WHEN TO PLACE AN INITIAL RESTORATION

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Increased knowledge of dental caries has resulted in a more preventive approach to dentistry. The dental profession has recognized that while the restoration of a tooth is often necessary to prevent the extension of a carious lesion and restore the tooth to function (Leake 1988), dental caries cannot be cured or "treated away" with restorations (Anusavice 1989; Eccles 1989). Evidence from the dental literature shows that areas of enamel demineralization often arrest and may remineralize (Hunter & Hunter 1989; Elderton & Osman 1991; Pitts & Kidd 1992). Caries that do not arrest usually progress very slowly, requiring an average 3-4 years for an approximal lesion in a permanent tooth, and 1-2 years for an approximal lesion in a primary tooth, to move through the enamel and into the dentin (Pitts 1983; Shwartz *et al.* 1984). This rate varies considerably between patients, however. Patients with poor oral hygiene may experience more rapid rates of decay, and remineralization is less likely. Faced with this knowledge, deciding when to restore a carious lesion can be difficult.

Background

"A dental lesion starts at the tooth surface with the demineralization of the enamel which appears clinically as a white spot. Morphologically, this initial lesion has an intact surface but the sub-surface is demineralized (Nikiforuk 1985). At this stage, the **incipient lesion** may be arrested or even reversed through a process involving the saliva with its concentrations of minerals and fluorides (von der Fehr *et al.* 1970; Ostrom *et al.* 1984). The process of arresting or reversing the incipient lesion is enhanced by preventive measures such as using a fluoride dentifrice or fluoride rinse or by having fluorides applied topically. In normal populations an initial lesion that develops into a clinical cavity does so slowly and intermittently" (Leake 1988). Cavitation occurs when the enamel overlying a carious lesion breaks down (Waggoner & Ashton 1989).

Traditionally, management of dental caries was characterized by early detection and prompt restoration. The dental profession believed that established caries could be managed only by removing the diseased tooth tissue and replacing it with an artificial substance, such as amalgam (Elderton 1988; Eccles 1989).

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Consistent with this belief, the profession attempted to diagnose carious lesions at early stages and restore lesions while they were small (Grondahl 1989). If left untreated, it was believed that a carious lesion could quickly progress to involve the pulp where it would cause much more serious problems (Pitts & Kidd 1992).

Knowledge of dental caries has advanced substantially in the recent past. We know now that caries progression through the enamel and dentin is much slower than once believed. Many carious lesions that are not visible clinically, or that appear as a white spot on the tooth's surface, arrest or remineralize without any intervention by dental personnel (Stephens *et al.* 1987; Elderton & Osman 1991; Neilson & Pitts 1991). These remineralized or arrested sites may become more caries resistant than sites that have never experienced dental decay (Eccles 1989; Hunter & Hunter 1989).

The increased knowledge surrounding dental caries has resulted in a more conservative approach to restorative dentistry. Early lesions should be treated with preventive agents, such as topical fluoride, to aid in the arresting or remineralization process (Anusavice 1989, 1992; Elderton & Osman 1991), while periodically checking for evidence that the lesion is not progressing. However, past studies have indicated that dentists occasionally restore carious lesions earlier than the scientific literature indicates is necessary (Espelid *et al.* 1985; Thylstrup *et al.* 1986; Nuttall & Pitts 1990), and we assume this still to be the case.

A dentist must consider many factors when determining whether or not a carious tooth should be restored. After reviewing the literature on restorative dentistry and decision making, Anusavice (1992) listed 12 factors that affect a dentist's restorative decision making.

1) presence of pain or other discomfort
2) extent of caries, discolouration, or other deficiency
3) patient's perceived need to restore function
4) patients perceived need to enhance esthetics
5) size of restorations to be placed
6) risk of fracturing remaining tooth structure
7) caries history and current caries status
8) preferences of the dentist and the prevailing standard of care

9) ability of the dentist to perform the procedure
10) risks and benefits of procedure to the patient
11) ability of patient to pay for a given treatment
12) acceptance by the patient

The relative importance of each of these factors varies with the patient being examined and the examining dentist. However, Anusavice (1992) stressed that "the physiological and psychological benefits to the patient must outweigh the known potential risks" of the procedure chosen.

A great deal of variability exists among dentists in their diagnosis of caries and their decision of when to treat caries (e.g. Espelid *et al.* 1985; Espelid 1986; Heidmann *et al.* 1987; Kay *et al.* 1988; Kay & Kill-Jones 1992; Noar & Smith 1990; Nuttall & Pitts 1990; Thylstrup *et al.* 1986). One reason for this variability is that each dentist may interpret and weigh the importance of each of Anusavice's (1992) 12 factors differently. Another reason might be a dentist's lack of awareness of new evidence concerning the reversibility of incipient lesions and the slow progression rates of established lesions.

One way of reducing dentist variability would be to introduce specific treatment criteria (Evans *et al.* 1987). Establishing treatment guidelines based on the best available scientific evidence may allow a public dental program to appropriately allocate funds to obtain the best possible outcomes of treatment and prevention.

