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Understanding and Practising Minimally Invasive Caries Management

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Section 1: Defining minimum intervention oral healthcare and minimally invasive dentistry

For many clinicians, when and where they attended dental school continues to heavily influence their views on caries management. Many were taught to treat carious lesions using pre-determined GV Black cavity shapes (Class I, II, III, IV and V). This mechanistic, surgical approach consisted of cutting holes with a specific geometry and dimension, purely for the benefit of the restorative material being placed, which was often dental amalgam. Little or no concern was given to caries pathology, control of the caries process, or the histology of the affected tissues. Unfortunately, this approach did nothing to reduce the caries susceptibility for the individual patient or reduce the incidence of caries within the larger community.

A contemporary, holistic, and primarily preventive approach to caries management now puts the patient and their individual oral biology at the forefront. Minimum intervention oral healthcare (MIOC), is a team-delivered, patient-focused oral health delivery framework applicable to any of the restorative disciplines (including cariology) and crosses all patient demographics, with suitable modification (see Figure 1). It involves four interlinked domains of care:

- **Identifying problems**
  Includes disease/lesion detection, longitudinal patient susceptibility assessment, diagnosis, prognosis and patient-focused care planning.
- **Prevention & control**
  Primary and secondary prevention of lesions, control of the disease process, encouraging changes in patient behaviour.
- **Minimally Invasive Dentistry (MID)**
  Minimally invasive operative interventions are a form of tertiary prevention for cavitated, active and physically uncleansable carious lesions in patients who comply with ongoing primary preventive protocols. The underlying tenet is to conserve and preserve as much viable tooth structure as possible, while maintaining the integrity and viability of the tooth, in preparation for the definitive restorative treatment.
- **Review & recall**
  Re-assessment of the treatment(s) provided, monitoring of patient adherence to behaviour change and adopting a personalised recall frequency dependent on longitudinal susceptibility assessments[1,2,3]

