The use and maintenance of visible light activating units in general practice

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Aim The present study to investigate the use, care and maintenance of light units in everyday clinical practice was undertaken to complement light unit emission surveys, with a view to developing a protocol for light unit use and care in everyday clinical practice.

Method The investigative work comprised a survey of selected practices in the Blackburn area with follow-up practice visits to examine light units *in situ,* and to glean additional information in respect of light unit use and care in the practice environment.

Results Completed questionnaires were returned by 54 of 77 selected practices — a 70% response, including information in relation to 164 light units. Subsequently, 100 (61%) of these light units were examined in 42 practices according to a standardised protocol. The use and care of the light units included in the study was found to be very variable. In addition to finding that 28 (28%) had inadequate light output (<300 mW/cm^2), many of the light units were found to be damaged or repaired (47, 47%). Thirty five (35%) of the light units inspected were found to have varying amounts of material adherent to the light guide exit portal.

Conclusion It is concluded that practitioners should address practical aspects of their increasing reliance on light units, and to this end, guidance is offered on visible light curing and the care and maintenance of light units.

Visible light activated materials (light-cured materials) have been in use in dentistry for almost 25 years and, with a continuing trend of increasing use in every day practice, have revolutionized clinical dentistry.[1] Light-cured materials, including composites and compomers, are presently used primarily for a range of restorative procedures, and despite their limitations[2] will, for the foreseeable future, remain the materials of choice, notably in the restoration of anterior and selected posterior teeth. Visible light activation units (light units) also have limitations, because of changes in the wavelength of light emitted and reduction in the intensity of emissions, which are generally imperceptible to the operator and chairside assistant.[3]

Recent studies[2–6] carried out to investigate the effectiveness of light units in clinical use, indicate that the routine assessment of light output intensity is not carried out regularly, and a significant proportion of units tested (> 60%) may be found to have insufficient light output.[4] These studies also show that practitioners remain unaware of the importance of care and maintenance of this essential item of equipment. Allocating time, within one's busy schedule, for monitoring and maintaining light units is a prerequisite for quality restorations and essential to patient care.

The variables that largely determine the effectiveness[1,4] and performance of a light unit,[7] regardless of type and assuming correct use,[1,3] are the quality of the light it emits and the intensity of the emission.[2,4]

The quality of light that a light unit emits is determined by the age of the bulb,[3,7] which should not normally exceed 6 months; the integrity of the bulb reflector,[7] which should be free from frosting and blackening; and the appropriate filtration of the light.[2] The intensity of emission is reduced by debris adherent to the light guide tip, repeated sterilisation of the light guide, damaged or chipped light guides, broken or excessive bending of fibre-optics, and variations in input voltage to the bulb.[2,7]

For successful curing of light-cured materials, containing camphorquinone as the initiator, the peak wavelength is 470 nm[8]. Light of wavelength of < 450 nm and > 500 nm is of limited value.[1,9] Subjective assessment of the intensity of light output is not sufficient to determine peak wavelength.[1,2,4] An effective and accurate device is required to monitor the output of the light unit. Such a device is a radiometer[9] (or light meter) which is tuned to respond to light of 470 nm. The reading taken by a radiometer is known as the 'power density', and is measured in milliwatts per centimetre squared (mW/cm^2). Studies recommend[2,3,8] that power density should exceed 400 mW/cm^2 to produce a well cured restoration, and a reading of <300 mW/cm^2 indicates the need to cure for longer or to replace the bulb. Results are comparable[4,8] provided the same meter is used to assess power density of a particular light unit.

The present study was undertaken to compliment curing light emission surveys by investigating the use, care and maintenance of light units in everyday clinical practice. The purpose was to investigate the existing knowledge and attitudes of selected general dental practitioners in the North West of England and to investigate the adequacy of the units in the practitioners' practices in terms of light output. Based on the findings of the investigations and the related review of the existing literature, a light unit maintenance protocol was devised and is presented as an addendum to this paper.

Materials and methods

Information obtained from District Health Authorities in Lancashire and North Manchester indicated that there were 899 general dental practitioners working in the area. Dental practices were identified, for possible inclusion in the study, using the British Telecom Yellow Pages for each area.[10] Consideration of the geographic distribution and nature of the practices in the selected location indicated that the practices in the Blackburn Directory would form a valid sample for the North West of England.