Anusavice (1992) recently summarized a dentist's treatment choices for teeth in various states of decay and these choices have been reproduced in Table 1. However, Table 1 does not address some specific issues that need to be included in treatment guidelines. For example, what defines moderate or extensive caries? Many authors recommend restorative treatment for carious lesions with visible cavitation, but what if the lesion is not visible? What radiographic criteria should be used to determine the need for restorative treatment? Should the same criteria apply to both smooth surfaces and pit and fissure decay? What modifications, if any, need to be made when treating primary dentition? These issues make it necessary to

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define more specific guidelines for when to restore a carious lesion in a primary tooth.

Table 1. Treatment options for teeth in various states of decay
(adapted from Anusavice 1992).

CLINICAL CONDITION	POSSIBLE TREATMENT OPTIONS
Pits & fissures with no visible decay	• seal surfaces at risk
Questionable occlusal caries	• oral hygiene instruction • fluoride treatment • pit & fissure sealant • re-evaluate at recall appointments
Questionable proximal caries	• oral hygiene instruction • fluoride treatment • re-evaluate at recall appointments
White spots	• protect against further demineralization using fluorides and/or sealants
Arrested caries	• protect against further demineralization • restore if unesthetic or extensive cavitation exists
Incipient active caries	• preventive resin restoration
Moderate or extensive caries	• restore • extract if tooth destruction is significant

Purpose

To reduce treatment variability and ensure the appropriate allocation of funds in the North York Public Health Department's Community Dental Division, restorative guidelines are necessary. Using the most current scientific evidence available in the English dental literature, this report will develop recommended guidelines for when permanent and primary teeth with coronal caries should be restored.

Methods

The literature review carried out for this paper was not intended to be exhaustive. The objective of this paper is to review the various standards found in the current literature, and to locate additional information to support, modify, or refute these standards. For these reasons, not all of the published articles and studies that discuss the placement of dental restorations will be cited in this paper.

To locate articles and studies in the dental literature that discuss when a carious coronal lesion should be restored, computer-aided literature searches for articles published in the years 1983-1992 were carried out using CD/ROM and MEDLINE. Three searches were performed to locate review articles that discussed scientifically-based treatment criteria. The search strategies used were, (1) Medical Subject Heading (MeSH) of **dental caries** combined with a title and abstract search for the word "treatment", (2) MeSH of **dental caries diagnosis**, and (3) MeSH of **dental caries therapy**. A fourth search was also carried out using the MeSH of **dental caries prevention and control** combined with a title and abstract search for the word "treatment", but this search was not limited solely to review articles. Results of all searches were limited to English language articles involving human subjects.

Determining when to restore carious primary (deciduous) teeth presents a special problem in that these teeth will eventually be shed. To locate information on primary tooth exfoliation and progression of caries in primary teeth, two other MEDLINE searches were performed. Using the Medical Subject Headings of **tooth exfoliation, deciduous tooth, root resorption, tooth loss, operative dentistry, oral surgery, or dental restoration**, along with a title and abstract search for the words "primary tooth" and "resorption," the literature was searched for articles published in the years of 1976-1992 that addressed when primary teeth are or should be shed. The literature was also searched for caries progression articles published in the years of 1983-1992 by combining the Medical Subject Heading **deciduous tooth** and **dental caries**. The results of these searches were limited to English

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language articles involving human subjects.

The initial four searches, aimed at articles reviewing when a carious tooth should be restored, identified 128 potential articles. These articles were examined to see if they contained standards for when a coronal carious lesion should be restored. Standards that were not based on any scientific evidence or clinical studies were excluded. Articles that focused on various restoration techniques and what materials should be used also were not included in this paper. This resulted in 31 of the 128 articles being selected for inclusion in this paper.

The literature searches on primary tooth exfoliation and caries progression in primary teeth resulted in the computer listing a total of 609 articles. After reviewing these studies, we found only 6 that addressed the prediction of primary tooth exfoliation and 5 that monitored caries progression in primary teeth.

Additional articles were identified from the references within the articles identified by the computer-aided searches. A few articles were located during previous literature searches performed to review the literature on topics of space maintenance (Woodward & Leake 1993), restoration materials (Woodward & Ryding 1993), and dental radiographs (Woodward & Main 1993).

Using the available scientific, evidence practice guidelines for when to place an initial restoration were drafted. When scientific evidence was lacking, expert opinion and other existing guidelines were considered.

After drafting the guidelines, this critical review of the literature and its recommended guidelines were reviewed by two panels. An Internal Staff Panel consisting of three dentists and one hygienist, all of whom work in North York's school-based dental program, initially assessed this report. Concerns and recommendations of the panel were discussed with members of the Community Dental Health Services Research Unit (CDHSRU) and necessary changes were made to accommodate the needs of those providing the dental services. This document was then reviewed by an External Panel of experts consisting of the President of the Royal College of Dental Surgeons, the President of the Ontario Dental Association, an Epidemiologist, an Ethicist, a Paedodontist, a General Practitioner, and a member

of the Internal Panel. Concerns and recommendations of the External Panel were discussed with members of the CDHSRU and recommended changes were made. The critical review and its guidelines were then finalized after approval by both the Internal and External Panels.

Findings of the Literature Review

At the conclusion of an International Symposium entitled, "Criteria for Placement and Replacement of Dental Restorations", summary statements and recommendations for restoration placement were developed (Anusavice 1989). "Operative procedures are indicated if:

(a) a coronal lesion can be judged to **extend well into the dentin** (unless it can be shown to be inactive with reference to past records or other information). For root caries, operative procedures may not (usually) be indicated unless a more advanced stage of dentin involvement exists.

