The following papers represent Proceedings from the European Festival of Oral Science, 25 – 28 September 2002, Cardiff, at the symposium "Minimally Invasive Dentistry – Concepts and Techniques", by Dan Ericson, Edwina Kidd, Dorothy McComb, Ivar Mjör and Michael Noack. The Academy of Minimally Invasive Dentistry, Acamid, initiated the symposium.

Minimally Invasive Dentistry – Concepts and Techniques in Cariology

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Abstract: The concept 'Minimally Invasive Dentistry' can be defined as maximal preservation of healthy dental structures. Within cariology, this concept includes the use of all available information and techniques ranging from accurate diagnosis of caries, caries risk assessment and prevention, to technical procedures in repairing restorations.

Dentists are currently spending more than half their time replacing old restorations. The main reasons for restoration failures are secondary caries and fractures, factors that are generally not addressed in the technical process of replacing a restoration. Prevailing concepts on minimally invasive dentistry seem to be 'product or technique-motivated', challenging one technique or product with another, rather than focusing on a general concept. New knowledge of caries progression rates has also led to substantial modification of restorative intervention thresholds and further handling of the disease. New diagnostic tools for caries lesion detection, caries risk assessment and focused preventive treatments have decreased the need for early restorative interventions. In parallel to this, new techniques for cutting teeth and removing decay have evolved.

This paper focuses on describing minimally invasive dentistry in cariology from a conceptual perspective, relating to clinical caries diagnosis, restorative intervention thresholds and operative procedures, with special reference to survival of tunnel and slot restorations and to repair vs. replacement of defective restorations.

Key words: minimally invasive dentistry, caries diagnolis, caries removal systems, restoration survival, restoration repair, secondary repair

Oral Health Prev Dent 2003; 1: 59–72. *Submitted for publication: 22.10.02; accepted for publication: 19.12.02.*

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PART 1 MINIMALLY INVASIVE DENTISTRY – CONCEPTS AND TECHNIQUES IN CARIOLOGY – AN INTRODUCTION

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This series of focus papers aims to provide a succinct view on the philosophy and provide some of the current evidence-base regarding *Minimally Invasive Dentistry* within the area of cariology. The aim is also to position the concept as a broad health-oriented approach to dental procedures and not only as a review of current technical restorative solutions. Certainly, the minimally invasive concept was not invented for the sole use within cariology, but has an immediate and rather self-explanatory status in this area.

Minimally Invasive has a positive and harmless chime to it when it comes to medical and dental procedures. It expresses a very precise excision of what has to be removed, without causing any damage to adjacent tissue. The phrase has been used with increased frequency and today one would find almost 9,000 references in PubMed, the first from 1966 (Barter). The phrase Minimally Invasive *Dentistry* first occurred in PubMed 1987 (Simonsen).

There are a number of similar phrases that lead ones mind towards the same focus, such as *Minimal Intervention Dentistry, Preservative Dentistry,* and *Atraumatic Restorative Treatment (ART)* (Widdop, 1989; Tyas et al, 2000; Peters and McLean 2001) to mention a few. Conceptually, they are all branches from the same tree. So, from a practical point of view there seems to be no purpose in going into semantics to force a separation between the terms that bear so much in common. Alas, the various terms might have had a certain pedagogic ring to them in their particular cultural setting to be understood by local peers.

The concept of minimally invasive dentistry within cariology has evolved because we now have a better understanding of the disease. We can intercept in its development (Truman et al, 2002) and have the technical possibilities to remove a minimal amount of healthy tooth substance and make smaller fillings (Tyas, 2000). There has been a change from "caries lesions are treated operatively" towards "caries lesions are treated by addressing their causes", i.e. turning from a symptomatic treatment scenario towards a causal one, as well as using a more tissue-preserving approach when restoring teeth (Ericson and Bornstein, 2001). New risk assessment tools as the 'Cariogram' for chair-side use, has been proven accurate and may help in planning preventive measures (Hänsel-Petersson et al, 2002).

One can also define a concept by defining what it is not: Minimally invasive dentistry is not restoring caries lesions as soon as they can be spotted with ones loupes. Minimally invasive dentistry does not promote early irreversible treatment modalities before the arsenal of biological preventive measures dealing with the disease causes are exhausted. It is perfectly clear that restorations have a limited survival if the disease is not controlled and such a premature introduction of the tooth to the re-restoration circle is not in agreement with available evidence (Mjör et al, 2000) and what the profession should stand up for today (Tyas et al, 2000).

However, terms and phrases that are not precisely defined are often used casually. For example, minimal intervention dentistry may be interpreted as "supervised neglect" and minimally invasive dentistry might imply that it is a technically oriented approach. Even the good old term *Conservative Dentistry* has a minimally invasive touch to it, as of course has *Preventive Dentistry.* Those well-known terms may theoretically be used to describe an approach to keeping ones teeth healthy with as few and as small fillings as possible. But, in introducing new concepts, new nomenclatures seem to be mandatory.

