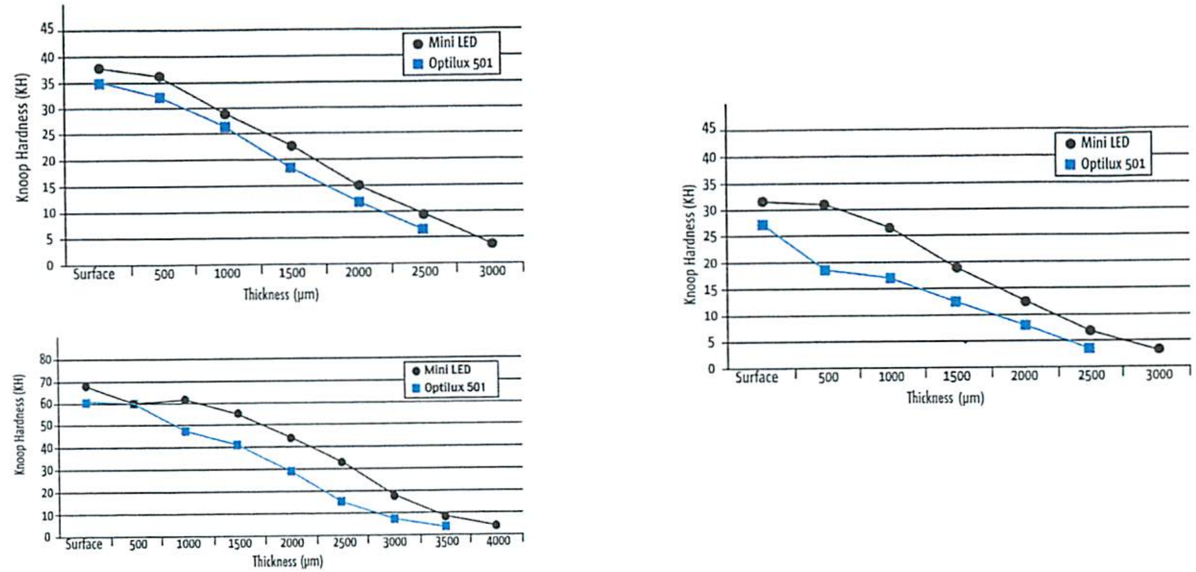


Figure 6b
Irradiation time obtained with LED

圖6b
使用發光二極管的照射時間



Results: With Satelec's Mini LED™ lamp, the times required to produce the same microhardness at a depth were shorter. It can be seen from this study that the curing time can be reduced by up to 88% for some composites. (See Figures 6a and 6b)

b. Study of the microhardness of various composite materials in relation to thickness, using two light-curing lamps[18]

The aim of this second study was to assess the depth of polymerization using two lamps, by studying Knoop microhardness. This investigation was carried out using two lamps – a conventional halogen lamp (Kerr/ Demetron Optilux 501®) and a new LED lamp (SEDR LED prototype, at the time of study) – and six composite resins (Z100MP, Herculite XRV®, Tetric Ceram®, Admira®, Definite® and GC Unifil S®). The irradiation time was nine seconds at full power for each lamp; six samples of each composite were used.

The microhardness study was carried out using the showed significant differences between the materials, but the comparisons of hardness in relation to thickness showed similar curves for the various composites. Three results are presented here. Within the limitations of this *in vitro* study, the depth of polymerization was found to be better with the LED lamp. (See Figures 7a, 7b, 7c)

3. Clinical cases using Satelec's Mini LED™ lamp

During the past decade, changes in the socio-economic environment, a reduced prevalence of dental caries, increased interest on the part of patients in cosmetic dentistry, a concern to spare tissue, and controversy over the potential toxicity of metallic restoration procedures, have led to an in-depth reassessment of treatment methods for anterior and posterior teeth. Composites, and direct and indirect adhesive techniques have, therefore, become basic elements in modern restorative dentistry. However, successful treatment depends on a whole array of interrelated factors. The quality of the materials used, the suitability of the instruments, and knowledge and mastery of operating techniques are all of fundamental importance for how long restorative procedures will last.

We carried out clinical procedures in various areas of adhesive dentistry (orthodontics [2], and direct and indirect restorative dentistry) using the LED technology for light curing of the materials employed in both direct and indirect techniques.

方法：本研究的目的是使用一個“參照物”鹵素燈(Kerr/Demetron Optilux 501)和一個發光二極管燈(Satelec's Mini LED)對比在(毫米的深度獲得相同的硬度。2毫米深的模型(圖5)充滿了9種不同的複合體，然後根據製造商的建議用鹵素燈進行照射。接著使用Leica VMHT 30顯微硬度測試儀對照射後產生的顯微硬度進行測試。然後使用發光二極管燈照射不同的複合體，直至在相同的深度達到鹵素燈照射獲得的相同硬度。我們隨即得到要獲得與鹵素燈同等效果所需的發光二極管燈照射的時間。

結果：使用Satelec's Mini發光二極管燈在同等深度獲得同等硬度的時間更短。這個研究顯示相同材料的固化時間可以減少達88%。(請看圖6a和6b)

Clinicians can now depend on LED technology, which is reliable and can be adapted to everyday practice at reasonable cost [18]. It is therefore possible to provide treatment using LED curing for adhesive techniques in many clinical situations. The method certainly has its place in the current therapeutic arsenal, even though conventional halogen curing has shown very good results and is still valid. It is, nevertheless, important to note that the shorter curing times obtained with LED lamps are proving of interest in dental restoration [6], not because of any time saved but because of clinical application. The absence of temperature increase means that the method satisfies the three essential considerations of Function, Physiology and Aesthetics. [5, 9, 13, 22, 3, 12]

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b. 使用兩種光固化燈對多種複合體材料的顯微硬度與厚度關係的研究[18]

第二個研究的目的是使用兩種燈，通過研究Knoop顯微硬度對固化深度進行評估。該研究通過兩種燈-一種傳統的鹵素燈(Kerr/Demetron Optilux 501®)和一種新型發光二極管燈(SEDR LED 原型燈, 研究時名稱) - 以及6 種樹脂(Z100MP, Herculite XRV®, Tetric Ceram®, Admira®, Definite® and GC Unifil S®)進行。每種燈的照射時間為全功率的9秒照射，每種複合體都使用6組樣品。

顯微硬度的研究是通過Leica VMHT 30硬度測試器進行的。每組樣品都測試了5次，每次500微毫米。統計分析顯示材料之間存在顯著性差異，但是不同材料硬度與厚度的關系比較則顯示相似的曲線。這裡展現了3 組結果。在這次非臨床研究範圍內，發光二極管具有較好的固化深度。(請看圖7a, 7b, 7c)

