

An Overview of Bleaching Techniques: I. History, Chemistry, Safety and Legal Aspects

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Abstract: The use of a variety of bleaching techniques has attracted much interest from the profession, as they are non-invasive and relatively simple to carry out. Coupled with the uncertain legal situation within the European community, and especially within the UK, this series of articles hopes to give a broad overview of bleaching techniques, their efficacy and relative safety, as well as update the current legal situation.

This article will give an overview of bleaching: history, chemistry and safety. In addition, it will summarize types of tooth discoloration, along with indications/contraindications for bleaching. Future articles will address in detail both home and power bleaching techniques, as well as the various ways to bleach non-vital teeth.

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Clinical Relevance: With the present uncertainty of the legality of bleaching, it is important to highlight that these techniques are relatively safe and non-invasive compared to veneers and full coverage crowns.

Tooth discoloration creates a wide range of cosmetic problems and the dental profession and the public expend considerable amounts of time and money in attempts to improve the appearance of discoloured teeth. The methods available to manage discoloured teeth range from:

- Removal of surface stain;
- Bleaching or tooth whitening techniques;
- Operative techniques to camouflage the underlying discoloration, such as veneers and crowns.

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The use of a variety of bleaching techniques has attracted much interest from the profession, as they are non-invasive and relatively simple to carry out. Contemporary bleaching systems are based primarily on hydrogen peroxide or one of its precursors, notably carbamide peroxide, and these are often used in combination with an activating agent such as heat or light. Bleaching agents can be applied externally to the teeth (vital bleaching), or internally within the pulp chamber (non-vital bleaching).^{1,2} Both techniques aim to bleach the chromogens within the dentine, thereby changing the body colour of the tooth. A variety of case reports and small clinical studies have shown that a 10% carbamide peroxide gel used in a bleaching tray at night, the so-called night guard vital bleaching technique, produces predictable

results,³⁻¹¹ as do hydrogen peroxide strips.¹² Similarly, 'power bleaching' using 35% hydrogen peroxide with or without light and/or heat activation has also been shown to be effective.^{13,14}

HISTORICAL BACKGROUND

Since the late 1800s, dentists have been preoccupied with aesthetic procedures, such as bleaching and tooth recontouring, but there were different views on the success of these procedures. Arguments against bleaching included the length of time to achieve a lightening effect and technique sensitivity, with teeth often reverting back to their original colour.¹³ By 1848, non-vital tooth bleaching with chloride of lime was practised,¹⁵ but according to Kirk, Truman is often credited with introducing the most effective technique for non-vital teeth at the time when chlorine was produced from a solution of calcium hydrochlorite and acetic acid, known as Labarraque's solution.¹⁶ Many different bleaching agents were also successfully used on non-vital teeth, including aluminium chloride, oxalic acid, pyrozone (ether-peroxide), hydrogen peroxide, sodium peroxide, sodium hypophosphate, sulphurous acid and cyanide of potassium.¹³ Apart from the reducing agent sulphurous acid, the rest were all oxidizing agents that worked directly or indirectly on the organic portion of the stain.

By the 1860s, vital teeth were also bleached externally using oxalic acid and later using hydrogen peroxide or pyrozone.¹³ This was followed in the

early 1900s with the addition of heated instruments or a light source to accelerate the process.¹ Non-vital tooth bleaching using pyrozone applied to the external labial surface of the tooth was superseded by internal bleaching within the pulp chamber using 35% hydrogen peroxide.¹⁷

In 1961, Spasser described a method of sealing a mixture of sodium perborate with water into the pulp chamber and leaving it *in situ* for one week when the patient would return to have the procedure repeated until the desired lightening effect was reached.¹⁸ This was known as the 'walking bleach technique' and was modified by Nutting and Poe,^{19,20} using a combination of 30% hydrogen peroxide and sodium perborate sealed into the pulp chamber for one week. These materials used together have a synergistic effect, but the technique suffered problems with cervical resorption, even though it was recommended that the gutta percha be sealed before the procedure was started.²¹ The thermocatalytic technique introduced by Stewart also suffered from the same problem of resorption, thought to be due to the use of a combination of high concentration of hydrogen peroxide and a heated instrument within the pulp chamber.¹ Heithersay²² found the incidence of resorption associated with tooth bleaching to be 3.9% and 9.7% when combined with trauma, while that associated with orthodontic treatment was 24.1%.