"The concept of minimal intervention dentistry has evolved as a consequence of our increased understanding of the caries process and the development of adhesive restorative materials" (Tyas et al, 2000). The conclusion from the authors in 2000 was that this concept embodies at least: Remineralization of early caries lesions, reduction of cariogenic bacteria in order to eliminate the risk of further demineralization and cavitation, minimum of surgical intervention of cavitated lesions, repair rather than replacement of defective restorations and, disease control.

However, it is necessary to expand the concept to include the mental processes and attitudes that are included in keeping the original tissues in a fit condition. So, as a consequence of our increased understanding and the current evidence-base, the concept on minimally invasive dentistry with respect to cariology should include the following processes:

1. Accurate diagnosis of risk, disease and lesions
2. Primary prevention
3. 'Just in time' restoration

4. Minimally invasive operative procedures
5. Secondary prevention

One of the key issues for this definition of minimally invasive dentistry is the fact that "fillings are not curative". That phrase was first published by G. V. Black early in the 20th century (Black, 1908) and is of course still true. The major reason for re-restoration is secondary caries (Mjör et al, 2000; Hickel and Manhart, 2001), and we know for certain that restorations do not have the assumed effect i.e. to stop disease, but rather to restore lost host tissue. As a solitary procedure, restoring teeth is predictably a temporary symptomatic treatment procedure. Therefore, the diagnosis of disease and risk for disease is important in order to target preventive treatment (Hänsel-Petersson et al, 2002; Tinanoff and Douglass, 2002).

Diagnosis of caries lesions is becoming more important, since the recognition of an early lesion seldom leads to its restoration, but to a number of non-restorative actions (Tinanoff and Douglass, 2002; Levine et al, 2002). The trend today is to delay the restorative intervention, particularly in countries with organized children's dentistry, where they are recalled on regular basis. In Scandinavia, restoration thresholds have become more and more 'into the dentine'. As an example, for occlusal cavities (on a second molar in a 20-year old) the threshold for operative treatment is a moderately sized open cavity and or/radiolucency in the dentine for approximately 70% of dentists in this area (Espelid et al, 2001). Similar data can be found for proximal caries lesions (Sundberg et al, 2000), and the drift of restoration thresholds has made it possible to study actual progression rates in populations (Mejare et al, 1999). This 'just in time' approach to restorative intervention may partly be an effect of knowledge on caries progression rates disseminating to the professionals as well as own clinical experiences and the incentives in a capitation system. In other countries such an approach might be regarded as close to neglect (Tan et al, 2002).

The minimally invasive operative procedures often result in smaller restorations. Such restorations are inherently less stressed and this would address the second most common reason for re-restoration, namely fracture of the filling (Mjör et al, 2000). The possibility to prepare small cavities and restore them has evolved as a consequence to adhesive materials (Tyas et al, 2000) and to new preparation and caries removal techniques (Banerjee et al, 2000). The procedures are often more time consuming than the preparation and placement of an amalgam filling, but in the context of a minimally invasive approach including all steps from diagnosis to secondary prevention, one can see the long-term esthetic and health benefits.

Concluding Remarks

Today, the means, methods and opportunities for minimally invasive dentistry seem to be at hand, but there is definitely a lack in incentives. Here we touch upon an Achilles heel of the practicalities of minimally invasive dentistry, as many reimbursement systems do not recognize non-operative procedures. The pecuniary incentives are often lacking, an important fact that must be addressed if our profession is going to change.

Even though a substantial base of evidence supports a minimally invasive approach to the caries disease (Tyas et al, 2000; Mejare et al, 1999; Mandari et al, 2001; McComb, 2001), we still need long term evaluations of programs and procedures (Bader and Shugars, 2001).

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PART 2 MINIMALLY INVASIVE DENTISTRY – CONCEPTS AND TECHNIQUES IN CARIOLOGY DIAGNOSTICS: A CORNERSTONE IN MINIMALLY INVASIVE DENTISTRY

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A diagnosis is not a goal in itself but it has been described as a mental resting place on the way to a treatment decision. Thus it would be difficult to deny that diagnostics are the cornerstone of minimally invasive dentistry. However, neither the path to the diagnosis, nor the decision taken on arrival, is clear cut and it is salutary to explore some of these confusions.

Diagnosis (from Greek, *through knowledge*) implies that it is not merely the recognition of lesions using more and more sophisticated tools (Stookey and Gonzalez-Cabezas, 2001), that is diagnosis of caries, but rather a trinity: Recognizing a lesion specific for the disease, determining whether it will progress and whether more lesions will appear. So, the fundamental purpose of a clinical caries diagnosis is to be able to detect and classify lesions in such a way as to select the most appropriate management. This might be to do nothing if a lesion is arrested, or preventive care of an active process. The latter may involve operative care to allow the patient to access and regularly disturb the biofilm. This operative decision assumes a particular importance since it is now realized that once a filling is placed a tooth potentially enters a repeat restorative cycle (Mjör et al, 2000), perhaps resulting in further destruction of the dental tissues.