The initial phase of the study comprised a postal survey of the 77 general dental practices selected. The questionnaire requested information in respect of the nature of the practice, its personnel, the pattern of use of light units, including details of typical curing

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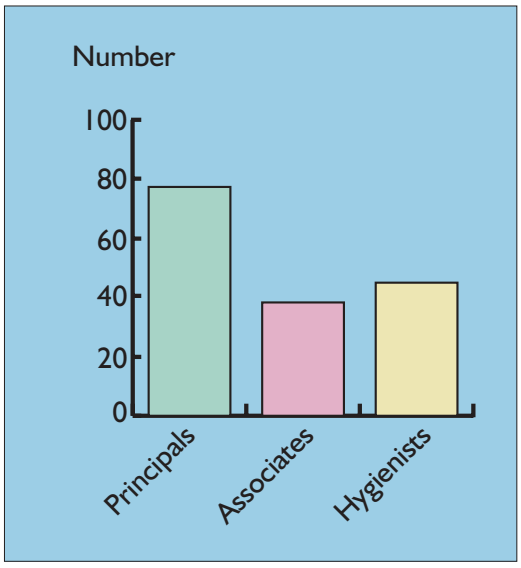

Fig. 1 Distribution of personnel in the practices surveyed

times and maintenance procedures, the use of radiometers and cross infection control measures.

The second phase of the study involved the principal investigator seeking an appointment at as many of the selected practices as possible, to visit and conduct a visual inspection and examination of the light units *in situ*. The purpose of the visit was to obtain additional information in respect of the care and maintenance of the light units and to undertake light output intensity tests. Examination of the light units was carried out at a time that was convenient for the practice, usually at the end of a clinical session, when a clinician was often available to answer any additional questions. Information concerning the age of the light unit, the history of repairs and the availability of replacement bulbs[2] was noted.

The visual inspection of each light unit was carried out according to a standardised protocol, and the observations were recorded on a data collection form. The inspection included consideration of the location of the light unit in the surgery; examination of the light guide tip for damage (cracks, crazing and chipping) and adherent debris; and assessment of the condition of the electrical lead and outer casing. The presence or absence of dust or debris on the fan screen was recorded, together with the number of light guide tips available for use with each light unit.

No inspection was undertaken of the light bulbs and filters. The condition of these components of the light units was assessed, at least in part, by the light output intensity test.[9] The light output intensity test was carried out according to the manufacturer's directions for the use of the Coltolux Light Meter (Coltene-Whaledent, Sussex, UK) and as previously described.[6] The light unit was activated for 10s, the light guide tip was placed over the light sensor for a further 10s, and the digital readout noted at the end of the time period. Three readings at least 1 minute apart were taken and the average digital readout was recorded for each light unit.

The principal investigator used the light unit at her practice as the control for monitoring the performance of the Coltolux Light Meter used in the survey. Following recommendations in the literature, the investigator's light unit was routinely monitored on a daily basis using a duplicate Coltolux light meter. Prior to visiting a practice, the reading was taken with both light meters of the control light unit. Batteries were renewed, as required, to ensure a constant reading. The survey meter was retested against the control on return. The inspection was completed by photographically recording the light unit and its component parts, *in situ,* using a Fuji DL-1000 Zoom Compact camera (Fuji Photo Film Co. Ltd., Japan).

The results obtained from both the questionnaire and the visual inspection were computed and analysed using SPSS.

Results

The questionnaire

Completed questionnaires were returned by 54 of the 77 selected practices — a 70% response. Information was returned in relation to 164 light units, of which 5 (3%) were designated as spare units. Two practices did not use light units, one being limited to orthodontics and the other to removable prosthodontics. All 52 practices, in which light units were used, indicated 100% satisfaction with the performance of their units.

Of those practices included in the study 33 (64%) provided mainly NHS treatment, 8 (15%) were essentially private and 11 (21%) indicated a mixed client base. The distribution of personnel employed in the practices surveyed is shown in Figure 1. The gender of the personnel was 88 (54%) males and 71 (43%) females.

Information concerning sharing of light units between personnel was recorded to determine who would be responsible for maintaining the light unit. In 32 (62%) practices, light units were used solely by one individual, the remainder being shared between personnel (Fig. 2).