(b) there are pulpal symptoms.

(c) there is impairment of occlusion or function due to improper contour or other deficiency.

(d) periodontal tissue health is adversely affected.

(e) the appearance of the lesion is unacceptable to the patient."

Smooth surface lesions that do not extend to or past the junction of the enamel and dentin, should not be restored but should be treated with topical fluoride (Anusavice 1989). The patient should be informed that this lesion can be arrested and even remineralized to some extent if proper oral hygiene procedures are practised. However, the patient must be told and understand that this responsibility is primarily his or hers; failure to practice proper oral hygiene procedures will probably result in the tooth requiring restoration in the future (Elderton 1985; Eames 1988; Anusavice 1989; Elderton & Osman 1991). Periodic assessment of the lesion by a dentist will be necessary to check the lesion's state (Anusavice 1989).

While precise and accurate diagnoses of the stage of pit and fissure caries is

difficult, small active lesions, lesions that are questionable, or cases where the activity of the lesion is in doubt, should receive pit and fissure sealant. This allows the dentist to conserve tooth tissue by eliminating the tooth-cutting procedures associated with placing a restoration (Anusavice 1989).

Other authors also support the conservative approach to restorative dentistry adopted at the Symposium (Pitts 1983; Elderton 1985, 1988; Elderton & Osman 1991; Surmont *et al.* 1991). However, restorative intervention of less advanced carious lesions has been suggested in some circumstances, based on patient behaviour or oral health. Restoration of an incipient carious lesion may be appropriate if there is a good probability that the pulp will be in jeopardy before the next exam because the patient is high caries-risk, has poor oral hygiene, or is an irregular dental attender (Klock & Kinder 1984; Elderton 1985, 1988; Tulloch *et al* 1989; Elderton & Osman 1991). Elderton (1985, 1988) also included loss of contact resulting in drifting, and tooth sensitivity to hot, cold, sweetness, etc., as reasons to consider restoring a tooth with a carious lesion.

If a restoration is necessary, a conservative approach should be practised; cavity design should be based largely on the position, shape, and size of the carious lesion (Elderton 1985; Eccles 1989; Anusavice 1989, 1992; Surmont *et al.* 1990; Elderton & Osman 1991).

Smooth Surface Caries

It is reported in the literature that a smooth surface carious lesions should extend at least into the dentin before it is restored (Pitts 1983; Elderton 1988; Anusavice 1989; Downer 1989; Eccles 1989; Mileman & van der Weele 1990; Surmont *et al.* 1990; Elderton & Osman 1991). However, it may be difficult to determine clinically how extensive a carious lesion is and therefore, many authors have suggested that cavitation of the tooth's surface should be present before restoring the tooth (Espelid *et al.* 1985; Espelid & Tveit 1986; Pitts & Longbottom 1987; Downer 1989; Hunter and Hunter 1989; Waggoner & Ashton 1989; Mileman & van der Weele 1990; Pitts & Kidd 1992).

Cavitation represents a stage of tooth decay that is not expected to recalcify (Kidd 1984; Mejare & Malmgren 1986; Mileman *et al.* 1986), and thus warrants restoration (Waggoner & Ashton 1989). The definition of the physical appearance of a cavitated lesion varies however, with some studies classifying teeth as cavitated without ever defining what actually represents clinical cavitation (e.g. Downer 1975; Pitts 1984; Thylstrup *et al.* 1986). Stephens *et al.* (1987) defined cavitation simply as a clinically detectable hole in tooth's surface, but is any destruction of the tooth's surface considered a hole? Many articles have defined cavitation as a break or discontinuity in the surface of a tooth's enamel (e.g. Marthaler & Germann 1970; Espelid & Tveit 1986; Mejare & Malmgren 1988; Neilson & Pitts 1991). This appears to be a more workable definition than that offered by Stephens *et al.* (1987). For this paper we have defined cavitation as a discontinuity in the surface of a tooth's enamel.

Some authors have recently suggested that not all cavitated lesions need to be restored (Klock & Kinder 1984; Pitts & Kidd 1992). A recent study by Neilson and Pitts (1991) suggested that restoring a small break or discontinuity in the enamel is not always necessary. Of the 2917 smooth surface carious lesions studied over a two year period, 77% of the non-cavitated lesions and 43% of the cavitated lesions (loss of surface contour of enamel) either remained static or remineralized.

Other factors should also be considered before restoring a tooth. A lesion should be judged to be active before restorative intervention begins (Klock & Kinder 1984; Elderton 1985; Elderton & Osman 1991; Anusavice 1992). Cavities that are progressing and that are causing problems for the patient may need restoring (Klock & Kinder 1984; Pitts & Kidd 1992). Therefore, clinicians should consider the likelihood of progression along with the consequences of treatment (Tulloch *et al.* 1988) before restoring a lesion.

Although placing restorations is a necessity of dental practice, practitioners should be aware that placing a restoration will subject most patients to a cycle of restoration placement, replacement and re-replacement (Anusavice 1992)."Caries in industrialized countries is a disease of slow progression and it is unlikely that a missed borderline dentinal lesion will pose an early threat to the viability of the

tooth" (Downer 1989). Thus, aggressive restorative treatment of early, non-cavitated carious lesions is warranted for only a few select patients.