Recently, newer techniques, such as inside/outside bleaching, have largely replaced older techniques, but essentially still involve filling an open pulp chamber with 10% carbamide peroxide, together with external application with the aid of a custom tray.

DEVELOPMENT OF NIGHT GUARD VITAL BLEACHING (NGVB)

Haywood²³ attributes the first description of successful home bleaching using hydrogen peroxide to Klusmier in 1968, who noticed that teeth whitened after treatment of a mouth injury using *Gly-oxide* (hydrogen

peroxide mouthwash) in an orthodontic retainer. The results were lighter teeth in addition to healing of the injury.

However, this technique received worldwide acceptance when described in 1989 by Haywood and Heymann using 10% carbamide peroxide in a custom made tray worn at night, the 'Night guard vital bleaching technique'.³

DEVELOPMENT OF POWER BLEACHING

In-surgery bleaching techniques used since the early 1900s were further modified in 1991 with the introduction of 30% hydrogen peroxide gels activated by conventional light curing units rather than a heat source. This technique is often referred to as 'power bleaching'. Although these power gels could be controlled easily compared to the previous liquids used, full mouth isolation was still needed to protect the gums and surrounding soft tissues. The power bleaching was frequently combined with home use tray systems to maximize the bleaching effect and give a kick start to the whitening procedure before the patient continues with NGVB at home. A further modification to the power bleaching system was the use of an argon laser as an activating light source to replace conventional curing lights.²⁴ The present day systems are activated by a variety of light sources: plasma arc lamps, Xe-halogen, LED light and diode lasers. However, light sources are not essential, there are systems that require chemical activation only and are merely painted on to the teeth with the usual use of gum and soft tissue isolation.²⁵

CURRENT BLEACHING MATERIALS

The home bleaching materials available today are a combination of different concentrations and flavours of both carbamide peroxide or hydrogen peroxide used in either custom made trays or one size fits all type trays. In addition to these are the relatively new hydrogen peroxide gels on polyethylene strips (Whitestrips [Procter and Gamble,

Cincinnati, Ohio, USA]) applied like medical plasters on the labial surface and lapping over the incisal edges of the teeth. Other recent additions include disposable trays pre-filled with 9% hydrogen peroxide gel which can be adapted to fit around teeth without the need for impressions or laboratories (Ultradent Products Inc. 505 West, 10200 South, South Jordan, Utah, USA).

The latest addition to power bleaching in the UK will be the concept of 'ultrasonic' power bleaching which utilizes a 6–7.5% hydrogen peroxide gel in upper and lower trays equipped with ultrasonic technology (SoniWhite Whitening System [DMDS UK, DMDS House, 18 Dover Street, Canterbury, UK]).

BLEACHING CLASSIFICATION

There are many different classifications of tooth whitening agents and systems used. These products can be classified according to the chemicals used or their place or mode of application/delivery or mode of action. The whitening of teeth in general is via extrinsic stain removal, bleaching or both. The mode of delivery can be via toothpastes, mouthrinses, chewing gums, bleaching gels and liquids with or without trays.

BLEACHING CHEMISTRY

The exact bleaching/whitening mechanism is not fully understood but is thought to involve the ingress of oxidizers and oxygenating molecules via enamel micropores along a diffusion gradient and via direct access of dentine. These reduce or cleave pigment molecule double bonds either to break down pigments to small enough molecules that diffuse out of the tooth, or to those that absorb less light and hence appear lighter.

Hydrogen peroxide forms a loose association with urea to produce urea peroxide (carbamide peroxide) which is easily broken down in the presence of water to release free radicals that penetrate through the enamel pores and into the dentine to produce the bleaching effect. The breakdown of

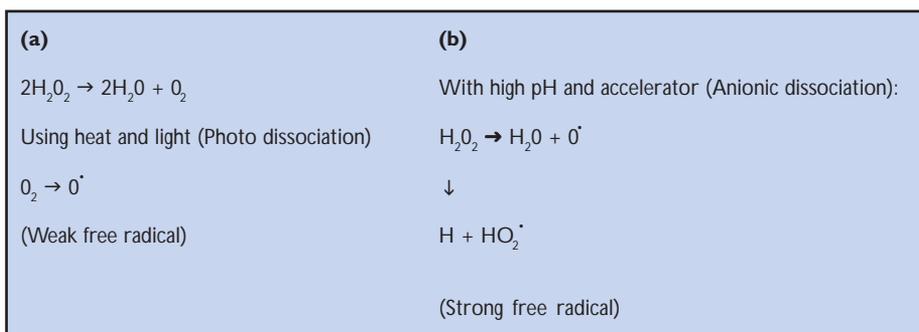


Figure 1. The breakdown of hydrogen peroxide into reactive free radicals: **(a)** photo dissociation and **(b)** anionic dissociation.

hydrogen peroxide into free radicals that penetrate through the tooth occurs via photo dissociation, anionic dissociation or a combination of the two once the process starts (Figure 1). Once the initiation has started both types of dissociation may occur.