Regarding the time taken to cure light-cured materials, the responses to the questionnaire indicated that, curing times for all light-cured materials in increments of < 1 mm depth was 10s in 2 (4%) practices, 20s in 29 (56%) practices and in 3 (5%), curing was undertaken for 30s. In the remaining 18 practices, 14 (30%) cured for a minimum time of 40s and 4 (5%) for 60s or longer. Manufacturers' instructions for light units were avail-

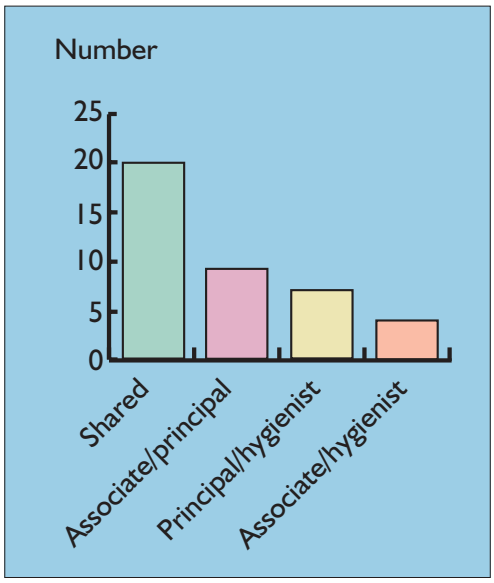

Fig. 2 Distribution of light units shared between personnel

Table 1 Methods used to prevent light-cured materials adhering to the exit portal of the light guide tip

Method used to prevent adherent debris	Number of practices
Nothing	6 (11%)
Don't touch the composite	24 (46%)
Place tip 1mm from restoration	3 (6%)
Vaseline on the tip	1 (2%)
Separate tip: celluloid strip	2 (4%)
Cover tip: disposable cover	8 (16%)
Wrap with cling film	8 (16%)
Total	52 (100%)

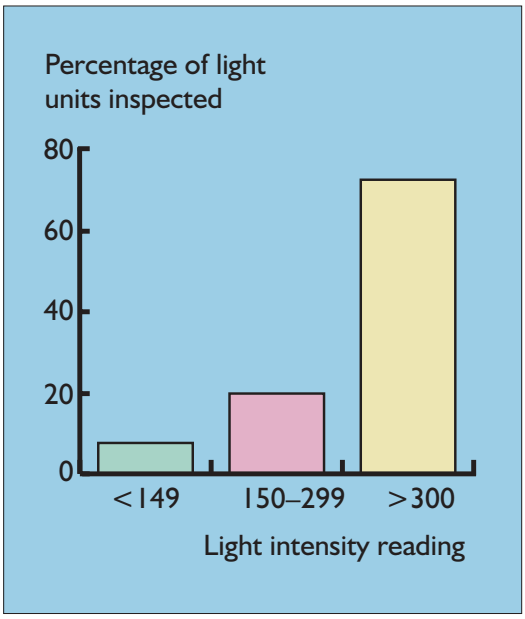

Fig. 3 Light intensity readings (mW/cm^2) of light units inspected

able in 32 (62%) of the practices. Light shields were used in 28 (54%) of the practices. The remaining practices either did not use a light shield (6, 11%) or did not know about the use of these devices (18, 35%).

The light output intensity of the light units ($n = 52$) used in 35 practices (67%) was not monitored routinely, as a consequence of the practice not owning or having access to a radiometer, let alone any form of light unit meter. Of the practices which had access to a radiometer ($n = 17$), 6 practices (35%) used it weekly, 8 (47%) monthly and the remainder did not know when it was used.

Forty-six practices (88%) reported using a variety of methods to prevent light-cured materials accumulating on the exit portal of light guide tips (Table 1). Techniques employed included separation by distance, that is, 'don't touch the composite' (24, 46%), or 'place tip 1mm from the restoration' (3, 6%), or separation by physical means (4, 8%), using 'Vaseline on the tip' or by placing a celluloid strip between the tip and the restoration. Sixteen (32%) practices, in total, used a disposable cover or cling film (grade not specified) to prevent accumulation of debris.

The commonest method used to ensure cross infection control between patients (Table 2) was a disinfectant wipe (36, 69%). Only 8 (16%) of the 52 practices using light units, indicated the routine use of either autoclaving or cold sterilisation to minimise cross contamination between patients. The remainder (8, 16%) relied on the disposable cover used to prevent accumulation of debris or washed the tip between patients with a bactericidal soap solution (1, 2%).