Judging activity of a carious lesion is difficult. For a regular dental attender, progression of a carious lesion can be monitored over a number of successive examinations, but for a new patient or an irregular dental attender, deciding lesion activity is difficult. Klock & Kinder (1984) suggested both lesion colour and lesion consistency as possible indicators of lesion activity. Lesions that are light (white, yellow-brown) are more likely to be active than darker (brown, black) lesions because darker lesions are more mineralized and contain less microorganisms. Lesions that are soft at their base are most likely active, but lesions with a hard and dry base are most likely inactive. Craig et al. (1981) also indicated that a firm darkened surface is characteristic of an arrested lesion.

Making a definite clinical diagnosis of approximal lesions is often not possible and radiographs are often used to aid in the diagnosis. However, radiographs can only provide the practitioner with an estimate of a lesion's extent and may underestimate or overestimate its actual size (Bille & Thylstrup 1982; Elderton 1985; Downer 1989; Pitts & Rimmer 1992).

A number of studies have been carried out to study the relationship between the radiographic image and the presence or absence of cavitation. These studies, summarized in Table 2, have used a variety of methods to establish a "gold standard", i.e. presence or absence of a cavity. Some studies have used direct clinical inspection or histological examination of extracted teeth (Marthaler & Germann 1970, Purdell-Lewis et al. 1974, Downer 1975, Mejare et al. 1985, Espelid & Tveit 1986, Kogon et al. 1987, Waggoner & Ashton 1988). This method is considered to be quite accurate, but one drawback is that the tooth must be extracted to be examined.

Another method employed careful observation of the tooth while it was being prepared for a restoration (Bille & Thylstrup 1982, Thylstrup et al. 1986, Mejare & Malmgren 1986, 1988). This method may not be as accurate as histological examination because the practitioner must restore the tooth to obtain the necessary information. Therefore, teeth which the practitioner diagnoses as not requiring a

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restoration, but which are actually cavitated (false negative), will be missed. This decrease in false negatives relative to true positives (restoring a tooth that is truly cavitated) increases the sensitivity values of these studies.

Direct inspection of a vital tooth's surface also has been used to determine the presence of cavitation (Rugg-Gunn 1972, Pitts & Rimmer 1992). When examining interproximal surfaces however, this can only be accomplished if an interproximal space exists that is large enough for the surface in question to be viewed. Tooth separators may be used to create an interproximal space and have received some attention in the recent literature (Pitts & Longbottom 1987; Stokes 1989; Rimmer & Pitts 1990; Pitts & Rimmer 1992). This simple and inexpensive procedure uses an orthodontic elastomeric separator (small rubber band) that is stretched and placed between the two teeth requiring separation. As the stretched separator tries to regain its shape, the pressure it exerts slowly forces the teeth apart and after a few days enough space is gained to view the surface in question.

Separating the teeth eliminates the probability component associated with using radiographs to diagnose cavitated carious lesions. A recent study by Rimmer and Pitts (1990) reported that patient acceptance of this technique was high, with about 80% of patients reporting no discomfort and most others reporting discomfort that was mild to moderate. However, because of the time required to separate the teeth, the patient must be seen twice within a week (Pitts & Longbottom 1987). This may not be practical except in situations where children have ready access to the dentist (e.g. school-based clinics).

For each study in Table 2, we determined the positive predictive value for three radiographic depths, outer half of the enamel, inner half of the enamel, and dentin. This value represents the portion of radiolucencies at a given depth that represented truly cavitated lesions, and may be thought of as the probability of a cavity being present. A mean positive predictive value and its standard deviation was then calculated for each radiographic stage. This mean is not intended to represent the absolute positive predictive value, but is only intended to represent a crude estimate of central tendency.

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Table 2. Studies investigating the relationship between the radiographic image (D-speed film) and the presence of interproximal cavitation in permanent posterior teeth.

STUDY	PROBABILITY OF CAVITATION BASED ON A RADIOLUCENCY THAT EXTENDS INTO THE			PREVALENCE OF CAVITATED LESIONS	SAMPLE SIZE T=TEETH S=SURFACES
	OUTER HALF OF THE ENAMEL	INNER HALF OF THE ENAMEL	DENTIN		
Marthaler & Germann 1970 (a)	0.31	0.61	0.84	0.21	395 S
Rugg-Gunn 1972 (a,b)	0.27		1.00	0.09	370 S
Purdell-Lewis et al. 1974 (d)	0.60	0.93	0.92	0.39	100 S
Downer 1975 (a,b,c)	0.14		0.92	0.36	185 S
Bille & Thylstrup 1982	0.14	0.20	0.58	0.34	158 S
Mejare et al. 1985 (c,d)	0.11	0.31	1.00	0.05	598 S
Espelid & Tveit 1986	0.73	0.89	0.95	0.66	151 T
Mejare & Malmgren 1986, 1988 (e)	n/a	0.61	0.78	0.70	60 T
Thylstrup et al. 1986	0.07	0.12	0.60	0.43	660 S
Kogon et al. 1987 (f)	0.49	0.53	n/a	0.49	125 S
Waggoner & Ashton 1989	0.29	0.39	0.65	0.26	158 S
Pitts & Rimmer 1992	0.00	0.11	0.50	0.01	1468 S
MEAN STANDARD DEVIATION	0.30 0.25	0.47 0.30	0.79 0.18		