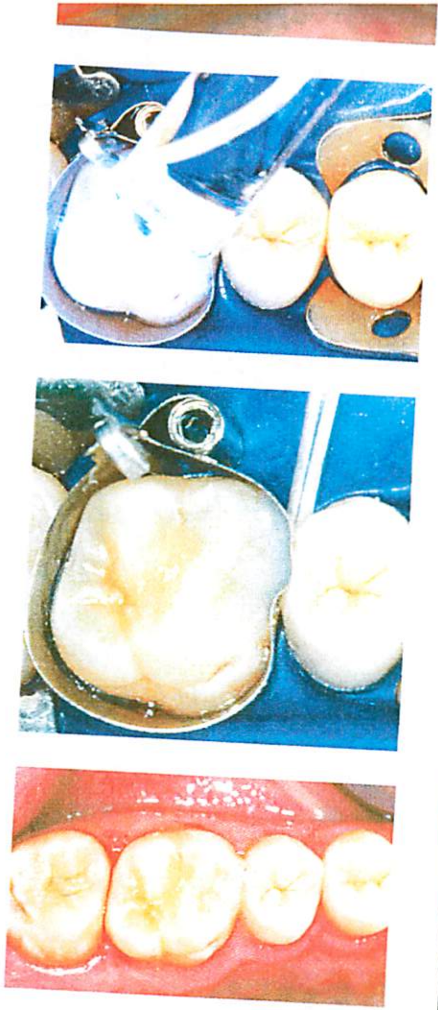
3. 使用Satelec's Mini發光二極管燈的臨床病例

在過去十年裡，社會經濟環境發生的變化、齲齒減少的趨勢、部分患者對牙科美容日益加強的興趣、對組織缺損的關心以及對金屬修復治療潛在毒性的爭論等，使我們對前牙和後牙治療方法重新進行深入的評估，複合體以及直接和間接粘接技術就成為當今修復牙科中最基本的元素。然而一個成功的治療取決於一系列互相關聯的因素，使用材料的質量、設備的匹配性、操作者的知識和熟練程度等對修復能夠維持多久都是至關重要的。

我們應用發光二極管技術在各種臨床牙科黏接治療中(矯正[2]、直接和間接修復等)對通過直接和間接技術放置的材料進行固化。

臨床醫師現在可以依靠可靠並適用於多種應用的發光二極管技術，而且成本合理[18]。在許多臨床情況下都可以用發光二極管對黏結劑進行固化。這種方法在當今的治療需選擇中佔有重要的一席，儘管傳統的鹵素燈依然有效並顯示很好的效果。但是我們還需要指出已經在修復領域激發起更多的興趣的發光二極管並不是因為其更短的固化時間[6]，而是因為它的臨床應用性能。在操作過程中溫度不升高意味著這種方法滿足了3 個基本條件：功能、生理學和美學[5, 9, 13, 22, 3, 12]。

讀者詢問卡編號 012

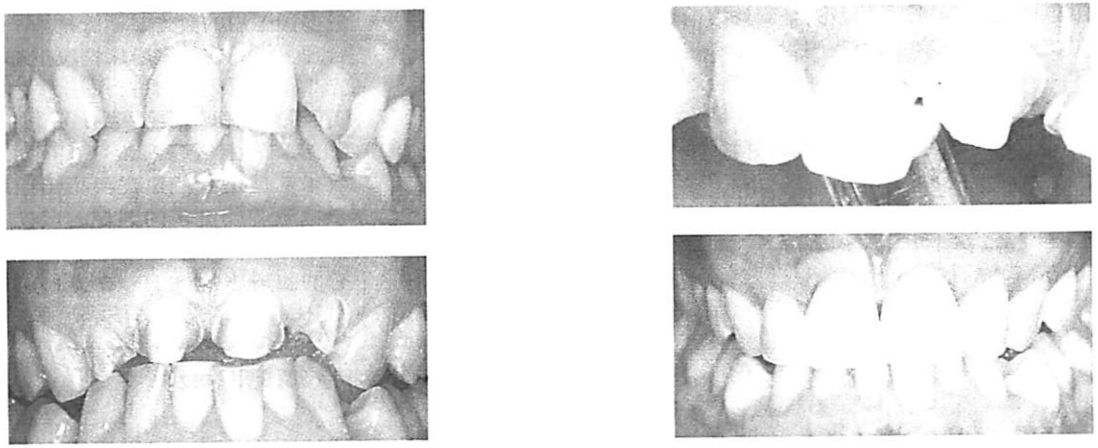


Figures 8a, 8b, 8c, 8d
CLINICAL CASE 1: Posterior layering (Composite: Dentsply DeTrey's EsthetX®)

圖8a、8b、8c、8d
臨床病例1 ：後牙分層(複合體：Dentsply DeTrey's EsthetX®)

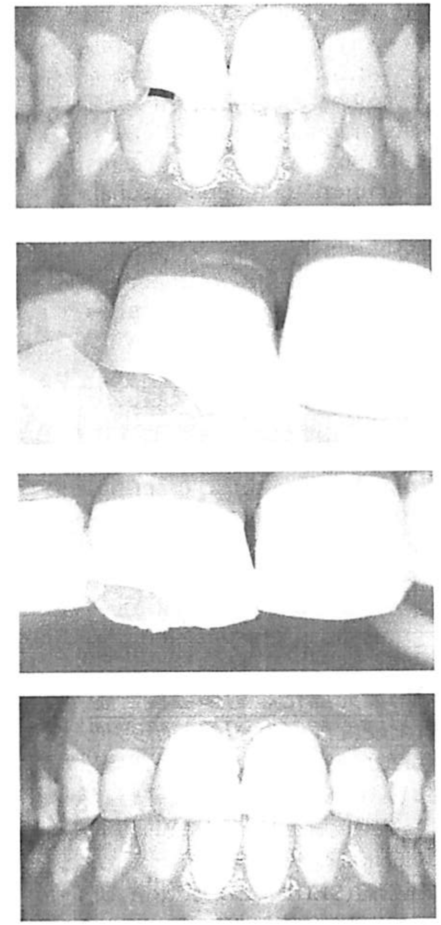
HELFT M. Effect of exposure time on depth of polymerization of a visible light-cured composite resin. J. Oral Rehabil. 1988 Mar; 15(2): 167-172.