The visual inspection

One hundred (61%) of the 164 light units, reported to be used in the practices surveyed, were available for visual inspection in 42 practices. Of these light units, 28 (28%) were found to have a light intensity output of < 300 mW/cm^2 (Fig. 3), defined as the minimum output necessary to cure light-cured materials.

Analysis of the age of the light units inspected for light intensity output, revealed a statistically significant difference ($\chi^2 = 5.033$, $P = 0.025$) between the light intensity output of 'old' (> 6 years old) and 'new'(< 5 years old) light units (Fig. 4). These results lend support to the findings of previous studies.[1–3]

The number of light guides available per light unit was limited to one in >90% of the practices. The lamp bulb had been replaced at some time, in the life of the light unit, in 66% of cases. For 34 (34%) of the light units, the bulb had been in routine clinical use for periods of < 6 months.

Thirty five (35%) of the light units inspected were found to have varying amounts of light-cured materials adherent to the light guide exit portal. Many (47, 47%) of the light units were found to be damaged or repaired (Fig. 5), with 38 (38%) of the light guide tips having been found to be cracked, crazed or chipped.

The condition of the electrical lead on the light units was assessed as poor in 18 (18%) cases. The problems identified included evidence of excessive twisting, damaged insulation or loose connections. In general the fans of the light units were found to be in a satisfactory condition: however, hazardous accumulations of dust were considered to be present on the blades of 8 (8%) of the fans.

Finally, concerning the location of the light units within the surgery (Table 3), work top placement predominated (79, 79%) but in many cases, the light units were considered inappropriately sited, being close to a sink or autoclave, or stored behind other equipment in a cupboard. Inappropriate siting of a light unit may result in electrical damage from water or other fluids, or damage to the unit by accident, excessive dust, heat and sunlight. Careless handling, especially dropping of the unit onto a work-surface, let

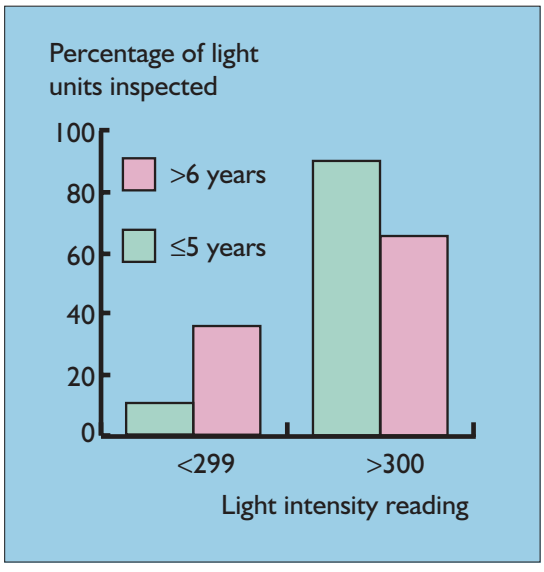

Fig. 4 Light intensity readings (mW/cm^2) according to age of light units

Table 2 Method used to limit cross infection

Method used to limit cross infection	Number of practices	
Disinfectant wipe	36	(69%)
Autoclaved	3	(6%)
Sterilised in glutaraldehyde solution	5	(10%)
Wrapped in disposable cover	7	(13%)
Washed with bactericidal soap solution	1	(2%)
Total	52	(100%)

Table 3 Location of the light unit in the surgery

Location of light unit	Number of light units	
Sited on the work top	79	(79%)
Mounted on the dental unit	8	(8%)
Cordless	1	(1%)
Mounted on the wall	10	(10%)
Stored in a cupboard	2	(2%)
Total	100	(100%)

alone the floor, will invariably displace components, which may have an adverse affect on the functionon of the light unit or pose an electrical hazard or risk.

Discussion

Visible light curing of light-cured materials is considered to be an integral element of everyday clinical practice.[3,8] While recent years have seen a number of innovations in photocuring and polymerisation technology, including argon lasers and plasma arc lights,[11] the results of the present study indicate that, at least in the North West of England, traditional forms of light units predominate.

A study conducted by Barghi[2] showed that similar results were obtained between a pilot and a larger scale study and could possibly be used to determine trends of care and maintenance of light units within surrounding areas. The authors believe that the sample in the present study, while small, is representative of at least the North West of England.