(a)   study did not specify the size of cavitation
(b)   study did not distinguish between inner and outer enamel images
(c)   x-rays with no radiolucency and enamel radiolucencies were grouped together
(d)   study used outer 2/3 and inner 1/3 of enamel
(e)   only teeth with a radiolucencies in the inner 1/2 of the enamel and the outer 1/2 of the dentin were selected for the study
(f)   study only involved teeth with radiolucencies in the outer and inner enamel

Table 2 shows that there is substantial variability among the results reported by the various studies. Some of this variation is due to the varying methods that were employed by the investigators of each study. The differences in the cavity prevalence among the studies also accounts for some of the variability in the results. Positive predictive values are positively associated with a disease's prevalence and will decrease as the prevalence decreases.

The results in Table 2 show that for seven of the twelve studies, the positive predictive values are below 0.50 for radiolucencies confined to the enamel indicating that the probability of a cavity being present is less than 50%. For all studies, this probability increases to 50% or more when the radiolucency is in the dentin. These findings support the common recommendation that an interproximal lesion should not be restored until the radiolucency has reached at least the dento-enamel junction (Pitts 1983; Elderton 1985; Hunter & Hunter 1989; Mileman & van der Weele 1990; Nuttall & Pitts 1990; Pitts & Kidd 1992). However, "it is unsafe to assume that nearly all radiolucencies which have reached the dentin represent cavities" (Pitts & Rimmer 1992), as some teeth meeting this criterion will not be cavitated (false positive).

The results of Table 2 also correspond with the general conclusions of a literature review by Grondahl (1989). Grondahl calculated that 60% of the radiolucencies extending into the dentin or further represented cavities.

Five of the studies in Table 2 reported positive predictive values above 0.50 at the inner enamel. Two of these studies reported very high positive predictive values at inner enamel level and positive predictive values of 0.60 and 0.73 at the outer enamel level (Purdell-Lewis *et al.* 1974, Espelid & Tveit 1986). We have found no recommendations in the literature to support restoring teeth with radiolucencies that are confined to the outer half of the enamel. The remaining three studies, Marthaler and Germann (1970), Mejare and Malmgren (1986, 1988), and Kogon *et al.* (1987) reported inner enamel positive predictive values of 0.61, 0.61, and 0.53, respectively. Restoring teeth based solely on radiographs and this predictive accuracy, would result in 39 or 47 of every 100 restorations being placed in non-cavitated teeth. Thus,

adopting the more conservative approach of only restoring lesions with a radiolucency at the dento-enamel junction or in the dentin appears to be more appropriate.

Conclusions:
(1)   Active, cavitated carious lesions should be restored.
(2)   For a carious lesion that cannot be adequately examined clinically, the radiolucency should extend to the dento-enamel junction before restorative intervention begins. For recommendations regarding the prescription of dental radiographs the reader is directed to the third report in this series, The use of dental radiographs in the North York Public Dental Program (Woodward & Main 1993).

Pit and Fissure Caries

Although traditionally the diagnosis of pit and fissure caries has involved the use of an dental explorer or probe, this practice has recently been questioned. Studies have reported that visually diagnosing caries in clean, dry teeth without using an explorer does not reduce the diagnostic accuracy (Downer 1989; Lussi 1991). "The retention of the explorer point in a fissure, for example, is dependent on a number of factors other than the presence of caries, including the physical characteristics of the point, the pressure exerted in applying it and the morphology of the fissure" (Downer 1989). Using forceful probing as a means to diagnose pit and fissure caries may enhance the breakdown of demineralized areas and may create a cavity where a cavity did not previously exist (Elderton 1985; Danish Medical Research Council 1986; Rock 1987; Downer 1989). Some authors have therefore suggested that explorers should be dull and used only to remove plaque and debris from the teeth (Eccles 1989; Rock 1987; Kidd 1984).

Others investigators still endorse the use of explorers for caries diagnosis. As recently as 1991, Waggoner cited "explorer tugback" as evidence of pit and fissure caries or questionably carious pits and fissures. A recent epidemiologic study of children by Ismail et al. (1992) also included the use of explorers when diagnosing caries. However, this study stressed that the examiners should be careful when using explorers for this purpose and not apply excessive force when probing. Following personal communication with R.J. Elderton (1989), the authors drafted the

following "rule" for explorer use:

" ...should only be used for removing debris to allow visualization; and where necessary for helping to decide whether or not there is cavitation. Under no circumstances should an explorer be used to press into the surface of a tooth or lesion with a force greater than what is required to blanch the area under a fingernail. After the visual inspection of a dried tooth surface, if a carious lesion is seen, then the examiner should use the explorer to check for the leathery or tacky surface characteristics of the lesion. Exploring should only be used to gain information about the texture of the margins and the base of the cavity."

Diagnosing pit and fissure caries has become more difficult in recent years (Eccles 1989; Verdonschot *et al.* 1992). Investigators have suggested that fluorides may be preventing, arresting, or remineralizing surface enamel lesions, but decay of the dentin still occurs (Kidd 1984; Eccles 1989; Weerheijm *et al.* 1989; Surmont *et al.* 1990; Verdonschot *et al.* 1992). Thus, fissures may appear sound, but the dentin below them may be carious (Weerheijm *et al.* 1989). This situation has led authors to develop two lines of treatment, one for fissures that are questionable (deep and narrow, and/or may be carious) and one for carious fissures. The monitoring approach that may be adopted for small smooth surface lesions is not appropriate for pit and fissure caries (Elderton 1985).

