Because the development of surface cavitation is a late stage in the caries process, there are opportunities to intervene in the process to arrest and reverse the lesion before committing to restorative procedures. The number of pre-cavitation white spot carious lesions typically exceeds the number of clinically detectable cavitated lesions by a considerable margin, so one needs to have a high index of suspicion when discovering a frank cavitation, as it often represents the “tip of the iceberg” in terms of sites with disease present.

Despite wide agreement amongst clinicians on the identification of surface cavitations, the detection of early stages of dental caries (pre-cavitation lesions) has always been problematic. A 2004 review of 29 caries detection criteria systems by Ismail1 concluded that the majority of the current caries detection systems were ambiguous and did not measure the disease process at its different stages. More recently, several new criteria systems have been proposed and evaluated, both to standardize nomenclature and methodology for clinical trials, and to benefit practitioners in having a more fine grained approach to assessing early lesions. There are some useful lessons for everyday clinicians (as well as budding dental epidemiologists) to be gained from this process.

ICDAS - a new word in the dental lexicon
Since 2002, an international group of caries researchers, epidemiologists, and restorative dentists have been working to develop and integrate the different definitions. The group selected a ‘foundation’ for a new system based on work relating to the histological extent of lesions on occlusal surfaces, adding on features of other systems, to arrive at the “International Caries Detection and Assessment System” (ICDAS), which is now in its second version.3,4 The ‘D’ in ICDAS stands for detection of dental caries by (i) stage of the carious process; (ii) topography (pit-and-fissure or smooth surfaces); (iii) anatomy (crowns versus roots); and (iv) restoration or sealant status. The ‘A’ in ICDAS stands for assessment of the caries process by stage (non-cavitated or cavitated) and activity (active or arrested).

The ICDAS approach categorizes six stages in the carious process, ranging from the early clinically visible changes in enamel caused by demineralization, through to extensive cavitation, as follows:

- Code 0 = Sound;
- Code 1 = First Visual Change in Enamel (seen only after prolonged air drying or restricted to within the confines of a pit or fissure);
- Code 2 = Distinct Visual Change in Enamel;
- Code 3 = Localized Enamel Breakdown (without clinical visual signs of dentinal involvement);
- Code 4 = Underlying Dark Shadow from Dentine;
- Code 5 = Distinct Cavity with Visible Dentine; and
- Code 6 = Extensive Distinct Cavity with Visible Dentine.

A primer on ICDAS methodology
Using the ICDAS approach for coronal caries, the first step is to classify each tooth surface as to being sound, sealed, restored, crowned or missing. It is...
<table>
<thead>
<tr>
<th>Table 1. Detection of the coronal carious lesion</th>
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<tbody>
<tr>
<td><strong>Stage of lesion development</strong></td>
</tr>
<tr>
<td>Dynamic interchange between enamel surface and plaque fluid/saliva</td>
</tr>
<tr>
<td>Early subsurface loss (code 1)</td>
</tr>
<tr>
<td>White spot lesion (code 2)</td>
</tr>
<tr>
<td>Lesion in dentine (code 4)</td>
</tr>
</tbody>
</table>

Important to differentiate between fully and partially sealed tooth surfaces, since partially sealed tooth surfaces may be at a higher risk of developing caries compared with sound or fully sealed surfaces. Sound surfaces (code 0) include those with developmental defects such as enamel hypoplasias; fluorosis; tooth wear (attrition, abrasion and erosion), and extrinsic or intrinsic stains.

At the earliest stage of caries, tooth surfaces may have a *first visual change in enamel* (ICDAS code 1), which is defined a little differently for pits and fissures compared with the same condition on smooth tooth surfaces. A code 1 lesion is present when the tooth surface is wet, but is evident after air drying for 5 seconds. At this stage of dental caries on occlusal surfaces, 55% of the lesions are either sound or confined to enamel, and 45% are in the outer one-third of dentine. On smooth tooth surfaces, these lesions are only seen clinically when the tooth surface is dry, and they cannot be seen clinically when the surface is wet with saliva. For assistance in recognizing white spot lesions as opposed to other hypomineralization lesions, the recent booklet by this author may be of value.