(2) DUNN WJ and TALOUMIS LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. Am J Orthod Dentofacial Orthop 2002 Sep; 122(3):236-41



Figures 9a, 9b, 9c, 9d
CLINICAL CASE 2: Ceramic veneers (Bonding composite: Ivoclar Vivadent's Varioloink II®)
(Carried out by Laboratories Creadent, Grabels, 34 Herault, France)

圖9a、9b、9c、9d
臨床病例2：烤瓷貼面 (黏結複合體：Ivoclar Vivadent's Varioloink II®)
(由法國Creadent, Grabels, 34 Herault技工室完成)



Figures: 10a, 10b, 10c, 10d
CLINICAL CASE 3: Anterior layering (Composite: Coltene Whaledent's Miris®)

圖10a、10b、10c、10d
臨床病例3 ：前牙分層(複合體：Coltene Whaledent's Miris®)

Bibliography:

diode resin polymerization compared to three other methodsIADR, San Diego, 2002: Abstract 3976

(14) PELISSIER B. Influence du mode d'irradiation lumineuse sur le degré de polymérisation des biomatériaux composites et derives Thèse Doctorat d'Université, Montpellier, Mars 2002: 283p

(15) PELISSIER B., CASTANY E., CHAZEL JC., VALCARCEL J., DE SOUFFRON N. et DURET F. An evaluation of depth of cure with two lamps: a Knoop hardness study Pan European Meeting, Cardiff 2002: Abstract 369.

(16) PELISSIER B., CHAZEL JC., CASTANY E. et DURET F. Lampes à photopolymériser EMC, Stomatologie/ Odontologie,22-020-A-05,2003,11p (to be published).

(17) RUEGGEBERG FA., ERGLE JW. et METTENBURG DJ. Polymerization depths of contemporary light-curing units using microhardness J. Esthet. Dent. 2000; 12: 340-349.

(18) STAHL F., ASHWORTH SH., JANDT D., MILLS RW. Light-emitting diode (LED) polymerization of dental composites: flexural properties and polymerization potential Biomater. 2000; 21:1379-1385.

(19) STANSBURY JW. Curing dental resins and composites by polymerization J. Esthet. Dent. 2000; 12: 300-308.

(20) STRYDOM C. Curing lights-the effects of clinical factors on intensity and polymerization. SADJ 2002 May; 57(5):181-6

(21) UHL A, MILLS RW, VOWLES RW et JANDT KD. Knoop hardness depth profiles and compressive strength of selected dental composites polymerized with halogen and LED light curing technologies. J Biomed Mater Res 2002;63(6):729-38

(22) UHL A., MILLS R.W. et JANDT KD. Polymerization and light-induced heat of dental composites cured with LED and halogen technology Biomaterials 2003 May;24(10) :1809-20

(23) UHL A., MILLS R.W. et JANDT KD. Photoinitiator dependent composite depth of cure and knoop hardness with halogen and LED light curing units Biomaterials 2003 May; 24(10) :1787-95

(24) YOON TH, LEE YK, LIM BS et KIM CW. Degree of polymerization of resin composites by different light sources. J Oral Rehabil 2002 Dec;29(12):1165-73

(3) DURET F., PELISSIER B., CREVASSOL B. Mise au point sur la lampe à polymérisation ultra-rapide plasmatique: bilan après 6 ans et mode d'emploi. Inf. .Dent.. 1999; 44: 3547-3558.

(4) FERRACANE JL. Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins J. Dent. Res.1985; 1: 11-14.

(5) HANNIG M et BOTT B. In-vitro pulp chamber temperature rise during composite resin polymerization with various light-curing sources. Dent Mater 1999 Jul;15(4):275-81

(6) HARRINGTON E., WILSON HJ., SHORTALL AC. Light-activated restorative materials: a method of determining effective radiation times J. Oral Rehabil. 1996 Mar; 23(3): 210-218.

(7) JANDT KD, MILLS RW, BLACKWELL GB et ASHWORTH SH. Depth of cure and compressive strength of dental composites cured with blue light emitting diodes (LEDs). Dent Mater 2000 Jan;16(1):41-7

(8) KURACHI C., TUBOY AM., MAGALHAES DV., BAGNATO VS. Hardness evaluation of a dental composite polymerized with experimental LED-based devices. Dent. Mat. 2001 Jul; 17(4): 309-315.

(9) LONEY RW and PRICE RB. Temperature transmission of high-output light-curing units through dentin. 19 Oper Dent 2001 Sep-Oct;26(5):516-20

(10) MILLS RW. Blue light emitting diodes: an alternative method of light-curing? Br. Dent. J. 1995; 178:169 letter.

(11) MILLS R.W., UHL A., et JANDT KD. Optical power outputs, spectra and dental composite depths of cure, obtained with blue light emitting diode (LED) and halogen light curing units (LCUs) Br Dent J 2002 Oct 26 ;193(8) :459-63

(12) MITTON BA et WILSON NH. The use and maintenance of visible light activating units in general practice. Br Dent J. 2002 Feb 23;192(4):182.

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Second-Generation LED Light-Curing In Restorative Procedures

第二代修復治療用發光二極管固化燈

DESCRIPTION

In the following article, an LED lamp and its operation are described (including emission spectra, the various generations, power and light intensity). The effectiveness of second-generation LED lamps is shown through studies of microhardness and clinical cases.

INTRODUCTION

A new type of polymerization lamp appeared on the market at the beginning of this millennium. These are called LED lamps: lamps which, as the light emitter, use an electronic semiconductor component related to diodes, replacing halogen or plasma lamps[3,16] It was the Japanese workers Iwakura and Ken who first had the idea of using LEDs in dentistry. The first experimental studies were performed by Kennedy and then the Englishman, Mills[10].

1. Description and operation of a light-emitting diode (LED)

The diodes used in dentistry are composed of a specific light-emitting material or component sandwiched between two electrodes, the whole arrangement being enclosed in a plastic covering. The main advantages of LEDs are that they operate at low temperature, are mechanically stable, have a very long life, and a very narrow emission spectrum.

Unlike other light sources, LEDs are affected little by time. Light-emitting diodes show reliability comparable to that of other semiconductor devices. The manufacturers guarantee a life of between 50,000 and 100.000 hours.[14]

a. Emission spectra of LEDs

Compared to halogen lamps or plasma lamps, the emission spectrum of an LED is sufficiently narrow (a few tens of nanometers), making filters unnecessary. There is, moreover, considerable similarity between the sensitivity spectra of photo initiators (benzophenone, acetophenone, thioxanthen-9-one, diketones, and dl camphorquinone) in dental composites and the emission spectra of an LED emitting in the blue-violet range.[14,16,23] The less powerful (first-generation) LEDs width of sensitivity spectrum did not cover all the photo initiators, requiring it to have two types of LED, one centering on 440nm and the other on 470nm.

The spectrum of a halogen lamp (Figure 1) has a steady increase in energy from ultraviolet to infrared. As the photo initiators are sensitive only in the blue and violet range, it is necessary to eliminate a large proportion of the spectrum emitted by these lamps, by using low-pass filters; everything beyond blue – from green to infrared – has to be eliminated. The only radiation allowed to pass is the blue and violet, i.e. short wavelengths in the range 400-500nm.