When a pit or fissure is very deep and narrow, fissure sealant is often applied to prevent caries developing. This same line of treatment should be taken in situations where a fissure may be carious, but evidence necessary to make a definite diagnosis is lacking i.e. questionable or suspicious caries (Eccles 1989; Surmont *et al.* 1990; Elderton & Osman 1991). When there is no evidence of dentin caries, a non-invasive technique using sealants can be practised. Dentists need not worry about sealing in active caries, as recent studies have shown that the bacterial count will decrease and the lesion will not progress (Eccles 1989; Elderton 1988; Mertz-Fairhurst *et al.* 1991; Roulet & Noack 1991; Waggoner 1991). In spite of this some advocate that radiographs be used to aid in the diagnosis of questionable caries, to

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determine if there is dentin caries below the enamel, not to diagnose enamel caries (Elderton 1985; Eccles 1989; Weerheijm *et al.* 1989; Wenzel *et al.* 1991).

Some authors have suggested that the presence of "a cavity," a highly suspicious fissure, or a radiograph indicating that dentin caries is present, are appropriate criteria to begin restorative intervention (Surmont *et al* 1990; Waggoner 1991), while others suggest that a pit and fissure cavity should extend into the dentin before restorative intervention begins (Elderton 1985, 1988; Eccles 1989). In either case, treatment should involve minimal cavity preparation to preserve as much of the tooth tissue as possible. If the cavity is small, or if it is found after some initial drilling that the carious lesion does not extend into the dentin, the dentist may stop drilling and place a "preventive resin restoration" (Anusavice 1989, 1992; Eccles 1989; Surmont *et al.* 1990). If dentin caries is found, only enough tooth tissue should be removed to place the appropriate restoration.

Conclusions:
(1) Initial diagnosis of pit and fissure caries should be visual, using an explorer or probe to remove debris.
(2) Probes or explorers may be used to check surface irregularities and textures, but the force used to press into the tooth's surface should be no greater than the force required to blanch the area under a fingernail.
(3) Questionable or suspicious pits and fissures should be treated with sealants.
(4) Pits and fissures that are carious or highly suspicious should receive restorative intervention. However, a restorative technique employing minimal cavity preparation should be a used to keep restoration size as small as possible.
(5) Radiographs may be used to aid in the diagnosis of dentin cavitation, but should be prescribed following the recommendations of the third report in this series, The use of dental radiographs in the North York Public Dental Program (Woodward & Main 1993).

Caries Primary Teeth

The decision to restore deciduous teeth is based on the underlying assumption that these teeth are needed for function (speech and chewing), to assure proper guidance of the emerging permanent teeth, and, in the case of anterior teeth, aesthetics. However, few articles discussing restoration criteria for primary teeth

exist in the literature. Evans *et al.* (1987) published criteria for treatment needs of primary dentition which were developed for use in epidemiological studies. Many of these criteria are very similar to the treatment criteria for permanent dentition discussed above. Primary teeth <u>should</u> be restored to, (1) eliminate pain or sepsis, or (2) prevent complications such as pulpal involvement, involvement of adjacent teeth, or loss of arch space. When in doubt about caries, preventive measures such as sealants or fluorides should be applied (Evans *et al.* 1987).

Evans *et al.* (1987) did not indicate what resources formed the foundation of their standards for not restoring teeth, but it appears that they are based on estimated ages of tooth exfoliation and estimates of caries progression rates in primary teeth. When the examiner does not foresee any complication arising from caries present in a primary tooth and when the cost of treatment is greater than the possible benefits, the tooth <u>should not</u> be restored. This includes:

a)   primary incisors in children aged 5 years or older;
b)   primary canines in children aged 10 years or older;
c)   any primary tooth, when two or more permanent teeth in the same series have already erupted;
d)   teeth that are already loose and ready to be exfoliated (Evans *et al.* 1987).

Estimates of approximal caries progression in primary teeth vary. Earlier studies by van Erp and Meyer-Jensen (1970), and Murray and Majid (1978) indicated that over 90% of enamel lesions progressed into the dentin within 12 months. However, van Erp and Meyer-Jensen pre-selected only active caries sites and "therefore a faster progression is expected" than studies where all caries sites are included (Solanki & Sheiham 1992). The method employed by Murray and Majid (1978) also may have over-estimated caries progression rates, because early enamel lesions were scored as sound and excluded from the study (Solanki & Sheiham 1992).

More recent estimates of caries progression in primary teeth have reported that the majority of enamel lesions will require more than 1.5 years to progress through the enamel (Craig *et al.* 1981; Shwartz *et al.* 1984). Craig *et al.* (1981) found that 74% of approximal enamel lesions and 90% of occlusal enamel lesions remained in the enamel over a 2 year period. However, these lesions received an application of

professionally applied topical fluoride after their initial diagnosis. Shwartz *et al.* (1984) found that the average lesion required 12 months to progress through the outer enamel and 10-12 months to progress through the inner enamel. Based on these rates, it seems appropriate that a primary tooth with caries confined to the enamel should not be restored if it is expected to exfoliate within about a year. If the tooth has not been shed after a year the carious lesion can be re-assessed. This yearly evaluation would coincide with the annual dental exams provided by the North York Public Health Department.