The next stage (ICDAS code 2) is called *distinct visual change*. At this stage, the lesion is non-cavitated, and can be seen when the tooth surface is wet with saliva. On pits and fissures, these lesions are wider than the confines of the pit or fissure area. Histologically, the majority of these lesions either extend to the deeper half of enamel or into the outer third of dentine. For proximal lesions, when viewed from the occlusal direction, the opacity or discolouration may be seen as a shadow confined to enamel, seen through the marginal ridge.

When a tooth surface shows signs of localized enamel breakdown because of caries, but with no visible dentine or underlying shadow, the lesions has advanced to stage 3 (ICDAS code 3). To confirm the visual assessment of a code 3 lesion in a fissure, a periodontal probe can be slid gently across the tooth surface, noting if the probe tip drops into the surface of the enamel cavity/discontinuity (note that sharp probes are not used).

The next stage (ICDAS code 4) represents those lesions where there are underlying shadows indicating that the carious demineralization has progressed into dentine; the dentine is discoloured, and the enamel surface is un-supported by the dentine. The shadowed appearance is often seen more easily when the tooth is wet. The darkened area has an intrinsic shadow which may appear as grey, blue or brown in colour. If the cavitation exposes dentine, then the carious process has progressed into a stage referred to as *distinct cavitation* (ICDAS code 5). There will often be visual evidence of demineralization at the cavity margins (opaque/white). A cavity that destroys at least one half of a tooth’s surface is referred to as *extensive* (ICDAS code 6).

For root surface lesions, Code 1 is a clearly demarcated area on the root surface or at the cemento-enamel junction (CEJ) that is discoloured (light/dark brown, black) but there is no cavitation, whereas Code 2 has the same appearance but there is cavitation (loss of anatomical contour ≥ 0.5 mm). The characteristics of the base of the discoloured area on the root surface can be used to determine whether or not the root caries lesion is active or not. These characteristics include texture (smooth, rough), appearance (shiny or glossy, matte or non-glossy) and perception on gentle probing (soft, leathery, or hard). Active root caries lesions are usually located within 2mm of the crest of the gingival margin.

When early (pre-cavitation) lesions are found, a decision should be made as to their likely activity. For active lesions, the surface of the enamel is whitish/yellowish opaque with loss of lustre, and feels rough...
Photo-Activated Disinfection

“This use PAD for endo, perio and for periimplantitis. We clean out the pocket or canal conventionally, irrigate it with the photosensitizing dye and then irradiate the dye with the PAD laser. The results are very good. We’re using it in cases where we have large lesions that we’re trying to resolve and we do see a marked improvement over conventional techniques. Endodontically, I’ve used it on cases where calcium hydroxide just hasn’t worked. PAD appears to be a superior course of treatment.”

Dr Andrew Nixon, Morrin Nixon Dental in Newcastle, NSW

Photo-activated disinfection (PAD) is a method of disinfecting or sterilizing a site (tissues, wounds and lesions of the oral cavity) by topically applying a photosensitizing agent (a dye) and irradiating the site with laser light at a wavelength absorbed by the photosensitizing agent. Destruction of the microbes occurs without damage to other tissues at the site.

Mechanism of action

The low power laser energy in itself is not particularly lethal to bacteria, but is useful for photochemical activation of the dye.

The photosensitive dyes release reactive oxygen species which cause membrane and DNA damage to the microorganisms. The oxygen free radicals from this process are broken down readily by catalase (present in all tissues and peripheral blood) and lactoperoxidase (in saliva). PAD does not give rise to deleterious thermal effects on teeth or soft tissues. PAD has been shown to be effective for killing bacteria in complex biofilms, which are typically resistant to the action of antimicrobial agents (Dobson & Wilson, 1992; Sarker & Wilson, 1993; Wilson, 1994). It can be used effectively in carious lesions, since visible red light transmits well across dentine (Burns et al, 1995).