The spectrum of a plasma lamp (Figure 2) is still wider, ranging from ultraviolet to infrared. In order to keep only the 400-500nm part, a "low pass" filter and a "high-pass" filter for everything below 400nm must be used.

描述

在下面的文獻中我們將詳細介紹一種發光二極管燈及其操作方式(包括輸出光譜、多種型號、功率和光線強度等)。第二代發光二極管固化燈的效果將通過細微的硬度以及臨床病例的使用展現在大家面前。

介紹

一種新型的固化燈在本世紀推出，稱作發光二極管燈。這種燈使用了電子半導體元件相關的二極管來替代鹵素或等離子燈[3,16]。發光二極管在牙科的應用概念首先由日本工作者Iwakura和Ken提出，首次試驗研究由Kennedy和Englishman, Mills[10]完成。

1、對發光二極管的描述和操作方式

用於牙科的二極管由發光材料或兩個電極夾著的成分構成，整個結構外面套有塑料。發光二極管的主要優點在於它們可以在低溫下操作，機械性能穩定、使用壽命很長並且輸出光譜非常窄。

不像其它的光源，發光二極管受時間的影響很小，與其它半導體設備相比顯示出更高的可靠性。製造商通常提供介於50000到100000小時的使用壽命保證。[14]

a. 發光二極管的輸出光譜

相對於鹵素燈和等離子燈，發光二極管的輸出光譜足夠窄(幾十個奈米級)，從而不需要過濾。光敏發生劑(苯甲酮、苯乙酮、噸-9-酮、雙酮類diketones和樟腦)的光譜敏感度和發光二極管在藍色-紫色範圍內輸出的光譜非常的相似。[14,16,23] 第一代發光二極管的光譜敏感度寬度不夠強大，無法覆蓋所有的光敏發生劑，需要使用2種發光二極管，一個440奈米的和一個470奈米的。

鹵素燈的光譜(圖1)從紫外線到紅外線的能量輸出穩定增強。由於光敏發生劑只在藍色-紫色範圍內有敏感性，所以有必要使用低通過率的過濾器去除這些燈發出的大多數光譜，任何超出藍色範圍的光譜(從綠色到紅外線)都必須被去除。允許通過的只有波長介於400到500奈米的藍色和紫色光線。

等離子燈的光譜(圖2)依然太寬，範圍從紫外線到紅外線。為了只保留400到500奈米的部分，必須使用"低通過"和"高通過"的過濾器來過濾掉400奈米以下的任何光譜。

由於射線的熱量很高，鹵素燈和等離子燈都配有冷卻風扇，用以對過濾器散熱。

在使用發光二極管燈的例子中，對發光二極管選擇了窄光譜，而且僅在材料成分發光。由於我們不用降低光譜，所以就不再需要過濾器了，從而也不需要冷卻風扇。

如果我們把發光二極管燈的能量與等離子燈或鹵素燈的能量進行比較(圖3)，發光二極管燈的所有能量都能被使用，但是後兩種燈只有50%到60%的能量能夠使用。於是人們常常說發光二級管燈的功率相當於其它燈的兩倍，這樣意味著一盞250兆瓦的發光二極管燈的功效等同於一盞500兆瓦的鹵素燈或等離子燈。事實上，經驗顯示這種功效比例基本為2倍有點過於誇大了(一些學者甚至認為能夠達到4倍的功效比例)，可能1.5倍的功效比例更為準確。

這並不意味著鹵素燈中的放射計不能用於發光二極管燈中，尤其是當後者釋放冷光源時，但是基本上需要將功效放大1.5到2倍。

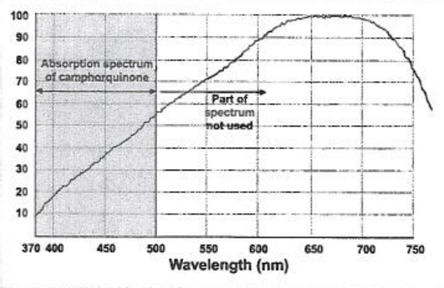


Figure 1
Emission spectrum for a halogen lamp

圖1
鹵素燈的輸出光譜

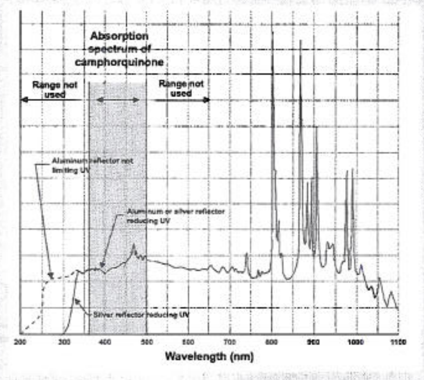
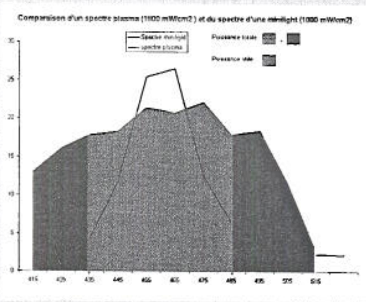
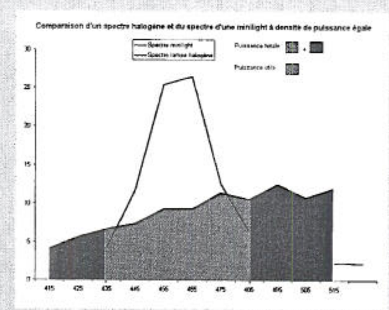


Figure 2
Emission spectrum of a plasma lamp

圖2
等離子燈的輸出光譜





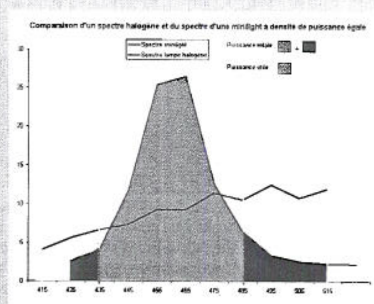


Figure 3a, 3b, 3c
Comparison of various spectra

圖3a, 3b, 3c
不同光譜的比較

As radiation has a high heat level, halogen and plasma lamps are fitted with cooling fans to dissipate heat from the filters.

In the case of an LED lamp, the spectrum of LED selected is narrow and appears only in the area of the component material. As we do not need to reduce it, the use of filters is not necessary, so there is no need for a fan.

If we compare the energy of an LED lamp with that of a plasma or halogen lamp (Figure 3), all of the energy of the LED lamp can be used, whereas only 50-60% of that produced by the other two types is useful. People therefore often say that an LED lamp is twice as effective as another lamp of equal power. Claims are made that a 250mW LED lamp was as effective as a halogen or plasma lamp of 500mW. In fact, experience has shown this factor of 2 (and some authors referred to a factor of 4) was something of an exaggeration. A factor of 1.5 is more accurate.