Evans *et al.* (1987) states that teeth that are loose and ready to be exfoliated should not be restored. This criterion is sensible, but if the tooth is not loose, Evans *et al* (1987) appears to be using chronological or dental age as a means of assessing how soon the tooth will shed. Average ages of primary tooth exfoliation can be seen in Table 3 (Ripa *et al.* 1982). The average ages of exfoliation for the 3 countries included in Table 3 are very similar, but variation does exist between the maxilla and mandible, between males and females, and between countries. Generally, females shed their teeth earlier than males and mandibular teeth are shed earlier than in the maxilla, except for the second molars which are all shed at approximately the same time.

Even within one country, the variation is actually quite large. From a total sample size of more than 6000 children, Ripa *et al.* (1982) reported a standard deviation of 1.5 to 2 years for most tooth types, meaning that only about 65% of the children fall within 1.5 to 2 years of the average. This variation is an important consideration for a public dental health program with a high rate of immigration from a number of different countries.

TABLE 3. Average age of tooth exfoliation for 3 countries (Ripa *et al.* 1982).

TOOTH	AVERAGE AGE OF EXFOLIATION (years)					
	MALES			FEMALES		
	ENGLAND	AUSTRALIA	UNITED STATES	ENGLAND	AUSTRALIA	UNITED STATES
Maxillary						
central incisor	7.6	7.0	6.8	7.4	6.8	6.6
lateral incisor	8.3	7.7	7.6	8.1	7.4	7.4
canine	11.6	10.5	11.3	10.8	10.1	10.6
first molar	11.0	10.8	10.9	10.6	10.2	10.5
second molar	11.7	10.9	11.7	11.6	10.9	11.4
Mandibular						
central incisor	7.0	6.4	6.0	6.5	6.1	5.6
lateral incisor	8.0	7.1	7.2	7.5	6.8	6.9
canine	10.7	10.2	10.4	9.8	9.3	9.6
first molar	11.3	10.3	10.6	10.6	9.8	10.2
second molar	12.1	11.1	11.8	11.6	10.8	11.4

According to Table 3, the age-based treatment criteria defined by Evans *et al.* (1987) may not be appropriate. Children 5 years-old may have an untreated carious incisor present for more than two years before the tooth is shed. The criteria for non-treatment of primary canines, 10 years or older, appears to match the average ages of exfoliation more closely. Evans *et al.* (1987) do not offer any age-based criteria for primary molars, although the canine criterion of 10 years of age would seem appropriate.

Much of the literature, especially surrounding space maintenance, suggests that a child's dental age is more important in determining treatment need than chronological age (Beierl & Hune 1974; Wright & Kennedy 1981; McDonald & Avery 1983; Daly & Walker 1990). Evans *et al.* (1987) suggest that if the child's chronological age is unknown and two or more permanent teeth of the same tooth type (e.g. canine) are present, a primary tooth should not be restored. This criterion may be more appropriate in determining if a primary tooth should be restored than the child's chronological age.

Ripa *et al.* (1982) reported that there is bilateral symmetry of tooth loss in the same arch. Generally, teeth of the mandibular arch exfoliate 6-12 months earlier than teeth of the maxilla, except for the primary second molars where both arches

exfoliate at the same time. Therefore, if one primary mandibular tooth has shed, the contralateral mandibular primary tooth should soon shed and corresponding maxillary teeth should shed within a year. This may be very useful in predicting tooth exfoliation on an individual basis. If one of the maxillary primary teeth has already shed, or if one of the maxillary permanent teeth has already erupted, the contralateral maxillary primary tooth should soon exfoliate. If all primary teeth in a series (e.g. all primary canines) are present however, chronological age and dental age, based on what other permanent and primary teeth are present, may have to be used to determine when a primary tooth will shed.

Articles on endodontic therapy of deciduous teeth have suggested that treatment is contraindicated if the roots have been more than 2/3 resorbed because the tooth will soon exfoliate (Sweet 1960; King et al. 1984). However, no literature is cited to support this suggestion.

Very few published studies have investigated the rate of root resorption in primary teeth. Both Brady (1924) and Schour and Massler (1938) published a chart of a child's average stage of tooth development, eruption, and absorption at various ages. These charts suggest that the time between initial resorption and exfoliation of primary teeth is approximately 3 years for incisors and canines and 4 years for molars. These rough estimates are substantially larger than the estimate of Provenza and Seibel (1986) who suggested that the average primary tooth requires up to 18 months to exfoliate. However, no methods or sources of data are included to support any of these estimates.

Four clinical studies have presented longitudinal data on the rate of root resorption in primary teeth in North American children (Fanning 1961, 1962; Knott & O'Meara 1967; O'Meara & Knott 1967). Data on the exfoliation period of primary mandibular molars, primary incisors (Fanning 1961, 1962), and primary canines (O'Meara and Knott 1967) when half or more of the root(s) has been resorbed are summarized in Table 4. However, O'Meara and Knott (1967), as well as a study of incisors by Knott and O'Meara (1967), reported the median time until the successor emerges rather than until the primary tooth is shed. Therefore, the median number

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of months until canine exfoliation should be less than what is listed in Table 4.