There are many different bleaching products on the market with various other additives for enhancing the bleaching procedure or to reduce possible side-effects; these will be considered in future articles.

SAFETY

A number of authors have investigated the safety of bleaching procedures²⁵⁻⁴⁴ but have tended to concentrate mainly on the use of carbamide peroxide used in at home bleaching systems.^{26-30,34-43}

TOOTH SENSITIVITY

The evidence on safety published to date on the whole tends to suggest that bleaching is a relatively safe procedure,^{26-32,36,37,42-43} but some workers have voiced concerns about potential structural changes that may occur as a result of bleaching.^{34,38-41} Relevant to this is sensitivity of teeth in some individuals during bleaching: a problem that has attracted little research attention to explain the phenomenon, even though two-thirds of patients experience sensitivity during home bleaching.⁴⁴

EFFECTS ON PHYSICAL PROPERTIES

Scanning electron microscopy studies of enamel bleached with carbamide peroxide show little or no change in morphology,²⁷ while other work shows areas of shallow erosions²⁸ or more substantial changes in enamel structure.³⁸⁻⁴⁰ Surface hardness and wear resistance has also been investigated, with equal disagreements to the overall effect of bleaching. The results range from no effect on toothwear^{32,45-47} to significant decrease in hardness and fracture resistance of enamel.^{34,41}

Recent research involving hardness testing, erosion/abrasion and SEM work, using one of the highest concentrations of hydrogen peroxide for tooth bleaching procedures and under worst case scenario conditions of a model *in vitro*, failed to show any evidence of deleterious effects on enamel or dentine.⁴⁸ One possible reason for the reported deleterious effect on enamel and/or dentine of bleaches reflect not the bleach itself but the pH of the formulation used.

EFFECTS ON ENAMEL/ DENTINE BONDING

Bonds to enamel/dentine may be altered following bleaching owing to the presence of hydrogen peroxide. Resin tags in bleached enamel are less numerous, less defined and shorter than those in unbleached enamel.⁴⁹ The residual oxygen in the tooth surface also inhibits the polymerization of the composite resin and disrupts the surface.^{50,51} However, bond strength improves if the procedure is delayed for 2 weeks post-bleaching.

WHY WHITEN TEETH?

There are many reasons given by patients for whitening their teeth and they include the following:

- Youthful appearance;
- Changing jobs;
- Getting married;
- Improving self-esteem.

In a study of patient satisfaction with their tooth colour, Odioso *et al.*⁵² reported up to a 50% indifference, while 30% were dissatisfied and 10% highly dissatisfied with their tooth colour. There are many factors that affect tooth colour, including the thickness or morphology of enamel, translucency, external/internal stains, recession and dentine exposure.

DISCOLORATION

The causes of tooth discoloration are varied and complex but are usually classified as being either intrinsic or extrinsic in nature (Figure 2). Extrinsic discoloration arises when external chromogens are deposited on the tooth surface or within the pellicle layer. Intrinsic discoloration occurs when the chromogens are deposited within the bulk of the tooth, usually in the dentine, and are often of systemic or pulpal origin.^{53,54} A third category of 'stain internalization' has recently been described to include those circumstances where extrinsic stain enters the tooth through defects in the tooth structure.⁵³

Intrinsic staining is further divided into metabolic, inherited, iatrogenic, traumatic and ageing causes. Iatrogenic intrinsic staining most often presents with tetracycline ingestion during tooth formation and is classically a banded appearance being yellow, brown, blue, black or grey in colour, depending on the severity (Figure 3). Traumatic causes of discoloration are seen frequently in the form of enamel hypoplasia, pulpal haemorrhagic products and root resorption. The darker tooth colour seen in ageing is the result of thinning/textural changes in enamel, as well as secondary and tertiary dentine deposition (Figure 4).