It goes without saying that a radiometer in a halogen lamp does not work for an LED lamp, in particular because the latter emits cold light. There is also the fact that it would be necessary to multiply by 1.5 to 2 the value displayed.

b. Different generations of LED

First generation LEDs used a number of LEDs and the power rarely exceeded 250mW. The second generation appeared in early 2003; these generally use a single LED and are much more powerful, at 600mW. The large increase in power suggests that in four or five years time LED lamps may replace halogen lamps. This observation should, however, be qualified by considering the low energy of radiation from an LED (i.e. "cold light" at the short wavelengths), and this factor could make them unsuitable for some thermo-reactive treatment processes, such as those using bleaching products. The leading first-generation products were 3M's Freelight (190mW), Dentsply's NRG (220mW) and – most powerful of the three – GC Corporation's e-light (250-280mW).

b. 不同型號的發光二極管

第一代發光二極管燈使用多個發光二極管，功率很少能夠超過250兆瓦。第二代產品在2003年早期上市，使用了單個發光二極管，功率要大得多，達到600兆瓦。功率方面的增加意味著在4年到5年的時間內發光二極管將替代鹵素燈，但是這個結論必須要考慮發光二極管的低能量輻射(比如短波長的“冷光源”)，這個因素可能使發光二極管不適合一些熱反應治療，如那些需要使用漂白產品的治療。第一代產品中的領先品牌是3M的Freelight(190兆瓦), Dentsply的NRG (220兆瓦) 以及功率最大的GC 公司的e-light (250-280兆瓦)。

第二代發光二級管燈出現在2003年早期，例如3M Espe's Freelight 2, Medical Universal's LeDeLight, Kerr's L.E.Demetron, Satelec's Mini LED 以及Ultradent's Ultra Lume等。作為當代的發光二級管燈其功率在400兆瓦到600兆瓦之間。我們在缺乏更嚴謹的研究情況下可以推斷它們的功率與目前市場上所有的鹵素燈是一樣的(圖4a、b、c)。

A second generation of LED lamps appeared early in 2003 such as, 3M Espe's Freelight 2, Medical Universal's LeDeLight, Kerr's L.E.Demetron, Satelec's Mini LED and Ultradent's Ultra Lume. As the power of the current LED lamps is between 400mW and 600mW, we can – in the absence of more rigorous studies – consider them to be equal to any of the halogen lamps on the market (Figures 4a, b, c).

c. Power and density of power

A lamp, of whatever type, has a power rating that relates to emission of light by the bulb, expressed in mW. As an example, the MiniLED™ – the lamp used in our experiments – power is approximately 550mW, though the power rating is rarely quoted in any literature. People prefer to consider the figure for intensity of light falling on the composite. This means power per surface area, measured as mW/cm².

In our example, the lamp produces 550mW, measured at the far point (or tip) of the light guide, which is 7.5mm in diameter. The circle of 7.5mm implies an area of about half a square centimeter ($A = \pi r^2$). This means, per cm², the light intensity of this lamp would be 550 x 2 = 1100mW/cm². Using a smaller light guide, of 5.5mm diameter (with a corresponding area of 0.25 cm²), the intensity of light received, and concentrated on that small area, would be four times as great, giving 550 x 4 = 2200mW/cm².

In fact, this is not altogether accurate, because the smaller the tip and more concentrated the light, the greater the losses. It is, therefore, more reasonable to talk of the intensity being in the region of 1700-1800mW/cm² [11]

Very often, the tips of LED lamps are smaller (7.5 or 8mm) than those of halogen lamps (10-12mm). This is because LED lamps use what are called turbo tips that are wider at the entrance than at the exit; this makes the light diverge more. At 2mm, at the level of a cusp, the diameter of the beam projected by the light conductor in the LED lamp is close to that of a halogen or plasma lamp, where the divergence is less.

It is, in principle, undesirable to use a wide light guide tip in an LED lamp. In clinical use, an LED lamp is a good choice, as its power is stable over time, ergonomically it is practical (noiseless, cordless) and there is virtually no rise in pulp temperature. A study that Palmer [13] presented to the IADR at San Diego in 2002, compared the rise in temperature caused by three types of lamps and showed the effectiveness of LEDs:

- 0.9°C after 40 seconds with an LED
- 3.6°C after 40 seconds with a conventional halogen lamp
- 1.9°C after 10 seconds with a fast halogen lamp
- 6.4°C after 10 seconds with a plasma lamp

2. Microhardness and exposure time

Studies investigating microhardness using second-generation LED technology have shown good results [7, 8, 21]. It was possible to measure polymerization of the materials employed clinically by using microhardness [4, 14, 17]. Two studies showed that – with LED technology – the results are satisfactory and exposure times are more compatible with general practitioners' everyday work.

c. 功率和強度

任何類型的燈都有一個燈泡輸出光線的功率等級，用兆瓦表示。比如我們在實驗中使用的MiniLED™的功率大約是550兆瓦，然而功率等級幾乎不被引用在任何文獻中。人們更傾向於了解真正照在複合體上面的光線強度。這意味著單位表面面積的功率，用兆瓦/每平方厘米表示。

在我們的例子中，固化燈產生550兆瓦功率，用燈光導向裝置的遠端(或頂端)測得，直徑為7.5毫米。直徑7.5毫米意味著面積達到半平方厘米($A = \pi r^2$)。這樣可以算出這種固化燈的每平方厘米的光照強度為550x2=1100兆瓦/每平方厘米。使用小一點的5.5毫米直徑的光線導向裝置(產生的面積為0.25平方厘米)，則在這個更小的區域能夠獲得更強的光照強度，達到550x4=2200兆瓦/每平方厘米。

事實上這並不完全精確，因為使用越小的光源頂端，光照就更集中，然而損失也越大。所以認為強度介於1700到1800兆瓦/每平方厘米之間是更為合理的。[11]