The caries process takes place in the biofilm, a community of microorganisms with a collective physiology (Marsh and Bradshaw, 1997). These bacteria are always metabolically active causing minute fluctuations in pH. This is the caries process and at the ultrastructural level it is a ubiquitous phenomenon which may lead to dissolution of the dental hard tissues (Kidd and Fejerskov, in press). This interaction of the caries process with the dental hard tissues may result in caries, the lesion, the reflection of the process, the consequence that we can see.

Caries diagnosis means detecting a lesion and making a decision about its activity. However, the decision is not necessarily clear-cut. It is not always a simple dichotomy – active or inactive. The problems are illustrated in Fig 1 that shows leathery, darkly colored lesions at the cervical margin of lower incisor teeth in an 80-year-old lady. The dentist must decide whether these lesions are already arrested, in which case no active therapy is required, or whether they are continuing to progress, in which case improved plaque control and fluoride treatment are very important. This decision is a clinical skill involving a careful history and examination of the patient by a socially sensitive and biologically aware professional. The decision could not be made on an isolated extracted tooth or on a histological preparation. In this lady these lesions are judged as active because the patient is in her 80's she is forgetful; she has Sjögren's syndrome with a dry mouth; disclosing reveals plaque on the lesions and although the patient can remove this, she often forgets to brush.

It is thought-provoking that in research of diagnostic methods the gold standard for diagnosis so

often involves a histological validation, where the biofilm, in which the caries process occurs, is usually missing. It also has to be removed to allow the dentist to see and assess the reflection of this activity, the carious lesion. It is potentially dangerous to work on reflections of reality because it is so easy to forget "where the action is". In the caries process "the action" is in the biofilm.

It is important to acknowledge that clinical decisions are all made under conditions of uncertainty and this uncertainty will inevitably result in variations in treatment planning decisions (Bader and Shugars, 1995).

The observation may be wrong, not expressing the true condition (not valid). Just as important as validity is reliability. Would the same diagnosis be obtained at re-examination by the same examiner (intra examiner reliability) or different examiners (inter examiner reliability)? It is 20 years since Elderton and Nuttall (1983) published their important, if depressing, study on variation among dentists in treatment planning. Fifteen dentists examined the same 18 young adults and came up with a huge variation as to which tooth surfaces required restoration. Studies like this surely argue strongly for the minimal intervention approach, together with careful reassessment (Lewis et al, 1996).

Relations between observations and the presence of disease may be uncertain and this also confounds diagnosis and treatment planning. To give but one example, what is the relevance of ditching and staining around an amalgam restoration? Do these appearances indicate new, recurrent disease beneath a restoration? Evidence from research would appear to indicate these appearances are not helpful in predicting the level of infection in the dentine beneath a restoration and these fillings do not need to be replaced (Kidd et al, 1995; Mjör and Toffenetti, 2000).

It also has to be admitted that uncertainties about the effect of the intervention will also influence a treatment planning decision. To give an example, the relationship between diet and caries is irrefutable (Krasse, 2001). Logically, therefore, dietary advice should be an important part of preventive treatment and yet the evidence that it is effective is lacking (Kay and Locker, 1996). This leads to the rather extraordinary situation that cariologists in Sweden and Denmark might have totally different approaches to caries control, when confronted by the same patients! The issue is not simple, as also reflected in the differences in use of caries diagnostic tools and how to act upon the findings in Europe, North America and Australia (Pitts, 2001; Rosenstiel, 2001; Tan, 2002). Among other explanations the differences may well symptomatic to whether one "believes in fillings" as a permanent solution or not.

Fig 1 Leathery, darkly colored lesions at the cervical margin of lower incisor teeth in an 80-year-old lady.

Concluding Remarks

Although these uncertainties make it inevitable that dentists will vary in both their diagnostic decisions and therefore their treatment planning decisions, there is no need for clinicians to be despondent about this. Dentists have the luxury of seeing their patients on recall when re-evaluation is not only possible; it is an essential part of the job. Of course patients must be kept fully informed of these deliberations and given two alternatives, with one being less invasive than the other; it is their right to give their informed opinion on which option should be chosen. Centuries ago Shakespeare wrote "The better part of valour is discretion" (Henry IV Part One) and perhaps this should also be applied to treatment planning decisions, especially those involving irreversible tooth preparations.

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PART 3 MINIMALLY INVASIVE DENTISTRY – CONCEPTS AND TECHNIQUES IN CARIOLOGY – DEFECT RELATED RESTORATIVE INTERVENTIONS OF CARIOUS LESSIONS

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Minimal invasive caries treatment is not primarily concentrating on the restoration of small defects but focusing on tissue preservation when treating any size of carious defects. Unfortunately there is more scientific information available about mechanical properties of dental materials than about technologies that might substitute the surgical removal of caries affected tissues with less invasive technologies. For both a more patient-orientated dentistry and to overcome the well-documented shortcomings of traditional operative treatment (Elderton et al, 1990) it is worth proving the possibilities and benefits of less invasive techniques.