Major clinical applications of PAD include disinfection of root canals, periodontal pockets, sites of periimplantitis and deep carious lesions (Walsh, 1997; Dortbudak et al, 2001).

An example of a PAD system is the DentoFex Savedent Red diode laser with a wavelength of 635 nm that uses tolonium chloride as the photosensitizing dye to sterilize a carious cavity and the infected dentinal tubules. Such systems would have obvious clinical relevance in terms of managing deep dentinal carious lesions. With the ability to rapidly and effectively sterilize the floor of deep carious lesions (to 1.0 mm), more conservative approaches to the removal of demineralized and infected tooth structure could be used. Of note, PAD is still able to exert significant effects even when the cariogenic organisms are protected in a matrix of demineralized dentine (Burns et al, 1995; Stringer et al, 2000).

The Photo-Activated Disinfection system is available from High Tech Laser on 1300-309-233 or in NZ: 0800-888-135.

when the tip of a blunt probe is slid gently across the surface. Active lesions will be in plaque stagnation areas, e.g. near the gingival and proximal surfaces below the contact point. If cavitated, in active lesions the cavity will feel soft or leathery on gently probing the dentine. For inactive lesions, the surface of the enamel can be whitish, brownish or black. The enamel may be shiny and feel hard and smooth when the tip of the probe is slid gently across the surface. For smooth surfaces, inactive caries lesions are typically located at some distance from the gingival margin.

Handling the early pre-cavitation lesion

Patients with pre-cavitation lesions should undergo a structured caries risk assessment, for which a range of chairside tools are available, such as the GC Saliva Check Buffer, Saliva Check SM, and Plaque Check + pH kits. The use of rapid testing methods (such as fermentation and solid phase immunoassays) provide information in a 5-minute time period so that advice to the patient can be personalized based on the data obtained.

Data from clinical trials demonstrate that Streptococcus mutans chairside immunoassay provides greater specificity than existing culture-based tests which use selective media.\textsuperscript{4-7} Moreover, clinical studies have also shown a correlation between mutans streptococci levels in dental plaque and its acidogenicity, as reported by fermentation testing using the GC Plaque Check test.\textsuperscript{9}

In detecting lesions at the pre-white spot or white spot stage, where preventive approaches can be brought to bear, the complexities of clinical decision making need to be borne in mind. Table 1 outlines some of the challenges for detection of lesions at various stages. Where white spots are present, gently drying the area will increase the contrast with the adjacent normal enamel and make these easier to display to the patient.

Light induced fluorescence is a powerful and simple tool for aiding clinical diagnosis of white spot lesions. Green and blue visible light elicit yellow fluorescence from healthy dental enamel, which can be seen if a composite curing light (LED, plasma arc or quartz tungsten halogen) is used to irradiate the tooth, and it is viewed through an orange protective
perspex shield (or orange protective glasses). Because the fluorescence signal arises predominantly from apatite minerals, loss of fluorescence occurs when mineral is lost from enamel. The same principle is used in the Inspektor™ system (Inspektor Dental Care, Amsterdam), which records the lesions. Software such as Inspektor Pro (Omni™ Pharmaceuticals) can then be used to calculate the mineral loss - for comparison after using remineralizing treatments. Another commercial QLF system is the QLF pro (Omnii Pharmaceuticals, USA), however most clinicians will find that using blue light with a filter provides the desired utility at low cost compared with the purpose built QLF systems. If images of this fluorescence are taken with a digital camera (fitted with an orange filter), the images can be quantified using software. This can help when discriminating carious white spot lesions from fluorosis, and possibly from other enamel opacities. White spot carious lesions are typically found beneath mature deposits of dental plaque, which produce organic acids through fermentation. A fermentation test (such as the GC Plaque Check + pH) is useful for assessing plaque cariogenicity at a particular site, and using this to educate and inform the patient regarding diet, lifestyle factors and oral hygiene. White spots and pre-white spots (seen with fluorescence but not visible under normal lighting conditions) can be screened for, paying particular attention to known risk sites, such as adjacent to brackets in patients with fixed orthodontic appliances. These areas can then be treated with topical CPP-ACP (GC Tooth Mousse™) or CPP-ACFP (GC Tooth Mousse Plus™) to reverse the subsurface mineral loss, and achieve a normal enamel translucency.