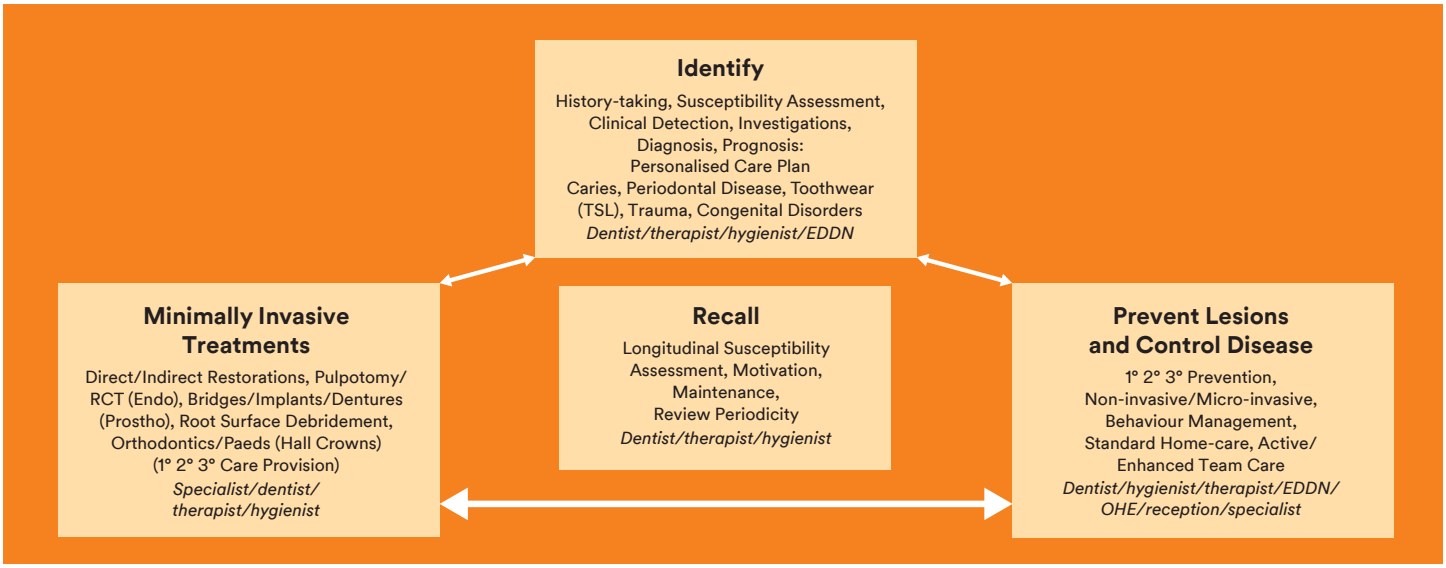

Figure 1: The Minimum Intervention Oral Health Care framework (MIOC) applied to the different disciplines within Restorative Dentistry (Conservative Dentistry & Endodontics, Periodontology, Prosthodontics and Orthodontics), showing the four interlinked domains and the oral healthcare team members responsible in each (EDDN – extended duties dental nurse, OHE – oral health educator). Minimally invasive operative dentistry forms one of the domains within the MIOC framework for delivering better oral health. TSL – tooth surface loss.[3]

It is important to appreciate that minimally invasive management of a single carious lesion only treats one tooth. It does not cure the patient of the caries process. However, the four domains of the MIOC framework listed above, along with ongoing patient interaction and engagement, aim to provide a complete and holistic solution to oral disease, including caries, management.

Why should the oral healthcare team intervene in the management of the caries process?[4]

There are two simple answers to this question: (1) to control the disease process, and (2) to prevent and/or treat existing lesions which are the negative consequence of the uncontrolled caries process. More specifically, caries intervention can be divided into three distinct, but interlinked, preventive phases:

- **Primary Prevention** – Ensures that the normal, healthy biochemical equilibrium within the plaque biofilm does not tip irreversibly towards pathological changes (biofilm dysbiosis).
- **Primary/Secondary Prevention** – Ensures that the ionic mineral equilibrium at the tooth surface is maintained or is re-balanced after initial demineralisation
- **Tertiary Prevention** – Preserves tooth structure and restores function and aesthetics in the dentition affected by progressing carious lesions in an effort to minimize the negative biological and physical impacts.

Who should intervene in the management of the caries process?[4]

Any "intervention" must directly involve and be focused on the individual patient. All members of the oral healthcare team (dentist, dental therapist, dental hygienist, extended-duties dental nurse, oral health educator, reception team, technicians) must reinforce the same messages in an effort to help the patient improve their oral health.

Another form of MI, or motivational interviewing, using behaviour modelling which includes capability, opportunity, and motivation determinants (COM-B), should underpin oral heath messaging and delivery. Patients must take responsibility for their own oral health and life-style choices. Psychological engagement of the susceptible patient is the most critical aspect in maintaining lifelong oral health.

Section 2: When should clinicians intervene in the caries process?[4,5]

Interventions available to manage all stages of the carious lesion, from the earliest ionic surface dissolution, to late-stage gross cavitation, tissue destruction, and pulp necrosis, are outlined in figure 2.

Non-invasive, primary preventive procedures include:

- **Biofilm Control** – Carried out by the patient at home and professionally by members of the oral healthcare team.
- **Mineralisation Control** – Using standard home-care applications of fluoride (toothpastes, mouthwashes) or calcium phosphate systems (e.g. β-TCP, CPP-ACP etc).
- **Dietary control** – The oral healthcare team advising patients in regard to dietary free sugar intake, frequency, amount, etc.