Since *Black*'s days, the traditional preparation approach has been to start with the enamel preparation followed by removal of carious dentin. Neither clinical nor scientific criteria of completeness of excavation are clear, because it is still unknown how to properly discriminate between infected, affected and sound or remineralizable dentin. Stained dentin is not a clear sign for infected tissue. Thus only soft and wet dentin, especially at the dentino-enamel junction, should be removed (Kidd et al, 1996). With recently introduced technologies to substitute round bur excavation, a new approach has to be discussed whereby enamel preparation has to be extended just as much as is necessary to ensure proper treatment of infected dentin. As a consequence, a future approach might be to first choose an effective treatment of carious dentin, followed by the decision for an adequate and compatible enamel preparation. The goal of a restoration then would be to improve the prognosis of the risk surfaces rather than just restoring geometrically the lost anatomical form:

1. Treatment of infected carious dentin
2. Enamel preparation: access to lesion center
3. Restoration: improved prognosis

A variety of potential substitutes for round bur excavation and the treatment of infected carious dentin is discussed (Yip et al, 1998; Banerjee et al, 2000a; Beeley et al, 2000):

- Mechanical excavation: round bur, sono-abrasion, air-abrasion, air-polishing
- Chemo-mechanical excavation
- Enzymatic digestion
- Photodynamic therapy
- Photoablation
- Ozone treatment
- Antibacterial therapy: ZnO, $Ca(OH)_2$, Fluorides, Chlorhexidine, Antibiotics

Carious dentin can be chemo-mechanically removed by softening the affected dentin with sodium hypochlorite gels followed by gentle removal of the tissue with modified excavators (Fig 1). The technique is safe (Dammaschke et al, 1999), allows adequate excavation (Banerjee et al, 2000b; Fure et al, 2000), is less painful for patients (Ericson et al, 1999) and is compatible with adhesive restorations (Haak et al, 2000). However, due to the limited effectiveness the indications are focused on pe-

dodontics, root caries lesions, anxious patients and stepwise excavation.

An interesting option is the enzymatic digestion of carious dentin by use of collagenases or proteinases. Over 90% of caries affected dentin could be solubilized in vitro with an experimental enzyme mixture (Pronase™ from S. griseus). However, the effectiveness has to be dramatically improved before clinical use can be considered (Beltz et al, 1999).

Even more tissue can be preserved by disinfecting carious dentin rather than removing it. In vitro the potential of lethal photosensitization of S. mutans by means of HeNe or GaAlAs Laser following sensitization with toluidine blue and aluminum disulphated phthalocyanine was demonstrated (Burns et al, 1995). Another approach that uses the antimicrobial effect of ozone gas was proposed for disinfection of water supplies and already clinically used in several medical indications. Exposure of carious dentin to O_3 led to a dramatic decrease of cariogenic pathogens within seconds (Baysan et al, 2000) (Fig 2). Furthermore in clinical studies the effectiveness and safety was demonstrated in primary root caries lesions. Recent reports also claim a beneficial clinical effect on fissure caries lesions (Holmes and Lynch, 2002). These promising results have to be confirmed by other researchers. Last, but not least, infected dentin could be disinfected with antibacterial substances, in particular antibiotics. The bactericidal effect has already been shown for metronidazole in vivo (Hoshino et al, 1989). In a two-step excavation procedure using a tetracycline derivate, a substantial decrease of total colony forming units as well as lactobacilli was found after a 6-week re-entry sampling (Wicht et al, 2003).

In summary, there are various promising techniques available for removal or disinfection of infected or affected carious dentin layers that will allow a more patient-orientated less aversive treatment of existing defects.

Under these circumstances enamel preparation is only necessary to ensure proper access for dentin treatment and penetration of acids, adhesives and (flowable) restorative materials. Therefore the preferred technique is strongly dependent on the dentin treatment option. Several techniques have been proposed for less invasive enamel preparation (Tyas et al, 2000; Peters and McLean, 2001):

- Hand instrumentation (ART)
- Rotary instrumentation
- Oscillating systems

Fig 1 Clinical example of chemomechanical caries removal. The approximal lesion (D3) was already cavitated before treatment and slightly extended with oscillating instruments. Then Carisolv Gel (Mediteam, Sweden) was applied and softened tissue removed with modified (dull) excavators.

- Air abrasion
- Hydrokinetic Systems (Laser)

Several studies have outlined the clinical procedure of ART (atraumatic restorative treatment) involving excavating with hand instruments and restoring cavities with glass ionomer cements (Frencken et al, 1994; Mjör and Gordan, 1999). In 3-year clinical studies survival rates of 59 – 88% were reported (Frencken et al, 1998). However, there are only limited data in high risk populations.