In common with the findings of recent surveys of light intensity output of light units,[2,4,6] the findings of the present study indicate that a large proportion of light units in general dental practice may be found to have unacceptably low outputs. A problem confounded by only 33% of practices surveyed having the means to monitor their light units for light intensity output. This is considered to be a cause for concern given the widespread acceptance of the importance and, in many cases, significant effects of incomplete polymerisation of light-cured materials,[1,8,11,12] notably visible light cured composites.

It is suggested that the time is long overdue when practitioners realise and come to terms with the need to replace the bulb in their light unit on a regular basis[7] (ie at least every 6 months). Similarly, light unit filters and light guides must be recognised to be vulnerable to damage[1,7] and when found to be damaged, must be replaced. The apparent widespread practice of persevering with a light unit which has outlived its useful life expectancy, let alone the failure to monitor the output and maintain light units, is considered unacceptable in terms of possible consequences to patients.

The performance of light units must not be judged on the basis of a subjective assessment of light output,[1,3,8] let alone misguided reliance on the concept that the bulb, filters and light guide tip are usable until such time as the unit stops functioning. Light units need care and maintenance to enhance performance,[12] monitoring regularly for deterioration and the replacement of parts, immediately they become defective. Such action will extend the longevity of light-cured restorations and enhance the benefits of light-curing to the patient.

Assuming a light unit to be performing satisfactorily and the operator to be employing appropriate light-curing techniques, the focus of attention should be the maintenance of the unit[7] and minimising the risk of cross infection between patients.[3,13]

Regarding the maintenance of light units, a suggested protocol is reproduced as an addendum to this paper. In applying such a protocol members of the dental team, and the dentist as leader of the team, should understand that in typical use, a light unit may need to be replaced as frequently as other equally heavily used items of equipment in the surgery.

The use of domestic grade cling film is not considered to be a simple, let alone effective, solution to the problem of cross infection control,[14] given variability and the possibility of microscopic holes in such film. Cling film is a multilaminate material, with domestic film typically comprising only a few laminate layers. Commercial quality (heavier duty) cling film comprises more laminate layers than domestic cling film and, as a consequence, the variability and incidence of defects in such films is much lower than in many forms of domestic film.

The issue of light units and cross infection control between patients may only be addressed, but not necessarily resolved, by the adoption of single-patient use light guides.[15,16] Such light guides may be viewed as costly and to suffer certain limitations; however, such disadvantages may be found to be far outweighed by the advantages of this measure to improve cross infection control to patients. Alternatively, clinicians may wish to consider the use of transparent film light guide covers[14] and the sterilisation of guides between patients.[17,18]

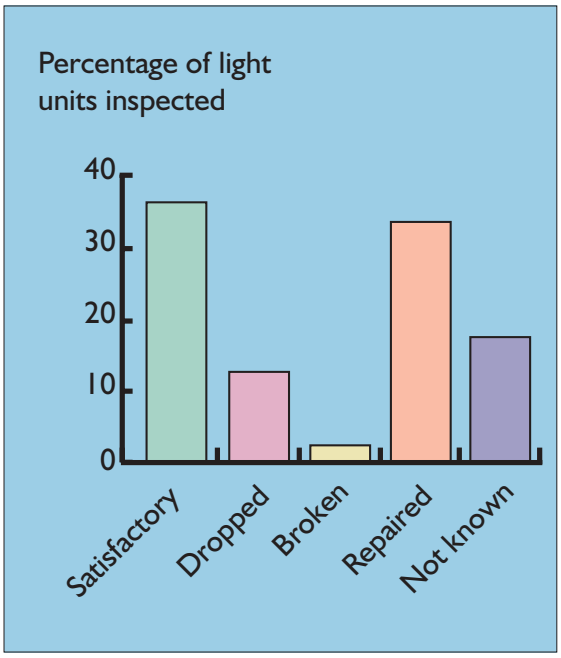

Fig. 5 Condition of light units inspected

If the decision is taken to adopt light guide covers and the sterilisation of guides between patients, practitioners must take into account the effects that sterilisation damage[17,18] and covers may have on the intensity of light output. Light guide covers are not necessarily fool-proof[14] and repeated autoclaving or cold sterilisation causes damage to light guides.[17,18] Re-polishing techniques may be used to improve energy transmission of light guide tips following damage.[18]

Conclusions

Photo-initiation and, in particular, the visible light curing of restorative materials has transformed certain aspects of everyday practice and is considered to still offer unrealised opportunities for new materials and techniques in many aspects of clinical practice. However, as indicated by the findings of the present study and related surveys, practical aspects of the increasing reliance on light units must be addressed. It is hoped that the protocol accompanying this paper will go some way to meeting this need.