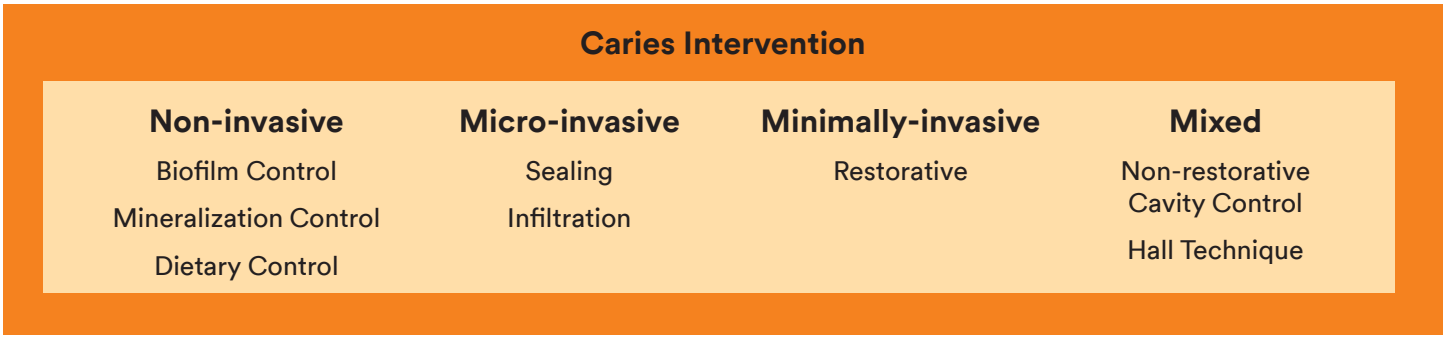

Figure 2 – The relevant patient-focused, team-delivered interventions to manage the caries process and carious lesions in susceptible patients (taken from Schwendicke F, Splieth C, Breschi L et al. When to intervene in the caries process? An expert Delphi consensus statement. *Clin Oral Invest,* 2019: 23: 3691-3703).[5]

Micro-invasive interventions for the primary or secondary prevention of caries include:

- **Sealants** – Preventive (non-extended 1°) or therapeutic (extended 2°) fissure sealants using flowable resin composite or, where moisture control is inadequate, glass-ionomer cements (GICs). Most effective on occlusal fissure surfaces.
- **Resin Infiltration** – Used for managing incipient white spot enamel lesions and areas of hypomineralisation on smooth surfaces.

Minimally invasive operative interventions are a form of tertiary prevention for cavitated, active and physically uncleansable lesions in patients who comply with the ongoing primary preventive protocols mentioned above.

The underlying tenet is to conserve and preserve as much viable tooth structure as possible, in an effort to maintain the biological integrity of the tooth and better support the definitive restoration.

As with all restorative treatments, one should consider the age of the patient, their systemic health as well as other risk factors before proceeding.

Section 3: Understanding what determines the extent of tissue excavation and ways to promote peripheral adhesion and seal.[6,7]

Carious tissue removal - The extent of tissue removal is dictated by the depth of the active, cavitated lesion and confirmed both clinically and radiographically. If, on radiographic examination, it is found that the lesion has spread into the outer third of dentine only, the support and integrity of the tooth-restoration complex can be maximized by removing carious tissues until sound dentine is revealed.

However, if the lesion approaches the pulp (inner third to quarter of dentine), maintenance of pulp vitality/sensibility should become the top priority and residual caries-affected, demineralized dentine should be left intact to avoid pulp exposure. In some cases, even traces of caries-infected dentine may be retained and sealed with an adhesive restorative material, in an effort to protect the vital pulp. Two additional factors should be considered when determining how much carious tissue should be removed when applying tissue-preserving, minimally invasive principles: where in the cavity the excavation is taking place (enamel-dentine junction (EDJ) or over the pulp) and the histological quality of the tissues (See Figure 3).

Histologically Sound Enamel – This is the ideal substrate to help support restorative margins and provide an optimal peripheral seal and bond. Demineralised, unsupported and weakened enamel must be removed using either rotary instrumentation or hand chisels, leaving a lightly bevelled finish to optimise the prismatic structure while creating an increased surface area for adhesion.

Dentine – The seal and bond of restorative materials is achieved primarily at the periphery of the restoration, adjacent to the EDJ. To optimise this bond, sound dentine should be retained wherever possible. However, a balance should be struck between attempting to reach sound dentine during caries removal while ensuring that the structure of the tooth isn't further compromised. For example, in a proximal carious lesion, excavating to peripheral sound dentine might result in a significantly sub-gingival cavity margin. Moisture in this sub-gingival region may compromise your adhesive and/or restorative material performance reducing the quality and longevity of the final tooth-restoration complex *(see figure 4, showing a supra-gingival proximal floor margin, kindly reproduced from DNJ Ricketts)*. In another example, an occlusal lesion in a molar tooth *(see figures 5-10; kindly reproduced from Banerjee A. Minimally invasive operative caries management: rationale and techniques. Br Dent J 2013: 214: 107-111),*[8] there is likely to be significant quantities of sound enamel available at the EDJ. Therefore, the dentine lesion can be managed more conservatively, retaining caries-affected dentine over the pulp, in an effort to avoid exposing the pulp.