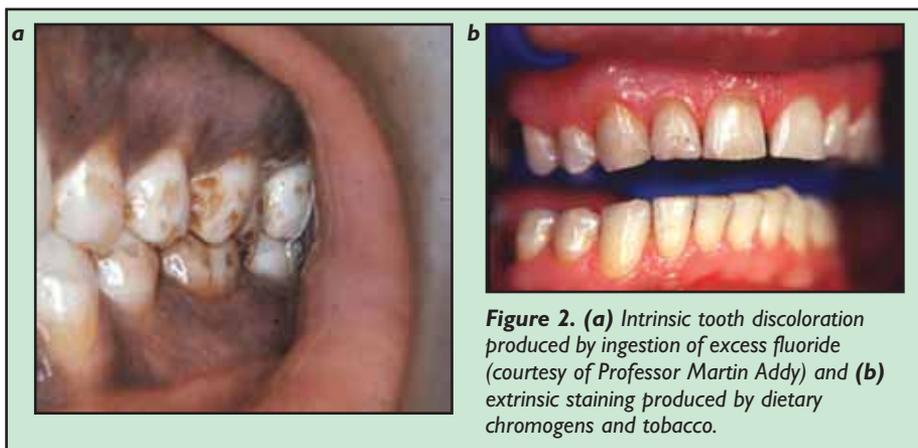


Figure 2. (a) Intrinsic tooth discoloration produced by ingestion of excess fluoride (courtesy of Professor Martin Addy) and (b) extrinsic staining produced by dietary chromogens and tobacco.

Extrinsic discoloration is caused by chromogens that attach to the tooth directly, such as tobacco, tea, coffee, red wine, spices, vegetables, medicines and plaque; or by those that attach indirectly by combining with another element to produce the stain. The latter group include polyvalent metal salts such as iron supplements and cationic antiseptics such as chlorhexidine, which combines with tea to produce the characteristic black and brown stains.

With time, cracks within teeth gain external stain which becomes internalized in the tooth or stains become internalized as a result of loss of enamel or recession. Hence, internalized stains can result from trauma, caries or restorations. Table 1 shows the types of tooth discoloration and the typical tooth colours they produce.

INDICATIONS AND CONTRA-INDICATIONS

Nearly every patient can have his/her teeth bleached but not every case is



Figure 3. Tooth discoloration produced by the incorporation of tetracycline into the dentine during tooth formation.

guaranteed to have a successful outcome or be enough to satisfy the aesthetic needs of the patient. The indications for bleaching are basically the same for both in-surgery and home bleaching but the clinician must decide which method is best suited to the patient's needs.

Indications

- Generalized staining;
- Ageing;
- Smoking and dietary stains such as those of tea and coffee;
- Fluorosis;
- Tetracycline staining;
- Traumatic pulpal changes.

In addition to tetracycline staining, there have been many reports of adult teeth stained by minocycline used to treat acne. Teenagers prescribed this drug may see their teeth change to a grey colour because the drug is laid down in the secondary dentine and is re-secreted in the saliva to soak the external surface of the tooth. Very severe tetracycline staining may not be amenable to bleaching alone and combination treatments such as bleaching and veneers may be considered. Prior bleaching reduces the amount of tooth substance removed in preparation of the veneers which would otherwise have been necessary in order to mask the stain and allow for porcelain build-up. Fluorosis with multiple spots of varying colours may require a combination of bleaching and microabrasion using

hydrochloric acid and abrasives/polishes.⁵⁵

As mentioned above, bleaching can be undertaken for most cases but some contra-indications are worthy of a mention. Patients with high expectations may never be satisfied and should be identified by asking a simple question as to what they hope to achieve with the bleaching procedure. Patients that reply 'Dazzling white' or words to that effect should be treated cautiously, while more reasonable replies may be a freshening look to the teeth or a little lighter. Decay, periapical lesions and sensitivity does not preclude those patients from bleaching, but these conditions have to be resolved prior to bleaching.

Contra-indications

- Patients' high expectations;
- Decay and periapical lesions;
- Pregnancy;
- Sensitivity, cracks and exposed dentine;
- Existing crowns or large restorations in the smile zone;
- Elderly patients with visible recession and yellow roots.

The most important contra-indication to bleaching is the patient with very high expectations that will never be satisfied following bleaching and for whom other forms of treatment should be considered. Existing crowns or restorations that need to be changed following bleaching may be considered a contra-indication for patients that do not want or cannot afford this extra financial burden. It is not always



Figure 4. Ageing discoloration produced as a result of thinning/textural changes in enamel as well as secondary and tertiary dentine deposition.