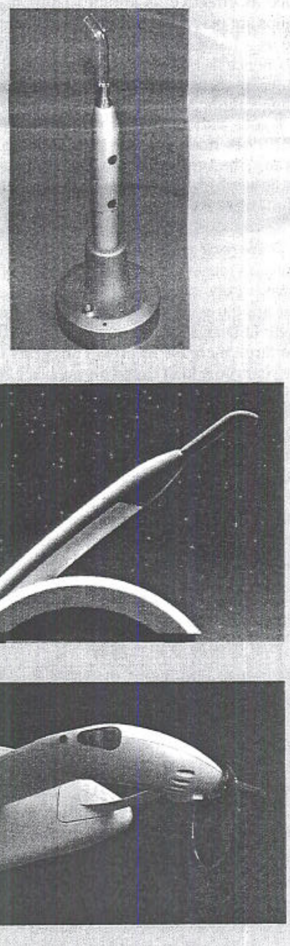


Figure 4a, 4b, 4c
Second-generation LED lamps

圖4a, 4b, 4c
第二代發光二極管燈

a. Time and microhardness

Light curing of composite materials or polymers using halogen lamps requires an exposure time of 20-40 seconds [1]. Clinicians must, however, be prepared to extend the time, especially when having to effect polymerization through the enamel or a mould, or when using composites that are opaque or dark-colored [22]. A composite material must be completely polymerized in order to be biocompatible and avoid the possibility of side effects. The degree of polymerization for a composite also depends on the nature and composition of the material. In addition, the degree of polymerization depends on the composite's curing reaction, i.e. on the wavelength at which its components react. [16, 19, 20, 24]

Does polymerization using LED technology enable the irradiation time to be reduced? A study and analysis measuring the time needed to obtain good in-depth hardness was performed.

Method: The aim of this study was to obtain the same hardness value at a depth (2mm) for a "reference" halogen lamp (Kerr/Demetron Optilux 501) and for an LED lamp (Satelec's Mini LED™). Moulds 2mm thick (Figure 5) were filled with nine different composites and then irradiated following the recommendations from the manufacturer of the halogen lamp. The microhardness was measured with a Leica VMHT 30 microhardness tester 30 minutes after irradiation. Then, for the LED lamp, irradiation time was adjusted to obtain the same hardness, at a depth, with the various composites. We thus found the time needed to get the same result as with the halogen lamp.

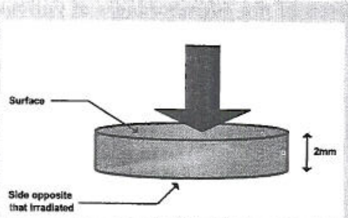


Figure 5
Composite sample being irradiated

圖5
複合體樣品被照射中

通常，發光二極管的光照頂端(7.5或8毫米)要比素鹵燈(10到12毫米)的小。這是因為發光二極管燈應用了渦輪頂端，在入口處較寬而在出口處較窄，使得光線更分散。在直徑2毫米的情況下，在頂端的層面，由發光二極管燈射出的光線直徑接近鹵素燈或等離子燈的光線直徑，但是分叉程度小。

原則上不建議在發光二極管燈上使用寬的光導向裝置。在臨床上發光二極管是好的選擇，因為它的功率穩定、操作更符合人體功學(無噪音、無線) 並且泵的溫度幾乎不會升高。Palmer [13]在2002年聖地亞哥IADR上展現的研究結果顯示，通過對鹵素燈、等離子燈和發光二極管燈三種燈泵溫度上升程度的比較，發光二極管的效果最佳。

- 使用發光二極管40秒後上升0.9度
- 使用傳統鹵素燈40秒後上升3.6度
- 使用快速鹵素燈10秒後上升1.9度
- 使用等離子燈10秒後上升6.4度

2. 顯微硬度和曝光時間

對第二代發光二極管技術的顯微硬度調查顯示良好的結果。[7, 8, 21] 可以應用顯微硬度對臨床試用的材料進行固化測試。[4, 14, 17]兩個研究顯示-使用了發光二極管技術- 結果令人滿意，而且曝光時間與多數操作者每天的工作相適應。

a. 時間和顯微硬度

使用鹵素燈對光固化複合體材料和複合體進行固化需要20到40秒的曝光時間[1]。臨床醫師通常還需要預留額外的時間，尤其是對牙釉質或模型上的材料進行固化的時候，或是使用不透明或深色複合體的時候。[22] 複合體材料必須充分固化才能達到生物兼容性並避免副作用。複合體的固化程度除了取決於材料的本質和成分之外，還取決於複合體的固化反應，如材料成分對波長的反應等[16, 19, 20, 24]。

使用發光二極管技術真的能使照射時間減少嗎？我們作了一個為獲得良好深度硬度所需時間的研究和測試。

Figure 6a

圖6a

Mfr 製造商	Composite 複合體	Shade 色度	Time Recommended by mfr 鹵素燈製造商建議照射時間	Time obtained w/Mini LED™ 發光二極管照射時間
Cavex	Quadrant Universal LC	A3	20s	8 sec
Kuraray Medical	Clearfil AP-X	A3	20s	8 sec
Dentsply Detrey	DEFINITE omc	A3	10s	10 sec
Kerr	XRV Herculite enamel	A3	Not available	10 sec
Kerr	XRV Herculite prodigy	A3	40s	10 sec
3M	Z100 MP	A3	40s	5 sec
3M	Filtek Z250	A3	20s	7 sec
Dentsply Detrey	Spectrum TPH	A3	20s	7 sec
Ivoclar Vivadent	Tetric Ceram Cavifil	A3	40s	10 sec

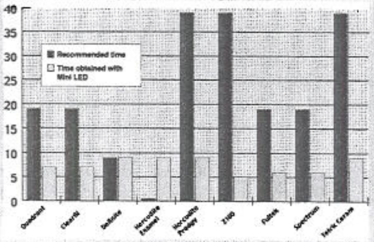
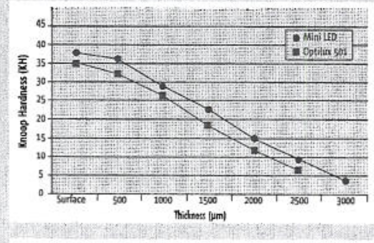


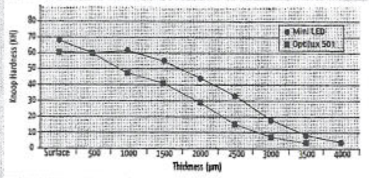
Figure 6b
Irradiation time obtained with LED

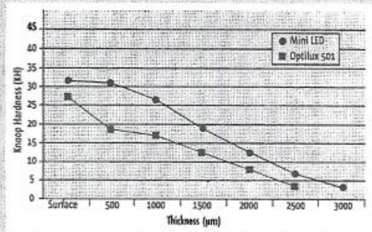
圖6b
使用發光二極管的照射時間

Figures 7a, 7b, 7c

圖7a, 7b, 7c







Results: With Satelec's Mini LED™ lamp, the times required to produce the same microhardness at a depth were shorter. It can be seen from this study that the curing time can be reduced by up to 88% for some composites. (See Figures 6a and 6b)

b. *Study of the microhardness of various composite materials in relation to thickness, using two light-curing lamps*[18]

The aim of this second study was to assess the depth of polymerization using two lamps, by studying Knoop microhardness. This investigation was carried out using two lamps – a conventional halogen lamp (Kerr/Demetron Optilux 501®) and a new LED lamp (SEDR LED prototype, at the time of study) – and six composite resins (Z100MP, Herculite XRV®, Tetric Ceram®, Admira®, Definite® and GC Unifil S®). The irradiation time was nine seconds at full power for each lamp; six samples of each composite were used.