Especially the oscillating systems with partially coated diamonded tips are beneficial for a defect related cavity design (Hugo et al, 1998) (Fig 3). Less damage to adjacent teeth as well as treatment times nearly as effective as those with rotary preparation make the use of air-scalers and Sonic-Sys micro tips (KaVo) indispensable for primary proximal lesions and render it advantageous for many other applications (Wicht et al, 2002).

With existing dental materials the risk for secondary caries is higher than that of primary caries even under ideal preventive schemes (Axelson et al, 1991). Therefore it can be argued whether a restoration of caries defects can be called treatment of disease. The goal of restorative procedure should therefore be an improved prognosis of the treated tooth. In contrast resin composites tend to accumulate more bacteria or plaque than other restorative materials. To overcome this problem the addition of antibacterial components has been proposed (Masuhara and Kadoma, 1985; Imazato et al, 1993;

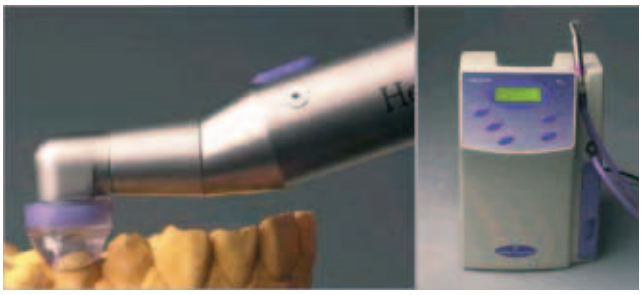

Fig 2 Ozone generating device (Healozone, USA) which delivers 0.0052% O_3 (v/v) at a rate of 13, 3 ml/s. For safety reasons, a dispensable rubber cup is attached to the handpiece to ensure proper adaptation to the teeth. After 10 to 20 s of treatment time the gas mixture neutralized with a reductant and pumped off.

Fig 3 Advantageous for preparation of primary approximal lesions are partially diamanted half sphere or half torpedo shaped tips for an airscaler with enhanced power (Soniflex, SonicSys Micro, KaVo, Germany).

Prati et al, 1993; Imazato et al, 1994). Several antibacterial components have been proposed, e.g.:

- Calcium hydroxide (Staehle et al, 1989)
- ZNO-Eugenol (IRM) (Fairbourn et al, 1980)
- Glass ionomer cements (Weerheijm et al, 1999)
- Dentin bonding systems (Scherer et al, 1990)
  - MDPB monomer (Imazato et al, 1994, 1997, 2001)
  - Glutaraldehyde in dental adhesives
- Triclosan (Wicht et al, 2003)
- Chlorhexidine (Jedrychowski et al, 1983; Takemura et al, 1983)

None of the discussed antibacterial materials has yet clearly demonstrated the evidence of a superior clinical long-term behavior. The balance between safety and, in particular, biocompatibility and degree of antibacterial property has to be determined in further research.

Concluding Remarks

In summary, there is uncountable information available about technical details and mechanical behavior of operative procedures. However, the majority of patients at least have mixed feelings when going to see their dentist, so there is room for improvement. Minimal invasive techniques offer the potential of a less bothering approach. However, the effectiveness of most of the techniques has to be improved and their clinical long-term success has to be demonstrated.

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PART 4 MINIMALLY INVASIVE DENTISTRY – CONCEPTS AND TECHNIQUES IN CARIOLOGY – REVIEWING THE EVIDENCE ON TUNNEL AND SLOT RESTORATIONS, CANADA

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The fact that dentists spend more operative time replacing restorations, largely due to recurrent caries (Mjör et al, 2000), has cast doubt on the effectiveness of traditional restorative therapy, with varying degrees of "extension for prevention", to prevent new disease. Clearly restorations have a finite life span and many factors impact on the performance of restorations including operator, patient and materials. Traditionally, technical factors have been overemphasized and measures to manage the infectious process have been underemphasized (Söderholm et al, 1998; Köhler et al, 2000). These issues require equal consideration. With greater understanding of the caries process, increased recognition of the weakening effect of restorations and the development of new materials, more minimally invasive operative procedures have been recommended (Tyas et al, 2000). A minimally invasive approach of the adjacent tooth is also warranted. Typically, in 60 – 70% of proximal preparations, the adjacent tooth is damaged and will develop caries more frequently as compared to an undamaged surface (Qvist et al, 1992).

Specific conservative operative techniques include the proximal "slot" or "box" preparation (Almquist et al, 1973), the proximal "tunnel" restoration

(Hunt, 1984) and the preventive resin restoration (Simonsen, 1980). A systematic review of the literature pertaining to specific conservative operative strategies (McComb, 2001) has revealed that use of more minimally invasive procedures alone does not guarantee greater restoration longevity and that misguided conservatism may increase restoration failure thus shortening the re-restoration cycle. The results do support the use of the most effective conservative operative procedures, for example the preventive resin and proximal "slot" restorations. More importantly, the limited effectiveness and lifetime of restorations in general revealed in the systematic review, argues strongly for increased recognition of the significance of the initial operative decision.