Types of Discoloration	Colour Produced
Extrinsic (Direct stains) Tea, coffee and other foods Cigarettes/cigars Plaque/poor oral hygiene	Brown to black Yellow/brown to black Yellow/brown
Extrinsic (Indirect stains) Polyvalent metal salts and cationic antiseptics e.g. Chlorhexidine	Black and brown
Intrinsic (Metabolic causes) e.g. Congenital erythropoietic porphyria (Inherited causes) e.g. Amelo/Dentinogenesis (Iatrogenic causes) Tetracycline Fluorosis (Traumatic causes) Enamel hypoplasia Pulpal haemorrhage products Root resorption (Ageing causes)	Purple/brown Brown or black Banding appearance: classically yellow, brown, blue, black or grey White, yellow, grey or black Brown Grey black Pink spot Yellow
Internalized Caries Restorations	Orange to brown Brown, grey, black

Table 1. Colours produced by various causes of tooth discoloration.

necessary to change composites following bleaching because some types of composites display a chameleon effect, taking on the shade of the surrounding tooth, blending in well if not quite perfectly. The other contra-indications mentioned above can be rectified before embarking on a bleaching course of treatment. For instance, in the case of decay; following removal of the decay and dressing of the teeth with glass ionomer, bleaching can be performed and a final definitive restoration placed about 2 weeks later to allow for the dissipation of the residual oxygen that may inhibit the composite bond to enamel/dentine. Similarly, apical lesions should be treated and the root canal filling sealed effectively using a glass ionomer material prior to bleaching. The sensitive patient can have fluoride desensitizing gels applied to teeth in the bleaching trays for a period of a few weeks prior to bleaching. These points will be covered in more detail in the following article on bleaching side-effects and their treatment. Elderly patients with yellow receded roots present a problem in that

the roots do not bleach as readily compared to the crowns, leaving an obvious mismatch that requires restorative dentistry to correct. If the patients are aware of this and are willing to undergo restorative work to address this issue, then it cannot be considered a contra-indication.

WHO BEST TO BLEACH?

Although it is difficult to predict the result of bleaching teeth for every individual, there are some guidelines gained from various studies, reports and personal experience. For instance, it is relatively predictable to bleach teeth of older patients with small pulps and various accumulated dietary stains as well as the ageing discoloration caused by secondary dentine deposition. In the author's experience, teenagers with yellow teeth or with basically white teeth except for the yellow canines tend to respond well with bleaching. Brown stains are more difficult to bleach but generally respond to longer bleaching regimes as do stains caused by nicotine.⁵⁶ White fluorosis spots do not

tend to bleach but will become less obvious as a result of the lightening of the surrounding tooth area.⁵⁶

Severe tetracycline staining may be very difficult to bleach but mild to moderate tetracycline staining tends to respond to extended bleaching regimes of 3–6 months.⁵⁶ Different brands of tetracycline present with different coloured tooth banding, which is especially difficult to treat as not all respond well to bleaching, leaving the possible need to use restorations to cover the non-responsive band.⁵⁶

CURRENT LEGAL SITUATION FOR BLEACHING WITHIN THE UK

The European cosmetic directive of 1976 prohibited the use of hydrogen peroxide in cosmetics except in certain products and to a limit included in that directive. *Opalescence* gel (10% carbamide peroxide) was introduced in 1992 by Optident Ltd (Valley Drive, Ilkley, West Yorkshire, UK) in the UK, and later that year the cosmetic directive from the EU was amended to ban the use of carbamide peroxide in cosmetics, except in oral hygiene products and only to the limit of 0.1% hydrogen peroxide. As a result, in 1993, at the order of the Department of Trade and Industry (DTI), this product was withdrawn from the market.