The microhardness study was carried out using the Leica VMHT 30 hardness tester. Five measurements were made for each sample, every 500µm. Statistical analysis showed significant differences between the materials, but the comparisons of hardness in relation to thickness showed similar curves for the various composites. Three results are presented here. Within the limitations of this *in vitro* study, the depth of polymerization was found to be better with the LED lamp. (See Figures 7a, 7b, 7c)

3. Clinical cases using Satelec's Mini LED™ lamp

During the past decade, changes in the socio-economic environment, a reduced prevalence of dental caries, increased interest on the part of patients in cosmetic dentistry, a concern to spare tissue, and controversy over the potential toxicity of metallic restoration procedures, have led to an in-depth reassessment of treatment methods for anterior and posterior teeth. Composites, and direct and indirect adhesive techniques have, therefore, become basic elements in modern restorative dentistry. However, successful treatment depends on a whole array of interrelated factors. The quality of the materials used, the suitability of the instruments, and knowledge and mastery of operating techniques are all of fundamental importance for how long restorative procedures will last.

We carried out clinical procedures in various areas of adhesive dentistry (orthodontics [2], and direct and indirect restorative dentistry) using the LED technology for light curing of the materials employed in both direct and indirect techniques.

方法：本研究的目的是使用一個"參照物"鹵素燈(Kerr/Demetron Optilux 501)和一個發光二極管燈(Satelec's Mini LED)對比在(毫米的深度獲得相同的硬度。2毫米深的模型(圖5)充滿了9種不同的複合體，然後根據製造商的建議用鹵素燈進行照射。接著使用Leica VMHT 30顯微硬度測試儀對照射後產生的顯微硬度進行測試。然後使用發光二極管燈照射不同的複合體，直至在相同的深度達到鹵素燈照射獲得的相同硬度。我們隨即得到要獲得與鹵素燈同等效果所需的發光二極管燈照射的時間。

結果：使用Satelec's Mini發光二極管燈在同等深度獲得同等硬度的時間更短。這個研究顯示相同材料的固化時間可以減少達88%。(請看圖6a和6b)

Clinicians can now depend on LED technology, which is reliable and can be adapted to everyday practice at reasonable cost [18]. It is therefore possible to provide treatment using LED curing for adhesive techniques in many clinical situations. The method certainly has its place in the current therapeutic arsenal, even though conventional halogen curing has shown very good results and is still valid. It is, nevertheless, important to note that the shorter curing times obtained with LED lamps are proving of interest in dental restoration [6], not because of any time saved but because of clinical application. The absence of temperature increase means that the method satisfies the three essential considerations of Function, Physiology and Aesthetics. [5, 9, 13, 22, 3, 12]

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顯微硬度的研究是通過Leica VMHT 30硬度測試器進行的。每組樣品都測試了5次，每次500微毫米。統計分析顯示材料之間存在顯著性差異，但是不同材料硬度與厚度的關系比較則顯示相似的曲線。這裡展現了3　組結果。在這次非臨床研究範圍內，發光二極管具有較好的固化深度。(請看圖7a, 7b, 7c)

3. 使用Satelec's Mini發光二極管燈的臨床病例

在過去十年裡，社會經濟環境發生的變化、齲齒減少的趨勢、部分患者對牙科美容日益加強的興趣、對組織缺損的關心以及對金屬修復治療潛在毒性的爭論等，使我們對前牙和後牙治療方法重新進行深入的評估，複合體以及直接和間接粘接技術就成為當今修復牙科中最基本的元素。然而一個成功的治療取決於一系列互相關聯的因素，使用材料的質量、設備的匹配性、操作者的知識和熟練程度等對修復能夠維持多久都是至關重要的。

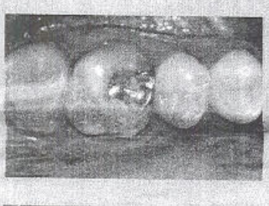
我們應用發光二極管技術在各種臨床牙科黏接治療中(矯正[2]、直接和間接修復等)對通過直接和間接技術放置的材料進行固化。

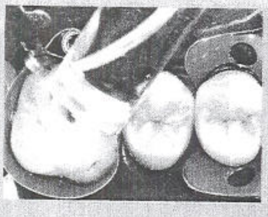
臨床醫師現在可以依靠可靠並適用於多種應用的發光二極管技術，而且成本合理[18]。在許多臨床情況下都可以用發光二極管對黏結劑進行固化。這種方法在當今的治療需選擇中佔有重要的一席，儘管傳統的鹵素燈依然有效並顯示很好的效果。但是我們還需要指出已經在修復領域激發起更多的興趣的發光二極管並不是因為其更短的固化時間[6]，而是因為它的臨床應用性能。在操作過程中溫度不升高意味著這種方法滿足了3 個基本條件：功能、生理學和美學[5, 9, 13, 22, 3, 12]。

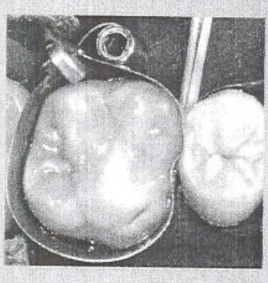
讀者詢問卡編號 012

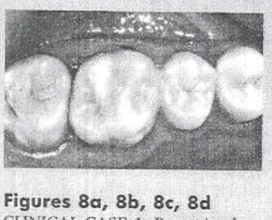
b. 使用兩種光固化燈對多種複合體材料的顯微硬度與厚度關係的研究[18]

第二個研究的目的是使用兩種燈，通過研究Knoop顯微硬度對固化深度進行評估。該研究通過兩種燈-一種傳統的鹵素燈(Kerr/Demetron Optilux 501®)和一種新型發光二極管燈(SEDR LED 原型燈, 研究時名稱) - 以及6 種樹脂(Z100MP, Herculite XRV®, Tetric Ceram®, Admira®, Definite® and GC Unifil S®)進行。每種燈的照射時間為全功率的9秒照射，每種複合體都使用6組樣品。