The Proximal "Tunnel" Restoration versus the Proximal "Slot" Restoration

The "tunnel" concept, which accesses proximal caries through an occlusal pit is designed to preserve the overlying proximal marginal ridge and maintain greater tooth integrity. A total of 9 clinical trials in permanent teeth and 2 in primary teeth resulted from the systematic search (McComb, 2001), all utilizing glass ionomer materials. Early small clinical trials with dedicated operators indicated the technique to be promising (Hasselrot, 1998) however larger clinical studies resulted in higher early failure rates (Pilebro et al, 1999). A high proportion of marginal ridge fractures and high rates of caries were associated with the technique. Residual caries, recurrent caries and progression of demineralized enamel remaining in the proximal area were all failure factors cited. Poor performance has also been documented in primary teeth. A recent study has confirmed these findings. Glass ionomer tunnel restorations (182) placed in permanent teeth in the Norwegian public dental service showed an estimated median survival time of 55 months over 3 – 6 years. (Nicolaisen et al, 2000) About 90% survived 3 years while only 35% survived 5 years. Both patient caries activity and operator skills affected survival. Example radiographs revealed the difficulties associated with the blind access. The technique is clearly difficult to execute, the extent of residual demineralized proximal enamel is not known and low restoration survival is associated with the limited preparation extension. The low effectiveness reported argues in favor of a more direct approach to proximal dentinal caries, using the proximal "slot" or "box-only" restoration.

Although only 3 clinical studies pertaining to proximal "slot" restorations in permanent teeth resulted from the systematic literature search (Lumley and Fischer, 1995; Kreulen et al, 1998; Nordbo et al, 1998), two were long-term (5 – 10 years) and the results were very favorable. The 10-year success rate for composite proximal preparations was approximately 70% (Nordbo et al, 1998). Failures were evenly divided between recurrent caries and technical failures of the restoration. Caries was largely reported in patients previously identified as high caries risk. No failures were recorded for a small number of silver amalgam proximal slot restorations over a period of 5 – 7 years (Lumley and Fisher, 1995). The clinical evidence therefore shows that the proximal slot-only restoration is a viable treatment option that is superior to "tunnel" restorations, provides similar or better longevity compared to traditional Class 2 restorations and preserves valuable tooth structure. A clinical example of a proximal "slot" or "box-only" restoration is given in Figs 1 – 5.

An in vitro comparison of cavity design and dimensions (Strand et al, 1995) for proximal "tunnels" and "slots" prepared by dentists on models supports the operative superiority of the proximal slot restoration. The study revealed: a) residual caries in 25% of tunnel preparations compared with 7% of slots, b) the overall amount of tooth substance removed was not significantly different in either type of preparation, and c) the mean distance from the cavity wall to the pulp was actually somewhat less for the tunnel preparations. In vitro evidence also suggests that the integrity of the proximal box restoration will be improved when the preparation includes retentive elements and unsupported enamel is eliminated (Summit et al, 1994). Internal retention is essential for non-adhesive materials but also provides additional support and resistance against occlusal forces for the micromechanical adhesive bond. When combined with effective disease control, technical excellence and appropriate material usage an effective conservative technique such as the proximal slot restoration is likely to provide a long re-restoration cycle and maximal preservation of remaining tooth structure.

General Conclusions

1. Operative conservatism alone does not guarantee increased restoration longevity and misguided conservatism may significantly decrease longevity.

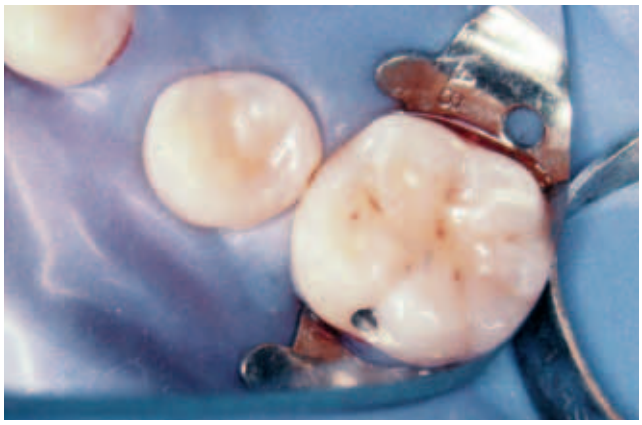

Fig 1 Pre-operative condition with cavitation

Fig 2 Initial proximal slot preparation

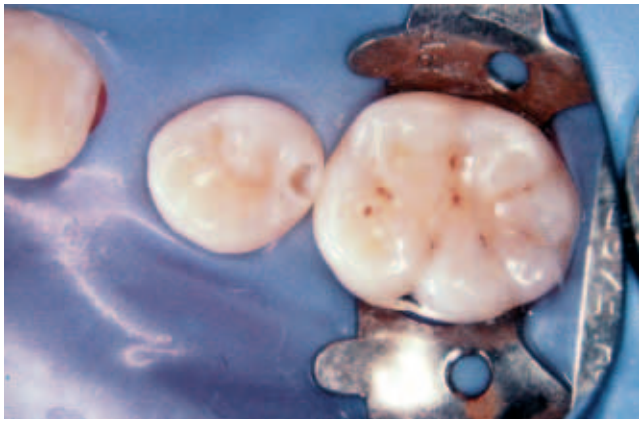

Fig 3 Preparation showing gingival floor demineralization and need for proximal contact clearance