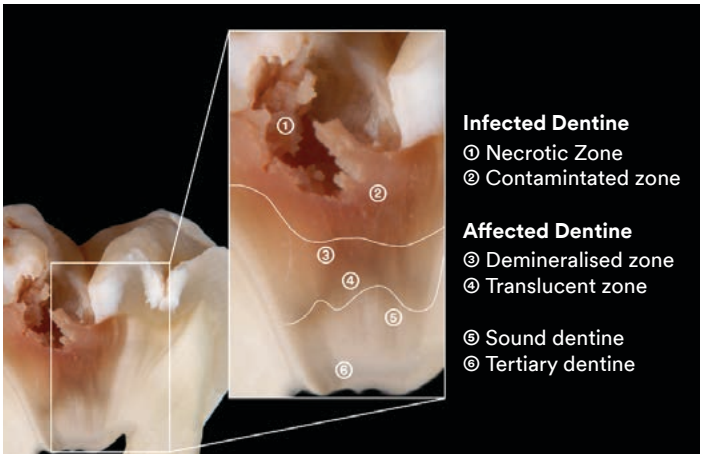

Figure 3: Histological zones of the carious lesion

Image courtesy of Prof. Leandro Hilgert and Prof. Soraya Leal, University of Brasilia (UnB), Brazil

Pulp status – While pulp vitality/sensibility may be difficult to determine, especially in teeth with deep carious lesions, the practitioner should err on the side of trying to restore the tooth as opposed to carrying out a pulpotomy or root canal treatment. Having said that, it is important for the patient to understand the clinician's decision-making process and be fully aware of benefits and risks of various treatments. All discussions and decisions should be carefully and contemporaneously recorded.

Restorability of the tooth – The amount, histological quality and anatomical distribution of the remaining coronal tissue needs to be assessed to determine its ability to support the clinically viable, definitive restoration.

Restoration type/material – An adhesive, direct restoration will require less cavity preparation as its retention will be enabled by nano-/micro-mechanical or chemical means. Indirect or direct, non-adhesive restorative materials require a further significant sacrifice of already weakened tooth structure to gain macro-retention and are not recommended routinely.

Patient factors – Caries susceptibility, adherence to recommended preventive practices, quality of biofilm control and occlusion, amongst others, are all determinants in deciding the extent of tissue excavation.

In summary, when practicing minimally invasive dentistry, decisions should be made with a suitable knowledge of:

- Tissue histology (with an appreciation of the ultrastructural changes occurring through the lesion which may include infected, affected and sound dentine),
- Dental biomaterial science (understanding the interactions of the chemical constituents of adhesives and restorative materials with tooth structure) and
- The quality of execution of the clinical procedure itself (moisture control, instrumentation, restorative procedures, handling materials etc).

Figure 4: A deep proximal carious lesion that has been prepared using minimally invasive, selective carious dentine removal principles. The peripheral excavation retains sound dentine at the EDJ in the floor of the box, with only a thin margin of sound enamel. The remaining brown-stained dentine is leathery caries-affected dentine with sound enamel margins around the remaining cavity walls. This selective carious tissue removal significantly reduces the risk of direct pulp exposure, reduces the final cavity volume and ensures efficient biofilm control of the more accessible tooth-restoration interfaces (courtesy of DNJ Ricketts).

Figure 5: A large active, cavitated, uncleansable carious lesion in a maxillary molar tooth. Note the frosty white appearance of the chalk-like demineralised and unsupported enamel at the periphery of the cavity and the dark brown, soft and wet caries-infected dentine beneath, overlying the pulp. The pulp still returned positive sensibility test readings and the lesion has not breached the pulp chamber or mesial/distal aspects of the tooth radiographically.

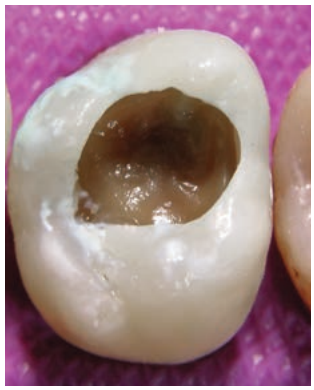

Figure 6: The demineralised peripheral enamel has been removed using a diamond bur in a rotary handpiece. Bio-active glass air-abrasion could also be used (see table 2). The margin has been lightly bevelled, leaving sound enamel at the periphery of the cavity. Direct instrument access has now improved to reach the soft, wet caries-infected dentine beneath.

Figure 7: The soft, wet, dark brown contaminated, caries-infected dentine has been selectively removed minimally invasively using a large rosehead bur in a rotary handpiece and hand excavators. Chemo-mechanical caries gels could also be used for this selective carious dentine removal (see table 2). Lightly discoloured, caries-affected, demineralised, leathery dentine has been retained in the cavity overlying the pulp, to prevent any risk of direct pulp exposure. The periphery of the cavity comprises of a large surface area of healthy enamel to provide an optimally sealed and bonded restoration.