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Addendum — guidance on visible light-curing

A Use of light — light-curing

A1. Inadequate curing of light-cured materials has many adverse effects. There are no disadvantages to prolonged curing.
A2. For effective curing, the direction of the beam and the proximity of the tip to light-cured materials are very important factors. Poor access necessitates prolonged or multi-exposure curing.
A3. Restorations with large surface areas require spot polymerisation, with several exposures covering overlapping areas. Scanning the surface of a large restoration will result in inadequate curing.
A4. Light guide tips must be free of adherent materials, especially on the light emitting surface, and sterilised between patients if not disposable. Non-autoclaveable tips must be protected in use, for example, using a clear sheath and cold sterilised between patients. Repeated sterilisation causes degradation of light guides.
A5. Use the light intermittently to avoid overheating.
A6. Light units must not be switched off until the fan has stopped running.

B. Care of light units

B1. Safe siting of the unit away from other devices (eg an autoclave), water, other fluids and potentially damaging materials. Locate for easy access but where the risk of inadvertent damage is minimised.
B2. Handle light units carefully, especially if moved between surgeries. Careless handling, especially dropping of the unit onto a work-surface, let alone the floor, will invariably displace components.
B3. Protect light units and spare components from exposure to splashes, excessive dust, heat and sunlight.
B4. Adhere to the manufacturer's recommendations for maintenance and replacement.

C. Maintenance of light units

All the principle components of light units, including the lamp, light guide, filter and fan must be inspected, on a regular basis, and replaced if found to be damaged or defective.

C1. Monitoring the intensity of the light output
The intensity of the light output of all light units should be tested at least weekly using a radiometer. Light intensity readings should be recorded in a logbook.
If the intensity of light output falls below 300 mW/cm^2, or is found to be very variable (+/– 50 mW/cm^2) between readings, action is required.
In the absence of a radiometer, extrude a 3mm high column of light-cured composite material onto a work surface and cure from above for 40s; then test the base of the 'column' for hardness. Consistency of results may be obtained by using a universal shade, from the same batch on a weekly basis. If partially set composite can be scraped from the bottom of the column, action is required.

C2. The light unit bulb
The performance of a light unit bulb cannot be judged on the basis of a subjective assessment of the light output.
Remember the colour of the light is the same, whether or not the frequency is effective.

C2.1. Is the bulb functioning properly?
- The bulb will require replacement after 3 to 6 months of regular use.
- Replace the bulb sooner, rather than later, if the bulb shows evidence of frosting or blackening.

C2.2. Check the reflector for deterioration
Blackening or whitening of the lamp envelope (reflector) is indicative of degradation of the reflective coating. When deterioration is apparent, the bulb must be replaced.

C3. The light guides
C3.1. Clean the light guide tip after use.
Remove any light-cured material found on the exit window. If found to be scratched, refinish the light guide exit window using a light guide maintenance kit.
C3.2. Review the conductance of the light guide
- The fibres in a fibre-optic light guide may be checked, by holding the distal end of the light guide up to the daylight and looking for black speckling or darkened areas. Replace the optic if more than 10% of the fibres are broken.
- If the damage to the guide is the result of cracking, crazing or fibre bundle light, it should be replaced.

C4. Are the filters intact, clean and free of cracks?
Filters remove unnecessary radiation and are placed between the light source and the light guide.
- The filters may be pitted, cracked, blistered or simply coated in dust after a relatively short period of use. Replace any filter with evidence of deterioration or damage.
- Consult individual light unit directions for use, for details of the materials and techniques to be used to clean dusty filters.
- Filters, like bulbs, are highly specific to different types of light unit and must be replaced with precision in the optical system of the light unit.

C.5 Vacuum intake exhaust ports to remove dust
Dust causes overheating and damage to the fan.
- A damaged fan is generally noisy, and apart from being hazardous, causes heat damage to other components, and must be replaced.
- The vacuuming of intake and exhaust ports must be undertaken with care. A little often is preferable to a lot occasionally.

C.6 Damaged lead?
Twisted or broken leads and plugs are hazardous and must be replaced.

C.7 Frequent problems?
Light units, which have outlived their reasonable life expectancy (up to 5 years of regular use), should be replaced.