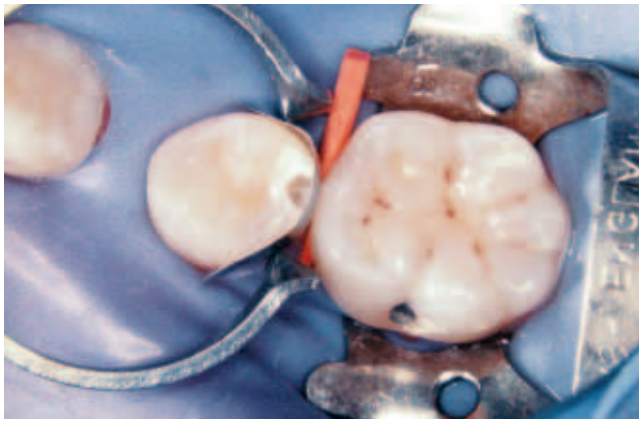

Fig 4 Matricing

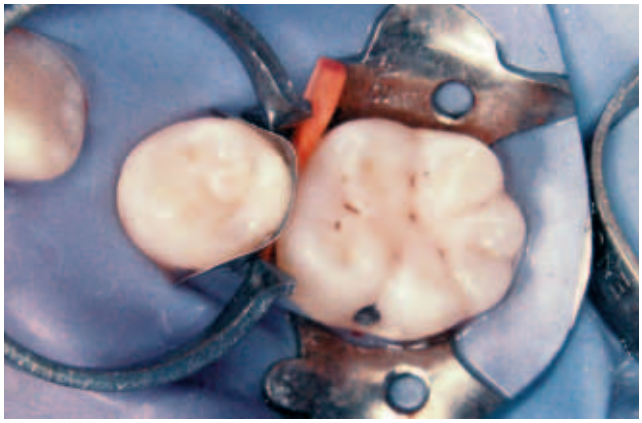

Fig 5 Restoration

2. All restorations have a finite life-span due to operator, patient and material factors and are subject to the re-restoration cycle.
3. A significant factor in restoration longevity is effecting a change in the oral milieu. Caries management strategies and technical factors require equal consideration.
4. It is logical that the more successful conservative restoration strategies will enhance tooth longevity but long-term evidence is required to substantiate this.

Major reviews of the clinical literature provide evidence for increased understanding of the significance of the initial operative decision and the potential for early restoration failure. A correct operative decision assumes that an active dentinal carious lesion has been accurately diagnosed and that no other more conservative therapy is possible to affect a successful outcome. Minimally invasive dentistry is the current evidence-based guiding principle for optimal care in the context of current patterns of disease. Successful conservatism demands current knowledge of caries progression, accurate diagnosis, patient-specific caries risk assessment

and appropriate prevention. The importance of prevention has been demonstrated in a recent clinical study. The regular use of sodium fluoride gel in dry mouth patients assumes greater significance for the prevention of secondary caries than the choice of restorative material (McComb et al, 2002). When operative intervention is necessary, technical excellence, biomaterials knowledge, including the benefits and limitations of contemporary materials, and adherence to basic operative principles are additional factors in restoration longevity. Attention to all these factors will ensure maximum restoration longevity and reduced impact of the re-restoration cycle.

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PART 5 MINIMALLY INVASIVE DENTISTRY – CONCEPTS AND TECHNIQUES IN CARIOLOGY – REPAIR OF RESTORATIONS

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Replacement of restorations comprises 50 – 70% of all operative treatment on adult patients. Most restorations in general dental practices are replaced with some diagnosis related to marginal defects. The most common marginal discrepancy involves the clinical diagnosis secondary (recurrent) caries, irrespective of the restorative material used (Mjör et al, 2000). This diagnosis invariably leads to replacement of restorations. The diagnosis is based primarily on "explorer catch" despite the fact that it is recognized that an explorer (probe) will catch in any crevice, carious or non-carious (Goldberg, 1990; Kidd et al, 1995) and replacement of all defective restorations due to risk of secondary caries may constitute over-treatment (Hewlett et al, 1993). There is a considerable increase in cavity size and removal of healthy tooth structure when preparing for a replacement filling (Gordan et al, 2002).

Great uncertainty exists related to the diagnosis of secondary caries lesions in dental school teaching programs (Clark and Mjör, 2001). This uncertainty is also reflected in the diagnosis of secondary caries lesions in general dental practice (Clark and Mjör, 2002 ongoing study). Other defects that may lead to replacement of restorations include marginal and bulk fracture of restorations, fracture of tooth, and for tooth colored restorations also marginal and bulk discoloration (Mjör and Toffenetti, 2000; Hickel and Manhart, 2001). They are all at the 10 – 15% level of frequency or less. Therefore, this succinct review will focus on the clinical diagnosis secondary caries and on examples of clinical refurbishing procedures.