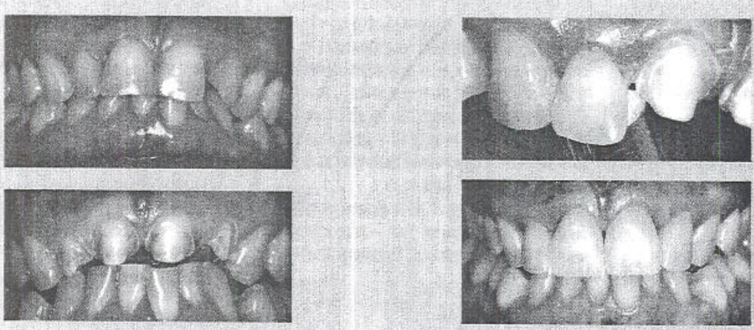






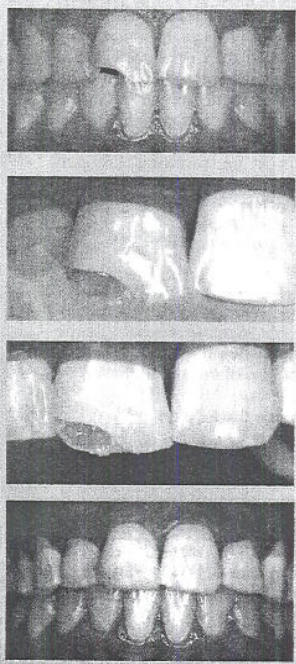
Figures 8a, 8b, 8c, 8d
CLINICAL CASE 1: Posterior layering (Composite: Dentsply DeTrey's EsthetX®)

圖8a、8b、8c、8d
臨床病例1 ：後牙分層(複合體：Dentsply DeTrey's EsthetX®)



Figures 9a, 9b, 9c, 9d
CLINICAL CASE 2: Ceramic veneers (Bonding composite: Ivoclar Vivadent's Varioloink II®)
(Carried out by Laboratories Creadent, Grabels, 34 Herault, France)

圖9a、9b、9c、9d
臨床病例2：烤瓷貼面 (黏結複合體：Ivoclar Vivadent's Varioloink II®)
(由法國Creadent, Grabels, 34 Herault技工室完成)



Figures: 10a, 10b, 10c, 10d
CLINICAL CASE 3: Anterior layering (Composite: Coltene Whaledent's Miris®)

圖10a、10b、10c、10d
臨床病例3：前牙分層(複合體：Coltene Whaledent's Miris®)

Bibliography:
參考文獻：

(1) BAHARAV H., ABRAHAM D., CARDASH HS., HELFT M. Effect of exposure time on depth of polymerization of a visible light-cured composite resin. J. Oral Rehabil. 1988 Mar; 15(2): 167-172.

(2) DUNN WJ and TALOUMIS LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. Am J Orthod Dentofacial Orthop 2002 Sep; 122(3):236-41

(3) DURET F., PELISSIER B., CREVASSOL B. Mise au point sur la lampe à polymérisation ultra-rapide plasmatique: bilan après 6 ans et mode d'emploi. Inf. .Dent.. 1999; 44: 3547-3558.

(4) FERRACANE JL. Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins J. Dent. Res.1985; 1: 11-14.

(5) HANNIG M et BOTT B. In-vitro pulp chamber temperature rise during composite resin polymerization with various light-curing sources. Dent Mater 1999 Jul;15(4):275-81

(6) HARRINGTON E., WILSON HJ., SHORTALL AC. Light-activated restorative materials: a method of determining effective radiation times J. Oral Rehabil. 1996 Mar; 23(3): 210-218.

(7) JANDT KD, MILLS RW, BLACKWELL GB et ASHWORTH SH. Depth of cure and compressive strength of dental composites cured with blue light emitting diodes (LEDs). Dent Mater 2000 Jan;16(1):41-7

(8) KURACHI C., TUBOY AM., MAGALHAES DV., BAGNATO VS. Hardness evaluation of a dental composite polymerized with experimental LED-based devices. Dent. Mat. 2001 Jul; 17(4): 309-315.

(9) LONEY RW and PRICE RB. Temperature transmission of high-output light-curing units through dentin. 19 Oper Dent 2001 Sep-Oct;26(5):516-20

(10) MILLS RW. Blue light emitting diodes: an alternative method of light-curing? Br. Dent. J. 1995; 178:169 letter.

(11) MILLS R.W., UHL A., et JANDT KD. Optical power outputs, spectra and dental composite depths of cure, obtained with blue light emitting diode (LED) and halogen light curing units (LCUs) Br Dent J 2002 Oct 26 ;193(8) :459-63

(12) MITTON BA et WILSON NH. The use and maintenance of visible light activating units in general practice. Br Dent J. 2002 Feb 23;192(4):182.

(13) PALMER T.M., YOST M.P., LATEY M.L., ASHTON J.A., SYNDERGAARD B.D. and CHRISTENSEN R.P.. Light emitting diode resin polymerization compared to three other methodsIADR, San Diego, 2002: Abstract 3976

(14) PELISSIER B. Influence du mode d'irradiation lumineuse sur le degré de polymérisation des biomatériaux composites et derives Thèse Doctorat d'Université, Montpellier, Mars 2002: 283p

(15) PELISSIER B., CASTANY E., CHAZEL JC., VALCARCEL J., DE SOUFFRON N. et DURET F. An evaluation of depth of cure with two lamps: a Knoop hardness study Pan European Meeting, Cardiff 2002: Abstract 369.

(16) PELISSIER B., CHAZEL JC., CASTANY E. et DURET F. Lampes à photopolymériser EMC, Stomatologie/ Odontologie,22-020-A-05,2003,11p (to be published).

(17) RUEGGEBERG FA., ERGLE JW. et METTENBURG DJ. Polymerization depths of contemporary light-curing units using microhardness J. Esthet. Dent. 2000; 12: 340-349.

(18) STAHL F., ASHWORTH SH., JANDT D., MILLS RW. Light-emitting diode (LED) polymerization of dental composites: flexural properties and polymerization potential Biomater. 2000; 21:1379-1385.

(19) STANSBURY JW. Curing dental resins and composites by polymerization J. Esthet. Dent. 2000; 12: 300-308.

(20) STRYDOM C. Curing lights-the effects of clinical factors on intensity and polymerization. SADJ 2002 May; 57(5):181-6

(21) UHL A, MILLS RW, VOWLES RW et JANDT KD. Knoop hardness depth profiles and compressive strength of selected dental composites polymerized with halogen and LED light curing technologies. J Biomed Mater Res 2002;63(6):729-38

(22) UHL A., MILLS R.W. et JANDT KD. Polymerization and light-induced heat of dental composites cured with LED and halogen technology Biomaterials 2003 May;24(10) :1809-20

(23) UHL A., MILLS R.W. et JANDT KD. Photoinitiator dependent composite depth of cure and knoop hardness with halogen and LED light curing units Biomaterials 2003 May; 24(10) :1787-95

(24) YOON TH, LEE YK, LIM BS et KIM CW. Degree of polymerization of resin composites by different light sources. J Oral Rehabil 2002 Dec;29(12):1165-73

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