Table 2. Clinical approaches for maximum interception

<table>
<thead>
<tr>
<th>Lesion Type</th>
<th>Occlusal lesion</th>
<th>Proximal lesion</th>
<th>Accessible smooth surface lesion</th>
<th>Root surface lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topical fluoride</td>
<td>Limited effect other than when used in varnish form.</td>
<td>Fluoride ions from dentifrices and varnishes promote remineralization.</td>
<td>Low fluoride ion concentrations will promote remineralization.</td>
<td>High concentration dentifrice, gel or varnish may cause arrest.</td>
</tr>
<tr>
<td>CPP-ACP (Recaldent™)</td>
<td>Not known</td>
<td>Causes regression or reversal of incipient lesions.</td>
<td>Causes regression or reversal, giving normal enamel appearance.</td>
<td>May cause hardening by remineralization.</td>
</tr>
<tr>
<td>Photoactivated disinfection (PAD) (see page 94)</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
<td>Limited data. May cause hardening by bio-oxidation of organic acids.</td>
</tr>
<tr>
<td>Surface protection with high fluoride release glass ionomers</td>
<td>Useful for protecting occlusal surfaces of erupting permanent teeth, e.g. Fuji VII</td>
<td>Can be applied in a thin layer on proximal surfaces when restoring adjacent teeth.</td>
<td>Applied in a thin layer to arrest the lesion and prevent further mineral loss.</td>
<td>Applied in a thin layer to arrest the lesion and prevent further mineral loss.</td>
</tr>
<tr>
<td>Light-activated fluoride</td>
<td>Not known</td>
<td>Additional benefit of light not studied.</td>
<td>Protection from further carious breakdown.</td>
<td>May cause hardening by remineralization.</td>
</tr>
<tr>
<td>Watch and wait</td>
<td>Very difficult to track using clinical examination. Opacity at fissure entrances indicates greater likelihood of dentine lesion.</td>
<td>Arrest or progression is difficult to assess clinically. Possible use for digital subtraction radiographs, and DI-FOTI.</td>
<td>Use blue light-induce yellow fluorescence to ascertain mineral gain. Normal enamel appearance when 85% of mineral regained.</td>
<td>Colour of root surface lesions is unreliable as an indicator. Can assess hardness with blunt probe (perio probe).</td>
</tr>
<tr>
<td>Monitor using Diagnodent</td>
<td>High reliability, using conical “A” tip</td>
<td>Need pen configuration with periscope tip</td>
<td>Score remains low until cavitation occurs</td>
<td>High reliability, using conical “A” tip or flat “B” tip</td>
</tr>
</tbody>
</table>

A recent large scale clinical trial conducted in Melbourne has demonstrated the value of CPP-ACP for lesion arrest and reversal, even in patients who live in fluoridated areas and who are using traditional preventive approaches, including a fluoride dentifrice, and access to professional dental care. In this trial, the radiographic progression and regression of dental caries was tracked in 2720 adolescents who used...
Ozone

Ozone (O₃) is a powerful oxidizing agent which neutralizes acids and its effects on cell structures, metabolism and microorganisms are well-documented in published papers in both dentistry and medicine (Bocci, 1993, 1996; Lynch, 2005). Research has shown that ozone disrupts the cell walls of microorganisms (bacteria and viruses) within seconds, leading to immediate functional cessation. This rapid effect susceptible to caries (Hellyer et al, 1990; Galan & Lynch, 1993). The micro flora of primary root caries lesions has been shown to contain large numbers of acidogenic and aciduric microorganisms, which correlate with the severity of root caries (Lynch & Beighton, 1993, 1994; Schuppach et al, 1995; Brailsford et al, 1998; Baysan, 2002).