A recent literature review on secondary caries revealed that limited research is available in this important area of clinical dentistry (Mjör and Toffenetti, 2000). The conclusions reached on the basis of the review were that initiation and progression of secondary caries lesions are localized surface processes adjacent to restoration margins. The lesions are similar to primary caries lesions and the same criteria should be employed as those used to diagnose smooth surface primary caries lesions: cavitation or loss of tissues, consistency or hardness of the affected tissues, degree of wetness of the tissues, and discoloration of dentin and enamel. A differentiation between active and arrested secondary caries lesions should be made in the same manner as for primary caries lesions, keeping in mind that arrested lesions usually do not require operative treatment, except for esthetic reasons if indicated. These conclusions have been supported by case reports (Mjör and Toffenetti, 2000; Mjör and Gordan, 2002).

Most defects leading to replacement of restorations are localized discrepancies, including clinically diagnosed secondary caries. Since this diagnosis is by far the most common reason for replacement of restorations, it will be used to illustrate how it can be dealt with using a minimally invasive approach by repairing rather than replacing restorations.

The presence of stained margins adjacent to tooth colored restoration is often confused with the presence of secondary caries. However, narrow gaps, crevices, ditches, and "microleakage" at the margin of restorations do not lead to secondary caries lesions (Mjör and Toffenetti, 2000). No evidence has ever been presented to show that staining of cavity margins predispose to the development of secondary caries lesions, but it has been pointed out that it is difficult to differentiate between secondary caries lesions and stained margins (Tyas, 1991).

Excess resin material extending beyond the cavosurface margin ("flash") may also cause marginal staining. If it becomes detached from the tooth surface, it may accumulate stained material that may be removed by light polishing. It is also important to keep in mind discolored restorations may either be due to bulk discoloration of the composite material, which is a material defect, or it may be caused by surface discoloration. Surface discoloration may be removed by simple polishing procedures while bulk discoloration requires replacement of the restoration.

Refurbishing procedures should be routinely attempted as the initial procedure to assess localized restoration defects, as a replacement would include sacrifice of healthy tooth structure (Gordan et al, 2002). They require only a few seconds of clinical time to show whether they alone will provide a successful outcome or not. Polishing/refurbishing procedures are cost effective and save tooth structure because the procedures are non-invasive. They have also been shown to reverse decisions to replace restorations (Cardoso et al, 1999).

Clinical Case Reports

Fig 1 shows a localized stained margin of a Class V composite restoration. Such discrepancies on the buccal or lingual surfaces may be easily accessed. This type of defect is often misdiagnosed as a secondary caries lesion. The staining often corresponds to an area where the cavosurface margin is in dentin. If the rest of the restoration is in good condition, including the color match, it may be repaired. A small part of the restorative material adjacent to the stained margin is removed in order to make a proper diagnosis, and it invariably shows that the defect does not extend deep into the tooth-restoration interface (Fig 2). After the small "exploratory" cavity is cleaned, it can be restored using conventional technique including acid etching, bonding, and insertion of a resin based composite material.

Secondary caries lesions are usually found at the gingival aspect of all types of restorations, except Class I which do not have a gingival margin and where secondary caries lesions are uncommon (Mjör, 1985; Mjör and Qvist, 1997). Access to the gingival aspect of restorations may be difficult, especially the interproximal areas in the posterior region of the dentition. However, interproximal defects in the anterior region may be reached (Figs. 3 and 4) and treated according to the principles of minimal intervention.

Concluding Remarks

It is difficult to clinically differentiate between secondary caries lesions and stained cavosurface margins. Both are localized defects at that may be repaired or refurbished.

Repair and refurbishing of defective restorations save tooth structure. It is also likely that these procedures will increase the longevity of restorations and therefore be cost-effective. The procedure also gives the operator an opportunity to examine more the quality of the restoration using such an explor-

Fig 1 Class V composite restoration with a stained margin adjacent to the gingival part of the restoration. This lesion was diagnosed as secondary caries.

Fig 2 A small "exploratory" preparation into the composite material adjacent to the stained defect shown in Fig. 1 revealed that the stain did not extend deep into the tooth/restoration interface. The small cavity preparation is ready to be restored using a conventional technique.

Fig 3 Lingual view of a Class IV composite restoration with a dark gingival area suggesting the presence of a secondary caries lesion.

Fig 4 The dark area at the gingival margin of the Class IV restoration shown in Fig.3 after it was accessed by removal a small part of the composite material. The defect was localized and the small cavity preparation is ready to be restored using a conventional technique.

atory approach. The chance to find hidden defects or caries increases, and the final decision might not be repair, but replacement in some instances. The minimal invasive approach provides more options. However, longevity data on repaired and refurbished restorations are lacking.

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