After the introduction of the Medical Devices (MD) Directive in 1993 and the subsequent issue of a CE mark to the product in Germany in 1994, *Opalescence* was re-launched in 1995 with a CE mark. The CE mark is an obligatory product mark for the European market, which indicates compliance 'certification' according to the requirements formulated in the approximately 22 European 'CE Marking Directives' and subsequent European standards. Therefore, the CE mark is important for manufacturers and importers placing products in the European market. However, the DTI still viewed this product as a cosmetic and deemed its supply illegal. Suppliers of this product were liable to 6 months in

prison and a £5000 fine or both; enforcement was under the terms of the Consumer Protection Act of 1987 and 1989 Cosmetic Product Safety Regulations. The manufacturers of the product (Ultradent Products, 505 West, 10200 South, South Jordan, Utah, USA) and its UK distributors then took the DTI and Department of Health to court because they alleged that they had breached article 4 of the MD directive by obstructing the sale of the product. At the trial in 1998, the court classified the product as a 'medical device'. Subsequently, in the Court of Appeal in 1999, the DTI won the appeal with the product reclassified as a cosmetic product and it was taken off the market. This classification was upheld in 2001 by the law lords but by then certain products had re-appeared on the dental market packaged without the whitening claims, making them cosmetic products, hence allowing companies to get round the rules applying to cosmetics.

The legal situation for the dental profession was further confused in 2000 when the Chief Dental Officer for England confirmed that the technique of bleaching was legal:

The Department of Health would not seek to interfere with a dentist's therapeutic decision to utilize a bleaching technique where a dentist considers this to be in the best interests of the patient's overall oral health care.

The issue in dispute is whether bleaching products are cosmetics or medical devices, but the current Government's view is that they are cosmetic products and are therefore illegal. Dentists using these products may be prosecuted by trading standards officers and are liable to a heavy fine, prison sentence and a criminal record. The dental indemnity organizations generally acknowledge the situation and, although they will endeavour to defend their members, cannot give any guarantee to success in these cases and warn their members undertaking these procedures that they are liable to prosecution. Clinical cases such as mottled anterior teeth where bleaching is

by far less destructive than a veneer or crown may be argued is in the best interest of the patient. The use of consent forms has attracted attention in that 'you cannot give consent to an illegal procedure' but this was used in legal defence to protect against some perverse sexual acts. The situation here cannot be compared at all and, under current guidance to practice issued by the General Dental Council, the use of consent forms must be advocated. In addition, simple information to the patient should be provided outlining the procedure, its prognosis and possible side-effects, as well as the alternative treatments available.

There have been many moves to correct this legal situation by the profession making presentations on efficacy and safety to the EU, but to date there is no change even though the technique of tooth bleaching is currently practised throughout the rest of Europe, the USA and the rest of the world.

Recently, LACORS (the co-ordinating body to trading standards offices) has issued a statement to its offices in England recognizing that the level of permissible hydrogen peroxide under the current legislation is far too low and that discussions are ongoing with the DTI and the EU to raise this limit. In the meantime, it advises that its members take a low key approach in enforcement and treat breaches accordingly.

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BOOK REVIEW

Human Disease For Dentists. D.J. Gawkrödger, ed. Blackwell Publishing Ltd, Oxford, 2004 (296pp., £29.99). ISBN 0-63206-453-6.

I was intrigued by the ambitious scope of this publication, especially considering the compact size. The book is intended as a guide to human disease for dental students, dentists and professional complementary to dentistry.

My review of this publication was based on its usefulness to me in my role as a busy GDP and I also asked the opinion of the PCDs I work with, to gain their perspective as to the book's usefulness in the day-to-day care of the dental patients we see.

Firstly, I found the list of contributors was an impressive 35 healthcare professionals. It was a little disappointing, however, that only one of these held a dental qualification.

Section One of the book deals with medical history-taking and examination,

which is covered in detail. In my personal opinion, the section on clinical examination would have benefited from offering more specific, practical advice on the sequential examination of the head and neck.

Section Two comprises 16 chapters, forming the bulk of this publication, and deals with various diseases and conditions ranging from cardiovascular to neurological to ear, nose and throat. There is also a 48 page colour illustration section at the back of the book, which is referred to in the text and relates primarily to manifestations of diseases which could easily be observed under dental examination.

Within this main section there is perhaps a little too much diverse information. For example, the chapter covering Ophthalmological diseases covers 6 pages. A better use of the space would perhaps be a section which covered anaphylactic shock or a similar dentally related medical condition.

Many of the diseases are dealt with superficially and the publication is not

intended as a mini medical textbook. At the end of each chapter, however, there are references for further reading and related websites, which is a useful research tool.

The section on accident and emergency, although useful, dealt purely with sudden collapse and covered CPR and management of a head injury.

An informative section on anaesthetics and pharmacology is followed by a question and answer session which both myself and my colleagues found useful and thought provoking.

To summarize, as a GDP I found this to be a helpful textbook, with easily accessible information that achieved its objective and would certainly complement other texts on the subject.