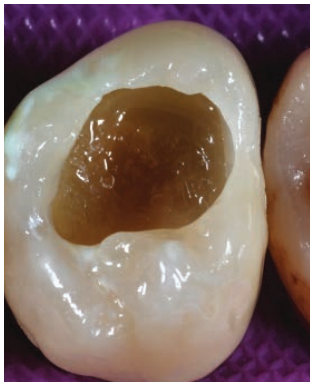

Figure 8: The enamel margins have been acid-etched with 37% orthophosphoric acid for 20 secs and the dentine for 10 secs, washed and dried to remove the surface moisture. An adhesive has been agitated into the cavity walls, air-thinned to remove any solvent and then light-cured for 20 secs. The shiny appearance indicates the presence of the cured bond ready for the resin composite to be added.

Figure 9: The pre-selected dentine shade resin composite has been placed in 2mm increments and light cured after each increment has been placed. Bulk-fill resin composites could be used up to a 4mm depth to reduce the time taken to restore this portion of the cavity. Space has been left for an overlying layer of enamel shade resin composite and fissure tints could be added at this stage for further restoration characterisation.

Figure 10: The final, definitive resin composite restoration after finishing. The tooth-restoration margins are not in occlusion and are easily cleansable by the patient. Continued biofilm control is paramount to the clinical success and longevity of this tooth-restoration complex.

Section 4: Methods for preserving pulp vitality/sensibility, avoiding pulp exposures, and practicing selective caries removal.

The ultimate aim of selective caries removal in the minimally invasive operative intervention of a deep carious lesion is to:

- Preserve tooth structure
- Maintain pulp viability
- Create a peripherally sealed tooth-restoration interface.

The clinical discriminators between the different histological zones of a carious lesion and some examples of excavation technologies available are presented in tables 1 and 2 *(adapted from Banerjee A, Watson TF. Pickard's Guide to Minimally Invasive Operative Dentistry, 10th Ed. Oxford University Press, 2015).*[4]

Discriminating method	Caries-infected dentine (highly bacterially contaminated)	Caries-affected dentine (demineralised)	Sound dentine
Visual	Often a colour gradient from: Dark brown → paler brown/translucent → yellow/white		
	Not always easy to assess clinically using non-selective, rotary excavation technologies		
Tactile	Soft/sticky/wet feel with a sharp dental probe (straight or Briault, easily deformed using a spoon hand excavator)	Both sticky/flaky and scratchy feel; "leathery" (offers some resistance to a spoon hand excavator)	Scratchy feel to a sharp dental probe
Caries detector dyes	'Fusayama' dyes – based on propylene-glycol, collagen-based stain. Attempts to discriminate infected versus affected but research has shown these dyes stain deeper collagen and permeate into affected/sound dentine zones leading to cavity over-preparation.		
Fluorescence	Fluorescence devices available to help discriminate between infected/affected dentine and sound dentine.		

Table 1: Clinical discriminators to help distinguish between the three histological zones of carious dentine (infected, affected, and sound). Note that these zones do not have distinct boundaries but have a gradient of histological/bacterial change through them from the enamel–dentine junction (EDJ) to the pulp.

Mechanism	Substrate affected	Clinical tooth-cutting technology
Mechanical, rotary	Sound or carious enamel and dentine	SS, CS, diamond, TC, ceramic and plastic burs*
Mechanical, non-rotary	Sound or carious enamel and dentine	Hand instruments (excavators, chisels), air-abrasion (alumina / bioactive glass (selective)), air-polishing (sodium bicarbonate / bioactive glass)†, ultrasonics, sono-abrasion
Chemo-mechanical	Carious dentine	Carisolv™ gel (amino acid-based), Papacarie® gel (papain-based), experimental pepsin-based solutions/gels (potentially selective)
Photo-ablation	Sound or carious enamel and dentine	Lasers
Others	Bacteria	Photoactive disinfection (PAD), ozone

*Works only on carious dentine; †primarily used for stain-removal. SS, stainless steel; CS, carbon steel; TC, tungsten carbide.

Table 2: Clinical tooth-cutting/caries removal technologies, the substrates acted on and their mechanism of action.

Section 5: Ways to increase the clinical longevity of the tooth-restoration complex

There is an ever-increasing number of direct restorative materials available[4] to create the definitive restoration when practicing MID.