Other factors may also need to be considered when trying to predict primary tooth exfoliation based on the degree of root resorption. Fanning (1962) reported that the presence of a carious lesion may hasten the resorption process, but a more recent study by Rune and Sarnas (1984) did not support this finding. Fanning (1961) also reported faster resorption for the incisors of females than males. However, all other studies of root resorption, including a second study of incisors by O'Meara and Knott (1967), have found no sex difference in the rate, although resorption may begin at a younger age in females (Fanning 1962; Knott & O'Meara 1967; O'Meara & Knott 1967; Rune & Sarnas 1984).

Table 4.   Mean number of months until a primary tooth exfoliates if one half, two thirds, or three quarters of the root(s) is resorbed (based on data from Fanning 1961, 1962, and O'Meara & Knott 1967).

Tooth	Mean number of months until exfoliation if root(s) is:		
	1/2 Resorbed	2/3 Resorbed	3/4 Resorbed
Maxilla			
Central Incisor	20	no data	6
Lateral Incisor	no data	no data	no data
Canine*	14	no data	9
First & Second Molars	no data	no data	no data
Mandible			
Central Incisor	13	4	2
Lateral Incisor	16	9	5
Canine*	10	no data	7
First & Second Molars	23	16	8

*   median number of months reported until successor emergence

Based upon the results of Fanning (1961, 1962), and O'Meara and Knott (1967) it appears that, on average, deciduous teeth will exfoliate within 1 year or less if their roots are 3/4 resorbed. Therefore, teeth with outer enamel caries will probably exfoliate before the lesion progresses into the dentin. However, the rates of root resorption for incisors and some canines may be even more rapid. The findings of Knott and O'Meara (1967) suggest that at least 50% of central and lateral incisors will be replaced by their successors within 11 months or less if only 1/2 of the root is absorbed. Although data for the 2/3 resorption stage is not available for canines, the findings at the 1/2 and 3/4 stages suggest that a canine with 2/3 of its root resorbed will probably exfoliate within 12 months, especially in the mandible.

Conclusions:

Primary teeth with an initial carious lesion should be restored if:
(1) there is a high probability that caries has progressed through the enamel; and
(2) there is a low probability that the tooth will be exfoliated within the next 12 months. The probability of a primary tooth being shed can be determined using dental age, chronological age, and root resorption, although dental age may be more accurate than chronological age.

(a) DENTAL AGE - A primary tooth will probably exfoliate within a year if one or more permanent teeth in the same series are present. Mandibular teeth are generally lost 6-12 months before maxillary teeth, except for the second molars which are all lost at the same time.

(b) CHRONOLOGICAL AGE - Average ages that primary teeth are shed are as follows:
> central incisors, 6-7;
> lateral incisors, 7-8;
> canines, 9-11;
> first molars, 10-11;
> second molars, 11-12.

(c) ROOT RESORPTION - Primary teeth are expected to exfoliate within 12 months if at least 3/4 of the root(s) are resorbed. Primary canines and incisors, especially in the mandible, may exfoliate more rapidly and may exfoliate within 12 months if at least 2/3 of the root is resorbed.

Note: In some instances, pain, function, and space maintenance may also need to be considered.

Recommendations for When to Place and Initial Restoration due to Caries

Permanent Teeth
Smooth tooth surfaces should be restored if:
(1)   there is a clinically detectable carious cavitated lesion i.e. a discontinuity in the tooth's enamel, or;
(2)   the tooth surface in question cannot be diagnosed clinically, but the radiolucency extends to the dento-enamel junction.

Pit and fissure surfaces should be restored if:
(1)   a clinically detectable carious lesion is present in the enamel, or;
(2)   a radiograph indicates that the dentin at the base of the pit or fissure is carious i.e. radiolucency in the dentin.

In both cases (1) and (2), cavity preparation should be as conservative as possible, removing only enough tissue to properly restore the tooth. This allows the practitioner to treat a lesion with a preventive resin restoration or sealant if the lesion is very small or if a false positive diagnosis has been made. This approach may also be considered for highly suspicious surfaces.

Primary Teeth
Primary teeth should be restored if:
(1)   there is a high probability that caries has progressed through the enamel; and
(2)   there is a low probability that the tooth will be exfoliated within the next 12 months. The probability of a primary tooth being shed can be determined using dental age, chronological age, and root resorption, although dental age may be more accurate than chronological age.
      (a)   DENTAL AGE - A primary tooth will probably exfoliate within a year if one or more permanent teeth in the same series are present. Mandibular teeth are generally lost 6-12 months before maxillary teeth, except for the second molars which are all lost at the same time.
      (b)   CHRONOLOGICAL AGE - Average ages that primary teeth are shed are as follows:
                  central incisors, 6-7;
                  lateral incisors, 7-8;
                  canines, 9-11;
                  first molars, 10-11;
                  second molars, 11-12.
      (c)   ROOT RESORPTION - Primary teeth are expected exfoliate within 12 months if at least 3/4 of the root(s) is resorbed. However, primary incisors and canines, especially in the mandible, may exfoliate more rapidly and may exfoliate within 12 months if at least 2/3 of the root is resorbed.

Note: In some instances, pain, function, and space maintenance may also need to be considered.

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