Ozone can now be considered as a clinical alternative management strategy for root caries, and this statement is well supported in the increasing volume of published research. Reversal of primary root caries lesions is associated with remineralization and a corresponding reduction in acidogenic and aciduric micro-organisms (Beighton et al, 1993; Lynch, 1994). This research has shown that ozone also breaks up the acidic products of cariogenic bacteria, which may be important in the aetiology of the developing carious lesion. Research by Baysan (2002), reported that ozone application for either 10 or 20 seconds was effective in achieving a kill of 99% or more (99.9% after 20 seconds) of micro-organisms in primary root carious lesions in vitro and in vivo and an application for a period of 10 seconds was still capable of reducing the numbers of Streptococcus mutans and S. sobrinus in vitro.

The KaVo HealOzone ozone treatment system has clinical significance, as the potential for microbial resistance to this treatment modality is insignificant. In view of its powerful oxidizing properties, O₃ can also attack many biomolecules such as the cysteine, methionine and the histidine residues of proteins and change the surface ecology of the carious lesion. Remineralization from salivary ions occurs readily, due to the surface changes on the exposed dentinal tubules.

Chemistry
Ozone (O₃) is naturally produced by the photodissociation of molecular O₂ into activated oxygen atoms, which then react with further oxygen molecules. This transient radical anion rapidly becomes protonated, generating HO₃, which, in turn, decomposes to an even more powerful oxidant, the hydroxyl radical (OH).

Indications
Exposed root surfaces in aged individuals with gingival recession are more

The Ozi-Cure ozone treatment system

a chewing gum containing 54.4 mg CPP-ACP (Recaldent™ gum) over a two-year period. The control group received an identical gum without CPP-ACP. Subjects were instructed to chew their assigned gum for 10 minutes three times each day. Standardised digital radiographs taken at the baseline and at the completion of the trial using the Dexion digital x-ray system were scored by a single examiner, and assessed for proximal caries at both the enamel and dentine level. The CPP-ACP gum slowed the progression of carious lesions compared with the control gum, while fewer surfaces experienced caries progression, relative to the normal sugar-free gum used as the control.

There are several unique challenges with proximal smooth surfaces - the plaque biofilm environment ecologically is more amenable to the development caries than other smooth surfaces, because of low pH, low oxygen tension, and poor access to saliva. It is difficult to access proximal surfaces for mechanical oral hygiene, and for visual examination or tactile exploration. Augmentation of clinical mirror/blunt probe examinations with bitewing radiographs is routine, however one must remember that the correlation between radiographic appearance and the histological extent of caries on proximal surfaces is imperfect. Devices such as fibre optic illumination and the Diagnodent pen (with its periscope tip) can play a valuable role here, when making decisions about how to manage radiolucencies which extend to or just beyond the DEJ.¹⁵

Occlusal surfaces are accessible for examination, but are often obscured by plaque and extrinsic stains. The enamel is damaged by forceful probing with sharp sickle probes, so probes used to examine occlusal surfaces should be blunt and the probing forces light. It may be necessary to use a powder abrasive cleaner to remove stains in order to see the surface details. The presence of opacity at the entrance to a fissure or pit (i.e. extending into the lateral fissure walls) is the anatomical equivalent to a white spot lesion on a smooth surface, but this feature cannot be seen unless the occlusal surface is clean and dry. The relatively poor access of deeper parts of occlusal fissures to saliva makes these areas unlikely to remineralize spontaneously. For fissures...
that have been cleaned of plaque and stains, the use of quantitative laser fluorescence for the presence of bacteria (Diagnodent) allows an estimate of the extent of caries to be gained - since lesions which have reached the dentine give strong fluorescence signals (above 30-35).

Once cavitation of enamel has occurred, restorative procedures are necessary, however this should be accompanied by preventive home care advice. Rapid chairside tests which can give results during a clinical consultation can provide useful data to assist the clinician in providing this preventive advice, and for educating the patient.

References


About the author
Professor Laurence J. Walsh is the technology editor of Australasian Dental Practice magazine. He is also a noted commentator on and user of new technologies and is the Head of The University of Queensland School of Dentistry.