Dental amalgam - has fewer clinical indications as a primary restorative material in the modern era thanks to the advent and rapid development of adhesive dental materials. Dental amalgam is facing a global phase-down in use due to the environmental concerns regarding the mining, processing and disposal of mercury.

Resin composites/dental adhesives - have been a popular material for many years now, thanks to their physical and aesthetic characteristics. These materials, however, require the use of a dental adhesive or bonding agent, which in turn require additional placement time. Having said that, adhesive technology is improving with laboratory studies showing an infiltrative hybrid zone formation even in caries-affected dentine. Bonding to caries-affected dentine is necessary when practicing MID and in avoiding pulp exposures. Hydrolysis and collagen breakdown at the adhesive-dentine interface are being overcome with improved water tolerance of the constituent chemistries and the potential anti-collagenolytic properties of modern adhesives. Modern "universal" adhesives are also becoming simpler to use, with fewer clinical steps, added radiopacity and laboratory-demonstrated bond strengths to caries-affected dentine for a more reliable and consistent operative technique and outcome.

Glass-ionomer cements – are popular due to their physical properties, ability to place in bulk, and their chemistry, which allows them to bond chemically to the tooth with some anti-cariogenic properties. With the development of glass hybrid technology, the physical characteristics of these materials are improving. There is potential that this class of material could be advocated for posterior, load-bearing definitive restorations in the future.

Tricalcium silicate cements - have found a place in the management of deep carious lesions, with experimental data showing direct bio-activity with tooth tissues, resulting in new mineral ion deposition and maintenance of pulp sensibility.

Manufacturers strive to produce the "ideal" material which is easy to handle and place but has optimal physical and aesthetic characteristics. The search continues...

Summary

Contemporary management of cavitated, deep carious lesions should follow the minimally invasive, selective tissue removal principles where tissue and pulp preservation are considered paramount. Restorative materials are advancing rapidly with respect to their chemistry and physical properties, allowing them to seal tooth structure. Preventive practice and managing patients' expectations regarding the maintenance of their oral health is paramount in the overall success of any operative procedure.

- The interlinked factors which should trigger minimally invasive treatment include (1) the presence of lesion cavitation, (2) poor lesion cleansability, and (3) lesion activity
- Patient control of plaque biofilm is paramount in the long-term success of any operative caries management
- Lesions should be excavated peripherally (at the enamel-dentine junction) to sound dentine to promote peripheral adhesion and seal of the tooth-restoration complex
- Selective caries removal, including retention of caries-affected dentine, should be considered when carious lesions are close to the pulp in an effort to avoid pulp exposure
- Modern adhesive materials can create a seal and bond to caries-affected dentine. This, along with minimally invasive tooth preservation and the consequent maintenance of pulp sensibility, ultimately increases the clinical longevity of the tooth-restoration complex
- The success of minimally invasive interventions requires communication based on trust between the patient and the oral healthcare team, as well as the commitment of the patient to maintain their oral health

Additional Information

MID Guidelines

There are many important guideline publications available for each of the different disciplines in Restorative Dentistry, including Periodontology, Prosthodontics and Endodontics. These often concentrate on standardising specific operative treatment protocols for more clearly defined clinical situations. These are published by expert panels representing professional learned societies, royal colleges and government bodies.

The discipline of Conservative & MI Dentistry in primary care covers a great breadth and variety of clinical situations affecting large, heterogeneous populations. Many management variables (technologies, procedures, materials, operator skills, knowledge, experience, and a multitude of patient factors including attitudes/behaviour/socio-economic status, etc.) all need to be considered when attempting to develop suitable treatment guidelines to help practitioners and their teams.[9]

In Conservative & MI Dentistry including Endodontics, there are several national and international learned societies and consensus panels, all providing useful information about the terminology, prevention and management of caries,[10,11,12,13,14] tooth wear and management protocols for broken-down teeth. The European Federation of Conservative Dentistry (EFCD) and the European Organisation for Caries Research (ORCA) have collaborated in an attempt to collate and generate pragmatic, evidence-based guidance for primary care practitioners.[5,15,16,17,18,19] These, along with many other published efforts, are trying to help the relevant stakeholders to manage patients, improve oral health linked to general health and increase awareness in populations of their role in valuing and taking responsibility for their personal healthcare future. Education and training courses exist to help dentists, dental therapists and team members learn about and implement MIOC (for example, the online, distance-learning masters programme in Advanced Minimum Intervention Dentistry (please Google "King's AMID" for more information)).

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